

Advanced Wastewater Treatment

Course #3201



Fleming Training Center



Advanced Wastewater Treatment Course #3201 February 28-March 4, 2022

Monday

- 8:30 Introduction and Welcome
- 8:45 Activated Sludge
- 11:00 Lunch
- 12:30 Pure Oxygen Systems Operational Control Options
- 2:00 Wastewater Math Review

Tuesday

- 8:30 Odor Control
- 10:00 Secondary Effluent Solids Removal
- 12:00 Lunch
- 1:00 Residual Solids Management
- 2:00 Fats, Oils, and Grease

Wednesday

- 8:30 Phosphorus Removal
- 10:00 Nitrogen Removal
- 12:00 Lunch
- 1:00 Nutrient Removal
- 2:30 Wastewater Reclamation and Reuse

Thursday

- 8:30 Practice Exam
- 12:30 Lunch
- 1:30 Plant Tour—TBD

Friday

- 8:30 TN Regulations
- 9:30 New and Emerging Technology
- 10:30 Exam Review
- 11:30 Exam and Course Evaluation
- 12:30 Final Exam

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State of Tennessee

Dept. of Environment & Conservation
Bureau of Environment

Fleming Training Center

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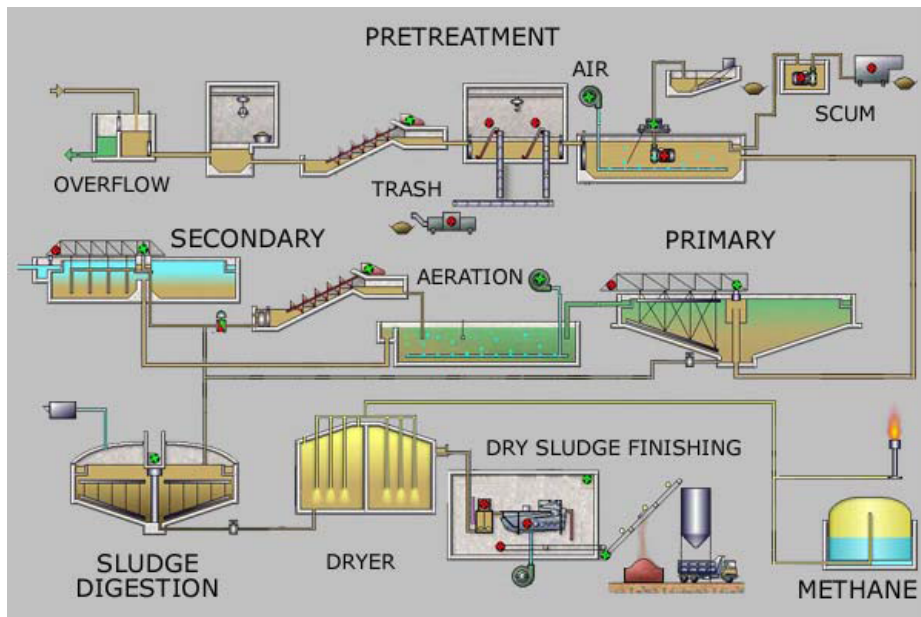
Advanced Wastewater Treatment

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Section 1

Activated Sludge



ACTIVATED SLUDGE

Advanced Wastewater Class

How do we treat wastes?

- Way of treating Wastewater
 - Suspended Film
 - Fixed Film (trickling filter, RBC)
- Biological Treatment Process
 - Natural occurring bacteria, protozoa, metazoan
- Chemical treatment (polymers, ferric salts, lime, alum, etc.)

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Activated Sludge

- Sludge particles produced in raw or settled wastewater by the growth of organisms in aeration tanks in the presence of DO.
- The term “activated” comes from the fact that the particles are teeming with bacteria and other microorganisms
- Activated sludge is different from primary sludge in that the sludge particles contain many living organisms that feed on the incoming wastewater

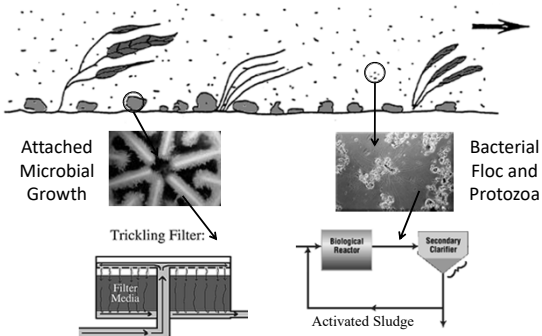
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Activated Sludge Process

- A biological wastewater treatment process that speeds up the decomposition of wastes in the wastewater being treated.
- Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated.
- After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is wasted or reused as needed.
- The remaining wastewater then undergoes further treatment.

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River vs. Treatment Plant



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Typical Activated Sludge Layout

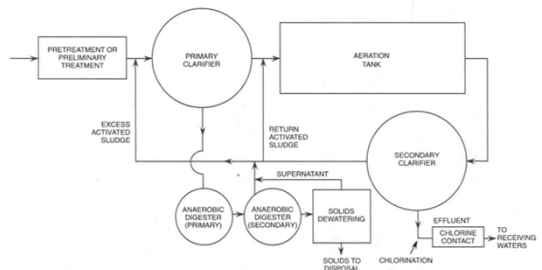


Fig. 11.2 Plan layout of a typical activated sludge plant

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Biological Treatment

- Wastewater treatment is biological in nature
- The naturally occurring organisms (or biology) clean the water for us far more efficiently than can be done physically or chemically.
- This is simply the same process that occurs in the stream, only much faster and in a smaller area

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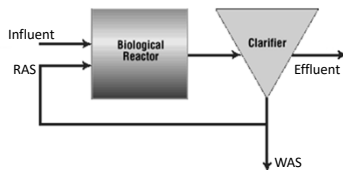
Biological Treatment

- The “bugs” (bacteria, algae, fungi, protozoa and metazoa) metabolize or eat the organic and some inorganic pollutants from the water.
- When the microorganisms are removed from the water in the clarifier, we have excellent “clean water” to discharge to a stream that exerts little oxygen demand upon the receiving stream

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Characteristics of Activated Sludge Process

- Flocculent Slurry of Microorganisms
- Quiescent Settling
- Return of Settled Solids to the Aerator
- Excess Solids Wasted from the System



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Goals of Activated Sludge

- Produce Clean Water (Clean Water Act)
- Remove Organic Pollutants (BOD, other)
- Reduction of Pathogenic Organisms
- Removal of Inorganic Pollutants (NH₄, other)
- Reduction of Sludge Volume (extended aeration)

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Activated Sludge Process Variations

- Conventional Aeration
 - Plug Flow
 - Step Feed
 - Contact Stabilization
 - Complete Mix
- Extended Aeration
 - Complete Mix
- Biological Nutrient Removal
 - Plug Flow
- Sequencing Batch Reactor (SBR)

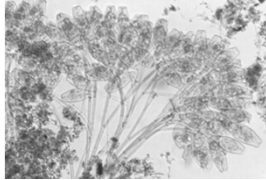
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Flocculent Slurry of Microorganisms

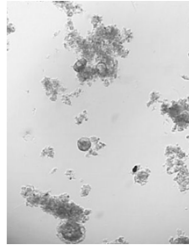
- Soil and Aquatic Bacteria, Protozoa and Metazoa
- Bacterial Flock quality depends upon growth conditions.
 - Abundant food, (high F:M) results in dispersed growth.
 - Floccing conditions occur at near starvation conditions.
 - Filaments grow when conditions occur that they like.
 - Filaments are good scavengers.

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Biological Floc



Stalked Ciliate (a type of Protozoa)



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Soil & Aquatic Organisms

- Treatment organisms live in:
 - Soil, streams, puddles, compost piles
 - They are responsible for rotting!
- Treatment organisms are not of Fecal origin!
 - Fecal organisms are:
 - Mostly strict anaerobes
 - Prefer: 98°F, dark and lots of food.
 - E-coli is a major fecal bacteria.

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Tough Bugs

- These aquatic and soil microorganisms used in wastewater treatment are very hardy
- They can survive being frozen or baked, wet or dry, dark or light and generally live in a state of starvation
- They are generally aerobic, but can live in anoxic conditions and some actually grow in anoxic conditions
- They prefer temperatures in the range of 7-36°C, but can survive higher temperatures

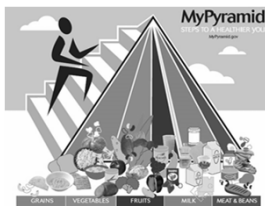
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Microorganism life

- Elements for microorganism life
 - Energy
 - Nutrients
 - Electron acceptors
 - O₂
 - NO₂
 - SO₄
 - CO₃
- Bacteria are tiny chemical factories that live at the molecular level rearranging atoms and molecules to ¹⁹live.

Microorganism Life

- Energy /BOD
 - BOD bugs, heterotrophic bacteria
 - Organic food material
 - Carbohydrates- sugar, starch, cellulose
 - Protein
 - Fat



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Microorganism Life

- Nutrients
 - Nitrogen, Phosphorus, micronutrients
 - From the sewage and wastewater
 - BOD: TKN:P:Fe
 - 100:5:1:0.5
- Balanced Bug Diet

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Microorganism Life

- Electron Acceptor
 - Oxygen, O₂
 - Nitrate, NO₃
 - Sulfate, SO₄
 - Carbonate, CO₃
- Each provides oxygen, but some have differing by products

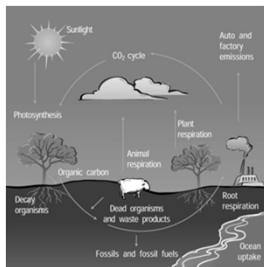
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Biochemistry

- Rotting, by heterotrophic bacteria:
 - $C_6H_{12}O_6$ (glucose) + Bugs + O₂ → More Bugs (energy and nutrients) + CO₂ + H₂O
- What is the formula backwards?
- $C_6H_{12}O_6 + O_2 \leftarrow CO_2 + H_2O + \text{energy}$

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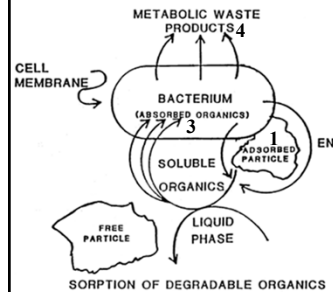
Photosynthesis!



- The Carbon Cycle
 - Matter is not created or destroyed, but its form is changed.
 - Carbon goes from Carbon dioxide to organic carbon (food) and back in a treatment plant.

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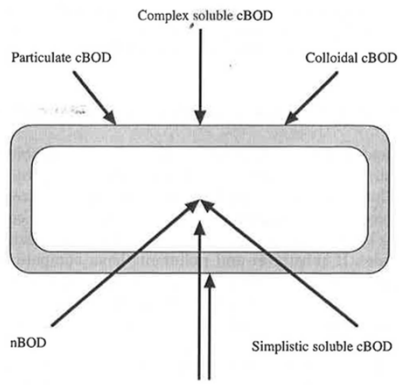
Microorganisms "Eating"



- Step 1 – Adsorb
- Step 2 – Enzymes break down organic matter into soluble particles
- Step 3 – Absorb
- Step 4 – Waste products (nitrogen gas for some, carbon dioxide, water and stable matter) and reproduce

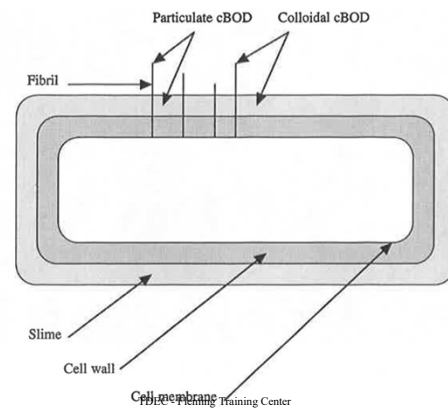
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Microorganisms

- Bacteria have a little tail, they swim around and eat food
- Once food runs low, they lose their tail and start leaving behind waste product that is sticky (polysaccharide slime)
- This sticky waste makes them stick to other bacteria and creates heavy floc
- If high slug of BOD, they don't lose their tail, they continue to swim around and don't have sticky stuff to attach to them, therefore, they don't floc and settle out.

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138 Protozoa joining

They bonded cells together and deposited a sticky polysaccharide.

139 Protozoa joining

PS granules deposited outside the cell.

140 Protozoa joining

PS granules deposited outside the cell.

FIGURE 14.4 Joining of protozoa

FIGURE 14.5 Polysaccharides (PS) deposition

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Treatment organisms

- Bacteria
 - 95% of MLSS
 - Reproduction can be as quick as 20 minutes
 - Floc is formed when individual bacteria stick together during times of near starvation.

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Bacteria

- Floccing and individual cells
 - Also called dispersed growth

Which one will settle better?

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Bacteria

- Small dense floc 100x & Phase

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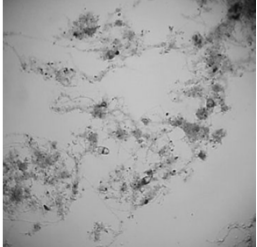
Bacteria

- Floc, MLSS=9000mg/L & filaments

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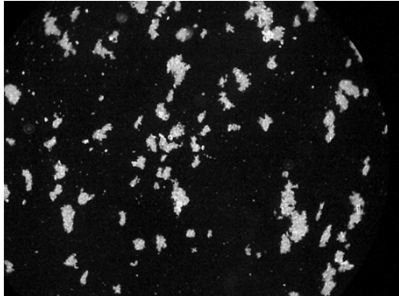
Floc

- Open structure
- Filament bridging,
- Excellent effluent, but...
- High SVI
- Potential for Bulking and Clarifier blanket wash out



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Darkfield, small floc



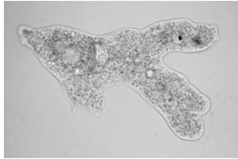
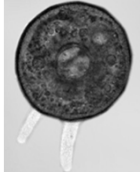
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Protozoa

- First animals
 - Amoeba
 - Flagellates
 - Crawling ciliates
 - Carnivorous ciliates
 - Stalked ciliates
 - Suctorians

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Amoeba, 1000x phase





- They move very slowly, the ultimate shape shifter.
- Generally associated with young biomass

Arcella vulgaris
Origin: Lake Ontario, NY, July 2003
45x, 0.66 N.A., brightfield

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Free Swimming Ciliate, *Litonotus*

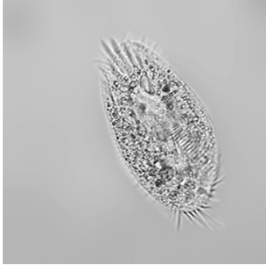


- Free swimming ciliates generally are younger biomass organisms but are common in many plants.

Litonotus sp. and *Paramecium* sp.
Origin: Lake Ontario, July 2003
10x, 0.25 N.A., oblique illumination

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Crawling Ciliates, *Euplotes*



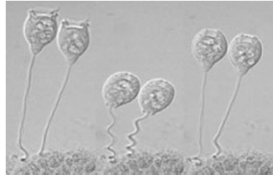
- Crawling Ciliates feed by crawling along floc and breaking away individual bacterial cells.
- They are common with medium to old biomass ages.

Euplotes sp.
Origin: wet moss, Nature Center near Ithaca, NY, May 2003
45x, 0.66 N.A., brightfield

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Floc and Vorticella

- Stalks are common mid range age protozoa.
- These are colonial some grow as individuals.
- They feed by drawing cells into their “mouth” with small cilia that create a visible twirling motion in the sample.



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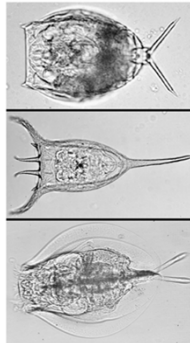
Metazoa

- Next higher life form
- More complex animal
- Slower growing so, common to older sludges

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Rotifer

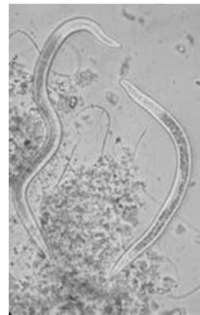
- Rotifers feed on bacteria and protozoa.
- They are strict aerobes



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Nematodes

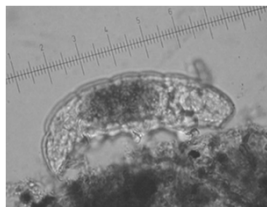
- Aquatic earthworms.
- Fast moving.
- The poke around the floc.
- Older sludge organisms that reproduce slowly.



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Waterbear

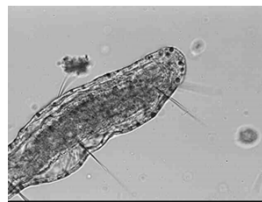
- Old sludge organism.
- Feeds on smaller protozoa.
- Does not like ammonia.



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Bristle Worm

- Aquatic earthworm
- They eat bacteria and protozoa.
- They are relatively active.
- They have red spots that are visible here and can turn biomass red colored.
- They have the capacity to make your biomass disappear.



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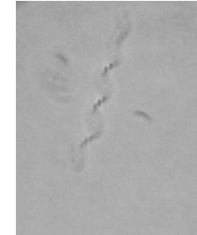
Bristle Worms on Baffle



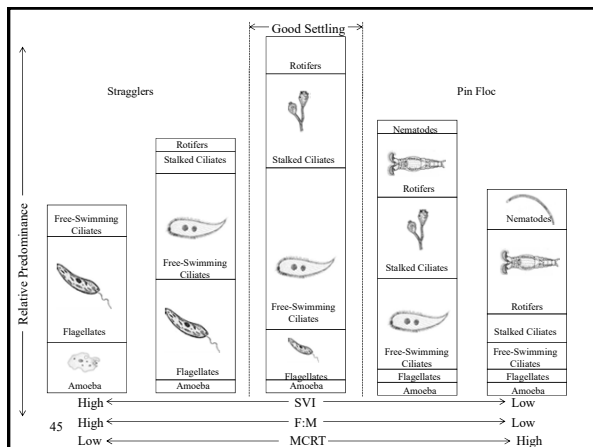
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Other Organisms

- Spirochete
 - Ex: Syphillus
- Sign of septic sample or septic conditions is the plant.



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Batch Sewage Treatment

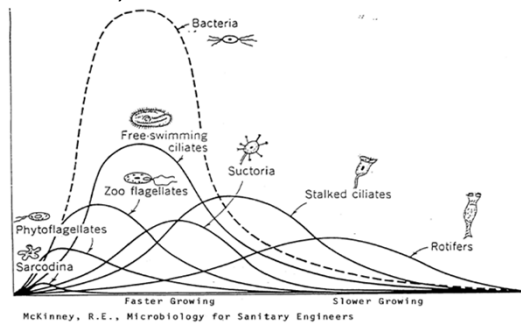
Start with a tank of Sewage
 BOD high
 TSS high
 Odor potential HIGH



Add lots of air and wait.

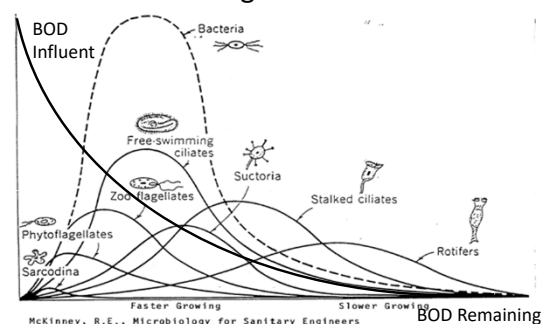
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Bacteria, Protozoa and Metazoa



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Food and Microorganisms



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In the Beginning

- Lots of BOD
- Microorganisms begin to grow
- Dashed line represents bacterial growth.
 - Lag Phase
 - Log Phase
- BOD begins to decline

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The process ages.

- BOD declines
- Bacterial population declines as food is eaten.
- Protozoa increase and decrease depending on food.

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Declining Phase

- All organisms in decline except highest life forms: Rotifers.
- BOD declining
- Bacteria declining
- Protozoa declining
- Metazoan at their peak.

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Treatment near complete

- With most food depleted most life forms in decline including Metazoas like Rotifers.
- BOD should be very low
- Treatment should be complete

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Bacteria Classification

- By Food Source
 - Heterotrophy, organic food, BOD
 - Autotrophy, inorganic food, ammonia
- By Oxygen usage
 - Aerobic, Facultative, Anaerobic
- By Shape
 - Round, Rods, Filaments (threadlike)

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Various Filaments

Beggiatoa, 50x

Thiothrix, 50x after S test

Nocardia, 100x

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Top 6 Reasons You May Have Filaments

- Low Dissolved Oxygen
- Low F:M
- Septicity
- Grease and Oil
- Nutrient Deficiency
- Low pH

- See Michael Richard Handout

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Quiescent Settling Conditions

- Clarifier loading and conditions determines performance
 - Hydraulic Load
 - Infiltration and Inflow
 - RAS/WAS
 - Pump surges, use Variable Frequency Drives (VFD)
 - Solids Load
 - Settling Characteristics
 - Hydraulic Load
 - RAS
 - Mode of Operation

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Return of Settled Solids to Aerator and Wasting Excess Solids

RAS

- Responsible for quick treatment
- Ideal to remove blanket at max. compaction
 - Approximately 1-2 hour retention time
- RAS process highly dependant on equipment and design
- Flexibility needed

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WAS

- Remove daily what grows in the past 24 hours.
- Grazing Control, Constant F:M
- Population Control, Constant MLSS, MLVSS
- Age Control, Constant MCRT
- Base wasting on pounds of solids, not gallons wasted

Draw/Describe you Plant

- Capacity, Design/Average
- Draw overhead view of aerator and clarifier
- Type of aeration
- Show piping of sewage, RAS & WAS



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Factors Affecting Plant Capacity

- What you have:
 - Design, Equipment, Raw water characteristics
- How you use it:
 - Process control strategy
 - Maintenance standards
 - Money
 - Managerial direction and support

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Factors Affecting Plant Capacity

- Capacity can change over time.
 - Design capacity
 - Real capacity, how it actually performs
 - Upgrades can increase capacity
 - Changes in limits decrease capacity
 - Poor maintenance decreases capacity
 - What can you do to increase real capacity?

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Capacity, Design Criteria

- Tennessee Department of Environment and Conservation (TDEC)
 - Division of Water Resources
 - Design Criteria For Sewage Works
 - Chapter 7 Activated Sludge
 - Chapter 5 Clarifiers



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Design Criteria, Activated Sludge



- General
- Types of processes
- Aeration tanks
- Aeration equipment
- Additional details
- Sequencing Batch Reactors
- Oxidation Ditch

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Activated Sludge Design Parameters

| Process | Flow Model | F/M (lbs/day BOD per lb MLVSS) | Sludge Age (Days) | MLSS (mg/L) | Detention Time (Hrs) | Basin Loading (lbs/day BOD per 1,000 ft ³ tank volume) | Activated Sludge Return Rate |
|-----------------------|----------------------|--------------------------------|-------------------|----------------------------------|----------------------|---|------------------------------|
| Conventional | Plug Flow | 0.2 – 0.4 (a) | 5 – 15 (a)(c) | 1,500 – 3,000 (a)(c) | 4 – 8 (a)(b)(c) | 20 – 40 (a) | 0.25 – 1.0 |
| Complete Mix | Complete Mix | 0.2 – 0.6 (a) | 5 – 15 (a)(c) | 2,000 – 5,000 (a) | 3 – 5 (a)(c) | 20 – 80 | 0.25 – 1.0 (a)(c) |
| Step Aeration | Plug Flow | 0.2 – 0.5 (d) | 5 – 15 (a)(c) | 1,500 – 3,000 (a)(c) | 3 – 5 (a)(c) | 20 – 60 | 0.25 – 0.75 (a)(c) |
| Contact Stabilization | Plug or Complete Mix | 0.2 – 0.6 (a)(c)(d) | 5 – 15 (a)(c) | 1,000 – 4,000 (a) (Contact) | 0.5 – 1.5 (a) | 30 – 75 (a) | 0.25 – 1.0 (a) |
| | | | | 4,000 – 6,000 (a) (Regeneration) | 3 – 6 | | |
| Extended Aeration | Plug or Complete Mix | 0.05 – 0.15 (a) | 10 – 30 (a) | 2,000 – 6,000 (a) | 18 – 36 (a) | 10 – 25 (a) | 0.25 – 1.0 (a) |
| High Rate | Complete Mix | 0.4 – 1.5 (a) | 5 – 10 (a) | 3,000 – 6,000 (c) | 1 – 3 (c) | 70 – 180 (b) | 0.3 – 1.0 (b) |
| Kraus Process | Plug Flow | 0.3 – 0.8 (c) | 5 – 15 (c) | 2,000 – 3,000 (c) | 4 – 8 (c) | 37 – 99 (c) | 0.5 – 1.0 (c) |

(a) State of Washington Design Criteria
 (b) Wastewater Treatment Plant Design: WPCF Manual of Practice
 (c) Waste Engineering: Treatment – Disposal – Reuse: Metcalf and Eddy, Inc 1991 3rd Edition, page 550
 (d) Recommended Standards for Sewage Works (10 State Standards): 1990, page 90-7

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Aeration Basin, Oxygen

- How much air do you need?
 - Enough to get good treatment
- Traditional Thumb Rule
 - 2.0 mg/L for BOD and Ammonia removal
 - 1.0 mg/L for BOD only
- Design Criteria: 7.4 Aeration Equipment
 - 7.4.1 Equipment sufficient to maintain min. D.O. of 2.0 mg/L at average design load and 1.0 mg/L at peak.
- What works for you?
 - Enough for treatment, too much wastes power
 - What is the condition of diffusers & blowers?

Aeration Basin, Oxygen

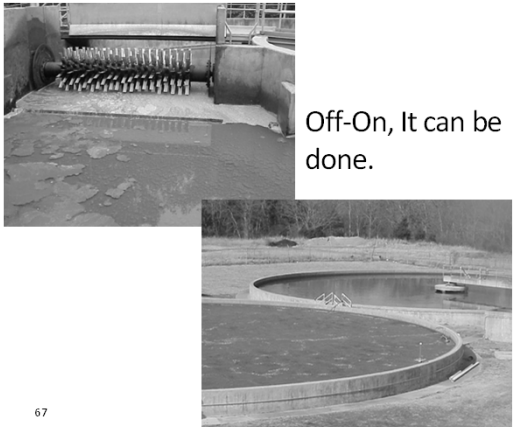
- What is the current D.O.?
 - Profile the basin
 - Different times of day and loading conditions.
 - When D.O. is low aerate more or service equipment
 - When D.O. is high stop aeration
- #1 Activated Sludge Myth
 - You must maintain a D.O. at a predetermined and constant level.

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Off/ On Aeration An Effective Way to Nitrify and Denitrify

- | | |
|---|--|
| <ul style="list-style-type: none"> • Benefits <ul style="list-style-type: none"> • Stop clumping • Recycle oxygen • Recycle alkalinity • Reduce blanket depth • Reduced effluent TSS • Improved settleability • Energy savings <ul style="list-style-type: none"> ▪ As high as 30% | <ul style="list-style-type: none"> • Requirements <ul style="list-style-type: none"> • Aeration capacity to quickly raise D.O. from zero. • Timers or other automation or • Determination to make manual off/ on work • Capable diffusers • Mixing • Cycle determination |
|---|--|

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Off-On, It can be done.

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Off/On Cycle Determination

- Automation: ORP, pH, Alkalinity, On to Ammonia Knee, Off to Nitrate Knee
- ORP, On to 200mV, Off to -50mV
- Calculated based on Oxygen and Nitrate residual / Oxygen uptake rate
- Trial and error
 - Start at 1-2 hr off, check NO₃, D.O., ORP, pH, Alk.

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Aeration Basin, Oxygen

- Target D.O.
 - Thumb rule
 - 1.0 mg/L D.O. for BOD removal
 - 2.0 mg/L D.O. for BOD and ammonia removal
 - Check at the end of aeration.
 - Are you meeting permit limit?
 - Yes
 - Is D.O. high?
 - Could blowers be turned "off?"


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Aeration Basin, Oxygen

- Not meeting Limits?
 - Is D.O. the limiting factor?
 - Check loading
 - Check diffusers
 - Check blowers
 - Check pipelines
 - Do SOUR test

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Check Diffusers



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Clarifiers

- Design Criteria: Chapter 5
 - Purpose 5.1.1
 - Clarifiers are designed to perform 3 functions in a treatment scheme:
 - Remove solids from liquid
 - Remove scum from liquid
 - Thicken solids



Athens, TN clarifier

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Clarifiers

- 5.2 Design Loading
 - Surface loading rate gpd/sq. ft.
 - Average Design Flow
 - Peak Design Flow is a 24hr flow, instantaneous peak flow may be much higher.
 - Solids loading rate lbs/day/sq. ft.
 - Weir loading max. 15,000 gpd/ft
 - Hydraulic detention time
 - HDT in primary clarifiers is not recommended to be greater than 2.5 hrs...since septic conditions...can occur

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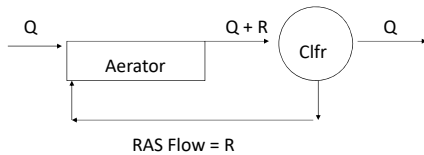
Clarifier Problems

- High Solids Loading
- De-nitrification
- Chemical Dependency
- Flow measurement and distribution
- Short-circuiting currents

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Clarifier Loading

- Solids Load, $\text{Flow} * \text{mg/L} * 8.34 = \text{lbs}$



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Clarifier Loading

- Baseline Knowledge, not regular calculation
- Must know Flow to each Clarifier (balance)
- Must have a measurement of RAS Flow
- Must have MLSS values or Sludge Units
- Must know clarifier area

76

Clarifier Blanket Condition

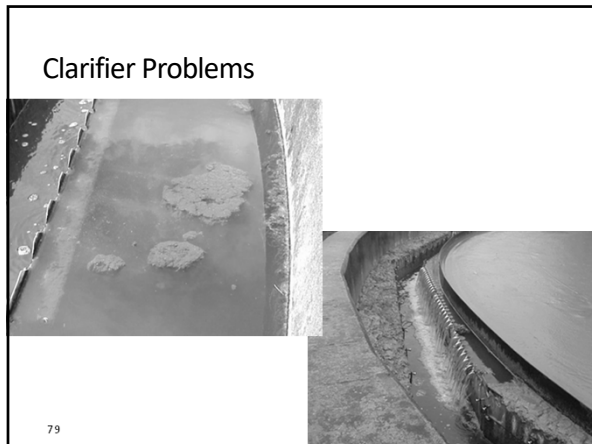
- Sludge Blanket Thickness
- Settleometer, not Graduated Cylinder
- Sludge Volume Index, Thumb rule 80-120 is ideal, another Activated Sludge myth!
 - Plants run outside of design, like highly under loaded startup plants will not follow the rules.

77

Clarifier Blanket Condition

- Denitrification, (clumping)
 - Remove it more quickly,
 - Increase D.O. to stop Denit, Lower D.O. to stop Nitrif.
 - Denitrify in the Aerator (Off/ On aeration)
- RAS Testing
 - Concentration
 - Dissolved Oxygen, minimum approx. 0.2 mg/L
 - pH, Low pH, <6.0su may indicate high CO₂, bug breath

78



Clarifier Chemical Dependency

- Flocculent and coagulant chemicals
- Great short term fix, but costly
- Find the real problem
 - Hydraulic overload
 - Solids overload
 - Biomass condition
 - Too young, Too old, Filamentous

80

Clarifier Short Circuiting

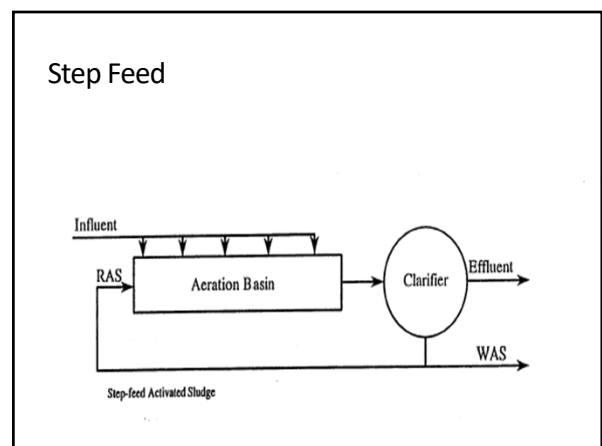
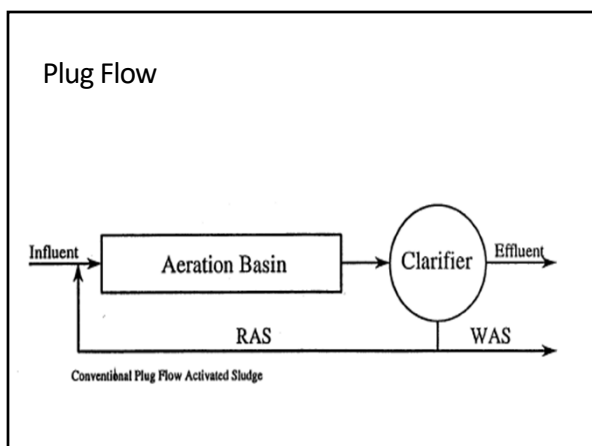
- Number ONE clarifier problem
- Theoretical Hydraulic Detention Time
- Actual Detention Time
 - Dye Dump, watch and time
- Baffles
 - Crosby (Stamford)
 - Center well
 - Flocculating center well

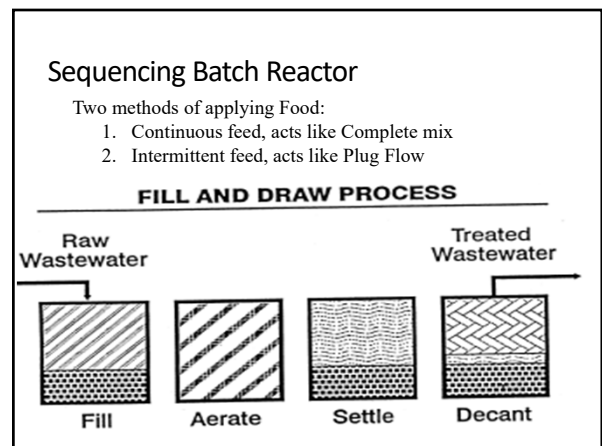
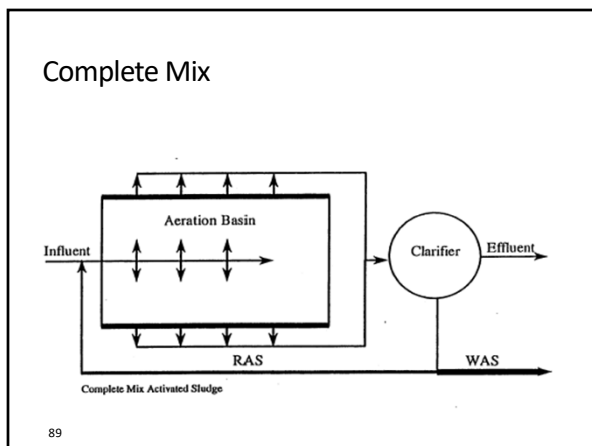
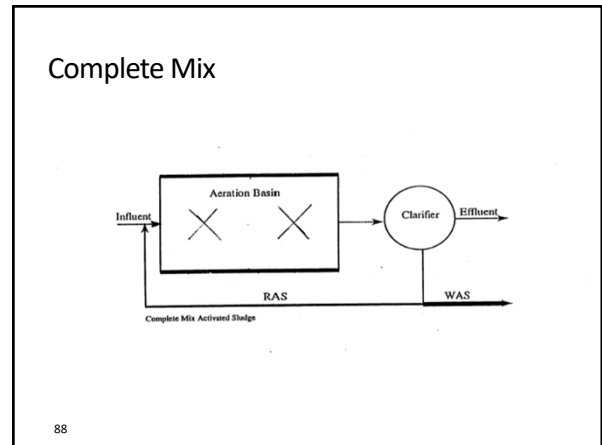
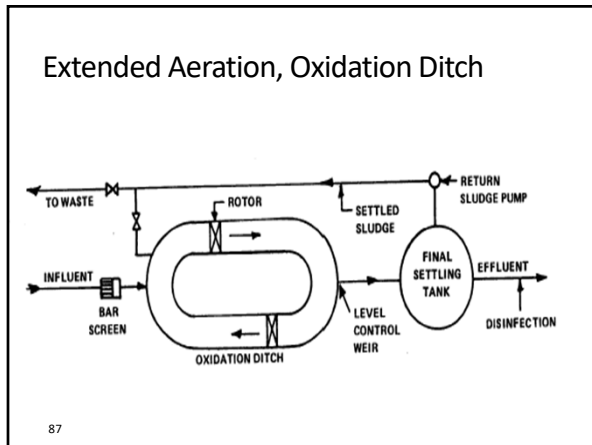
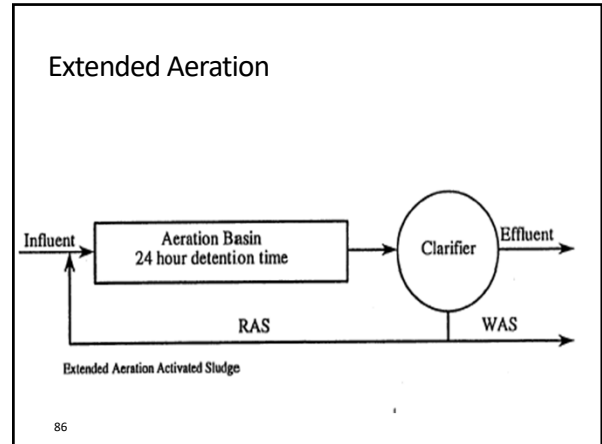
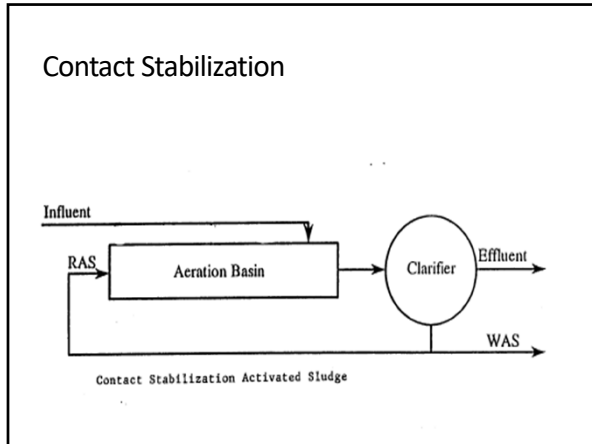
81

Activated Sludge Mode of Operation

- Complete mix
- Plug Flow
- Step Feed
- Contact Stabilization
- Fill and Draw (Sequencing Batch Reactor)
- Operator's most Powerful Tool for adjusting the plant.
 - Location of where the food is applied to the microorganisms

82





Plug Flow to Step Feed

- Strategy to deal with higher hydraulic or organic loads.
- Can reduce solids load to clarifier.
- Allows higher solids inventory in system without increasing load to clarifier.
- Also spreads organic load over more basin to match air or microorganism availability.

91

Changing Mode of Operation

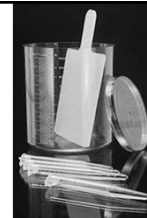
- Single most powerful operational tool!
- Operator Tools
 - Rate of return
 - Rate of wasting
 - Rate of aeration
 - Additional basins or units
 - Flow equalization
 - Industrial pretreatment
 - Change Mode of Operation

92

Activated Sludge, Review

- Definition
- Your plants
- Plant capacity
 - Design Criteria
 - Actual performance
 - Debottlenecking
- Modes of Operation
- Controlling the process

93



ACTIVATED SLUDGE PROCESS CONTROL

94

Process Control Tools

- Adjust
 - Air
 - Return rate
 - Waste rate
 - Mode of operation
 - Number of units used
 - Rate and location of sewage feed
 - Influent control: industrial pretreatment, I/I
- Human senses
 - Visual appearance, odors, noise

95

Process Monitoring Methods

- Process tests = Test performed in the aeration basin and or clarifier that indicate what the effluent quality will be when the water leaves the treatment plant
 - Flow, D.O., pH, temp., alkalinity, ORP, turbidity
 - Settler, Sludge judge
 - MLSS, MLVSS
 - Centrifuge spins
 - Microscopic evaluation
 - Oxygen Uptake Rate, Specific Oxygen Uptake Rate

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Process Control

- Test performed in the aeration basin and or clarifier that indicate what the effluent quality will be when the water leaves the treatment plant.
- Hydraulic Detention Time Delay
- Five day delay for BOD results
- Test which will give quick results & quick response to adjustments!

97

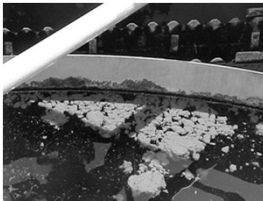
Sensory Process Control

- Odors
 - Fresh plowed field
 - Hog pen
- Turbulence
 - Boiling, dead spots
- Foam and Scum
 - Fresh, crisp, light-colored foam
 - Billowing white foam
 - Thick, scummy, dark foam



98

Sensory Process Control



- Clarifier
 - Bulking, sludge quality
 - Billowing, hydraulic overload
 - Clumping, denitrification
 - Ashing/Pin Floc, old sludge
 - Straggler Floc, young sludge

99

Process Control Tests

- Flow Rates, accurate flow measurements of premier importance.
- Locations
 - Influent Q
 - RAS,WAS, other
- Dissolved oxygen
 - Aeration tank effluent
 - Profiles-longitudinal, vertical

100

Process Control, continued

- pH
 - Indicator of toxicity
 - Indicator of nitrification problems
- Temperature
 - Use D.O. meter
 - Affects speed of bacterial metabolism, or perhaps no metabolism!

101

Process Control, continued

- Alkalinity
 - Necessary for complete nitrification
- ORP-Oxidation Reduction Potential, Redox
 - pH meter with ORP probe
 - Indicated the oxidative state of the solution
- Turbidity
 - Indicator of completeness of flocculation

102

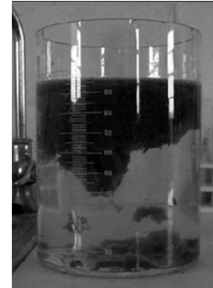
Process Control, continued

- **Settleometer**
 - Use settleometer not graduated cylinder
 - Indicator of clarifier performance
 - How well the biomass- settles and compacts
 - May give mixed signals
- **Sludge Judge, MLSS, MLVSS Centrifuge spins**
 - Indicators of biomass inventory

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Settleometer

- Basic Process Control
- 5min, How fast sludge settles
- 30 min, How well sludge compacts
- Supernatant turbidity, how well sludge flocculates
- Denitrification



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Settleometer

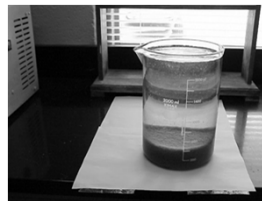
- **Reasons for NO Settling**
 - Dispersed Growth
 - Biomass Dead
- **Reasons for Slow Settling**
 - Young Biomass
 - Too much Biomass
 - Filaments



105

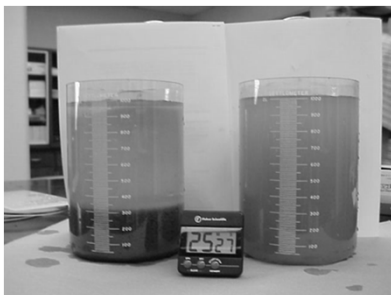
Settleometer

- **Reasons for fast Settling**
 - Old, over oxidized sludge with turbid supernatant
 - But wasting is not always the correct reaction,
 - Check color, history & SOUR



106

5 min. Normal, Dispersed



107

10 min.



108

15 min.



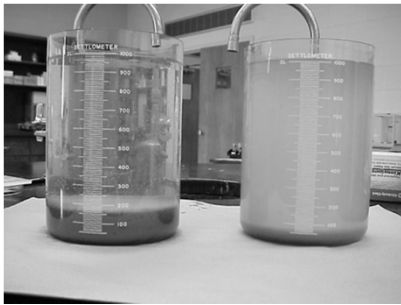
109

30 min.



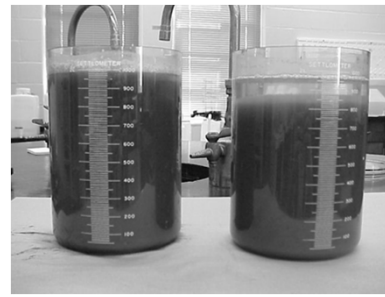
110

30 min. Right side dispersed growth settles poorly



111

30 min. Diluted Settles Better, Waste!



112

Biomass Inventory

- Inventory of Biomass should answer three questions
 - How much sludge is in the system?
 - Where is it located?
 - How long has it been there?
- Experience has shown us certain sludge ages give us certain effluent qualities.
- With these answers, process control is easy

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Biomass Inventory



- Suspended Solids
 - Aerator
 - Clarifier Core
 - Return Sludge
- Calculate pounds, age
- Thumb Rules
 - BOD Removal
 - MCRT, 0.5-1 Day
 - Ammonia Removal
 - MCRT 4-15 Days
 - Always exceptions!

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Microscopic Evaluation

- Flock analysis, Tab 9 Jenkins' Book
 - General shape, size, dispersed cells
- Protozoan/ Metazoan counts
 - General indicator of sludge age
- Filaments
 - Abundance, inside/outside flock, bridging
 - Non-Phase microscope, ID- Nocardia, Beggiatoa
- Slime Bulking
 - India ink test

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Oxygen Uptake Rate

- Rate at which microorganisms use oxygen
 - Indicator of speed of metabolism
 - Indicator of toxicity
 - Indicator of food abundance or ease of metabolism
- OUR varies with solids concentration
- SOUR accounts for solids variation
 - Commonly called
 - Respiration Rate

116

OUR/SOUR Testing



- Use Mixed Liquor
- ***Do Very quickly***
- SOUR needs MLVSS
- Graph and calculate
- Compare to book or historic values.

117

SOUR Values

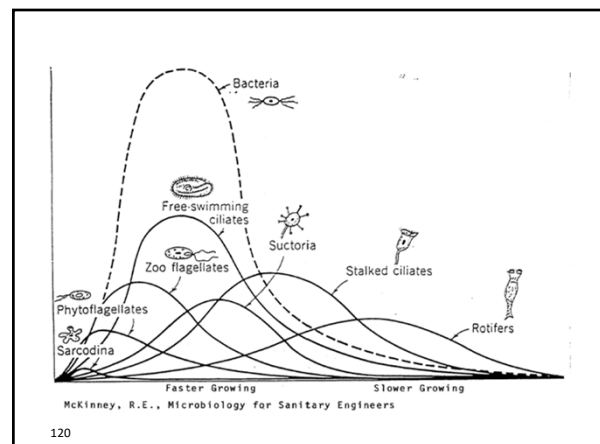
- SOUR >20mg O₂/hr/gm MLVSS
 - Logarithmic growth, Flagellates, dispersed flock
 - Settling Slow SSV₅>750cc/L
- SOUR 12-20mg O₂/hr/gm MLVSS
 - Declining growth, Ciliates, Flocks forming
 - Settling normal SSV₅=600-750 cc/L

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SOUR Values

- Sour <12mgO₂/hr/gm MLVSS
 - Endogenous Respiration, Rotifers and higher life
 - Pin Flock
 - Settling Fast, SSV₅<600cc/L
- Remember the growth graph

119



120

Process Control

- Choose a method that works for you.
- Collect the Data.
 - Data is the voice of the process.
- Use the Data!
- Make decisions based on the data!
- Graph the Data!
 - Picture of the numbers, picture of the process.
 - Control Charts

121

Process Control

- Human senses
 - Visual appearance, odors
- Process tests
 - Flow, D.O., pH, temp., alkalinity, ORP, turbidity
 - Settleometer, Sludge judge
 - MLSS, MLVSS
 - Centrifuge spins
 - Microscopic evaluation
 - Oxygen Uptake Rate, Specific Oxygen Uptake Rate

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Long Term Process Control

- F:M
- Food to Microorganism Ratio
- $\frac{\text{lbs. of Raw BOD}}{\text{lbs. of MLVSS}}$
- Even bugs want a adequate diet.
- Always at least 5 days late
 - Dependent on BOD

123

Review

- Characteristics of Activated Sludge
 - Flocculent M.O. Slurry, Settling, RAS,WAS
- Plant Capacity
 - Design, Actual, Debottlenecking
- Mode of Operation
 - The most powerful operator tool
- Process Control
 - Tests that document that the process will produce compliant clean water

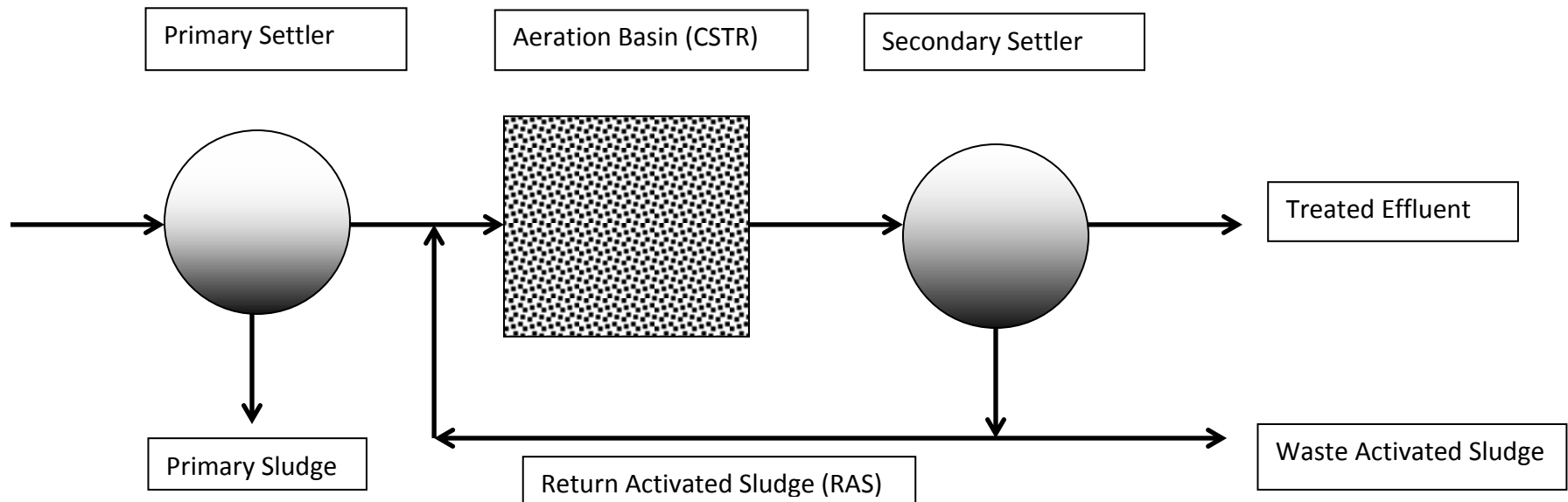
124

Any Questions?

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ACTIVATED SLUDGE PROCESS SCHEMATICS

COMPLETELY MIXED ACTIVATED SLUDGE PROCESS



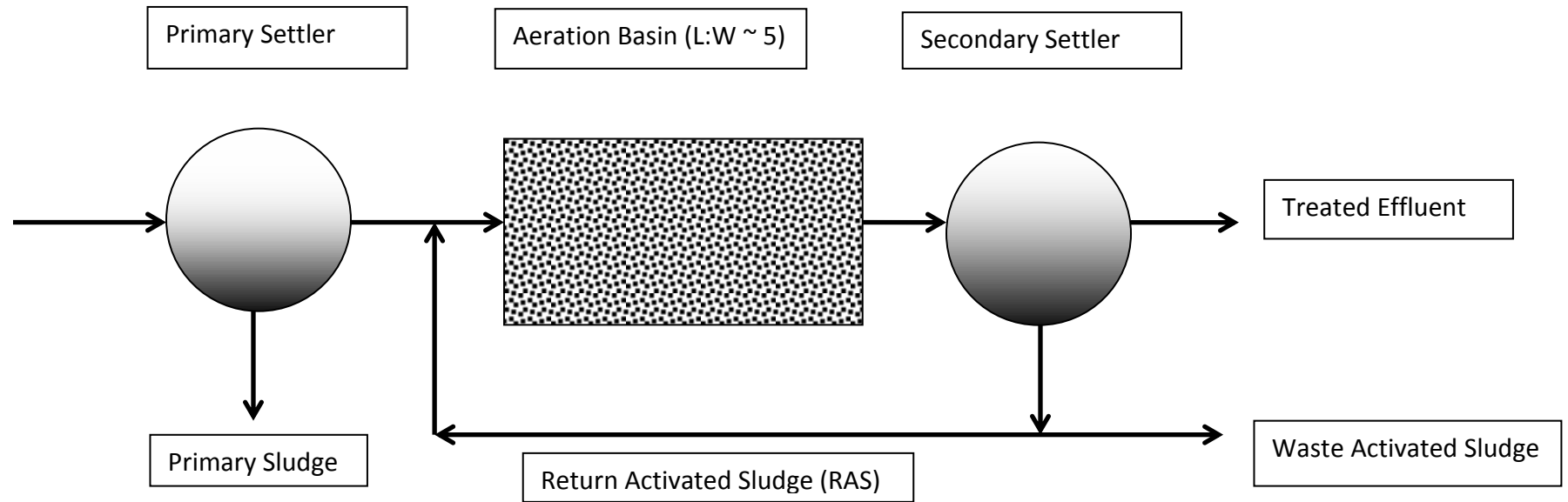
Advantages

1. Allows good nitrification since COD is uniformly low
2. Able to handle peak loads and dilute toxic substances
3. Used in smaller systems, like package plants

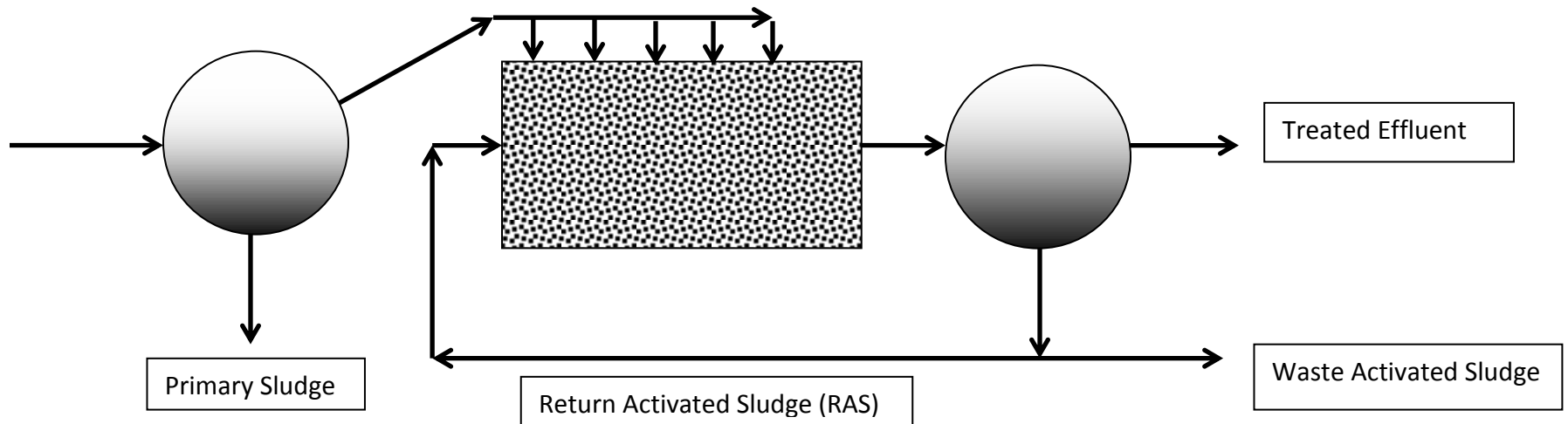
Disadvantages

1. Larger volume, high aeration costs
2. Not much operational flexibility
3. Associated with biomass instabilities like sludge bulking

CONVENTIONAL DISPERSED PLUG FLOW ACTIVATED SLUDGE PROCESS



STEP FEED MODIFICATION



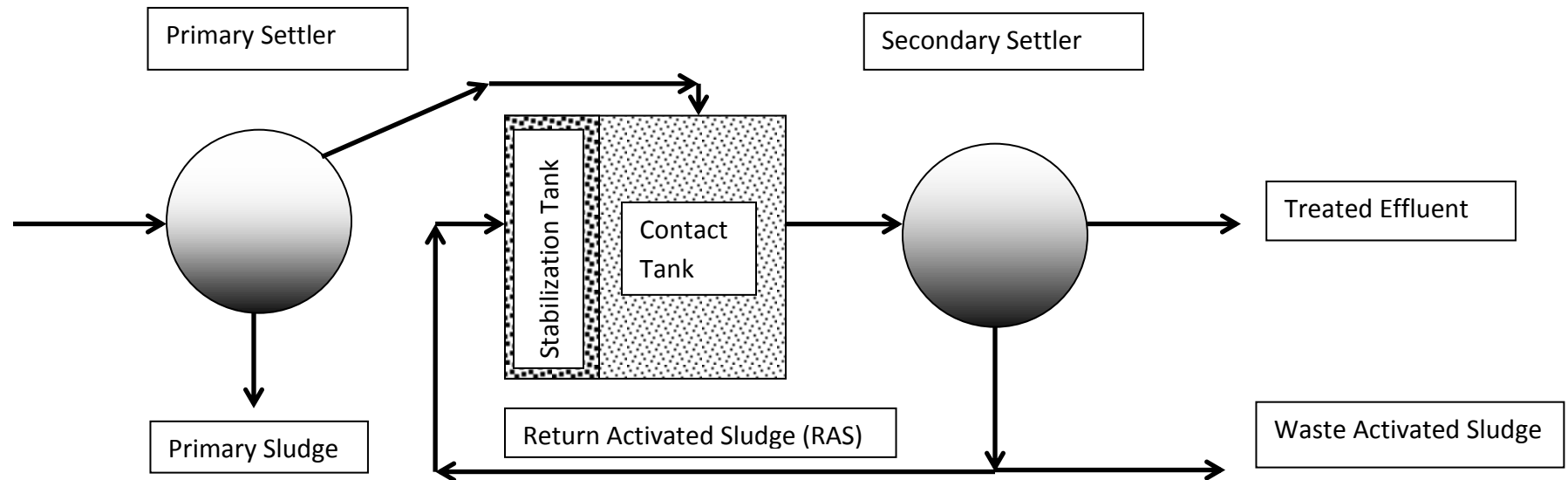
Advantages of Conventional Dispersed Plug Flow Process

1. Allows smaller volume than CSTR
2. Flexible operation, zone aeration, step feeding options, accommodates anoxic and aerobic processes with single biomass for biological nutrient removal
3. Less aeration than CSTR
4. Reduced mixing requirement, per unit reactor volume
5. Better settling characteristics

Disadvantages

1. High oxygen demand in inlet zone – mitigated by step feeding
2. May not buffer peak loads as well as CSTR, although less likely in activated sludge with high biomass
3. Higher construction costs due to serpentine flow in baffled reactor.

CONTACT STABILIZATION ACTIVATED SLUDGE



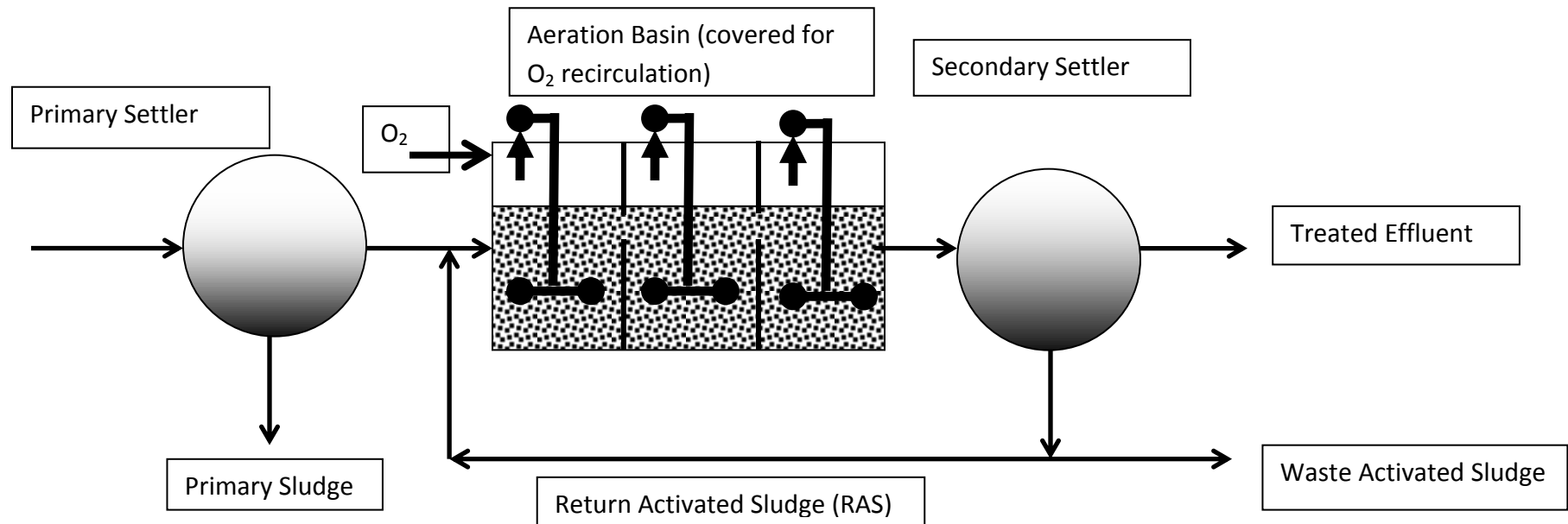
Advantages

1. Reduced aeration requirement with short contact tank residence time
2. Reportedly better settling sludge

Disadvantages

1. Complex operation
2. Possible reduced treatment for soluble contaminants in contact tank
3. Reduced ammonia removal

HIGH PURITY OXYGEN ACTIVATED SLUDGE



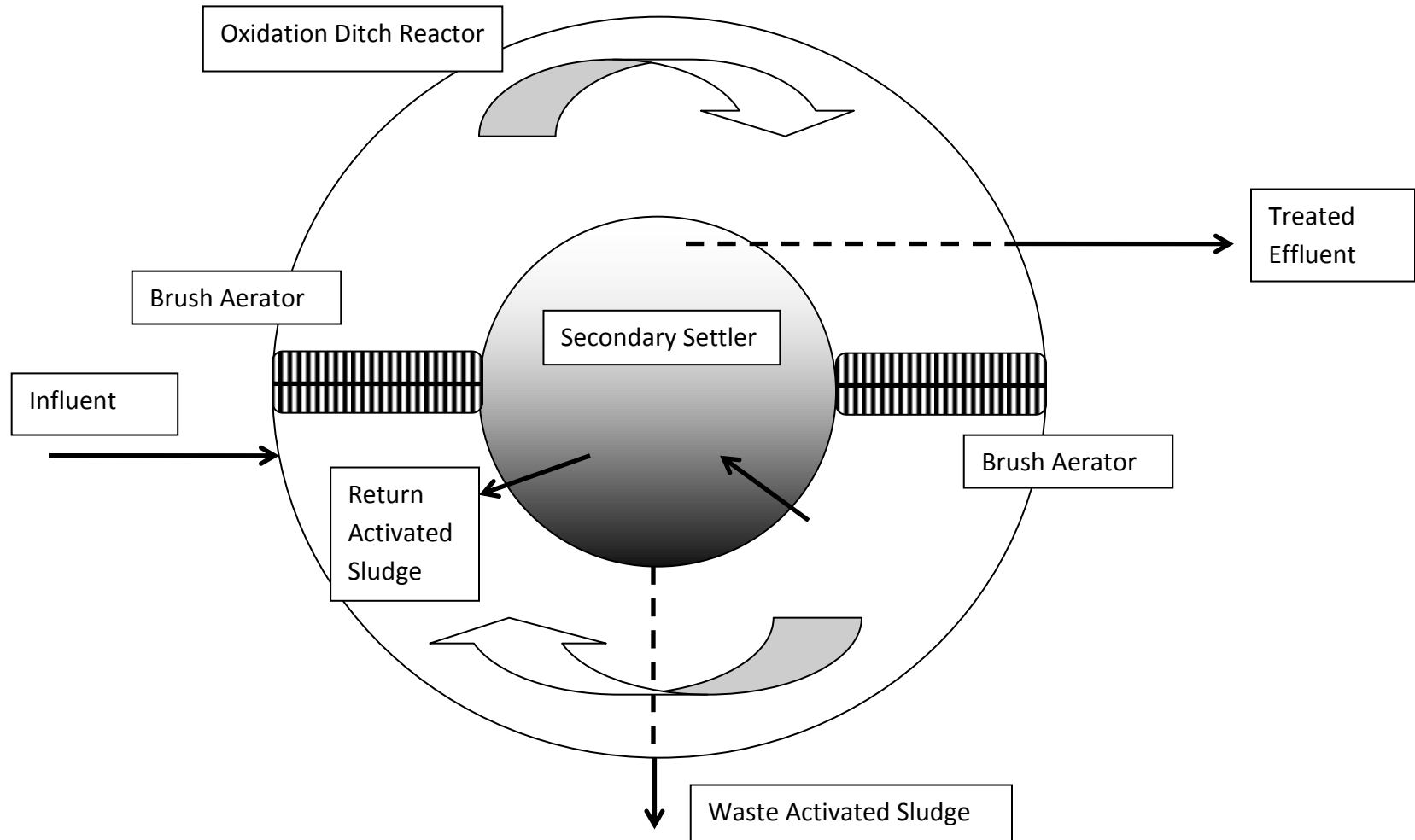
Advantages

1. Five times oxygen transfer rate over air
2. Smaller volume
3. Higher biomass concentration possible, but limited by secondary settler capacity

Disadvantages

1. Very expensive: covered tanks, high energy cost for O₂ generation, gas recirculation equipment
2. Headspace CO₂ accumulation and associated pH drop requires alkalinity addition
3. No flexibility (all aerobic processes)
4. Nitrification is problematic – low pH, short HRT produces high biomass at short SRT
5. Settling problems have been reported

OXIDATION DITCH (EXTENDED AERATION) ACTIVATED SLUDGE PROCESS



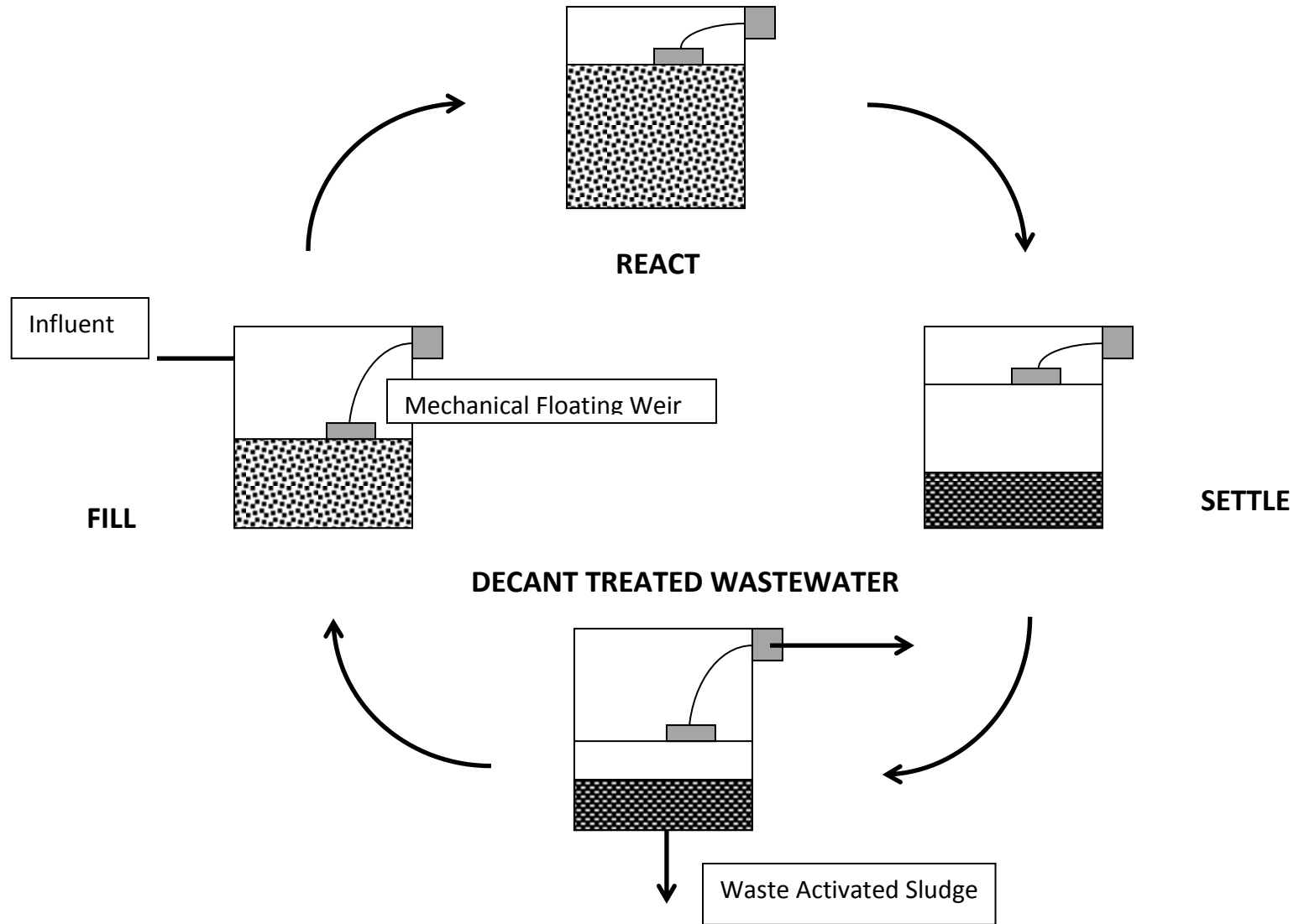
Advantages of Extended Aeration Oxidation Ditch

1. Typically small systems – less than 2 MGD (5 m³/min)
2. Flexible operation with placement and use of aerators – can be used for nutrient removal
3. Very stable process
4. No primary clarifier – simpler sludge handling
5. Good settling characteristics

Disadvantages

1. Long aeration time, larger reactor. Typical HRT > 24 hr.
2. Higher aeration requirement due to typically long SRT
3. Mechanical aeration equipment (rotors, large turbines) required to move water around the channel as well as aerate. Can create zones of high oxygen and add maintenance costs. More recent designs use diffusers for aeration and reduce mechanical requirement.

SEQUENCING BATCH REACTOR (SBR) ACTIVATED SLUDGE PROCESS



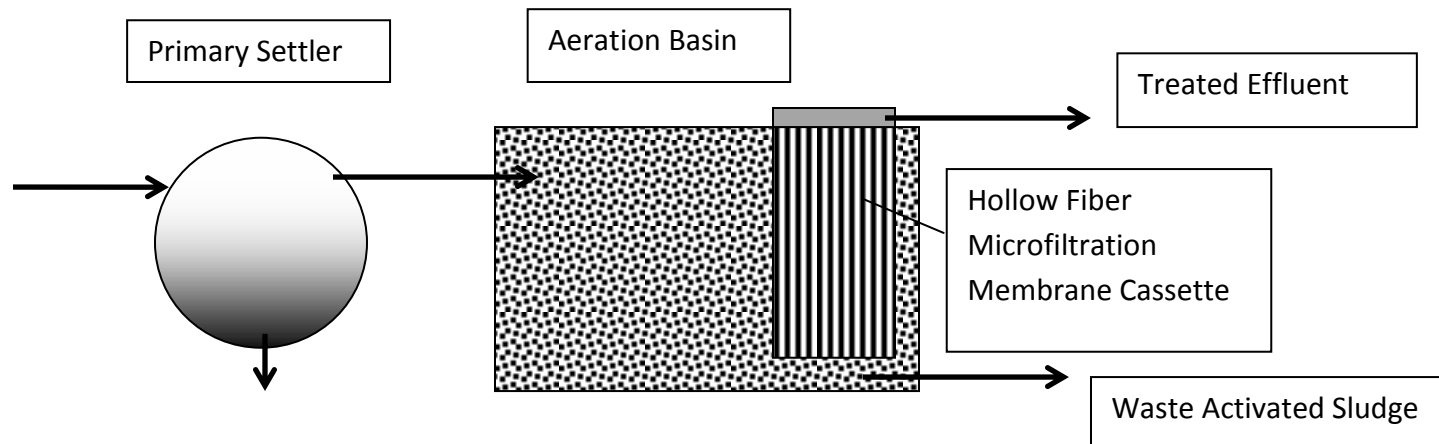
Advantages of Sequencing Batch Reactor (SBR) Process

1. Single tank for reaction and settling (requires two or more tanks for continuous operation)
2. Good settling (quiescent conditions) and no sludge storage
3. Flexible operation, automation possible
4. Typically for smaller plants
5. Often no primary clarifier – easier sludge handling

Disadvantages

1. Special decanting and aeration equipment (can't use diffusers in tank)
2. Need to recycle early decant if solids in weir trough
3. Setting system sequences (fill/decant/reaction times) can be complex, especially if anoxic denitrification is required

MICROFILTER MEMBRANE BIOREACTOR (MMBR)



Advantages

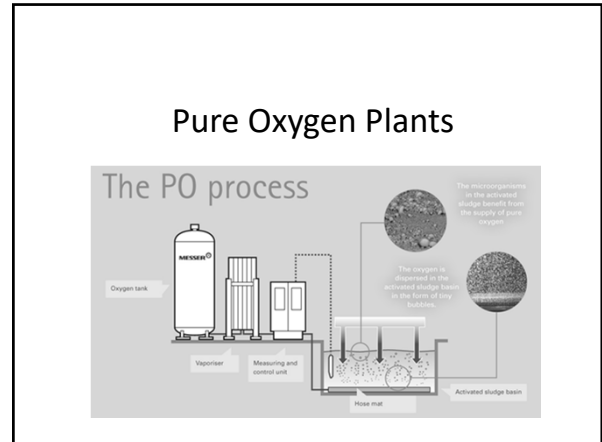
1. No secondary clarifier, virtually no effluent suspended solids, no RAS recycling
2. Maintains high MLVSS
3. Compact footprint
4. Primary clarifier optional

Disadvantages

1. Very high aeration requirements
2. Dual aeration system for mixing and to prevent fouling
3. Time-consuming membrane cleaning procedure
4. High capital costs for membrane system
5. Extra power requirements for vacuum on microfilter
6. Waste activated sludge is not thickened – larger volume to solids processing
7. Broken membranes result in low effluent quality

Pure Oxygen Systems

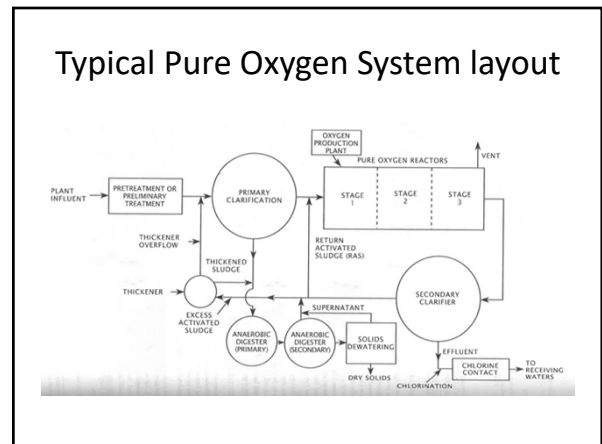
Advanced Wastewater Class



- ### Pure Oxygen Systems
- Dissolve high purity oxygen into WW with a high efficiency for use by microorganisms
 - This allows the use of smaller aeration tanks
 - Improved settleability and dewaterability of sludges
 - Offers most efficient treatment with smallest footprint

- ### Pure Oxygen Systems
- Pure oxygen rather than air is released below the surface or driven into the water by means of surface aerators
 - Diffuser mechanisms
 - Mechanical agitation
 - Turbulent mixers and surface aerators
 - Aerators are covered
 - [Video](#)

- ### Pure Oxygen Systems
- Reactors are “staged” (divided into 2-5 sections by baffles) and completely covered
 - Wastewater, return sludge, and oxygen are fed into 1st stage
 - Increased efficiency of oxygen use by capturing head space gases from prior stages and recycling them into subsequent stages



Moccasin Bend WWTP – Chattanooga Pure Oxygen Plant

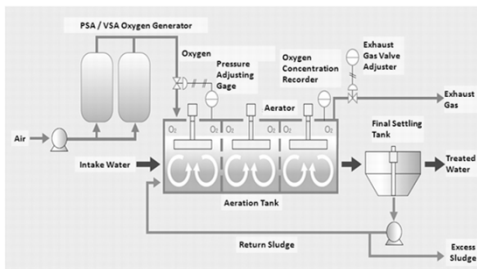


Moccasin Bend WWTP – Chattanooga Pure Oxygen Plant



- [Video](#)

Pure Oxygen System: UNOX



Pure Oxygen Systems

- Pressure maintained to prevent:
 - air from leaking into the reactors
 - diluting the oxygen concentration
 - possibly creating an explosive mixture
- Pure oxygen may be used to supply oxygen to any AS process mode
 - Conventional, step-feed, complete mix, or contact stabilization

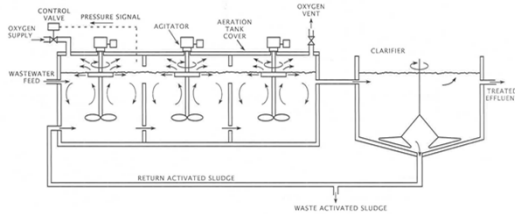
Pure Oxygen Systems

- In each of the succeeding stages, the gas above the mixed liquid in that state is reinjected into the ML
- As oxygen rich gas passes from one stage to the next, the oxygen is used by the AS microorganisms
- Atmosphere becomes more diluted by the CO₂ produced by the organisms
- Nitrogen is stripped from the solution

Pure Oxygen Systems

- Last stage has oxygen vent valve
 - Vents gas from last stage to atmosphere
 - Normally set to vent gas when the oxygen concentration drops below 50%
- As more gas is vented from last stage, more pure oxygen is released into 1st stage to maintain the desired 1-4 inches of water column pressure

Pure Oxygen System with surface aerators



Pure Oxygen Systems

- Control Guidelines:
 1. Reactor Vent Gas – mixture of unused oxygen, inert gases, and CO₂ is continually discharged from last stage of reactor
 - Low oxygen purity reading (25% or below) = sufficient oxygen not present
 - BOD removal may not occur
 - High oxygen purity reading (50% or higher) = too much oxygen being wasted with the by-product gas

Pure Oxygen Systems

- Control Guidelines:
 2. Reactor Gas Space Pressure
 - Gas space pressure is set by controlling the vent rate in last stage
 - This will automatically establish the pressure level throughout the reactor
 - During high loadings, increase oxygen transfer and production by increasing pressure set point

Pure Oxygen Systems

- Control Guidelines:
 3. Dissolved Oxygen
 - DO probe can be located in diversion box prior to secondary clarifier or in last stage of reactor
 - Indicates amount of DO in ML
 - Typically operate with range 4-10 mg/L
 - If organic load increases, which would drop DO level, adjust vent valve to more open position, which will increase oxygen production

Pure Oxygen Systems – Process Safety

- Potentially explosive or flammable conditions can be present when pure oxygen is mixed with any hydrocarbon
 - Gasoline, fuel oil, lubricating oils
- Requires additional safety devices:
 1. Lower Explosive Limit Combustible Gas Detector
 2. Liquid Oxygen Low Temperature Alarm
 3. Emergency Trip Switch



Pure Oxygen Systems – Process Safety

1. Lower Explosive (LEL) Combustible Gas Detector – Indicates potential explosive conditions within the reactor, analyzes samples from 1st and last stages
 - Air will automatically be directed to the reactor gas space to purge the system
 - Purge will continue until normal readings are obtained
 - Also install LEL combustible gas detector at headworks

Pure Oxygen Systems – Process Safety

2. Liquid Oxygen (Storage Tank) Low-Temperature Alarm – alarm and shutdown of liquid storage system if heated water recirculation within the vaporizer reaches a low level temp
 - If vapor falls below -10 degrees F
 - -20 degrees F triggers shutdown

Pure Oxygen Systems – Process Safety

3. Emergency Trip Switch –unsafe conditions within the compressor system, liquid oxygen system, or electrical panels
 - Manual switch
 - Last resort
 - Located away from source of danger in easily accessible location



Any Questions?



Activated Sludge Operational Control Options

Advanced Wastewater Class

Activated Sludge Process

- Very complex process
- Quality of effluent depends on:
 - Characteristics of plant influent flows
 - How the actual process is controlled
- 2 very important factors:
 1. Return Activated Sludge (RAS) rate
 2. Waste Activated Sludge (WAS) rate

Activated Sludge Process

- Biological Nitrification
 - Converting ammonium (NH_4^+) to nitrate (NO_3^-)
 - Most effective way to remove ammonia unless total nitrogen removal is required
 - If total nitrogen (TN) removal required: Nitrification-Denitrification
 - Extension of activated sludge process

NH_4 (ammonia) → NO_2 (nitrite) → NO_3 (nitrate)

Return Activated Sludge

- RAS – the MLSS settled in a clarifier and then returned to the aeration tank
- RAS makes it possible for microorganisms to be in the system longer than the flowing wastewater
- For conventional AS operations, RAS is usually 20-40% of the incoming wastewater flow

Return Activated Sludge

- 2 Basic Approaches:
 1. Controlling RAS flow rate independently from the influent flow
 2. Controlling RAS flow rate as a constant percentage of the influent flow

Constant RAS Flow Rate Control

- Continuously changing MLSS concentration
 - MLSS at min during peak influent flows
 - MLSS at max during low influent flows
- Aeration tank and 2^o clarifier must be looked at as a system in which MLSS are stored in the aeration tank during min. flow and transferred to clarifier as flows increase

Constant Percentage RAS Flow Rate Control

- A programmed method for maintaining a RAS flow rate that is a constant % of influent flow rate
- Theoretically designed to keep the MLSS more constant through high and low flow periods

Comparison of RAS Control Approaches

| | |
|--|--|
| <p>Constant RAS Flow</p> <ul style="list-style-type: none"> • Simplicity • Maximum solids loading on the clarifier occurs at start of peak flows • Requires less operational time • F:M ratio constantly changing | <p>Constant % RAS Flow</p> <ul style="list-style-type: none"> • Variations in MLSS concentration are reduced and the F:M ratio varies less • The MLSS will remain in the clarifier for shorter time periods, which may reduce the possibility of denitrification in the clarifier • Clarifier subjected to max hydraulic loading when reactor has max sludge so solids washout may occur |
|--|--|

Methods of RAS Flow Rate Control

- Most commonly used techniques to set the rate of sludge return flow:
 1. Monitoring depth of sludge blanket
 2. Settleability approach
 3. SVI (Sludge Volume Index) approach

Sludge Blanket Depth

1. Series of air lift pumps mounted within the clarifier at various depths
2. Gravity flow tubes located at various depths
3. Electronic sludge level detector
4. Sight glass finder
5. Plexiglass core sampler (Sludge Judge)
6. Some type of portable pumping unit with a graduated suction pipe or hose (siphon)

Sludge Blanket Depth

- Should be kept from 1 – 3 feet as measured from clarifier bottom at the sidewall.
 - Measurements made at same time each day
 - Best time is during period of max daily flow
 - Measure daily
- Adjust RAS to control blanket depth at a level that provides the highest effluent quality

TABLE 2.2 STANDARD OPERATING PROCEDURES FOR RAS CONTROL

| Process | RAS Control Method | Mode of Operation | What to Check | Frequency of Adjustment | When to Check | Condition | Probable Cause | Response |
|---------------------------------|-----------------------------|--------------------|--------------------|-------------------------|--------------------------|--|---|--|
| Complete Mix or Plug Flow | Constant Flow | Manual | Sludge Blanket | Daily | Every 8 Hr | High Satisfactory Low | Low RAS Rate — High RAS Rate | Increase Return Continue Monitoring Decrease Return |
| | | | % of Influent Flow | 2 Hr | Every 2 Hr | High Satisfactory Low | Variations in Daily Influent Flow | Adjust to Desired % of Influent Flow |
| | Constant % of Influent Flow | Manual | Sludge Blanket | Daily | Every 8 Hr | High Satisfactory Low | % of Flow Too Low — % of Flow Too High | Increase % of Flow Continue Monitoring Decrease % of Flow |
| | | | % of Influent Flow | Daily | Every 8 Hr | High Satisfactory Low | % of Flow Too Low — % of Flow Too High | Increase % of Flow Continue Monitoring Decrease % of Flow |
| Constant % of Influent Flow | Automatic | Sludge Blanket | Daily | Every 8 Hr | High Satisfactory Low | % of Flow Too Low — % of Flow Too High | Increase % of Flow Continue Monitoring Decrease % of Flow | |
| | | % of Influent Flow | Daily | Every 8 Hr | High Satisfactory Low | % of Flow Too Low — % of Flow Too High | Increase % of Flow Continue Monitoring Decrease % of Flow | |
| Control by Sludge Blanket Level | Automatic | Sludge Blanket | Daily | Every 8 Hr | High or Low Satisfactory | High Ratio — Low Ratio | Return Too High — Return Too Low | Fit Controller or Manually Adjust Accordingly Continue Monitoring |
| | | | | | | | Return Too High — Return Too Low | Decrease Return Continue Monitoring Increase Return |

Settleability Approach

- Based on results of the 30 minute settling test
- Settleability = the percentage of volume occupied by the sludge after settling for 30 minutes
- Sample collected from aeration basin

Settleability Approach

- Assumes that measurements made with settling cylinder will accurately reflect the settling in a clarifier
- "Benchtop Clarifier"
 - Mallory Settleometer
 - Wide mouth beaker
 - Graduated cylinder – the narrow shape hinders settling and gives different readings

Settleometer

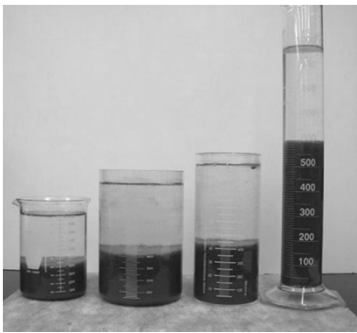


Photo by Brett Ward

Settleability Approach

- Determine the RAS flow as a percentage of the influent flow in MGD when the influent flow is 7.5 MGD and the sludge settling volume (SV) in 30 minutes is 275 mL/L.

$$\text{RAS Flow, \%} = \frac{\text{SV, mL/L} \times 100\%}{1,000 \text{ mL/L} - \text{SV, mL/L}}$$

Settleability Approach

- Another way to calculate the RAS flow as a percentage of the influent flow is by using a chart
 - Find SV value on y axis
 - Draw a vertical line up to curve
 - Draw horizontal line from that point to left vertical axis

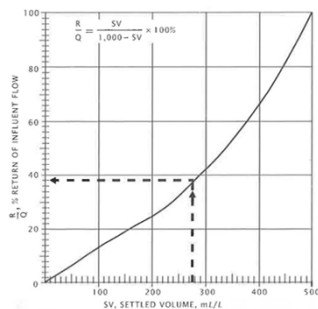


Fig. 2.7 Chart for calculating return sludge flow

SVI Approach

- Sludge Volume Index (SVI) – a calculation that indicates the tendency of AS solids to thicken or become concentrated during the sedimentation/thickening process
 - Incorporates the SSV_{30} value and MLSS concentration
- The volume in mL occupied by 1 gram of MLSS after 30 min of settling

SVI Approach

- $SVI, \text{ mL/g} = \frac{\text{Settled Sludge Volume (30 min), mL/g}}{\text{Mixed Liquor suspended Solids}}$
- The real value in the SVI is not in calculating the RAS flow, but in its use as a process stability indicator
- Changes in the SVI at a constant MLSS are more important than the value

Effects of Changes on RAS aeration time

TABLE 2.3 EFFECTS OF CHANGES ON RETURN SLUDGE AERATION TIME (RSAT)

| Process Control Guidelines | Change Made | Effect on SVI | | Effect on Nitrification | |
|--|---------------|---------------------|----------|-------------------------|----------|
| | | Increase | Decrease | Increase | Decrease |
| Sludge Change | Increase RSAT | | x | | x |
| | Decrease RSAT | x | | x | |
| Return Sludge Flow | Increase | x | | | x |
| | Decrease | | x | x | |
| Process Air Rate (DO) | Increase | | x | x | |
| | Decrease | x | | | x |
| Plant Loading lbs COD or BOD per 100 local plant MLVSS | Increase | Increase Plant Q | x | | x |
| | | Decrease MCRT | | | x |
| | Decrease | Decrease Plant Q | | x | x |
| | | Increase MCRT | | | x |

NOTES:
 1. Changes made in the aeration system are reflected in the secondary clarifiers by how well the sludge settles.
 2. When making a process change, you must consider what changing one control guideline does to the others.
EXAMPLE: a. An increase in the return sludge flow will decrease the Return Sludge Aeration Time (RSAT).
 b. An increase in the process air rate is like increasing the RSAT.
 c. An increase in plant Q can result in a return sludge increase.
 d. An increase in the return sludge flow can cause a step change that was made to increase the RSAT.

Waste Activated Sludge

- One of the most important controls
- Amount of WAS impacts:
 1. Effluent quality
 2. Growth rate of microorganisms
 3. Oxygen consumption
 4. Mixed liquor settleability
 5. Nutrient quantities needed
 6. Occurrence of foaming/frothing
 7. Possibility of nitrifying

Waste Activated Sludge

- Objective: Maintain a balance between the microorganisms under aeration and the amount of incoming BOD (food)
- Growth rate = the increase in activated sludge in one day
- Remove the amount of microorganisms that grow in excess of the death rate
- “steady state” is desirable

Waste Activated Sludge

- Approach “steady state” by controlling:
 1. Sludge Age
 2. F:M (Food to Microorganism Ratio)
 3. MCRT (Mean Cell Residence Time)
 4. Volatile Solids Inventory
 5. MLVSS Concentration
- Best mode of process control = the one that produces high-quality effluent

Waste Activated Sludge

- Remove a portion of RAS
 - Takes advantage of the gravity settling and thickening that occurs in 2nd clarifier
- Remove from mixed liquor in aeration tank
 - Advantage is not wasting excess amounts of sludge since a large quantity of ML is involved
- Pumped to Thickening, Dewatering, Digestion, Biosolids facility

Waste Activated Sludge (WAS)

- Solids removed from the activated sludge process.

The diagram illustrates the process of Waste Activated Sludge (WAS) removal. It shows a 'Biological Reactor' on the left and a 'Clarifier' on the right. An arrow points from the Biological Reactor to the Clarifier. Below the Biological Reactor, an arrow labeled 'WAS' points down to the text 'To solids handling process'. Similarly, below the Clarifier, an arrow labeled 'WAS' points down to the text 'To solids handling process'.

Methods of WAS - Sludge Age

- Sludge age = the length of time a particle of SS has been undergoing aeration in the AS process
- Sludge Age, days = $\frac{\text{SS Under Aeration, lbs}}{\text{SS Added, lbs/day}}$
- Disadvantage: BOD/solids ratio fluctuates
- In most AS plants, sludge age ranges from 3-8 days

Methods of WAS - F:M

- Food to Microorganism Ratio = ensures the AS process is being loaded at a rate that the microorganisms in the MLVSS are able to use most of the food supply in the ww being treated
- Too much or too little food can cause operating problems and effluent quality could drop

Methods of WAS – F:M

1. “Food” concentration is estimated by BOD or COD tests
2. The amount of food applied is important to F:M calculation
3. Quantity of microorganisms is represented by MLVSS concentration
4. Operation by or calculations of the F:M ratio should not be based on daily tests – can use 7 day moving average

Methods of WAS – F:M

F:M = $\frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$

TABLE 2.5 TYPICAL RANGES FOR F/M LOADINGS

| | Conventional AS Range F/M | Extended Aeration F/M | High-Rate Range F/M |
|------------------|---------------------------|-----------------------|---------------------|
| BOD | 0.1 to 0.5 | 0.05 to 0.1 | 0.5 to 2.5 |
| COD ^a | 0.06 to 0.3 | 0.03 to 0.06 | 0.3 to 1.5 |
| TOC ^b | 0.25 to 1.5 | 0.1 to 0.25 | 1.5 to 6.0 |

^a Assumes BOD/COD for settled wastewaters = 0.6.
^b Assumes BOD/TOC for settled wastewaters = 2.5.

Methods of WAS - MCRT

- Mean Cell Residence Time = the average time that a microorganism will spend in the AS process
- Allows the operator to control the organic loading
- A logical way to calculate how much to waste

Methods of WAS - MCRT

- The MCRT also determines type of microorganisms present
 - Direct influence on the degree of nitrification
- MCRT 15-20 days will generally produce nitrified effluent
- MCRT 5-10 days will generally **not** produce nitrified effluent
 - *Unless wastewater temps are unusually high*

Methods of WAS - MCRT

TABLE 2.6 MCRT NEEDED TO PRODUCE A NITRIFIED EFFLUENT AS RELATED TO THE TEMPERATURE

| Temperature, °C | MCRT, Days |
|-----------------|------------|
| 10 | 30 |
| 15 | 20 |
| 20 | 15 |
| 25 | 10 |
| 30 | 7 |

Methods of WAS – Volatile Solids Inventory

- If wasting is done from RAS, you must measure the volatile suspended matter in RAS to obtain average concentrations
 - RAS VSS, mg/L
- You also must determine if volatile suspended matter is constant, increasing, or decreasing in the aeration tank
- If continuous wasting is practiced, you should check the RAS volatile suspended solids at least once every shift and make the appropriate WAS flow adjustments

Methods of WAS – Volatile Solids Inventory

Assuming volatile solids in aeration tank stays constant:

- If RAS volatile conc is decreasing, the WAS flow rate must be increased
- If there is an increase in the RAS volatile conc, the WAS flow rate must be decreased

Assume aeration tank volatile solids matter constant.

| MLVSS CONTENT | RAS VOLATILE CONTENT | → | WAS FLOW RATE |
|---------------|----------------------|---|---------------|
| Constant | Decreases | → | Increase |
| Constant | Increases | → | Decrease |

Assuming volatile solids in aeration tank is changing:

- Decrease in volatile content causes decrease in RAS, you must decrease RAS wasting
- Increase in volatile content causes increase in RAS volatile solids, you must increase WAS wasting

Assume aeration tank volatile solids matter changes.

| MLVSS CONTENT | RAS VOLATILE CONTENT | → | WAS FLOW RATE |
|---------------|----------------------|---|---------------|
| Decrease | Decrease | → | Decrease |
| Increase | Increase | → | Increase |

Methods of WAS - MLVSS

- Mixed Liquor Volatile Suspended Solids
- Maintain a constant MLVSS concentration in the aeration tank to treat the incoming ww organic load
- Commonly used
- Ex: If MLVSS of 2,000 mg/L produces a high quality effluent, you waste sludge to maintain that concentration

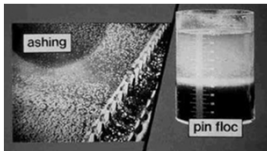
Respiration Rate as a Control

- The reason for all the tests/observations is to confirm that the organic matter in the ww has been properly stabilized and the MLSS will settle properly in the 2° clarifier
 - Overstabilized = fast settling sludge, may have turbid effluent due to pin floc
 - Understabilized = slow settling sludge, hard to keep in clarifier, may turn septic in RAS system
- Respiration Rate gives insight into health of microorganisms and activity of MLSS

Overstabilized Organic Matter

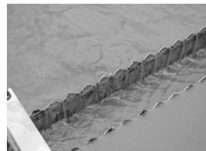
Overstabilized Organic Matter

- Generally produces fast-settling sludge
 - May cause high effluent turbidity
 - Pin-floc



Understabilized Organic Matter

- Generally results in sludge that is slow to settle
 - Hard to keep in the clarifier
 - May turn septic in the return sludge system



Respiration Rate as a Control

- Respiration Rate a.k.a. Specific Oxygen Uptake Rate (SOUR)
- Can alert you to changes required in WAS, RAS, aeration tank, detention times, and quantity of oxygen required
- Should be conducted at least weekly, preferably daily

Respiration Rate

- Standard Methods: Oxygen Consumption Rate and Specific Oxygen Consumption Rate
- Sample should be same temp as basin from which it was collected
- Increase DO by shaking in partially filled bottle or by bubbling air or oxygen through it (low DO ≤ 2.0 mg/L)
- After reading has stabilized, record initial DO and start timing
- Record data over 15 min period, or until DO becomes limiting (less than 1 mg/L)



Respiration Rate as a Control

- High RR = microorganisms are aggressively using large quantities of O_2 to stabilize food supply
- Low RR = unhealthy or inactive microorganisms, or a sludge that settles rapidly (turbid effluent/pin floc)

Respiration Rate as a Control

- **Less than 4 mg O_2 /hr/gm MLSS** = biological population not healthy. Possible toxic load
- **4 – 9 mg O_2 /hr/gm MLSS** = typical extended aeration/endogenous respiration. Also found where organic matter is slow to biodegrade. Typically indicate overstabilized organic matter
- **10 -20 mg O_2 /hr/gm MLSS** = Normal for most conventional AS processes
- **More than 20 mg O_2 /hr/gm MLSS** = Rapidly biodegradable organics, typical of high rate AS processes. Could also indicate understabilized organic matter

Microscopic Examination

- Can be used as indication of the condition of the activated sludge treatment process
- Majority of BOD is removed by common zoogeal microorganisms
- Important indicators:
 1. Protozoa
 - Eat bacteria and help produce clear effluent
 2. Rotifers
 - Indication of a stable effluent

Microscopic Examination

- If most of the microorganisms are protozoa (ciliates) and rotifers, you can expect good settling sludge
- A decline in microorganisms, especially ciliates, is frequently a warning of poor settling sludge

Microscopic Exam

Amoeboids

- Start-up
- Recovering from upset



Flagellates

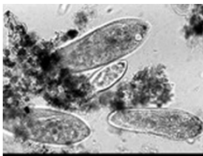
- Associated with light, dispersed, straggler floc
- Low population of microorganisms
- High organic BOD



Microscopic Exam - Ciliates

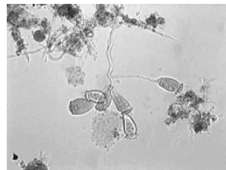
Free-Swimming

- Large number bacteria
- Feed on bacteria = clear effluent
- Associated with good degree of treatment



Stalked

- Present when free-swimmers are unable to compete for food
- Large number of stalked ciliates plus rotifers indicate stable and efficiently operating process



Microscopic Exam

Rotifers

- Combined with ciliates indicates stable effluent and efficiently operating process



[Wastewater Microbiology as Process Control Video](#)

Microscopic Exam

- Allow operator to detect a change in:
 - Organic loading
 - Level of a toxic chemical before the AS process becomes upset
- Changes in type and number of microorganisms should be compared with:
 - Observations of settling characteristics (SSV_{30})
 - Calculated F:M ratio

AI West Method

- Not controlled by attempting to achieve preconceived levels of variables
- Define sludge quality and process status to determine process adjustments using control tests:
 - Sludge blanket depth
 - MLSS
 - RAS concentrations
 - Sludge settleability
 - Etc.

In conclusion

- What matters is the quality of the effluent
- Be alert for changes
- Be ready to make adjustments
- Try not to adjust RAS or WAS rates by more than 10 or 15% from one day to the next
- Select a method you can understand, record and analyze data, and stick with that method

Any Questions?



Activated Sludge – Vocabulary

| | | | |
|-----------|--------------------------|-----------|--|
| _____ 1. | Absorption | _____ 20. | Heterotrophic |
| _____ 2. | Activated Sludge Process | _____ 21. | Mean Cell Residence Time (MCRT) |
| _____ 3. | Adsorption | _____ 22. | Mechanical Aeration |
| _____ 4. | Aeration Tank | _____ 23. | Mixed Liquor |
| _____ 5. | Aerobes | _____ 24. | Mixed Liquor Suspended Solids (MLSS) |
| _____ 6. | Anaerobes | _____ 25. | Mixed Liquor Volatile Suspended Solids (MLVSS) |
| _____ 7. | Anoxic | _____ 26. | Nitrification |
| _____ 8. | Biomass | _____ 27. | Oxidation |
| _____ 9. | Bulking | _____ 28. | Protozoa |
| _____ 10. | Coagulation | _____ 29. | Reduction |
| _____ 11. | Ciliates | _____ 30. | Rotifer |
| _____ 12. | Composite Sample | _____ 31. | Septic |
| _____ 13. | Denitrification | _____ 32. | Sludge Age |
| _____ 14. | Diffuser | _____ 33. | Sludge Volume Index |
| _____ 15. | Endogenous Respiration | _____ 34. | Supernatant |
| _____ 16. | Facultative | _____ 35. | Zoogleal |
| _____ 17. | Filamentous Bacteria | | |
| _____ 18. | Floc | | |
| _____ 19. | F/M Ratio | | |

- A. Clumps of bacteria and particles or coagulants and impurities that have come together and formed a cluster. Found in aeration tanks, secondary clarifiers and chemical precipitation processes.
- B. When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor as long as it is in the aeration tank.
- C. Bacteria that must have molecular (dissolved) oxygen (DO) to survive. Aerobes are aerobic bacteria.
- D. The clumping together of very fine particles into larger particles (floc) caused by the use of chemicals (coagulants).
- E. This test is a measure of the volume of sludge compared to its weight. The volume occupied by one gram of sludge after 30 minutes settling.
- F. The organic or volatile suspended solids in the mixed liquor of an aeration tank. This volatile portion is used as a measure or indication of the microorganisms present.
- G. Describes the organisms that use organic matter for energy and growth. Animals, fungi and most bacteria are these.
- H. The taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil)
- I. The addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances.
- J. A device (porous plate, tube, bag) used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.
- K. Oxygen deficient or lacking sufficient oxygen, but nitrate is available.
- L. A condition produced by anaerobic bacteria. If severe, the wastewater produces hydrogen sulfide, turns black, gives off foul odors, contains little or no dissolved oxygen and the wastewater has a high oxygen demand.
- M. Microscopic animals characterized by short hairs on their front ends.

- N. These bacteria can use either dissolved molecular oxygen or oxygen obtained from food materials such as sulfate or nitrate ions. In other words, these bacteria can live under aerobic or anaerobic conditions.
- O. Bacteria that do not need molecular (dissolved) oxygen (DO) to survive.
- P. Suspended solids in the mixed liquor of an aeration tank.
- Q. A situation where living organisms oxidize some of their own cellular mass instead of new organic matter they adsorb or absorb from their environment.
- R. An expression of the average time that a microorganism will spend in the activated sludge process.
- S. Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge does not settle properly. In the activated sludge process, this is usually caused by filamentous bacteria or bound water.
- T. A measure of the length of time a particle of suspended solids has been retained in the activated sludge process.
- U. A class of protozoans distinguished by short hairs on all or part of their bodies.
- V. A biological wastewater treatment process that speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to the wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or reused (returned to aeration tank) as needed. The remaining wastewater then undergoes more treatment.
- W. Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.
- X. Liquid removed from settle sludge. This liquid is usually returned to the influent wet well or to the primary clarifier.
- Y. The tank where raw or settled wastewater is mixed with return sludge and aerated.
- Z. A group of motile microscopic organisms (usually single-celled and aerobic) that sometimes cluster into colonies and often consume bacteria as an energy source.
- AA. The use of machinery to mix air and water so that oxygen can be absorbed into the water.
- BB. A mass or clump of organic material consisting of living organisms feeding on the wastes in wastewater, dead organisms and other debris.
- CC. Jelly-like masses of bacteria found in both the trickling filter and activated sludge processes.
- DD. The gathering of a gas, liquid or dissolved substance on the surface or interface zone of another material.
- EE. Bacteria that grown in a thread or filamentous form. A common cause of sludge bulking in the activated sludge process.
- FF. An aerobic process where bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrogenous BOD" (first stage is called the "carbonaceous BOD")
- GG. A collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour period. Each individual sample is combined with others in proportion to the rate of flow when the sample was collected.
- HH. The anoxic biological reduction of nitrate nitrogen to nitrogen gas. An anoxic process that occurs when nitrite or nitrate ions are reduced to nitrogen gas and nitrogen bubbles are formed as a results of this process. The bubbles attach to the biological floc in the activated sludge process and float the floc to the surface of the secondary clarifiers. This condition is often the cause of rising sludge observed in secondary clarifiers or gravity thickeners.
- II. The addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under aerobic conditions (no dissolved oxygen present), sulfur compounds are reduced to odor-producing hydrogen sulfide (H₂S) and other compounds.

Activated Sludge – Review Questions

- In the activated sludge process, microorganisms convert organic matter to _____.
 - New cells, carbon dioxide and water
 - New cells, ammonia and water
 - Carbon dioxide, water and nitrate
 - Carbon dioxide, water and chlorine
- The basic components of the activated sludge process are _____.
 - Thickeners and digesters
 - Screens and clarifiers
 - Sand filters and chlorine contact chambers
 - Biological reactors and clarifiers
- Solids that settle to the bottom of clarifiers and are pumped back to the head of biological reactors are referred to as _____.
 - RAS
 - WAS
 - TSS
 - Total residual chlorine
- The amount of time that microorganisms spend in the activated sludge process before they are wasted is called the _____.
 - Total residual chlorine
 - MLSS
 - MCRT
 - WAS
- The presence of these microorganisms indicate a good settling sludge:
 - Amoebas and flagellates
 - Ciliates and Rotifers
 - Ciliates and Waterbears
 - Rotifers and Nematodes
- Protozoans are _____.
 - Bacteria
 - Microscopic plants
 - Single-celled animals
 - Worms
- Conventional activated sludge processes are designed to remove soluble carbonaceous BOD from wastewater.
 - True
 - False
- Return activated sludge is typically pumped back to which of the following?
 - The headworks
 - Primary clarifier
 - Influent side of a biological reactor
 - Effluent side of a biological reactor

9. The measure of biochemical or organic strength of wastewater is referred to as:
- TRC
 - TSS
 - BOD
 - F:M
10. Potential visual indicators of low DO concentrations include _____.
- Presence of filamentous bacteria
 - Turbid effluent
 - Dark gray to black mixed liquor
 - All of the above
11. The MCRT for most conventional activated sludge processes is typically _____.
- 5 – 15 days
 - 5 – 15 hours
 - 20 – 30 days
 - 20 – 30 hours
12. RAS flow is typically a percentage of plant influent flow that is based on _____.
- Temperature and pH levels
 - BOD and nutrient concentrations
 - Mean cell residence time
 - Inert solids and metal concentrations
13. Nitrification is a two step process. At the end of the second and final step, to what has ammonia been oxidized?
- Nitrite
 - Nitrate
 - Ammonium hydroxide
 - Nitric acid
14. What is the final product of Denitrification?
- Ammonia
 - Nitrite
 - Nitrate
 - Nitrogen gas
15. A pure oxygen system would be used instead of a conventional system for all of the following reasons **except**:
- Low operating costs
 - Increased microorganism efficiency
 - Optional smaller footprint/smaller aeration tanks
 - Improved settleability and dewaterability of sludges
16. What treatment process can be used to remove ammonium (NH₄⁻) from wastewater, but not total nitrogen?
- Denitrification
 - Dewatering
 - Anaerobic digestion
 - Nitrification
17. Pure oxygen reactors are staged to increase the efficiency of the use of oxygen.
- True
 - False

18. All of the following are special measurements that are used as control guidelines to efficiently and safely operate a pure oxygen system **except**:
- Reactor vent gas
 - Reactor gas space pressure
 - Internal lubricating oil system
 - Dissolved oxygen
19. Hydrocarbons can be detected before they reach the reactor by installing a lower explosive limit (LEL) combustible gas detector in the plant headworks.
- True
 - False
20. Pure oxygen does not pose a fire hazard since it makes up 21% of the Earth's atmosphere.
- True
 - False
21. RAS makes it possible for microorganisms to be in the system longer than the flowing wastewater.
- True
 - False
22. The most commonly used techniques to set the rate of sludge return flow include all of the following **except**:
- Settleability approach
 - Monitoring depth of sludge blanket
 - Sludge Volume Index approach
 - Intermittent use of a bypass
23. Theoretically, the sludge blanket depth should be kept from _____ feet as measured from clarifier bottom at the sidewall.
- 0 – 2 feet
 - 1 – 3 feet
 - 3 – 6 feet
 - 7 – 9 feet
24. If a plant is utilizing the Settleability approach to control the RAS flow rate, they should be using a 1000 mL graduated cylinder to hold their mixed liquor.
- True
 - False
25. You must determine the SSV_{30} and MLSS concentrations before you can calculate the SVI.
- True
 - False
26. The amount of WAS in your system can impact all of the following **except**:
- Growth rate of microorganisms
 - Oxygen consumption
 - Mixed liquor settleability
 - Possibility of nitrifying
 - Influent BOD levels

27. Sludge Age is the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process.
- True
 - False
28. Operation by or calculations of the F:M ratio should not be based on daily tests, but instead on a 7 day moving average.
- True
 - False
29. A Mean Cell Residence Time of 5 – 10 days will generally produce a nitrified effluent.
- True
 - False
30. Overstabilized organic matter will generally result in a sludge that is slow to settle and therefore difficult to keep in the clarifier.
- True
 - False
31. A low respiration rate is indicative of an unhealthy or inactive population of microorganisms.
- True
 - False
32. If most of the microorganisms are protozoa (ciliates) and rotifers, you can expect a good settling sludge.
- True
 - False
33. A plant that operates in extended aeration mode will have a high F:M ratio and short sludge age.
- True
 - False
34. Which of the following activated sludge process modes is defined by the TN Design Criteria for Sewage Works as being characterized by the introduction of wastewater at 2 or more points in the aeration basin?
- Plug Flow
 - Contact Stabilization
 - Step Feed
 - Extended Aeration
35. A Sequencing Batch Reactor (SBR) will always have at least 2 basins in different phases at different times and treatment is taking place at some level during all cycles.
- True
 - False

Answers to Vocabulary:

- | | | | | | | | |
|----|----|-----|----|-----|----|-----|----|
| 1. | H | 10. | D | 19. | W | 28. | Z |
| 2. | V | 11. | U | 20. | G | 29. | II |
| 3. | DD | 12. | GG | 21. | R | 30. | M |
| 4. | Y | 13. | HH | 22. | AA | 31. | L |
| 5. | C | 14. | J | 23. | B | 32. | T |
| 6. | O | 15. | Q | 24. | P | 33. | E |
| 7. | K | 16. | N | 25. | F | 34. | X |
| 8. | BB | 17. | EE | 26. | FF | 35. | CC |
| 9. | S | 18. | A | 27. | I | | |

Answers to Review Questions:

1. A
2. D
3. A
4. C
5. B
6. C
7. A
8. C
9. C
10. D
11. A
12. C
13. B
14. D
15. A
16. D
17. A
18. C
19. A
20. B
21. A
22. D
23. B
24. B
25. A
26. E
27. A
28. A
29. B
30. B
31. A
32. A
33. B
34. C
35. A

Advanced Wastewater Treatment – Math Refresher

Loading Rate

1. The flow to an aeration tank is 750,000 gpd. If the BOD content of the wastewater entering the aeration tank is 250 mg/L, how many pounds of BOD are applied to the aeration tank daily?

2. The daily flow to an aeration basin is 7,880,000 gpd. If the COD concentration of the influent wastewater is 150 mg/L, how many lbs of COD are applied to the aeration basin daily?

Food to Microorganism Ratio

3. An activated sludge aeration tank receives a primary effluent flow of 1.3 MGD with a BOD concentration of 178 mg/L. The mixed liquor volatile suspended solids is 2300 mg/L and the aeration tank volume is 390,000 gallons. What is the current F:M ratio?

4. The desired F:M ratio of an extended aeration activated sludge plant is 0.6 lbs COD/lb MLVSS. If the 3.3 MGD primary effluent flow has a COD of 175 mg/L, how many lbs of MLVSS should be maintained in the aeration tank?

Solids Inventory

5. An aeration basin is 150 ft. long, 45 ft. wide and holds a wastewater depth of 15 ft. If the aeration basin has an MLSS concentration of 2275 mg/L, how many pounds of MLSS are under aeration?

6. The aeration tank of a conventional activated sludge plant has an MLSS concentration of 3500 mg/L with a volatile solids content of 73%. If the volume of the aeration tank is 200,000 gallons, how many pounds of volatile solids are under aeration?

MCRT

7. An activated sludge system has a total of 28,750 lbs of mixed liquor suspended solids. The suspended solids leaving the final clarifier in the effluent is 500 lbs/day. The pounds suspended solids wasted from the final clarifier is 2975 lbs/day. What is the solids retention time (MCRT) in days?

8. Determine MCRT from the following information:

Aeration tank = 1,500,000 gal

MLSS = 3170 mg/L

Final Clarifier = 107,000 gal

S.E. SS = 25 mg/L

Flow = 3,200,000 gpd

C.C. SS = 1875 mg/L

WAS pump rate = 68,000 gpd

WAS = 7050 mg/L

What every operator should know about activated sludge

Dave Flowers

| Knowledge | Principle | A practical consideration |
|--------------------------------------|--|--|
| Activated sludge | Microorganisms are brought into contact with wastewater containing “food” (measured as biochemical oxygen demand [BOD]) and oxygen. Under good conditions, the food (our waste) is consumed by the microorganisms. We then separate the microorganisms, leaving behind clean water (effluent). | Microorganisms thrive under the right environmental conditions. Of particular importance are <ul style="list-style-type: none"> • population (number of microorganisms), • pH, • temperature, • mixing, • contact time, • oxygen, and • presence of life-sustaining nutrients. |
| Conventional activated sludge system | This process is typically an aeration tank followed by solids–liquid separation and, if needed, a return activated sludge pump. There also has to be a method of air or pure-oxygen addition and a method of removing excess microorganisms, which are called waste activated sludge (WAS). | Conditions needed for this type of system include <ul style="list-style-type: none"> • 8 to 12 hours of detention time in the aeration tank (more for extended air), • 1500 to 3500 mg/L of mixed liquor suspended solids (MLSS), • adequate mixing, • a dissolved-oxygen (DO) concentration of about 2 mg/L, and • a good food-to-microorganism ratio (F:M). |
| MLSS (population) control using F:M | To balance the waste load of food (lb of BOD ₅ per day) to the population of microorganisms, you need a F:M of 0.2 to 0.5. | WAS is removed, or wasted, from the secondary system to maintain the proper F:M. To calculate F:M, divide the food by the biological mass in the entire secondary system. <ul style="list-style-type: none"> • Food = flow (mgd) × 8.34 lb/gal × BOD₅ mg/L. • Microorganisms = [aeration tank volume (million gal) × 8.34 lb/gal × mixed liquor volatile suspended solids (MLVSS) mg/L] + [clarifier tank volume (million gal) × 8.34 lb/gal × clarifier coretaker¹ total volatile suspended solids (TVSS) (mg/L). • So, F:M = food ÷ microorganisms. |

¹ A coretaker device is used to take a sample of clarifier water that reaches from the floor to the water’s surface. This sample is run into a bucket then mixed well and analyzed for total volatile suspended solids (TVSS) (mg/L). In this case TVSS and MLVSS both are a measure of microorganisms present in the total activated sludge system.



| Knowledge | Principle | A practical consideration |
|---|--|--|
| MLSS (population) control using mean cell retention time (MCRT) | Another way to balance the waste load of food (pounds of BOD ₅ per day) to the population of microorganisms is to maintain an MCRT of 5 to 15 days. | To calculate MCRT, measure the pounds of biomass in the entire secondary system and divide by the pounds of biomass wasted each day. Typically, a target MCRT is maintained. For example, if you had a 10-day MCRT, you would waste 10% of the biomass each day. If the effluent is low in TVSS, this loss of microorganisms is typically ignored in the MCRT calculation. |
| pH | The pH should be between 6.5 and 8.5. | Microorganisms do not grow well in pH outside this range. Be especially mindful of pH if the water supply is soft, such as from a lake. |
| Temperature | Operators can't control influent temperature; however, a common range is between 10°C and 38°C (50°F and 100°F). | Understand that microorganisms can have difficulty growing at temperatures higher than 38°C (100°F). Cooling may be necessary. For every 10°C rise in temperature, microorganism respiration doubles. During cold temperatures a higher population will be needed to achieve the same treatment results – that means a lower F:M or higher MCRT. |
| Mixing | Regardless of the aeration tank configuration, the tank should be well-mixed. | Good mixing will ensure that the microorganisms are in good contact with the food, the oxygen, and each other. Check for this by measuring DO, MLSS, or total suspended solids at several locations within the tank – the results should be similar at each location. |
| Contact time or hydraulic retention time | The hydraulic retention time (HRT) within the aeration tank must be long enough for the microorganisms to consume all the freely available food. | HRT is calculated by dividing the aeration tank volume by the volume of flow per day, then multiplying by 24 hours per day to get a result of hours. An easy method of checking if the HRT is long enough is to check the oxygen uptake rate (OUR) leaving the aeration tank (before solids–liquid separation). If the rate is endogenous – meaning the microorganisms have consumed all freely available food and are burning their reserves and consuming each other – the HRT is long enough for the flow, load, and MLSS concentration. |

| Knowledge | Principle | A practical consideration |
|---------------------------|---|---|
| Oxygen | Maintain a DO residual concentration of at least 2 mg/L anywhere in the aeration tank. | This is a rule of thumb. One can run at a lower DO. A higher DO may be necessary if low DO filaments are present and DO is not penetrating to the inner floc. Approximately 0.45 kg (1 lb) of oxygen is needed to consume 0.45 kg (1 lb) of BOD ₅ . Approximately 2.0 kg (4.3 lb) of oxygen is needed to convert 0.45 kg (1 lb) of ammonia. |
| Life-sustaining nutrients | As a rule of thumb, microorganisms need, pound for pound, 100:5:1:0.5 for BOD ₅ :N:P:Fe. That means for every 100 lb of BOD ₅ , they need 5 lb of nitrogen, 1 lb of phosphorus, and 0.5 lb of iron. | The phosphorus must be available to the microorganisms and is generally referred to as orthophosphate. It passes through a 10-µm filter. Nitrogen here is generally referring to ammonia-nitrogen. |
| Oxygen uptake rate | OUR is the "breathing rate" of the microorganisms, sometimes referred to as "respiration rate." OUR = mg of oxygen consumed per L per h. | There is a correlation that the respiration rate of the MLSS is higher when freely available food is present. Monitor OUR at the points where flow is entering and exiting the aeration tank. The exit point should show an endogenous respiration rate. Respiration rate also will vary in relation to the concentration of microorganisms. |
| Solids-liquid separation | After culturing microorganisms in an aeration tank under excellent environmental conditions, the "quality biomass" will settle well in a clarifier or separate well in a membrane. The sidewater depth is typically between 3.7 and 4.6 m (12 and 15 ft). The surface overflow rate of the clarifiers is typically less than 24,450 L/m ² ·d (600 gal/ft ² ·d) at average flow and less than 48,900 L/m ² ·d (1200 gal/ft ² ·d) during the peak hourly flow. Return activated sludge (RAS) rate is typically 50% to 150% of the plant flow. However, the upper range will be lower for large plants. | A quality biomass will flocculate (come together or "stick" together) under mild agitation. This agitation often occurs as MLSS leaves the aeration tank and flows to the clarifier. Many clarifiers have inlet baffles that serve this purpose. RAS pumps (if required) must remove an adequate quantity of activated sludge to maintain a reasonable sludge depth – depth of blanket – 0.15 to 0.6 m (0.5 to 2 ft) is typical. Avoid a higher than necessary RAS rate to maintain a low sludge blanket. |
| Settleometer testing | Using a settleometer, conduct a settling test. Five- and 30-minute test results should be placed on a trend chart at the testing frequency, which is often daily. | After experiencing long periods of excellent performance, these trends will allow observation of impending settling problems. Follow-up may be microscopic examination for filaments, adjustments to the WAS rate. |
| Sludge volume index (SVI) | SVI is the volume occupied by 1 g of MLSS after 30 minutes of settling. $SVI = \left(\frac{[30\text{-minute settling volumes as mL/L}] + [MLSS concentration as mg/L]}{MLSS concentration as mg/L} \right) \times 1000 \text{ mg/g} = \text{mL/g}$. | <ul style="list-style-type: none"> • SVI of less than 80 mL/g = generally very good settling. • SVI between 80 and 150 mL/g = good settling. • SVI greater than 150 mL/g = generally poor settling and requires corrective action. <p><i>Microscopic examination is a good start. Look for filaments, microorganism diversity, and nutrient deficiency for starters.</i></p> |

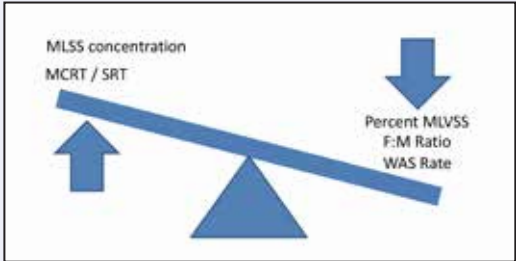
Dave Flowers is president and operator at Natural Water Solutions LLC (Cedarburg, Wis.).

What every operator needs to know about activated sludge


Sidney Innerebner



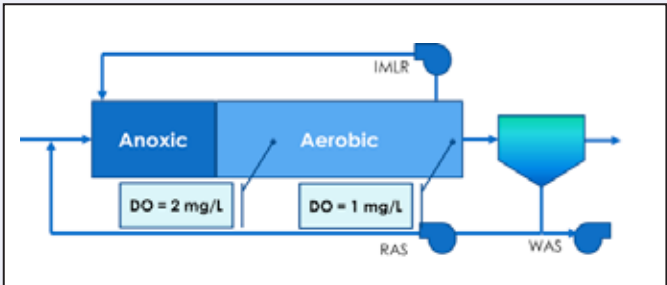
| Knowledge | Principles | Practical considerations |
|---|---|--|
| <p>Mean cell residence time (MCRT) or solids residence time (SRT) or sludge age measures the amount of time solids spend within the system.</p> | <p>MCRT/SRT controls activated sludge microbiology and sludge settling characteristics.</p> | <p>MCRT/SRT is the amount of time the mixed liquor suspended solids (MLSS) spends moving between the aeration basin and secondary clarifier before it is removed from the system either through the waste activated sludge (WAS) line or by escaping into the final effluent.</p> <p>It is calculated by taking the total pounds of MLSS in the system and dividing it by the total pounds leaving the system each day. If a 10-day sludge age is desired, then 10% of the total MLSS must be removed from the system each day. Effluent pounds often are not included in the calculation because the concentration is small compared to the other parts of the equation and won't have a big effect on the result.</p> $MCRT = \frac{\text{Aeration basin pounds} + \text{Clarifier pounds}}{\text{WAS pounds} + \text{Effluent pounds}}$ <p>Typical SRT ranges vary depending on system type:</p> <ul style="list-style-type: none"> ■ conventional = 5 to 15 days and ■ extended aeration = 20 to 30 days. <p>Many operators define MCRT as including the MLSS in the aeration basin plus the MLSS in the secondary clarifier, while SRT includes only the MLSS in the aeration basin. Engineers also may calculate an aerobic SRT, which only includes the MLSS in the aerated zones of the aeration basins. Aerobic SRT is used to ensure the system has adequate sludge age for nitrification.</p> |

| Knowledge | Principles | Practical considerations |
|--|--|--|
| <p>MCRT or SRT controls the aeration basin activity.</p> | <p>Process control variables are interrelated.</p> | <p>MCRT/SRT is the primary control variable for activated sludge. Once an MCRT/SRT is selected, it will control the wasting rate, MLSS concentration, MLSS growth rate, food-to-microorganism ratio (F:M), and microbiology.</p> <p>It is not possible to control more than one of these variables at a time.</p>  <p>The teeter-totter graphic above illustrates the relationships among process variables. As MCRT/SRT increases, fewer pounds of MLSS are removed from the system, which means the wasting rate must go down. Removing less MLSS each day causes the MLSS concentration (mg/L) to increase over time. If MLSS is increasing and the amount of biochemical oxygen demand (BOD) entering the facility remains about the same, then the amount of food per microorganism decreases. All of the variables in the diagram above are calculated using the MLSS concentration, which is controlled by MCRT/SRT.</p> <p>The last relationship is the ratio of mixed-liquor volatile suspended solids (MLVSS) to MLSS. Inert material coming into the facility (sand, grit, eggshells) can't be broken down by microorganism and passes through unchanged. As the SRT/MCRT increases, more inert material accumulates in the system. At the same time, the MLSS concentration levels off because the microorganisms grow slower when less food is available (lower F:M). The combination of effects causes the total solids concentration (MLSS) to increase while the percentage of volatile solids (MLVSS) decreases. A healthy activated sludge system that is not adding chemicals typically will have an MLVSS to MLSS ratio in the 0.75 to 0.85 range.</p> <p>If the MCRT/SRT is decreased, everything on the left side of the teeter-totter will decrease, and everything on the right side of the teeter-totter will increase.</p> |
| <p>Washout-MCRT or washout-SRT refers to the minimum sludge age needed to control microorganism populations and achieve treatment goals.</p> | <p>The MCRT/SRT must be long enough to retain desired microorganisms and short enough to flush out undesirable filamentous bacteria.</p> | <p>MLSS is a diverse community of bacteria, protozoans, and metazoans. Each of these organisms has a minimum time requirement to reproduce. Most of the bacteria in the system reproduce rapidly and can, according to some sources, double their numbers every 20 minutes. Other bacteria, like the nitrifying bacteria, take much longer to reproduce. Ciliates can divide every 4 to 5 hours.</p> <p>The washout-MCRT or washout-SRT is the minimum MCRT/SRT required to keep a particular organism in the system. Microorganisms constantly enter the facility in the influent. If the MCRT/SRT is too low, the organisms will be washed out of the system as fast as they enter, and a stable population won't develop. The MCRT/SRT chosen will determine which microorganisms live, thrive, and survive.</p> <p>Some examples of estimated washout MCRT/SRTs at 20°C:</p> <ul style="list-style-type: none"> ■ <i>Nocardioforms</i> = 1.5 days ■ Phosphate accumulating organisms = 2 days ■ Ammonia oxidizing bacteria (AOB) = 1.8 days ■ Nitrite oxidizing bacteria (NOB) = 2 days ■ <i>Sphaerotilus natans</i> = 3 to 7 days ■ <i>Microthrix parvicella</i> = greater than 10 days <p>In practice, select an MCRT that is two to three times higher than the washout SRT to keep a desired organism in the MLSS.</p> |

| Knowledge | Principles | Practical considerations | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|--|---|--------------------------------------|--|--|--|--|-----|-----|--------------------------------------|------|-----|-----|-----|----------|------|-----|-----|-----|--------|------|-----|-----|-----|--------|------|-----|-----|----|----------|
| <p>Selecting the right MCRT or SRT</p> | <p>The target MCRT or SRT depends on treatment goals and water temperature.</p> <p>Growth rates for <i>Microthrix parvicella</i> and the nitrifying bacteria converge as water temperatures decrease. As a result, many water resource recovery facilities (WRRFs) that nitrify experience foaming events in the winter months. Good MCRT/SRT control can mitigate the effect.</p> | <p>The right MCRT/SRT for a facility depends on whether or not nitrification is required to meet permit limits. Washout MCRT/SRTs for nitrifying bacteria depend on temperature.</p> <table border="1"> <thead> <tr> <th rowspan="2">Temperature</th> <th colspan="3">Washout SRT (days)</th> <th rowspan="2">Safe minimum operating SRT to nitrify (days)</th> </tr> <tr> <th>AOB</th> <th>NOB</th> <th><i>Microthrix parvicella</i> foaming</th> </tr> </thead> <tbody> <tr> <td>10°C</td> <td>5.0</td> <td>4.0</td> <td>~12</td> <td>12 to 16</td> </tr> <tr> <td>15°C</td> <td>2.8</td> <td>3.0</td> <td>~20</td> <td>6 to 9</td> </tr> <tr> <td>20°C</td> <td>1.8</td> <td>2.0</td> <td>>25</td> <td>4 to 6</td> </tr> <tr> <td>25°C</td> <td>1.0</td> <td>1.5</td> <td>--</td> <td>3 to 4.5</td> </tr> </tbody> </table> <p>Other things to keep in mind when selecting an MCRT/SRT:</p> <ul style="list-style-type: none"> ■ A minimum MCRT/SRT is needed even when nitrogen removal is not a requirement. If the MCRT/SRT is too low, the MLSS flocs that form won't be large or heavy enough to settle in the clarifier. ■ As MCRT/SRT increases, aeration costs increase. ■ Longer MCRT/SRTs will encourage the growth of undesirable organisms like <i>Microthrix parvicella</i>, which may result in foaming and settling issues. Stay below the washout MCRT/SRTs for these organisms. ■ Check your operating data. Is there a past MCRT/SRT that produces the best sludge volume index (SVI)? | Temperature | Washout SRT (days) | | | Safe minimum operating SRT to nitrify (days) | AOB | NOB | <i>Microthrix parvicella</i> foaming | 10°C | 5.0 | 4.0 | ~12 | 12 to 16 | 15°C | 2.8 | 3.0 | ~20 | 6 to 9 | 20°C | 1.8 | 2.0 | >25 | 4 to 6 | 25°C | 1.0 | 1.5 | -- | 3 to 4.5 |
| Temperature | Washout SRT (days) | | | Safe minimum operating SRT to nitrify (days) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | AOB | NOB | <i>Microthrix parvicella</i> foaming | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10°C | 5.0 | 4.0 | ~12 | 12 to 16 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15°C | 2.8 | 3.0 | ~20 | 6 to 9 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20°C | 1.8 | 2.0 | >25 | 4 to 6 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25°C | 1.0 | 1.5 | -- | 3 to 4.5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Building MLSS without BOD is impossible.</p> | <p>Every pound of BOD entering the treatment facility will produce a fixed amount of new MLSS. This is the yield.</p> | <p>Sometimes, treatment facilities will increase their MCRT/SRT in anticipation of a future increase in the BOD loading rate. They are attempting to build a bigger inventory of MLSS to keep the F:M within a targeted range. This is problematic for several reasons.</p> <p>First, the yield (microorganism growth) for a given amount of BOD or ammonia is fixed. For every pound of BOD that enters the aeration basin, about 0.6 pounds of MLVSS will be produced. Think about your own food intake and building mass. The MLSS concentration will go up with a longer MCRT/SRT even when BOD is not available because inert material (sand, grit, eggshells) starts to accumulate in the aeration basin.</p> <p>Remember: MCRT/SRT controls the MLSS concentration and the F:M. Select an appropriate MCRT/SRT and allow the other variables to self-adjust. You can't control more than one at a time.</p> <p>The operations and maintenance manual and the design drawings for a treatment facility may include a table that shows the design MCRT/SRT, MLSS concentration, and F:M. This exact combination of variables can never be met at a facility because</p> <ul style="list-style-type: none"> ■ the WRRF will never operate at 100% of capacity, ■ the fraction of inert material in the influent wastewater often is unknown, and the design engineer must make a reasonable assumption, and ■ the inert fraction changes from day to day. | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Return activated sludge rate (RAS) controls the secondary clarifier.</p> | <p>RAS removes settled MLSS and returns it to the aeration basin. The ability to return MLSS is the primary difference between a lagoon system and an activated sludge system.</p> | <p>RAS controls several key parameters for the secondary clarifier, including</p> <ul style="list-style-type: none"> ■ clarifier solids residence time, ■ sludge blanket depth, ■ solids loading rate (lb of MLSS/ft²•d), and ■ RAS concentration (mg/L). $\text{Solids loading rate (SLR)} = \frac{(\text{Flow}_{\text{RAS}} + \text{Flow}_{\text{INF}})(\text{MLSS}, \frac{\text{mg}}{\text{L}})(8.34)}{\text{Clarifier area, ft}^2}$ <p>Typical SLRs for secondary clarifiers are between 1.0 and 1.4 lb/ft²•hr. When sludge settleability is poor, the SLR must be decreased. SLR can be decreased by placing another clarifier into service or by reducing the MLSS concentration or by turning down the RAS rate.</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| Knowledge | Principles | Practical considerations |
|---|--|---|
| Using the settleometer test to measure sludge quality | <p>The settleometer predicts how the MLSS will flocculate, settle, and compact in the secondary clarifier.</p>  | <p>The settleometer test uses a fresh, 2-L sample of MLSS from the end of the aeration basin just before the secondary clarifiers. The sample is gently mixed and then transferred to a 2-L Mallory settleometer and is allowed to settle.</p> <p>The following data should be recorded:</p> <ul style="list-style-type: none"> ■ settled sludge volume after 5 minutes (SSV_5), ■ settled sludge volume after 30 minutes (SSV_{30}), and ■ time when nitrogen gas bubbles produced by denitrification forces some or all of the MLSS to rise back to the top. <p>The SSV_5 measures sludge settling velocity. In the first few minutes of the test, MLSS floc particles are settling freely in the water but soon begin to collide with one another.</p> <p>Many facilities will see a strong seasonal variation in the SSV_5 even when filamentous bacteria are not present in excess. The density of floc particles is very close to water. As water temperatures decrease, water becomes denser and gets closer to the density of the floc particles. SSV_5 may be lower in the summer (faster settling) and higher in the winter (slower settling) even when filaments are not present.</p> <p>The SSV_{30} measures sludge compactability. If the settleometer is allowed to sit undisturbed for an hour or two, the MLSS will not continue to compact much more than it did at 30 minutes. The SSV_{30} represents the highest possible return and waste activated sludge concentrations attainable by the secondary clarifier. SSV_{30} may increase due to increases in sludge concentration or due to an abundance of filamentous bacteria in the MLSS.</p> <p>To compare sludge compactability from one day to the next, use the SVI calculation. SVI indicates the volume in milliliters that one gram of MLSS occupies after settling.</p> $SVI, \frac{mL}{g} = \frac{(SSV_{30})(1000 \frac{mg}{g})}{MLSS \frac{mg}{L}}$ <p>After the settleometer test is complete, analyze the supernatant for total suspended solids (TSS). Compare this result to secondary effluent performance. If the effluent TSS and supernatant TSS are about the same, then the clarifier is performing as well as it can given the sludge settling characteristics. If the effluent TSS is higher, it indicates an issue with the clarifier operation such as denitrification occurring in the sludge blanket, sludge blankets that are too deep, or hydraulic surge.</p> |
| Selecting the right RAS rate | Typical RAS rates are between 25% and 125% of the influent flow. | <p>The RAS rate should be selected to meet the following goals:</p> <ul style="list-style-type: none"> ■ Rates are as low as possible to conserve energy. ■ Maintain blanket depth below 2 ft at all times. ■ Prevent denitrification from occurring in the sludge blanket and deteriorating effluent quality. <p>Ideally, the RAS flow rate will be linked to the influent flow and a constant percent return can be maintained. When this level of control does not exist, facilities may adjust RAS rates several times a day based on sludge-blanket-depth readings, or they may select a RAS rate that works well for most of the day and leave it there despite higher pumping costs.</p> |

| Knowledge | Principles | Practical considerations | | | | | | | | | | | | | | | | | | | | | | | | |
|--|--|--|----------------------|----------|-----------------------|----------------------------|--------------|----------------|---------------|--------------|-----------------|-----------------|-------------|---------------|-----------------------|----------------|----------------|----------------|----------------|----------------|-------------------|----------------|----------------|-------------------|--------------------|-----------------|
| <p>Predicting the RAS concentration</p> | <p>Clarifiers thicken the underflow to a predictable extent but can't do better than the settleometer.</p> | <p>RAS concentration is a function of the RAS pumping rate and can be calculated using this formula:</p> $RAS, \frac{mg}{L} = \left(\frac{Flow_{Influent}}{Flow_{RAS}} + 1 \right) (MLSS, \frac{mg}{L})$ <p>When the RAS rate goes up, the RAS concentration goes down and vice versa. Be careful! The formula may give a mathematical answer for the RAS concentration that simply isn't achievable. Look at the settleometer test results for the maximum RAS concentration that reasonably can be expected.</p> <p>Example: A facility has an MLSS concentration of 2500 mg/L, and the settled sludge volume after 30 minutes is 250 mL. The MLSS fills one-fourth of the volume of the settleometer so the MLSS concentration in the blanket is (2500 mg/L)(4) = 10,000 mg/L. It won't matter how low the RAS pumping rate is set; RAS cannot be thickened beyond 10,000 mg/L.</p> | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Selecting a target dissolved-oxygen (DO) concentration for the aerated zone</p> | <p>Microorganisms require oxygen to break down BOD and convert ammonia to nitrate.</p> | <p>Up to 50% of a facility's total operating costs may be from operating high-horsepower blowers to provide oxygen and mixing for the aeration basins. The DO should be kept as low as possible while still meeting all treatment goals. Excess DO will not harm the activated sludge process, but it does waste energy and money.</p> <p>MLSS DO concentrations must be high enough to prevent the growth of low DO filaments like <i>H. hydrosis</i> and <i>S. natans</i> that can interfere with settling. Generally, DO concentrations greater than 1 mg/L will suffice. DO concentrations also must be high enough to support nitrification in facilities with ammonia limits. The nitrifying bacteria can be inhibited or slowed down when the DO concentration drops below 2 mg/L. A good target range for DO is between 1.5 and 2.5 mg/L in the aerated zones.</p> <p>Some types of activated sludge systems, such as high purity oxygen (PureOx), integrated fixed film activated sludge (IFAS), and systems operating at food-to-microorganism ratios higher than 0.4 lb MLVSS/lb BOD, require substantially higher DO concentrations.</p> | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Selecting a target oxidation-reduction-potential (ORP) value for the anoxic and anaerobic zones</p> | <p>ORP can be used to measure indirectly very low concentrations of DO and nitrate in wastewater.</p> | <p>Each type of biochemical activity occurs within its own range of ORP.</p> <table border="1"> <thead> <tr> <th>Biochemical activity</th> <th>Location</th> <th>Approximate ORP range</th> </tr> </thead> <tbody> <tr> <td>Polyphosphate accumulation</td> <td>Aerated zone</td> <td>+50 to +250 mV</td> </tr> <tr> <td>Nitrification</td> <td>Aerated zone</td> <td>+150 to +350 mV</td> </tr> <tr> <td>Denitrification</td> <td>Anoxic zone</td> <td>-50 to +50 mV</td> </tr> <tr> <td>Polyphosphate release</td> <td>Anaerobic zone</td> <td>-40 to -175 mV</td> </tr> <tr> <td>Acid formation</td> <td>Anaerobic zone</td> <td>-40 to -200 mV</td> </tr> <tr> <td>Sulfide formation</td> <td>Anaerobic zone</td> <td>-50 to -250 mV</td> </tr> <tr> <td>Methane formation</td> <td>Anaerobic digester</td> <td>-200 to -400 mV</td> </tr> </tbody> </table> <p>*Using silver/silver chloride reference.</p> <p>Exact ORP values should be verified at each WRRF because basic water quality can affect the values. The type of electrode used and the fill solution strength also can affect the result. (See the Operator Essentials column from the January 2013 issue of <i>WE&T</i> for more information.)</p> | Biochemical activity | Location | Approximate ORP range | Polyphosphate accumulation | Aerated zone | +50 to +250 mV | Nitrification | Aerated zone | +150 to +350 mV | Denitrification | Anoxic zone | -50 to +50 mV | Polyphosphate release | Anaerobic zone | -40 to -175 mV | Acid formation | Anaerobic zone | -40 to -200 mV | Sulfide formation | Anaerobic zone | -50 to -250 mV | Methane formation | Anaerobic digester | -200 to -400 mV |
| Biochemical activity | Location | Approximate ORP range | | | | | | | | | | | | | | | | | | | | | | | | |
| Polyphosphate accumulation | Aerated zone | +50 to +250 mV | | | | | | | | | | | | | | | | | | | | | | | | |
| Nitrification | Aerated zone | +150 to +350 mV | | | | | | | | | | | | | | | | | | | | | | | | |
| Denitrification | Anoxic zone | -50 to +50 mV | | | | | | | | | | | | | | | | | | | | | | | | |
| Polyphosphate release | Anaerobic zone | -40 to -175 mV | | | | | | | | | | | | | | | | | | | | | | | | |
| Acid formation | Anaerobic zone | -40 to -200 mV | | | | | | | | | | | | | | | | | | | | | | | | |
| Sulfide formation | Anaerobic zone | -50 to -250 mV | | | | | | | | | | | | | | | | | | | | | | | | |
| Methane formation | Anaerobic digester | -200 to -400 mV | | | | | | | | | | | | | | | | | | | | | | | | |

| Knowledge | Principles | Practical considerations | | | | | | | | | | | | | | | |
|---|--|---|---|--------------------------------|-----------------------------------|------|-----|----|------|-----|------|------|-----|----|------|-----|-----|
| <p>Selecting the right internal mixed-liquor recycle (IMLR) ratio</p> | <p>Many systems are equipped with recycle pumps that take MLSS from the end of an aerated zone and return it to the beginning of an anoxic zone for denitrification.</p> | <p>The IMLR ratio determines the amount of denitrification that can be expected. For the table below, an influent total nitrogen concentration of 50 mg/L as N was used. This is typical for domestic wastewater.</p> <table border="1"> <thead> <tr> <th>Percent of IMLR compared to influent flow</th> <th>Percent total nitrogen removal</th> <th>Estimated effluent total N (mg/L)</th> </tr> </thead> <tbody> <tr> <td>100%</td> <td>50%</td> <td>25</td> </tr> <tr> <td>200%</td> <td>67%</td> <td>16.5</td> </tr> <tr> <td>300%</td> <td>76%</td> <td>12</td> </tr> <tr> <td>400%</td> <td>83%</td> <td>8.5</td> </tr> </tbody> </table> <p>Notice that the amount of nitrogen removed tapers off with increasing IMLR flows. This is because both nitrate and oxygen are being returned to the anoxic zone. The oxygen will always be used first. To get the best possible denitrification performance, use tapered aeration as shown in the example below to reduce the amount of DO recycled.</p>  <p>Warning: Denitrification requires a carbon source. If the influent ratio of BOD to nitrogen isn't at least 3:1, the process may be carbon limited. In a carbon limited system, increasing the IMLR won't continue to decrease effluent nitrate concentrations.</p> | Percent of IMLR compared to influent flow | Percent total nitrogen removal | Estimated effluent total N (mg/L) | 100% | 50% | 25 | 200% | 67% | 16.5 | 300% | 76% | 12 | 400% | 83% | 8.5 |
| Percent of IMLR compared to influent flow | Percent total nitrogen removal | Estimated effluent total N (mg/L) | | | | | | | | | | | | | | | |
| 100% | 50% | 25 | | | | | | | | | | | | | | | |
| 200% | 67% | 16.5 | | | | | | | | | | | | | | | |
| 300% | 76% | 12 | | | | | | | | | | | | | | | |
| 400% | 83% | 8.5 | | | | | | | | | | | | | | | |
| <p>Using control charts to improve process control</p> | <p>Track only the most important variables.</p> | <p>Good process control requires control charts that are both available and current.</p> <p><i>Available</i> means that all staff members are looking at the data. Keeping daily charts on a breakroom white board helps to ensure that everyone is working toward the same goals and is aware of current conditions.</p> <p><i>Current</i> means that data is entered every day. A good starting point for charting process control is to watch these four variables:</p> <ul style="list-style-type: none"> ■ SRT or MCRT ■ SSV_5 ■ SSV^{30} ■ SVI <p>For facilities that nitrify, tracking effluent ammonia and nitrate also is desirable.</p> <p>Plot the data. Plot a 3- or 5-day running average as well to smooth out variations from sampling and analysis. Look for trends. Don't wait for a parameter to go out of limits. Several data points heading in the same direction is cause to investigate why they are trending in that direction.</p> | | | | | | | | | | | | | | | |

Sidney Innerebner is principal and owner of Indigo Water Group LLC (Littleton, Colo.). (Ron Schuyler provided the text above on ORP in the January 2013 issue of WE&T.)

Section 2

Odor and Corrosion Control



Odor and Corrosion Control

Advanced Wastewater Class



What is Odor?

- “It smells like money to me!”
 - “Fresh” wastewater does not have an offensive odor
- Chemical/physical interaction with olfactory hairs
- Complex – depends on humidity, temperature, pH
- Subjective – no two people perceive odors alike
- Anaerobic decomposition of organic compounds containing sulfur or nitrogen
- Two major culprits – H₂S and NH₃

2

Need for Odor Control

- With increased population, collection systems are being stretched farther and farther away from the WWTP
 - Longer collection systems create longer flow times to reach the WWTP
 - Increased travel times can cause the wastewater to become septic and therefore cause odor and corrosion problems
- Also with increase population, the buffer zone initially around a WWTP is being encroached upon with neighborhoods being built around WWTP
- Good housekeeping is an effective means for controlling odors

3

Characteristic Odors

| | Formula | Typical Threshold Odor, mg/L | Comments |
|------------------|---|------------------------------|------------------------|
| Ammonia | NH ₃ | 0.037 | Sharp, pungent |
| Cadaverine | H ₂ N(CH ₂) ₅ NH ₂ | 0.24 | Putrid, decaying flesh |
| Dibutylamine | (C ₄ H ₉) ₂ NH | --- | Fishy |
| Hydrogen Sulfide | H ₂ S | 0.00047 | Rotten eggs |
| Indole | C ₂ H ₆ NH | --- | Fecal |
| Thiocresol | CH ₃ C ₆ H ₄ SH | 0.0001 | Skunk, rancid |

Summary of odors we can detect from various substances and the threshold odor concentration (the level at which our nose first detects an odor)

4

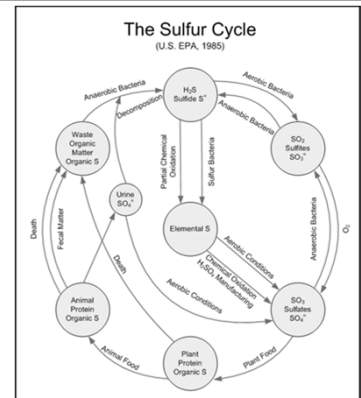
Odor Measurement

- Difficult to define nature, cause, extent with just the human nose
 - FYI – Taste and odor are closely related
- Threshold Concentration Level
 - Odor is diluted until no longer detectable
 - Odor panel (group of people)
 - Olfactometer (instrument)
- Olfactometer, odor panel



5

Sulfur Cycle



6

The Main Characters

- H_2S and NH_3 are easily identified and give off most offensive odors
- Difficult to measure in liquid phase
 - Volatile, tend to off-gas when disturbed
 - More easily measured in atmosphere
- Many types of test/monitoring devices
 - Color change strip or disc
 - Electronic device (with or w/o high alarm)
 - Data log for record of long term exposure

7

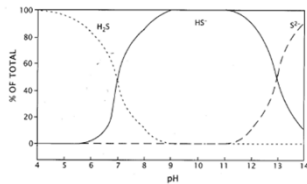
H_2S – Hydrogen Sulfide

- Colorless, combustible, toxic gas; heavier than air (S.G. = 1.19)
- Characteristic rotten egg odor
 - But at high concentrations it is not noticeable
- Can cause almost instantaneous unconsciousness, permanent brain damage (at concentrations commonly found in unvented lift stations), or even death
- Anaerobic bacteria reduce SO_4^{-2} to HS^-
 - HS^- goes into equilibrium with air layer
 - In water, HS^- no problem
 - In air, HS^- becomes H_2S

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H_2S – Hydrogen Sulfide

- Hydrogen sulfide causes most problems at a pH < 5
 - At a pH below 5, all sulfide is present in the gaseous H_2S for and most of it can be released from wastewater and may cause odors, corrosion, explosive conditions and respiratory problems.



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Sulfate to Sulfide Conversion

- DO
- ORP
- BOD
- Detention time
- Temperature
- Sulfur Concentration

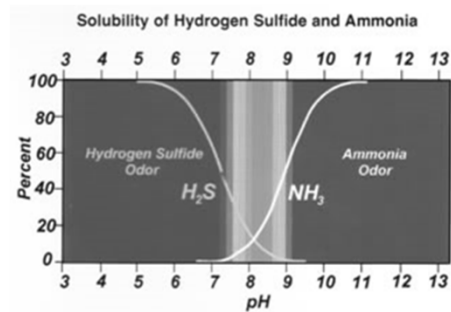
10

Sulfate to Sulfide Conversion

- DO, ORP, BOD, and Detention Time are all related
 - As DO increases, ORP increases (and vice versa)
 - BOD affects the amount of DO in waste stream
 - Detention time supports the oxidation of BOD
- As temperature increases, reduction rate of SO_4^{-2} to HS^- increases
 - Reaction rate doubles every $10^\circ C$ (up to $40^\circ C$)
 - Areas with higher temps have more problems than areas with lower temps
- Sulfur concentration rarely a limiting factor

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pH Chart



12

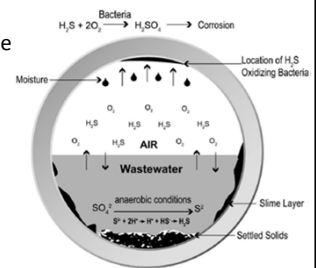
H₂S Toxicity

- Easily detectable at low concentrations
 - Rotten egg odor
- Will fatigue olfactory system even at low concentrations
 - If you smell hydrogen sulfide and then it goes away, move quickly to a well-ventilated area
- Higher concentrations will mask olfactory system entirely
 - Always use a gas meter, the nose is not always reliable
- Length of exposure vs. Concentration
 - Long term exposure to 10 ppm vs. 30 min. at 600 ppm
- Deaths due to H₂S poisoning have been reported

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H₂S Corrosion

- H₂S is biologically converted to H₂SO₄ in the presence of water and oxygen
- Corrosion occurs: pipe crown, lift stations, headworks, sludge storage and dewatering, and others



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H₂S Corrosion

- H₂SO₄ attacks:
 - Concrete
 - Pipe failure, trench collapse
 - Metal
 - Manhole ladders, support structures
 - Electronics
 - Copper wiring converted to non-conductive copper sulfide

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NH₃ - Ammonia

- Toxic, distinct odor
- Very corrosive, especially to copper
- Primarily occurs in lime stabilization process
 - Increase in pH will increase NH₃
- Most common treatment is acid-based scrubbers

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Control Strategies

Possible Control Strategies

- Minimize hydraulic detention time in pipes and wet wells
- Maintain DO in the wastewater
- Ensuring sufficient flow velocities to prevent solids deposition in pipelines and channels
- Routinely cleaning structures to remove slime, grease and sludge accumulation
- Treating liquid and solids recycle streams
- Changing or enforcing sewer-use ordinance
- Routinely and frequently disposing of screenings and grit
- Immediately removing floating scum/solids
- Promptly and thoroughly cleaning process units as they are removed from service

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Control Strategies

- There are 2 major methods of odor control
 - Chemical addition to the wastewater
 - Mechanical control by odorous air treatment, where odorous vapors can be contained and collected
- Also Biological
- Video - [Evoqua](#)

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Chemical Controls

- Try to keep sulfides in aqueous solution
- Manipulates factors that contribute to H₂S formation:
 - DO
 - BOD
 - ORP
 - pH, etc.

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Chemical Controls

- Chlorination
- Oxygen and aeration
- Ozone
- Chromate
- Metallic ions
- Nitrate compounds
- pH control

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Chlorine – Cl₂

- Often used to destroy hydrogen sulfide at the point of application
- 8 to 10 lbs Cl₂ for 1 lb H₂S
- Dangerous to handle Cl₂; bleach adds to cost
- Strong bactericide
 - Reduces bacteria responsible for sulfide production by inhibiting the growth of biofilm inside sewer lines
 - Could also neutralize bacteria in WWTP

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Chlorine – Cl₂

- Chlorination is one of the oldest and most effective methods used for odor control
- Chlorine is a very reactive chemical and oxidizes many compounds in wastewater

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Chlorine – Cl₂

- Reaction between Cl₂ and H₂S
 - $\text{H}_2\text{S} + 4\text{Cl}_2 + 4\text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 + 8\text{HCl}$
- Reaction between Cl₂ and NH₃
 - $\text{NH}_3 + \text{Cl}_2 \rightarrow \text{NH}_2\text{Cl} + \text{HCl}$ (monochloramine)
 - $\text{NH}_2\text{Cl} + \text{Cl}_2 \rightarrow \text{NHCl}_2 + \text{HCl}$ (dichloramine)
 - $\text{NHCl}_2 + \text{Cl}_2 \rightarrow \text{NCl}_3 + \text{HCl}$ (trichloramine)

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Chlorine – Cl₂

- The most important roles that chlorine plays in controlling odors are to
 - Inhibit the growth of slime layers in sewers
 - Destroy bacteria that convert sulfate to sulfide
 - Destroy hydrogen sulfide at the point of application
 - This controls requires less chemical than trying to oxidize the odor once formed
- This means that chlorine should be added in the collection system prior to the plant

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Chlorine – Cl₂

- Doses as high as 12 mg/L Cl₂ for every 1 mg/L H₂S (in solution, not in the atmosphere) may be needed to control the generation of hydrogen sulfide in sewers
- Dangerous to handle Cl₂; bleach adds to cost

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Hydrogen Peroxide – H₂O₂

- Widely used, relatively safe to handle
- Non-toxic by-product (O₂)
 - adds to waste stream DO
- Requires good mixing, long contact time
 - typical to have multiple feed points
 - Can need 15 minutes to 2 hours of contact time
- Less than 5 lb H₂O₂ per 1 lb H₂S
 - Usually a 2:1 to 4:1 of H₂O₂ to S₂- is needed for control

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Hydrogen Peroxide – H₂O₂

- Reacts in 3 possible ways to control odors
 - Oxidant action
 - Converts H₂S to sulfate compounds (SO₄⁻)
 - Oxygen producing
 - Keeps system aerobic
 - Bactericidal to the sulfate-reducing bacteria
 - Kills bacteria that produce odors

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Hydrogen Peroxide – H₂O₂

- Benefit: increases DO and slows sulfide formation
- Typical 5 lb O₂ to 1 lb H₂S
- Only suitable for force mains
- Requires storage and handling of liquid O₂

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ORP Adjustment

- All of the oxidizing agents will increase ORP
 - ozone may be exception
- Another method may be to add nitrate upstream
 - Bacteria prefer to take O₂ from nitrate instead of sulfate
 - Reaction also adds DO to system and raises ORP
 - Bioxide® - trade name, in wide use

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Ozone – O₃

- Powerful oxidizing agent that effectively removes odors
- Toxic
- Must be generated on-site (\$\$\$)
- Very short contact time, less than 1 min
- Rarely used
 - Although, Water Authority of Dickson County installed an ozone generator in March 2012 at one of their lift stations.

31

Chromate – CrO₄²⁻

- Effectively inhibit the sulfate reduction to sulfide.
- Cause serious toxic conditions that limit their usefulness.

32

Metallic Ions

- Iron or zinc (mainly) has been used to precipitate sulfide compounds.
 - React with sulfides and settle out
 - Sulfur is permanently removed from waste stream
 - Zinc is rarely used anymore due to effluent and sludge limitations
- Has a toxic effect on biological treatment such as sludge digestion and therefore has limitations
- Inexpensive, safe to handle
- Typically fed upstream of problem area
 - Avg. 4 to 5 lbs iron for 1 lb sulfur
- Disadvantages - sludge, low pH
- Added benefit – can also precipitate out phosphorus

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Nitrate Compounds – NO₃⁻

- The first chemicals used in the anaerobic breakdown of wastes are nitrate ions
- If enough nitrate ions are present, the sulfate ions will not be broken down
- The cost of this type of treatment to halt hydrogen sulfide production is very high and, at present, is not practical

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Potassium Permanganate – KMnO₄

- Very costly
- Rarely used in this application
- Non-corrosive, stable
- Effective for wide range of odor-causing agents
- Precipitates out sulfide compounds

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pH Control – Continuous

- Increasing the pH of the wastewater is an effective odor control method for H₂S
- By increasing the pH above 9, biological slimes and sludge growth are inhibited.
- Any sulfide present will be in the form of HS⁻ ion or S⁻ ion (above pH 11) rather than as H₂S gas, which is formed and released at low pH values

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pH Control – Shock Treatment

- Short-term, high pH (greater than 12.5) slug dosing with sodium hydroxide is effective in controlling sulfide generation for periods of up to a month or more depending on sewer temperature and sewer conditions

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pH Control

- Small pH drop can cause large shift in equilibrium (vapor vs. aqueous)
- Lime and caustic soda most commonly used to keep pH up
- Continuous control disrupts WWTP
- Shock pH treatment used instead
 - pH to 12 for 10 to 20 min or so to destroy biofilm
- Pipe crown corrosion sometimes controlled by spraying with caustic soda

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Metal Precipitation

- Most common treatment method
- Iron (or zinc) added to waste stream
 - React with sulfides and settle out
 - Sulfur is permanently removed from waste stream
 - Zinc is rarely used anymore due to effluent and sludge limitations
- Inexpensive, safe to handle
- Disadvantages - sludge, low pH
- Typically fed upstream of problem area
- Avg. 4 to 5 lbs iron for 1 lb sulfur
- Added benefit – can also precipitate out phosphorus

39

Mechanical Controls

- Attempt to remove or neutralize the ambient vapor H₂S
- Covers, scrubbers, ventilation, and use of non-corrosive liners or coatings

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Safety

- Safety items that should be considered when working with or installing chemical odor control systems include:
 - Personal protective equipment
 - Proper lockout/tagout procedures
 - Handling chemicals
 - Secondary containment

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Covers

- Installed over problem area and generated gas is vented off and treated
- In anaerobic digesters, H₂S is removed and remainder of gas is used as fuel
- Materials should be corrosion resistant
- Work well for odor control

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Scrubbers

- Combined with cover and ventilation
 - Gas is collected and vented out to scrubber
- Packed bed of non-corrosive media
 - Chemical misted down from top
 - Gas pulled up from bottom
- Some are multi-stage: separate sections for oxidation, pH, etc.
- Effective for odor and corrosion control
 - Lift stations, clear wells, and other

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Chemical Mist Odor Control System

- Wet scrubber, no media
- Bleach is recirculated
 - KMnO_4 and H_2O_2 can also be used
 - NaOH only used when H_2S concentration in gas phase is high
- Softened water is used to minimize scaling

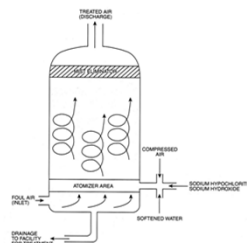
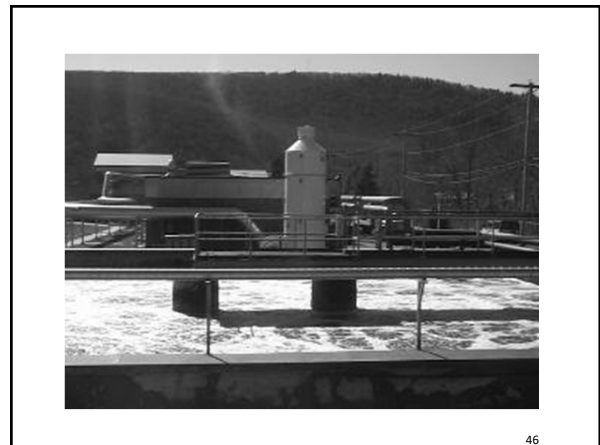


Diagram excerpted from Chapter 1: Odor Control. In *Advance Waste Treatment*.

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Packed Tower Scrubber with Countercurrent Air Flow

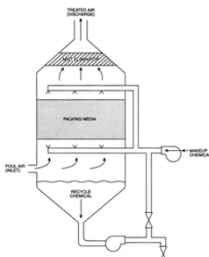


Diagram excerpted from Chapter 1: Odor Control. In *Advanced Waste Treatment*.

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- Oxidant used:
 - Chlorine
 - Sodium hydroxide
 - Bleach
 - Hydrogen peroxide
 - To remove hydrogen sulfide
 - Sulfuric acid, diluted
 - To remove ammonia

● [Video](#)

Packed Tower Scrubber with Cross Air Flow

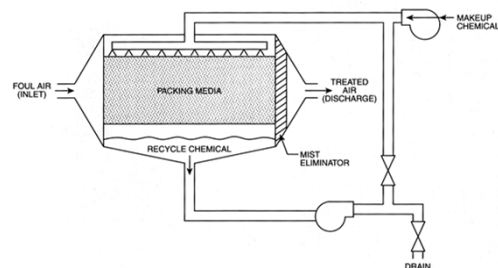


Diagram excerpted from Chapter 1: Odor Control. In *Advance Waste Treatment*.

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Biological Odor Control Systems

- Rely on Biological oxidation of odorous air
- Remove a variety of inorganic compounds from foul air streams
 - Given adequate contact time and balanced environmental conditions

1. Odor Removal Tower/Biotrickling Filter
2. Biofiltration

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Biological Odor Control Systems

Advantages:

- Simple operation
- Lack of chemicals
- Ability to treat high volumes of gas economically

Disadvantages:

- Space
- Limited gas transfer capability
- Media fouling
- The need for balanced environmental conditions
- Sometimes questionable reliability

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Biological Odor Control Systems – Odor Removal Tower (ORT)

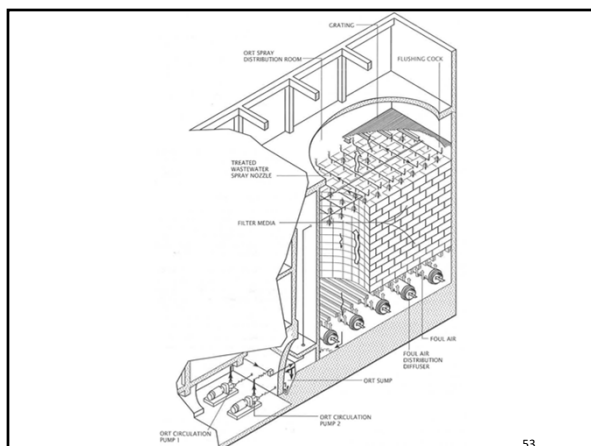
- Also called a Biotrickling Filter
- Essentially a deep bed trickling filter that is lightly loaded
- Containment vessel with inorganic media to support microbial growth
- 2 flow streams:
 - Liquid – maintain the biomass on the media
 - Air – carry the odors

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Odor Removal Tower (ORT)

- Foul air and off gases from the plant process systems are captured and piped into the bottom of the odor removal tower
- Odorous air passes up through filter media and odors are oxidized
- Air is discharged to atmosphere at top of the tower

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Odor Removal Tower (ORT)

- Hydraulic loading : 2-3 gpm/sq ft to produce a nitrifying zoogelal mass
- Organic loading: 0.5 lb BOD/day/cu yd media
- Secondary effluent, single-pass operation
 - Plugging of spray heads minimized
 - Prevents build-up of H_2SO_4
- pH must be maintained above 6.0

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Biological Odor Control Systems - Biofiltration

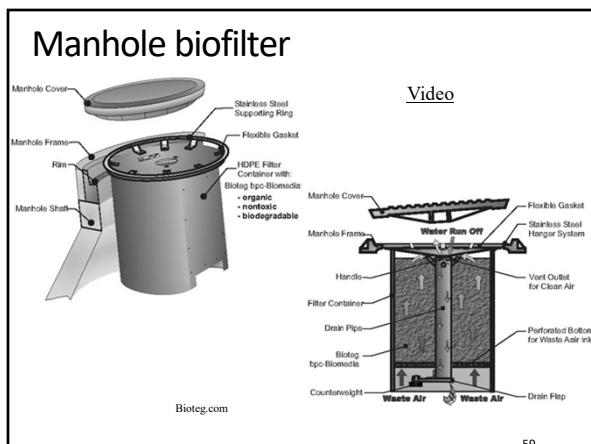
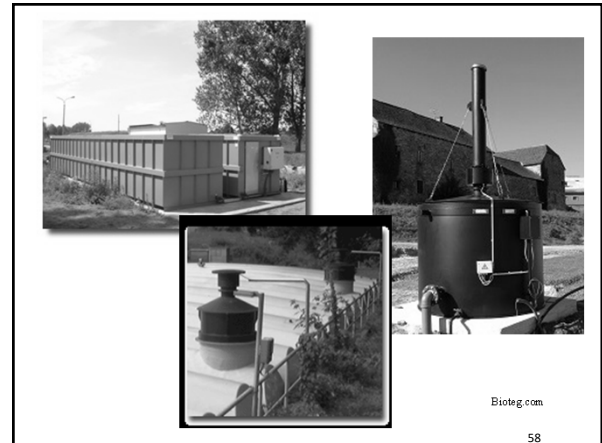
- Biological process using soil, compost, or other media as substrate for microbes
- Sufficient residence time required for microbes to accomplish effective treatment
 - Must use low air velocity
 - For H₂S removal, residence time ranges from 40-60 seconds
 - Some compounds require longer
 - Can be designed to remove odorous VOCs

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Biofiltration

- Key elements:
 1. Media
 - Wood chips, compost, soil, peat moss
 2. Air distribution
 3. Moisture
- Lifecycle is dependent on contaminant concentration, but typically ranges from 2-3 years
 - Inorganic media – 10 years

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Activated Carbon Adsorption

- Removes pollutants by surface adhesion
- Adsorption = the process in which odorous components are removed from a gas through adherence to a solid
- Or
- Adsorption = the gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material

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Activated Carbon Adsorption

- Physical = physical adsorption
- Chemical = chemisorption
- Activated carbon is highly porous
- Adsorption takes place on the walls of the pores within the carbon

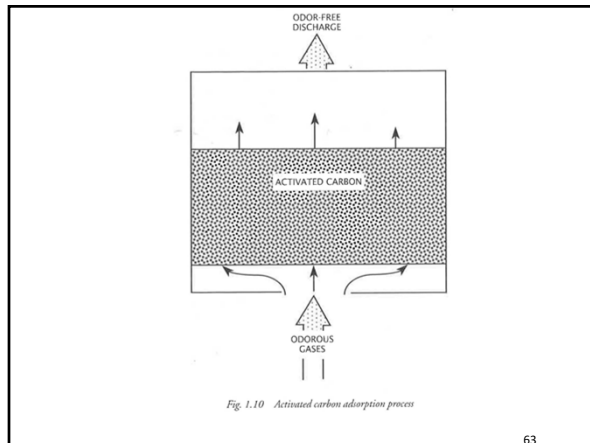
Video

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Activated Carbon Adsorption

- Typically consist of stainless steel or fiberglass vessel with single or dual bed of GAC, through which odorous air is discharged
- Several feet of GAC
- Fixed or portable units
- Well suited for use as a “polishing” unit
 - In support of other odor control systems
 - Carbon very effective on organic sulfur compounds

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An Activated Carbon System



Diagram excerpted from Chapter 1: Odor Control. In *Advance Waste Treatment*.

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Activated Carbon Adsorption

1. Virgin
 - Greater capacity for removing VOCs
 - Removes H₂S, but at 1/3 capacity of impregnated carbon
2. Caustic impregnated
 - Greater H₂S capacity, but lower ability to remove other odorous compounds
3. Water washable
 - Can be regenerated multiple times with water
 - More expensive, but more cost-effective long term
4. High-capacity carbon
 - Very high H₂S removal, but one time use

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Activated Carbon Adsorption

Advantages:

- Fairly consistent reliability
- Simple operation
- Ability to increase adsorbent capability by the use of additive compounds
- Accommodation of high gas flow rates by use of multiple units

Disadvantages:

- Potentially high regeneration costs
- Short use time due to high concentrations of odorous compounds
- Reactivity of caustic-impregnated material
- Fouling of the adsorbent by particulate matter
- Disposal of spent carbon if it is classified as a hazardous waste

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Regeneration of Activated Carbon

- Eliminates the need for hazardous waste disposal
- Landfill space is conserved
- Generally, regenerated carbon has less capacity than virgin because of the reduction in available pore space
 - Thermal

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Regeneration of Activated Carbon

- Thermal
 - Cost is less than purchasing new carbon
 - Regenerated carbon has less capacity due to reduction in available pore space
- Chemical
 - Caustic-impregnated carbon can be partially restored by in-place sodium hydroxide regeneration
 - Flushing with water, draining, adding new sodium hydroxide
 - Not recommended – bed fires and explosions

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Regeneration of Activated Carbon

- Hot air
 - Used when VOCs are nonflammable
 - Hot air applied countercurrent to adsorption flow
 - As temperature rises, desorbed organics transfer to the regeneration stream
 - The gas stream is then treated by a thermal oxidizer, where the VOCs are destroyed

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Ozonation

- Ozone is a powerful oxidant
- Mixing chamber where odorous air is mixed with ozone
- Odorous air is oxidized and odors are eliminated
- Contact time is critical – 15 seconds is minimum mixing and contact time
- Ozone is unstable and must be manufactured on site

70

Electrolytic Chemical Scrubber Using a Brine Solution

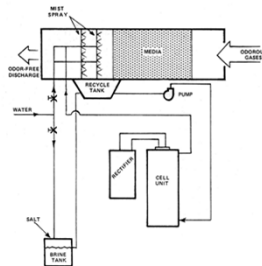


Diagram excerpted from Chapter 1: Odor Control. In *Advance Waste Treatment*.

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Ventilation

- Wet wells, covered tanks, covered channels
- Introduces oxygen to vapor phase and keeps liquid phase from becoming anaerobic
- Bonus! - provides safe environment for operators and minimizes buildup of flammable or explosive gases

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Liners and Coatings

- Very effective at controlling corrosion
- Liners used widely to repair damaged pipes
- Many types:
 - Slip liners
 - Cured-in-place pipe
 - Specialty concrete
 - Epoxies

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Electronics Protection

- Degree of protection depends on severity of corrosion potential
- Achieved by airtight enclosures, air conditioned workspaces, corrosion resistant coatings, and/or nitrogen-purged systems

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Masking Agents

- Counteractants
 - impose stronger, more pleasant odor over problem
- Neutralizers
 - attempt to combine with odor and reduce its effect



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Masking Agents



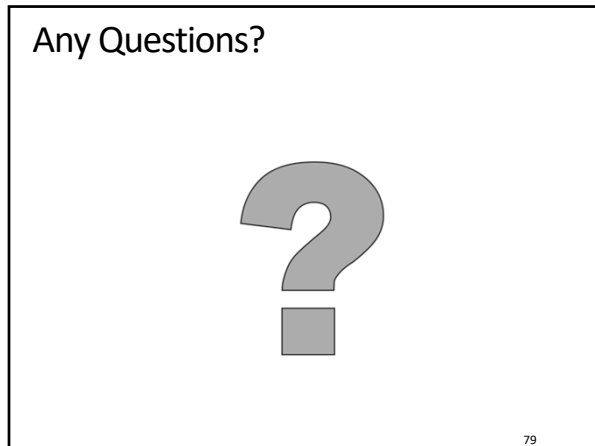
- Consider this:
 - Never mask the odor of a toxic substance
 - Not a substitute for good operation or housekeeping
 - Odor problems should be controlled at their source

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Procedures to Solve Odor Problems

- Evaluation of plant performance
- Examination of engineering or design features of plant
- Identification of source or cause of problem
- On-site inspection and investigation of the problem areas

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Odor Control - Review Questions

1. The most common source of sulfide in wastewater is biological activity in the collection sewer or treatment plant.
 - a. True
 - b. False
2. The threshold odor level is the average level at which odors are considered objectionable as measured by an odor panel.
 - a. True
 - b. False
3. Treatment plant operators develop “educated noses” and are usually able to detect odors most other people would not notice.
 - a. True
 - b. False
4. Adsorption is the taking in or soaking up of one substance into the body of another substance.
 - a. True
 - b. False
5. At a pH below 5, all sulfide present in wastewater is in the gaseous form.
 - a. True
 - b. False
6. In a biological odor removal tower, odors will not be removed from the gas stream until a biomass is established on the filter media.
 - a. True
 - b. False
7. Chemical mist and packed bed odor control units are examples of wet scrubber systems.
 - a. True
 - b. False
8. Regenerated carbon has the same capacity for odor removal as new carbon.
 - a. True
 - b. False
9. Besides chlorine, what other chemical(s) are used to control or prevent odors?
 - a. Chlorophenol
 - b. Dichloramine
 - c. Hydrogen peroxide
 - d. Sodium hypochlorite
 - e. Both C and D
10. Odors caused by hydrogen sulfide can be controlled by increasing the pH to levels above 9.0.
 - a. True
 - b. False

11. Microorganisms that can use either molecular (atmospheric) or combined (bound) oxygen are called:
 - a. Anaerobes
 - b. Facultative organisms
 - c. Obligate aerobes
 - d. Strictly aerobic microorganisms
 - e. Strictly anaerobic microorganisms

12. Hydrogen sulfide causes the most serious problems at what pH range?
 - a. Less than 5
 - b. 5 to 7
 - c. 7, neutral
 - d. 7 to 9
 - e. Greater than 9

13. Odors in AIR cannot be treated by:
 - a. Absorption
 - b. Adsorption
 - c. pH adjustment
 - d. Ozonation
 - e. None of the above

14. Conditions that favor hydrogen sulfide production are also associated with other problems such as:
 - a. Corrosion of concrete pipelines and manholes
 - b. Explosive gas mixtures
 - c. Respiratory hazards for operators
 - d. All of the above
 - e. None of the above

15. Ways that chlorine controls odors include(s):
 - a. Destroying bacteria that convert sulfate to sulfide
 - b. Destroying hydrogen sulfide at the point of application
 - c. Inhibiting the growth of slime layers in sewers
 - d. All of the above
 - e. None of the above

16. Steps followed (not in order) in procedures used when attempting to solve odor problems include:
 - a. Evaluation of plant performance
 - b. Examination of engineering or design features of plant
 - c. Identification of source or cause of problem
 - d. On-site inspection and investigation of the problem areas
 - e. All of the above

17. Offensive-smelling inorganic gases found in treatment plants include:
 - a. Ammonia
 - b. Hydrogen sulfide
 - c. Mercaptans
 - d. Methane
 - e. A and B

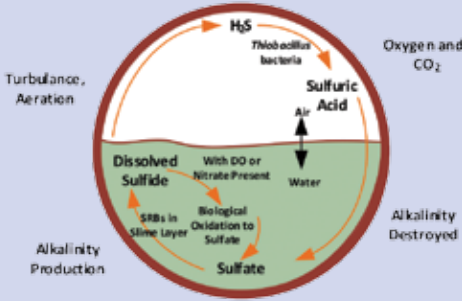
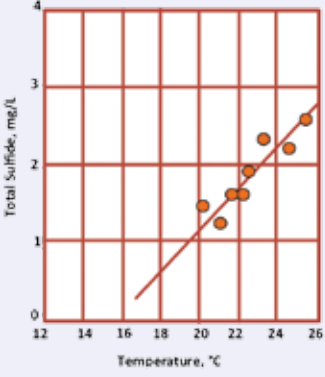
18. Safety items that should be considered when working with or installing chemical odor control systems include:
- Personal protective equipment
 - Proper lockout/tagout procedures
 - Handling of chemicals
 - Secondary containment
 - All of the above
19. Oxidants commonly used in packed bed scrubber systems include all but:
- Chlorine
 - Hydrogen peroxide
 - Ozone
 - Sodium hydroxide
 - Sodium hypochlorite
20. Wastewater is tending to become more septic, and thus causing more odor and corrosion problems, because collection systems are being extended farther and farther away from treatment plants.
- True
 - False

Answers:

- A
- B
- B
- B
- A
- A
- A
- B
- E
- A
- B
- A
- C
- D
- D
- E
- E
- E
- C
- A

What every operator needs to know about collection system odor and corrosion control

Jorj Long

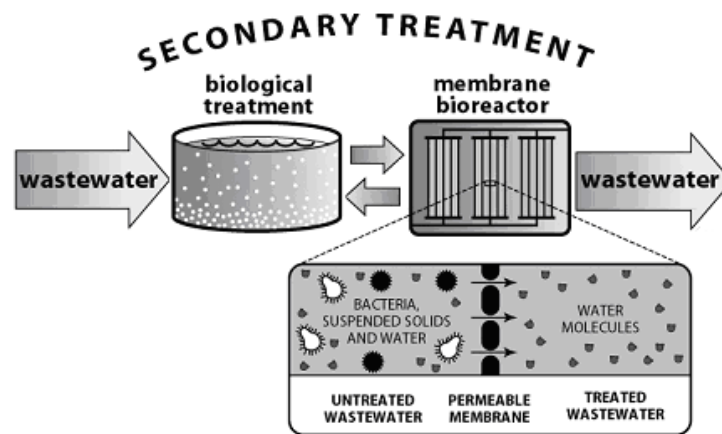
| Knowledge | Principle | Practical considerations |
|-------------------------|---|---|
| Anaerobic conditions | When oxygen transfer is limited, as in wastewater force mains, sulfate-loving bacteria thrive. | Bacteria use the sulfate ion (SO_4^-), which is naturally abundant in most source waters, as an oxygen source for respiration. This results in hydrogen sulfide (H_2S). |
| Corrosion | Hydrogen sulfide directly attacks such metals as iron, steel, and copper as well as concrete. | Corrosion occurs on the concrete pipe crown, on the wall of manholes, within junction structures, and inside wet wells that remain moist but are not submerged continuously. |
| The sewer sulfide cycle |  <p>The diagram illustrates the sewer sulfide cycle. At the bottom, sulfate is converted to dissolved sulfide by SRBs in a slime layer, a process that produces alkalinity. Above the water surface, dissolved sulfide can be oxidized back to sulfate by Thiobacillus bacteria, which consumes oxygen and CO₂. This process produces sulfuric acid, which can run down the walls into the wastewater, destroying alkalinity. Turbulence and aeration can also release hydrogen sulfide gas into the air.</p> | <p>In the slime layer, sulfate is reduced to sulfide and some alkalinity.</p> <p><i>Thiobacillus</i> bacteria living above the water on the sewer walls oxidize hydrogen sulfide gas to sulfuric acid.</p> <p>Turbulence releases hydrogen sulfide into the air.</p> <p>The acid runs down the walls into the wastewater. Acid erodes the concrete along the way.</p> <p>When the acid reaches the wastewater, it destroys the alkalinity previously generated and becomes sulfate again.</p> <p>The cycle begins anew.</p> |
| Temperature effects |  <p>The graph plots Total Sulfide (mg/L) on the y-axis (0 to 4) against Temperature (°C) on the x-axis (12 to 26). A series of data points shows a clear upward trend, indicating that as temperature increases, the concentration of total sulfide also increases.</p> | <p>Warmer wastewater contains more sulfide; more sulfide leads to more hydrogen sulfide; more hydrogen sulfide leads to more sulfuric acid.</p> <p>More sulfuric acid leads to more corrosion and more sulfate in the wastewater.</p> <p>The cycle (see above) continues.</p> |

| Knowledge | Principle | Practical considerations |
|--|--|--|
| Ideal conditions for odor and corrosion | Certain conditions lead to the most odors and corrosion. | These conditions include <ul style="list-style-type: none"> ■ long force mains and flat sewers with debris, ■ warm wastewater temperatures, ■ high ratio of biochemical oxygen demand (BOD) to soluble BOD, and ■ high sulfate levels. |
| Odor of compounds | Hydrogen sulfide Ammonia Methylamine Acetone Butyric acid Mercaptans | Rotten eggs Dirty diapers Fishy, rotten Fruity, sweet Rancid Skunk, putrid to strong garlic |
| Actions in collections system to reduce odors that affect downstream treatment | Adding chemicals such as ozone, sodium hypochlorite, or hydrogen peroxide oxidizes hydrogen sulfide, ammonia, and volatile fatty acids (VFAs). | Odor mitigating chemicals are not sulfide-specific and will react with other constituents in wastewater. They react readily with oxidizable material, including BOD, in the sewer. VFAs are a subset of BOD and are oxidized easily. However, biological phosphorous removal requires VFAs in influent or a sufficient amount of rapidly biodegradable chemical oxygen demand (COD) that can be fermented to form VFA to trigger phosphorus release. |
| | Adding nitrate creates anoxic conditions and prevents fermentation, so hydrogen sulfide does not form. | Nitrate serves as an electron acceptor for biological actions, very similar to aeration, in the collection system. Under anoxic conditions, readily oxidizable VFA is consumed by the bacteria, so nitrate addition not only prevents VFA formation but can destroy VFA that already exists. |
| | Adding iron salts precipitates sulfide without significantly altering wastewater chemistry. | VFAs are not destroyed or affected. |
| | pH control can be effective. Hydrogen sulfide is a weak acid; it dissociates into HS ⁻ and S ⁻² ions. Maintaining a pH above 9 keeps most of it in its ionized form and prevents its release to the headspace. | A pH between 9 and 10 will not adversely affect VFA formation, but pH above 11 will slow or stop the rate of fermentation. |
| | Vapor phase odor control – such as wet scrubbers – can control odors and corrosion. | Sidestreams can create problems. Chemical blowdown can contain high chlorine concentrations. Whether routed to the treatment facility headworks or discharged to the collections system, the chlorine oxidizes VFA. |

Jorj Long is the deputy director of operation technology for Black & Veatch (Overland Park, Kan.) and is a certified operator.


Section 3

Secondary Effluent Solids Removal



Solids Removal

Secondary Effluent



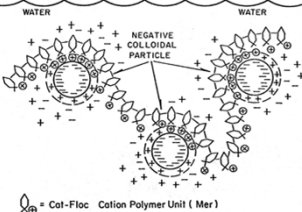
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Physical-Chemical Treatment

1. Coagulation: clumping together of very fine particles into larger particles (microfloc) caused by the use of chemicals (coagulant) added during rapid mixing
2. Flocculation: gathering together of fine particles after coagulation to form larger particles (floc) by gentle mixing
3. Liquid/solids separation (gravity, DAF)

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Coagulation/Flocculation Process



- Nonsettleable solids resist settling due to particle size & natural forces between particles
- Suspended, colloidal (fine silt, bacteria, viruses) & dissolved (color, chemicals)

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Coagulation/Flocculation Process

- WW solids tend to have negative charge
 - Including bacteria
- Destabilization adds chemicals to change or neutralize charge of particles

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Coagulation/Flocculation Process

- During the coagulation phase, chemicals are added to the wastewater and rapidly mixed with the water
 - Certain chemical reactions occur quickly resulting in the formation of very small particles, usually called "pinpoint floc"
- Flocculation follows coagulation and consists of gentle mixing of the wastewater
 - The main purpose is to bring together microfloc particles

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Flocculation Process

- The speed of the paddles becomes very important
 - Too rapid a speed may mechanically break up the floc
 - Too slow a speed may not provide enough mixing and may promote dead spots within the tank where mixing does not occur

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Liquid/solids Separation

- Liquid/solids separation step follows flocculation and is almost always conventional sedimentation by gravity settling
 - Although other processes are used occasionally like DAF, gravity filtration and membrane filtration

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Chemical Treatment

- Regardless of the form of chemical treatment process, the most important process controls are:
 - Provide enough mixing energy to completely mix the chemical with the water
 - Control the mixing intensity during flocculation
 - Control the chemical dose

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Chemical Treatment

- Often, filters are installed after chemical treatment to produce a highly polished effluent
- Chemicals can also be used as a “band-aid” effectively during problem situations
 - Reduce sludge bulking
 - Upstream equipment failure
 - Accidental spills entering the plant
 - Seasonal overloads

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Chemical Treatment

- Aluminum (3+) (alum) or iron (3+)(ferric) metal salts are used to coagulate wastewater solids
 - The cationic (positively charged) metals salts adsorb onto negatively charged wastewater solids and neutralize their negative charges

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Chemicals Used to Improve Settling

- Aluminum Sulfate (Dry)
- Aluminum Sulfate (Liquid)
- Ferric Chloride
- Lime
- Polymers

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Aluminum Sulfate (Alum)



- $\text{Al}_2(\text{SO}_4)_3 \cdot 14 \text{H}_2\text{O}$
- Reacts with alkalinity in water to form aluminum hydroxide as the precipitate
- Works best at pH of 5.8 to 8.5 with sufficient alkalinity
- Dry alum: powder, lump form
- Liquid alum: pH < 4; very corrosive
- 1 mg/L alum consumes 0.5 mg/L alkalinity

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Alum

- Alum will support a bacterial growth and cause sludge deposits in feed lines if wastewater is used to transport the alum to the point of application
 - These growths can clog feed lines
 - By keeping a velocity high enough to scour the lines continuously, this problem can be reduced

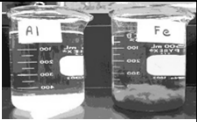
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Alum

- A 1% solution will have a pH of 3.5
- Overdosing of alum may decrease the pH to a point that will reduce biological activity
- A lower pH may also allow chlorine to further decrease the pH and affect the aquatic life in the receiving streams

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Ferric Chloride (FeCl₃)



- Highly corrosive
- Liquid is 35-45% strength; will crystallize at 30°F
- Effective over wider pH range than alum; works better in cold water, forming heavier, denser floc
- Reacts with alkalinity to form iron hydroxide (Fe(OH)₃)
- 1 mg/L consumes 0.6 mg/L alkalinity
- Decomposes in presence of light, producing hydrochloric acid


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Lime (Ca(OH)₂)

- Calcium hydroxide or quicklime
- Coagulate solids or adjust pH
- Quicklime must be mixed with water (slaked) before used
- Heat generated when water is added
- Inspect mixers and pumps daily for wear
- Irritates skin, eyes, lungs on contact

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Chemical Handling Safety



- Full face respirator
- Acid resistant goggles/ face shield
- Rubber gloves and boots
- Rubber suit/apron
- Emergency eye wash and shower (within 25 ft of storage and feed systems)

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A Polymer Map

- Polymers fed in very small doses
 - < 1%
- Solutions made in water prior to use.
- High to very high MW polymers require several hours to hydrate.

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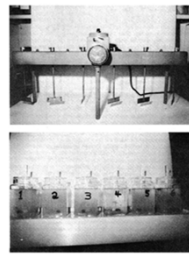
Polymers

- Advantages
 - Little effect on pH
 - Make work better in cold water with low turbidity
 - Produces less sludge
- Disadvantages
 - Overfeeding can clog filters
 - Must clean up spills immediately-slick & often corrosive (low pH)

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Jar Testing Equipment

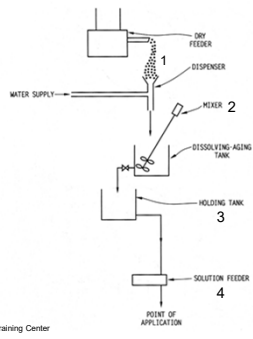
- Most valuable tool in operating & controlling chemical treatment process
- Simulates coag./floc. with different chemicals and/or doses
- Full scale plant operation may not match results



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Dry Chemical Feed System

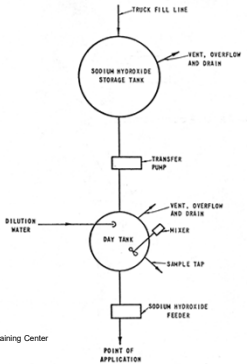
- Accurately controls dosage
- Known amount of chemical and water (1) mixed using high speed mixer (2)
- Solution held in day tank (3)
- Metered output ensures proper dosage into WW (4)
- Safety: dust dangerous if inhaled or on contact with skin/eyes



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Liquid Chemical Feed System

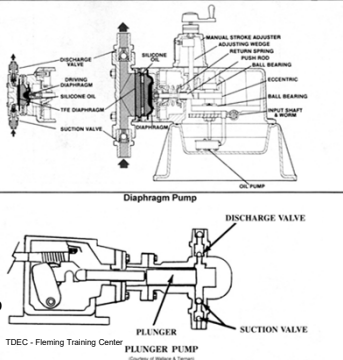
- May draw directly from storage tank or diluted in smaller tank then fed
- Positive displacement metering pump



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Positive Displacement Pumps

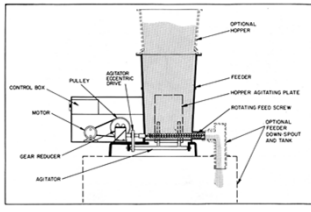
- Top: flexible rubber, plastic or metal diaphragm draws liquid in and out. When raised, suction is exerted. When depressed, liquid is forced through the discharge valve.
- Bottom: easy to adjust piston stroke to regulate chemical feed.



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Screw Feeder

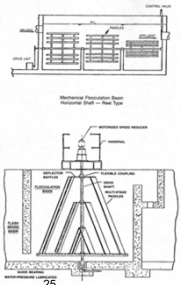
- Maintains desired output by varying speed and/or amount of time screw rotates as chemical is discharged
- Must keep screw clean
- Chemical may cake in hopper



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Mechanical Flocculators

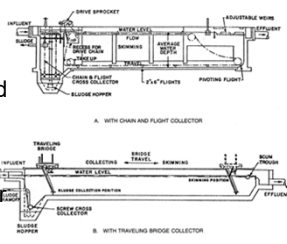
- Done in same or separate tank as sedimentation
- Tapered flocculation
- Paddle speed critical
- Top: variation in paddle size to control floc shearing
- Bottom: variable speed drive unit



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Rectangular Sedimentation Clarifiers

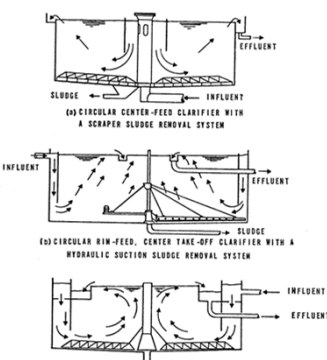
- Rectilinear flow
- Influent enters one end
- Flow hits baffle & moves by gravity to opposite end where effluent overflows outlet weirs
- Settled sludge moved by flights or bridge to hopper
- A return scraper skims scum into trough



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Circular Clarifiers

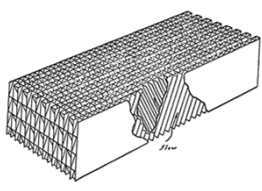
- Sludge collected at center of conical base
- Scum and oil removed by radial arm at surface
- PM & visual inspection: worn parts, corrosion, proper operation
- Hazards due to slips, trips, drowning, exposure to diseases, electrocution



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Tube Settler Module


- Shallow depth sedimentation
- Reduces settling time
- Tubes of steel or fiberglass
- Allows basin to settle larger flow
- Requires more frequent sludge removal



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Causes of Short Circuiting

- Flow not uniform
- Water density due to temperature (surface vs. bottom) or suspended solids differences
- Strong winds
- High inlet/outlet velocities
- Solutions: weir plates, baffles



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Factors Considered in Clarifier Design

- Weir Overflow Rate, gpd/ft
- Surface Overflow Rate, gpd/ft²
- Detention Time, hrs
- Solids Loading Rate, lbs/day/ft²

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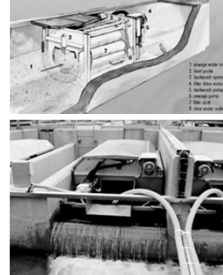
Wastewater Filtration

- Microscreens
- Gravity Filtration
- Synthetic Media Filter
- Continuous Backwash, Upflow & Deep-Bed Granular Media Filtration
- Surface Filtration
- Cross Flow Membrane Filtration

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Microscreens



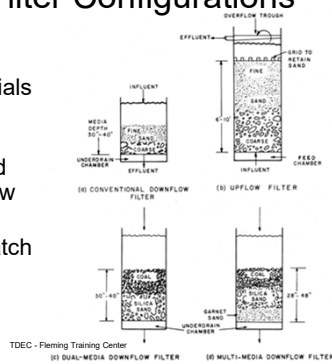
- Straining occurs over submerged section of microfabric
- 20-25 μm PE, PPE, stainless steel wire, copper or Teflon screen
- Filters out very small SS, decreases turbidity & improves effectiveness of disinfection
- Blinding or clogging due to iron or magnesium: clean with hot water or steam

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Gravity Filter Configurations

- Deep bed filtration
- One or more materials and/or grades of material
- Most are rapid sand filter with gravity flow from top down
- Most operate on batch basis
- Underdrain collects filtered WW
- [Video](#)



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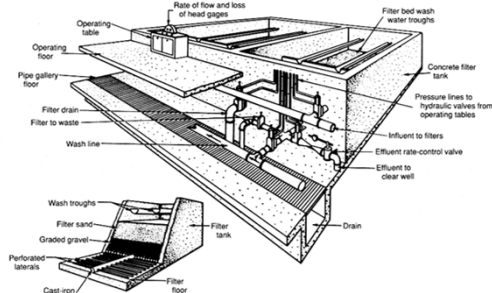
Gravity Filter Configurations

- Backwashing indicated by headloss
 - Backwashing a sand filter, treated water is used in order to avoid contamination of the filter bed
 - Incomplete cleaning leads to formation of mudballs
 - After a proper washing, the head loss should be less than 0.5 foot at start-up
- For depth filtration the multimedia filter, the finer, denser media (sand) is placed on the bottom with the coarse, lighter media (anthracite) on the top.
 - The coarse media removes larger solids that would quickly clog the finer media
 - The fine media will surface strain solids that penetrate the full depth of the coarse media bed

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Rapid Sand Filter



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Filter Operating Strategy

- Calcium scaling can occur within the filter and on the surface of the sand media granules when calcium ions and sulfate or carbonate ions are present in the filter influent flow.
 - Usually this happens when lime or sulfuric acid are used for pH control.
 - Prevention or controlling of scaling can be accomplished in several ways:
 - Use caustic in place of lime, or hydrochloric acid in place of sulfuric acid in neutralization
 - Use scale retardant/dispersant available from water treatment chemical suppliers
 - Keep sand bed moving whenever the influent flow is off by introducing clean water, or wash the sand with clean water for four hours before securing the filter.

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Synthetic Medium Filter

- Schreiber Fuzzy Filter: wastewater flows upward through polyvalinadene media between a lower fixed plate & upper movable plate.
- To clean, upper plate is raised mechanically. Flow to filter continues as air is introduced to scour/wash media periodically (external blower). Freed solids continuously exit filter during washing.

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Synthetic Medium Filter

- Closed, self contained unit
- Small footprint
- No odors or flies
- Filter media is compressible, so porosity can be altered
- Media life: > 10 yrs
- No media loss

Clayton County, GA NE STP uses five 7' X 7' filters handling up to 15 MGD at 30 gpm/sq ft.

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Bottom Feed Cylindrical Filter

- Continuous backwash, upflow, deep bed silica sand media filter
- Do not have to be taken out of service for backwashing
- Fewer and/or smaller filters due to continuous operation
- [Video](#)

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Surface Filtration: Disk Filters

- Cloth membrane as filter media removes fine particles
- Each disk has 6 pie-shaped sections mounted vertically to hollow tube that collects filtered effluent
- Low head-gravity feed
- Filter is static during filtering
- Backwashes automatically base on water level differential
- Disks rotate only during cleaning
- Maintains continuous filtration during backwash
- [Video](#)

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Membrane Filtration

- Membrane filtration processes are classified on the basis of the size of the particle they separate from the wastestream
 - Microfiltration (MF)
 - Ultrafiltration (UF)
 - Nanofiltration (NF)
 - Reverse Osmosis (RO)
- The separation technique involves a thin, semipermeable membrane that acts as a selective barrier that separates the particles on the basis of molecular size

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Membrane Filtration

OSMONICS The Filtration Spectrum

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Cross Flow Membrane Filtration

- WW pumped at high velocity along surface
- Driving force is pressure differential between WW side and effluent side
- Table: particle size & mw retention capacities for KOCH membranes

| REVERSE OSMOSIS | | | | | | |
|-----------------|------------------------------------|----|-----|-------|--------|----------------|
| Membrane Type | Molecular Weight Cut-Off (Daltons) | 10 | 100 | 1,000 | 10,000 | Classification |
| RO-100 | 100 | ■ | | | | Water |
| RO-100 | 100 | ■ | ■ | | | Water |

| ULTRAFILTRATION | | | | | | |
|-----------------|------------------------------------|-------|--------|---------|-----------|----------------|
| Membrane Type | Molecular Weight Cut-Off (Daltons) | 1,000 | 10,000 | 100,000 | 1,000,000 | Classification |
| UF-100 | 100,000 | ■ | | | | Water |
| UF-100 | 100,000 | ■ | ■ | | | Water |
| UF-100 | 100,000 | ■ | ■ | ■ | | Water, Soluble |
| UF-100 | 100,000 | ■ | ■ | ■ | ■ | Water, Soluble |
| UF-100 | 100,000 | ■ | ■ | ■ | ■ | Water, Soluble |

| MICROFILTRATION | | | | | | |
|-----------------|---------------------|-----|-----|-----|-----|----------------|
| Membrane Type | Pore Size (Microns) | 1.0 | 0.5 | 0.2 | 0.1 | Classification |
| MF-100 | 1.0 | ■ | | | | Water |
| MF-100 | 1.0 | ■ | ■ | | | Water |
| MF-100 | 1.0 | ■ | ■ | ■ | | Water, Soluble |
| MF-100 | 1.0 | ■ | ■ | ■ | ■ | Water, Soluble |
| MF-100 | 1.0 | ■ | ■ | ■ | ■ | Water, Soluble |

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Cross Flow Membrane Filtration

- Microfiltration membranes
 - Have pores ranging from 0.1-2.0 microns
 - Less common
- Ultrafiltration membranes
 - Most common
 - Pore sizes range from 0.005-0.1 micron
 - Examples of particles that are retained are:
 - Emulsified oils
 - Metal hydroxides
 - Proteins
 - Starches
 - Suspended solids
 - Examples of molecules that pass through the pores
 - Water, alcohols, salts, sugars

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Cross Flow Membrane Filtration

- Nanofiltration
 - Have pores between UF and RO
 - Effective at removing salts
- Reverse Osmosis
 - The tightest membrane process that allows only water to pass through the membrane
 - Retains salts and higher molecular weight components
 - Used for tertiary treatment producing water with low BOD/COD and of near-potable water quality

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Membrane Configuration

- Membranes are housed in various types of modular units
- The basic types of membrane configurations are:
 - Tubular
 - Hollow fiber
 - Spiral
 - Plate and frame
 - Ceramic Tube or Monolith

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Hollow Fiber Cartridge

- Semi-permeable polymer membrane
- Water (permeate) passes through, but solids are rejected
- Membrane fouling due to oils and greases
- Chemically cleaned in place using water, caustics, surfactants, & acids prescribed by manufacturer (2-3 times/week)
- 5-40 psi
- 3-10 yr membrane life

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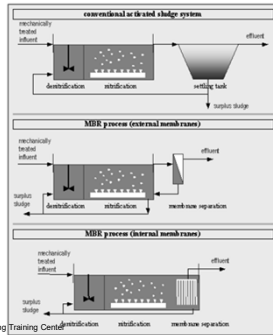
Spiral Wound Module

- Pack large surface area into compact design.
- Membrane cast on non-woven polyester flat sheets & put into spiral modules.
- Operate at 50-150 psi.

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Membrane Bioreactors

- Membrane immersed in WW
- Flat plate microfiltration
- Eliminates need for secondary clarification and filtration
- MLSS: 15,000-30,000 mg/L
- [Video](#)

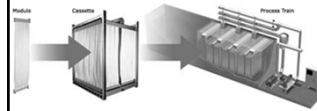


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Membrane Bioreactors

- Sludge age > 40 days
- Cleaned 2-3 times/year in place
- >99.9% removal bacteria & viruses



50

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Solids Removal from Secondary Effluents - Review Questions

1. Coagulation is a process of gentle mixing to ensure contact between the coagulant chemicals and the suspended particles.
 - a. True
 - b. False
2. Dry alum is corrosive unless it absorbs moisture.
 - a. True
 - b. False
3. The settling rate of particles is faster at a warmer temperature than it is at a lower temperature.
 - a. True
 - b. False
4. The conventional single-media filter bed commonly used in potable water systems is generally unsatisfactory in removing solids found in wastewater because of plugging.
 - a. True
 - b. False
5. In a dual-media filter, the finer, denser sand is placed over the coarse media, anthracite.
 - a. True
 - b. False
6. Downflow filters are designed to remove suspended solids by either the surface-straining method or the depth filtration method.
 - a. True
 - b. False
7. The cause of mudball formation in a filter is inadequate oil and grease removal by earlier processes.
 - a. True
 - b. False
8. Growth of algae and slime in gravity filters can be controlled with occasional applications of chlorine ahead of the filter.
 - a. True
 - b. False
9. The rate of flow through a granular media filter is expressed as the surface loading rate.
 - a. True
 - b. False
10. The performance of treatment chemicals during a jar test does **not** depend on:
 - a. Chemical concentration
 - b. Mixing intensity
 - c. Method of application
 - d. Time of day sample is collected
 - e. Time of reaction

11. The most critical water quality indicator influencing the performance of polymers is:
- Ammonia
 - Conductivity
 - Hardness
 - pH
 - Phosphate
12. What could be the possible causes of the floc being too small in a chemical coagulation and flocculation system?
- Change in pH
 - Chemical feed pump adjusted too low
 - Improper chemical dosage
 - Paddle speed in flocculators too fast
 - All the above
13. Which of the following tests should **not** be run daily for process control when chemicals are used to reduce effluent suspended solids?
- Chemical dosage
 - Chemical viscosity
 - Influent and effluent suspended solids
 - pH
 - All the above
14. A jar test can **not** be used to determine:
- The most economical dosages
 - The pH of the sample
 - The plant response to wastewater changes by using lab equipment
 - What the clarity will probably be in the plant effluent
 - None of the above
15. Short-circuiting in a clarifier may be caused or made worse by:
- Differences in the density of suspended solids in the influent
 - High inlet and outlet velocities
 - Strong winds blowing across the surface of the tank
 - Temperature differences within the tank
 - All of the above
16. What is the one invariable requirement in all jar test procedures?
- Chemicals of the highest possible purity should be used
 - Jar test apparatus must have at least 6 jars
 - pH of the samples must be within the range of 6.5 to 8.5
 - Test conditions should match actual plant conditions
17. Clarifier efficiency is determined using:
- Effluent grab samples
 - Influent and effluent 24-hour composite samples
 - Nephelometric measuring devices
 - 24-hour sludge accumulation (volume) measurements
 - None of the above
18. Colloids are very small, finely divided solids that remain dispersed in a liquid for a long time due to their small size and electrical charge.
- True
 - False

19. Paddle speed must be controlled during flocculation, if it is too great it can shear and break up the floc that has formed.
 - a. True
 - b. False

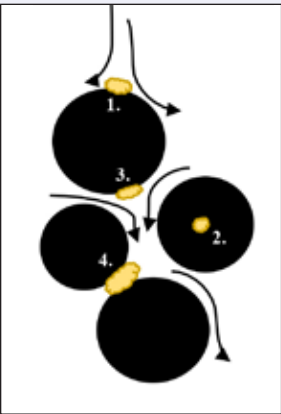
20. Microfiltration is the most effective membrane filtration because it utilizes the smallest pore size of all membrane filtration processes.
 - a. True
 - b. False

Answers:

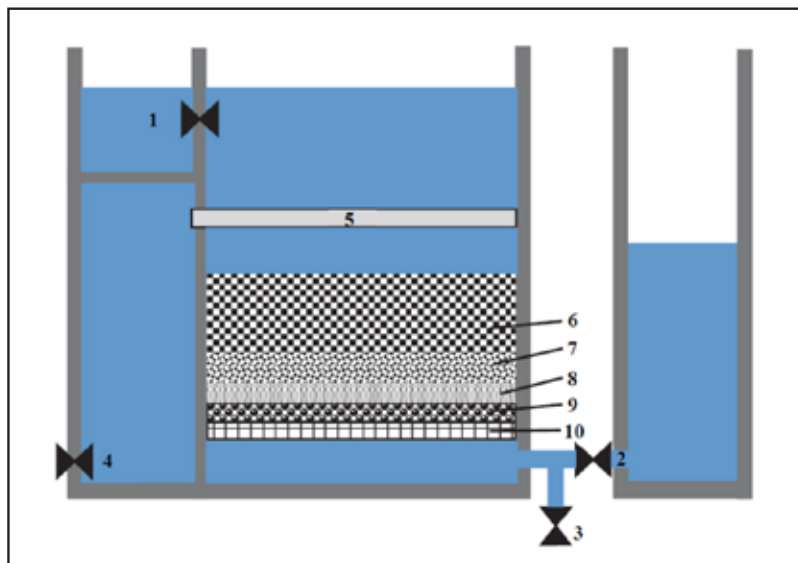
1. B
2. B
3. A
4. A
5. B
6. A
7. B
8. A
9. A
10. D
11. D
12. E
13. B
14. B
15. E
16. D
17. B
18. A
19. A
20. B

What every operator needs to know about filtration

Chris Maher

| Knowledge | Principles | Practical considerations |
|---|---|---|
| <p>There are three major filtration technologies: granular media, cloth media, and membrane filtration.</p> | <p>Granular media filtration is the most common and employs a deep bed of "grains," most commonly garnet sand, silica sand, or anthracite coal. Manufactured grains also are used.</p> <p>In cloth media filtration, water is passed through a sheet of tightly woven fabric or other fibrous material.</p> <p>Membranes are made from various organic and inorganic materials and can be manufactured with specific pore sizes to exclude the passage of specific size particles.</p> | <p>Granular media filters typically are used after a coagulation process that increases the size of the particles to be removed, such as is found in water treatment or tertiary wastewater processes.</p> <p>Cloth media filtration can operate with lower head loss and footprint as compared to granular media and increasingly is being investigated for use in primary treatment as a replacement or supplement to primary clarification.</p> <p>Membranes provide the highest level of filtration, but gravity is an insufficient driving force. Auxiliary pressure is needed to force water through the membrane.</p> <p>Any type of filter will accumulate the removed solids and eventually require backwashing to clean the filter. The resulting waste typically becomes an internal recycle stream.</p> |
| <p>Granular media removal mechanisms</p> | <p>There are four ways in which a particle is removed:</p> <ol style="list-style-type: none"> 1. interception, the particle is held against the grain by the force of the approaching water; 2. adsorption, the particle forms a weak chemical interaction with the grain; 3. sedimentation, the particle settles in an eddy on the backside of the grain; and 4. straining, the particle is lodged between two grains.  | <p>As filtration continues and more particles are removed the number of pore spaces between the grains decreases.</p> <p>This results in two factors.</p> <ul style="list-style-type: none"> ■ An increase in the velocity of the water moving through the filter occurs. The higher velocity will break-up particles and drive them further into the depth of the filter. ■ Increased resistance will result in increasing head loss across the filter. <p>Because smaller particles can penetrate deeper, filters often are designed with multiple types of media. Smaller grains that result in smaller pore spaces are used on the bottom of the filter to remove the smallest particles. Eventually particles will break through the media into the filter effluent.</p> <p>The loss of pore space equates to the situation of pumping the same flow through a smaller pipe. The head loss, or height of water above the media surface will increase until flow must be shut off to the filter.</p> <p>Either breakthrough of material (high turbidity) or high head may trigger a backwash.</p> <p>Straining is an undesirable removal mechanism because it plugs the filter. If this happens at the surface of the filter, it is said to be blinded.</p> |

Granular media filter process



| Knowledge | Principles | Practical considerations |
|--|---|---|
| <p>Granular media</p> | <p>Media is characterized and selected based on three factors.</p> <ul style="list-style-type: none"> ■ Effective size represents the diameter of the grain as determined by a sieve shaker analysis. The effective size is the sieve size which will pass only 10% by weight of a media sample. It is abbreviated as d_{10}. ■ Uniformity coefficient is the ratio of the sieve size that will pass 60% by weight of a media sample to the effective size. It is abbreviated as d_{60} / d_{10}. ■ Specific gravity is the measure of the density of the grain as compared to water. It is abbreviated as sp.gr. ■ The effective size and specific gravity are chosen to achieve a settling velocity of the grain, which happens according to Stokes Law. <p><i>Velocity</i></p> $= \frac{(gravity \times diameter^2 \times (Sp. Gr. - 1))}{18 \times kinematic\ viscosity\ of\ process\ water}$ | <p>The effective size and uniformity, and to some degree, the shape of the media determine the porosity of the filter bed. Solids removal happens in the pore spaces so these are important operational parameters to consider.</p> <p>In a multimedia filter the smallest particles should be removed near the bottom, so this layer should have the smallest diameter grains. The top layer will have larger diameter grains which will increase the Stokes settling velocity. To compensate, the top layer must have a significantly lower specific gravity than the bottom layer.</p> <p>Media settling velocities generally range from 0.1 to 0.2 m/s (0.3 to 0.7 ft/s). Stokes Law also predicts that over time the smallest grains of a single media will rise to the top of the media layer. This results in a layer of “fines”, with a lower porosity, at the surface of the layer. Surface straining is enhanced by these fines on the top layer and increases the likelihood of blinding. Solids also can accumulate at the layer interfaces.</p> <p>Over time the media can be worn down to a smaller effective size. While this may lead to better removal it also will shorten run-time and increase backwashing.</p> <p>The filter bed should be sampled occasionally to determine the effective size. It also is good practice to remove the fines layer by shaving off approximately the top 12 to 25 mm (0.5 to 1 in.) of media. Operators should also drain and inspect the filter surface for cracks, holes, and mounds in the media.</p> |
| <p>Granular media filter process arrangement</p> | <p>See figure above.</p> | <ol style="list-style-type: none"> 1. Influent valve 2. Effluent valve 3. Backwash valve 4. Backwash waste valve 5. Backwash waste trough 6. Media 1 (high diameter, low sp.gr.) 7. Media 2, optional (medium diameter, medium sp.gr) 8. Media 3, optional (small diameter, high sp.gr) 9. Support gravel 10. Underdrain system (effluent collection) |

| Knowledge | Principles | Practical considerations |
|---------------------------------------|--|---|
| Granular media filter operating modes | <p>There are four main operating strategies.</p> <p>In constant rate control, the effluent flow valve is modulated to achieve the flow setpoint. The filter is backwashed when the setpoint cannot be met with the valve fully opened.</p> <p>Constant level control occurs when water level above the media is measured and an effluent flow control valve is modulated to achieve the level setpoint. The filter is backwashed when the level increases to a preset level with the valve fully opened.</p> <p>Declining rate control occurs when filter units are connected in parallel through the influent header and a maximum water level is set. The flow rate through each individual filter will decrease through the runtime and the level will rise. When the level is exceeded, the dirtiest filter (usually longest run-time) is backwashed, filtration rate is restored and the water level drops.</p> <p>Influent-controlled operation occurs when the filtration rate is allowed to decline until a maximum water level is reached, but the influent arrangement allows for each filter to operate at a different level. The filter is backwashed when the level exceeds setpoint.</p> | <p>The physical construction of the filter system is tied to the operating mode. Therefore, the operating mode affects the complexity of the system. Constant level filters require effluent flow control valves while constant-rate filters require both flow control valves and flow meters.</p> <p>The need for these controls is eliminated in declining rate and influent controlled filter systems, but they require greater available head loss, particularly in influent controlled filters. Process water may need to be pumped if this head is not available. Further instrumentation is used to measure level and head loss.</p> <p>The operational goal is to maximize the filter run-time while producing the desired effluent quality.</p> <p>On-line turbidity analysis can be a useful tool to monitor effluent quality, troubleshoot filter systems, and prevent premature backwash.</p> |
| Granular media filter backwashing | <p>During backwash, filtered water is pumped through the effluent piping and underdrain, up through the media, and exits the filter through the waste valve. The flow rate must be high enough to expand the bed and carry the particles over the backwash trough.</p> <p>At the end of a backwash, the grains settle. Because the settling velocity is directly proportional to the size and density of the grain, a multi-media bed will re-stratify as it settles.</p> | <p>Backwash water must be pumped through the filter, returned (possibly pumped) to the beginning of the mainstream process, and the solids retreated. This can cause costs to accumulate quickly.</p> <p>A commonly accepted backwash rate is 15 gal/min•ft² of filter area.</p> <p>An air scour or surface wash arm generally is used to break up the filter surface and allow solids to escape the filter bed.</p> <p>It is common to see a spike in turbidity when the filter is returned to service. The particles have been sheared to a very small size by the backwash and can now pass through the filter media. For this reason a "filter to waste" step often is added. In this step, the initial effluent produced in the filter run is wasted.</p> <p>Many filter systems will include a backwash waste equalization tank. This tank prevents the large volume of water used in backwash causing a slug flow to the mainstream process. Backwash should use no more than 5% of the filter influent flow.</p> |

| Knowledge | Principles | Practical considerations |
|--|---|--|
| Other types of granular media filtration | <p>Filters also can have different configurations and abilities, such as</p> <ul style="list-style-type: none"> ■ upflow configuration (Flow is introduced to the bottom.), ■ biologically activated (This allows the growth of a thin film of biomass on the media.), ■ chemically activated (A metal salt or other chemical is dosed or impregnated in the media.), and ■ dynamic bed (The media is continuously pumped from the bottom of the filter, backwashed with filtrate, and the clean media deposited on the top of the bed.). | <p>Nitrification filters are biologically activated and generally are used on secondary effluent for separate-stage conversion of ammonia to nitrate. The process is aerobic so a blower system is used to aerate the filter bed through diffusers in the base of the media.</p> <p>Denitrification filters (also biologically activated) are used to convert excess nitrate in effluent to nitrogen gas. Dissolved oxygen must be absent and the bacteria need carbon for food, so a carbon source (such as methanol) often is included.</p> <p>When backwashing these filters, enough biofilm must be left on the media for adequate treatment to begin when the filter is returned to service. Media for these filters is manufactured or selected to provide greater surface area (porous media) for the biofilm.</p> <p>Similarly, phosphorus accumulates in chemically active filters. Backwash produces a concentrated phosphorus stream that should be planned for.</p> <p>A typical dynamic sand bed uses a conical bottom and an airlift pump to bring sand up through a central pipe. The sand falls through a static washer and the solids are carried to waste by a side stream of filter effluent.</p> |
| Cloth media filter removal mechanism | Cloth media filters operate as sieves. Particles larger than the opening size (pore size) cannot pass through the filter. | Filter media is manufactured to achieve pore uniformity and down to a pore size of 10 μm . Coagulation and flocculation may still be needed depending on the application. |
| Cloth media | Cloth media is constructed of durable synthetic threads or fibers, for example, nylon. The media is either woven or pile. Woven media is similar to a sheet, with a single layer of media. Pile media has depth, similar to carpet, with fibers attached to a woven backer. | The media type influences the design and operation of the filter, but the important difference is that solids are retained through the depth of pile media, so the filter accumulates more solids before backwash. |
| Cloth media filter process arrangement | Cloth media filters commonly are designed as rotating discs, hence they are also called disc filters. | <p>The number of discs per unit varies, and discs can be added to increase capacity.</p> <p>Discs can be divided further into wedges that can be removed for maintenance while the filter remains in service.</p> <p>The discs are double-sided in a frame-and-plate construction and the direction of flow can either be outside to inside where effluent is collected from inside the frame, or inside to outside where backwash waste is collected from inside the frame.</p> <p>The system can be designed for the discs to be fully or partially submerged. Fully submerged filters typically are outside to inside and influent solids can settle in the filter tank; a solids withdrawal mechanism is then provided.</p> |
| Cloth media filter operating modes | <p>Because the pore size is fixed and the system operates at comparatively low head, breakthrough is less of a concern.</p> <p>Most often the filter is operated on head loss. As the filter becomes plugged the influent level will increase. At set point, the filter will rotate and backwash.</p> | These filters can operate at lower head loss than granular media filters, but care must be taken to accommodate diurnal flow variations. They have the advantage of being able to continue filtration during backwash so less redundancy can be considered. |

| Knowledge | Principles | Practical considerations |
|--------------------------------|---|---|
| Cloth media filter backwashing | As in granular media, filtrate is forced backwards through the media to dislodge the particles from the pore and carry it away from the filter. | With woven cloth, a high pressure water system typically is used to spray the media and the solids are collected in a trough as they fall from the media. With pile media, the pile usually is vacuumed so filtrate is sucked back through the media to carry solids away. |
| Compressible media filters | Compressible media is a fibrous material that has exceptional "memory", meaning it can expand back to its original size and shape after being compressed. The pore size is controlled by the amount of compression. The filter bed depth also is changed in conjunction with the compression. | Because the properties of the filter media can be changed by compression, these filters are highly customizable and have a wide array of applications. They can be used to filter secondary effluent, wet weather bypass, or primary effluent. In a typical arrangement, the media is retained between two compression plates. In backwash, the media can be allowed to expand to a high degree of porosity and vigorously backwashed without the possibility of media loss. |
| Membrane filtration | The pore space of a membrane filter is incorporated in the molecular structure of the membrane material and controlled by the manufacturing process. Larger pore size membranes act as sieves, excluding particles larger than the pore. As pore size is reduced to the point of excluding ions, the membrane is said to be semi-permeable. In this case a salt concentration difference develops across the membrane creating osmotic pressure. | There are four levels of membrane treatment. Each one is determined by its pore size. <ul style="list-style-type: none"> ■ Microfiltration membranes remove particles down to 0.05 μm; this removes bacteria. ■ Ultrafiltration membranes remove particles down to 0.0025 μm; this removes viruses. ■ Nanofiltration membranes remove particles down to 0.001 μm (1 nm); this removes synthetic chemicals and aqueous salts. ■ Reverse osmosis membranes remove particles down to 0.1 nm; this removes aqueous salts and metal ions. |
| Membrane operation | As in the other types of filtration, the head (now pressure) required to move flow through a membrane depends on flow rate and pore size. | As pore size decreases more head is needed to produce the same flow rate. In membrane filtration this means that process water must either be pumped on the influent side, or vacuumed on the effluent side. |
| Membrane cleaning | Membranes must be cleaned to maintain production rates and prevent fouling. Fouling can occur by the growth of biofilms on the membrane or by the precipitation and accumulation of chemical salts in the pores. | Air scour cleaning and chemical cleaning are common. More essentials on membranes can be found in January 2011 and September 2016 issues of <i>WE&T</i> . WEF members can access these columns at www.wef.org/operator-essentials . |

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| Knowledge | Principle | Practical considerations |
|--|--|---|
| Tertiary treatment process | A process unit is used after secondary settling tanks whereby membrane filtration equipment is free-standing or submerged in basins to further separate solids and/or contaminants from secondary effluent and before discharging to post-treatment processes. | <p>In lieu of an MBR activated sludge system, a conventional activated sludge process followed by secondary settling tanks may use membrane filtration as a tertiary process.</p> <p>In lieu of conventional tertiary filters for increased solids removal, membrane filtration can be used – either as submerged- or free-standing-membrane filtration skids using pressured membranes.</p> <p>Tertiary membrane treatment can provide exceptional high-quality effluent. Specifically, it can remove</p> <ul style="list-style-type: none"> ■ dissolved solids, ■ organic compounds, ■ nutrients, ■ colloidal and suspended solids, and ■ pathogens (including viruses). |
| Solids thickening | Submerging membrane filtration equipment in an activated sludge tank to remove free water thickens the remaining sludge. This enhances the downstream solids treatment processes and enables tank volumes to be reduced. | <p>Microfiltration and ultrafiltration membranes are used for in-tank solids thickening.</p> <p>Flux rates usually are 20% to 25% of the flux rate for the MBR application.</p> <p>Filtration can increase solids concentrations from less than 1% to between 4% and 6%.</p> <p>This solids thickening enhances biological activity by providing an environment with more concentrated suspended solids.</p> <p>This also better controls process temperature by removing a heat sink source (free water) and enables the heat energy to be used in the biological process.</p> |
| Membrane treatment of stormwater and peak influent flows | A membrane-based process using a physical–chemical treatment regime for infrequent treatment of stormwater and/or peak flows can accomplish cost-effective treatment and flow management operations across a wide range of flow conditions. | <p>This provides a secondary treatment quality in a side-stream process parallel to the normal facility biological process.</p> <p>It is a cost-effective method to treat a wide range of peak flows while minimizing and optimizing the continuous flow biological process configuration and operation.</p> <p>The process can be placed into and removed from operation as infrequent higher-than-normal flow events occur.</p> |
| Temporary and reusable treatment facilities | Prefabricated, manufactured MBR activated sludge treatment facilities can be self-contained on a frame and transported by truck. These units can be installed to provide temporary, permanent, and reusable treatment facilities on construction sites or in underdeveloped areas until centralized collection systems and treatment facilities are available. | <p>These units are available from a few of the leading system suppliers.</p> <p>Prefabricated units can be delivered with all components, including fine screening, disinfection, blowers, pumps, controls, and instruments.</p> <p>These units provide a cost-effective solution for remote, isolated, small, temporary, and growth-oriented applications during construction and as a long-term solution.</p> |

| Knowledge | Principle | Practical considerations |
|-------------------------------------|---|---|
| Reverse osmosis | Reverse osmosis (RO) uses pressurized membrane filtration equipment to further remove solids and contaminants from wastewater. RO produces exceptional quality water. | <p>This process uses nanofiltration or RO membranes.</p> <p>RO normally is not used in a wastewater treatment facility flow regime unless a high-quality effluent suitable for indirect water reuse and/or manufacturing purposes is required.</p> <p>RO involves diffusion of particles making the process dependent on pressure and flow among other conditions.</p> <p>This process has been identified to remove such dissolved solids as pharmaceuticals and personal care products.</p> |
| Advanced preliminary treatment | Membrane systems require proper screening and grit removal to function properly. | <p>Advanced preliminary treatment must remove large, sharp, and/or stringy materials, which damage, plug, and/or clog the membranes.</p> <p>Screening should be two-dimensional – not just bar screening – and have perforations equal to or less than 3 mm. The actual size of the screen opening needed depends on what membranes are used.</p> <p>Grease content entering a membrane system should not exceed that of normal domestic wastewater.</p> |
| Membranes are hydraulic restrictive | Membranes provide a physical barrier to remove the solids from effluent. | <p>Membrane filtration is simply very fine straining or removal of pollutants by size exclusion. (RO is an exception as it also can remove some dissolved compounds.)</p> <p>The volume of flow passing through the membranes is related directly to the membrane area provided. The volume and area create the limit of permeate peak flow rate.</p> |
| Temperature | Membrane performance changes with water temperature. | <p>The viscosity of water changes as water temperature changes.</p> <p>The flow-through characteristics of membranes drop with lower water temperature.</p> <p>For consistency, membrane performance usually is normalized to 15°C when comparing flux rates among different membranes.</p> |
| Fouling | Membranes become dirty – or “foul” – as they are used to process flow. | <p>Fouling is a parameter that is controlled; this control is referred to as flux maintenance. This consists of removing accumulated solids from the membrane surface.</p> <p>Fouling conditions and the necessary flux maintenance depends on the membrane being used.</p> <p>Typical types of flux maintenance (membrane cleaning) include air scouring the membranes, back pulsing the flow, backwashing the membranes, and subjecting the membranes to a chemical cleaning.</p> |

Terry Gellner is a professional engineer and president of TnT Engineering LLC (Willoughby, Ohio).

OPERATOR ESSENTIALS

What every operator should know about polymers

Paul J. Kemp

| Knowledge | Principle | A practical consideration |
|---------------------|--|---|
| Polymer | A synthetic organic material mixes with or dissolves in water and alters the behavior of suspended material in the water. Polymers are a chain of repeating chemical groups linked together end-to-end. | This type of material can be used to enhance the performance of clarifiers, thicken process solids into sludges, or condition sludges for dewatering. |
| Suspended solids | Suspended solids consist of undissolved material mixed in a liquid medium. | Particles with the same charge repel each other, preventing contact and thereby preventing settling. |
| Destabilization | This is the step in which the static charge that keeps suspended solids suspended is neutralized by the polymer and/or coagulant. | This requires a material that has an ionic charge (<i>cationic</i> = [+], <i>anionic</i> = [-]) that is the opposite of the one present on the suspended solids. |
| Coagulation | Coagulation is the process that results from destabilization that allows suspended particles to accumulate into bigger clumps. | Think of this process as making a snowball. By pressing snowflakes together, they stick together to make a "single" bigger clump. |
| Coagulant | Coagulants can be inorganic metal salts or synthetic organic polymers. Coagulants focus on destabilization and serve to allow coagulation. | Inorganic materials are commonly alum, polyaluminum chloride, and ferric chloride or sulfate. Organic coagulants will vary. |
| Flocculation | Flocculation is the process of gathering coagulated solids together to form much larger clumps. | Think of the polymer strands as a long fishing line with hooks distributed along its length. The hooks grab coagulated solid clumps, and because the strand is so long, it tangles around the clumps like spaghetti does around meatballs. |
| Coagulant aid | A coagulant aid is a secondary material that works on coagulated material to enhance or perform flocculation. | Sometimes, a coagulant aid is needed when the coagulated materials (the "snowballs") are too fine or not dense enough (too light) to settle on their own. |
| Molecular weight | Molecular weight is a measure of the size (length) of a polymer molecule. Technically, molecular weight is the mass in grams of 6.02×10^{23} molecules of a single chemical. | During manufacturing, polymer chains don't all come out the same length. Molecular weights are reported as one of three categories: high (10,000 to 100,000 g), very high (100,000 to 1 million g), or extremely high (more than 1 million g). |
| Charge density | Charge density is a measure of the fraction of a polymer that has active sites on the polymer molecule. | Using the fishing line analogy again, charge density would refer to how far apart the hooks are spaced. |
| Chemical components | The main ingredient in polymers is polymerizable organic chemical that constitutes the molecular "backbone," the part that links the rest of it together. Inorganic products are usually iron or aluminum salts. (Some salts of aluminum are polymeric.) | <p>Polymers are named for the chemically reactive groups that are chained together to make them.</p> <p>Using the fishing line analogy, polymers are named for the type of hooks mounted on the line.</p> <p>For example, a polyacrylate is based on acrylic acid and will carry a negative charge. A polyamine has an ammonia molecule hanging out in the open and will carry a positive charge. A nonionic polyacrylamide has an ammonia molecule built into it and will not have a charge, but it has areas that are more positive than the rest of the polymer.</p> |



| Knowledge | Principle | A practical consideration |
|------------------------------------|--|--|
| Jar test | This is the single most useful tool an operator can have to work with polymers and coagulants. It enables an operator to compare products, compare dosages, and set operating conditions for any process involving suspended solids management. | When working on clarifier performance, or sludge thickening, the jar test procedure is the best predictor of what will happen in process. Jar testing technique is a topic that requires considerable attention but is extremely easy to learn and use (see article, p. 44). |
| Percent active | When process chemicals are provided as solutions, they consist of a product that affects a process, and something to carry it – called a “vehicle.” The amount of a mixture that is process-reactive is given as a percent of active ingredient. | This parameter is important if a product is to perform reliably in a process. This value should be verifiable by batch/lot number certification upon receipt of a shipment of material. There also are laboratory procedures that can confirm this value; however, they are not simple. |
| Retained sample | Retained samples are valuable to confirm that what you expect is what you receive. Samples from polymer screenings and from preceding shipments are essential for quality assurance (QA). Polymer suppliers will make samples available to prospective users at no cost. They usually will provide the sample that they used to perform the screening. | Polymer samples have a shelf life, usually in the 6-month range. It is important to perform QA testing on the first incoming shipment following any bid using the samples retained from the polymer screening that preceded the bid. Thereafter, samples should be kept from each shipment to check against the next batch received. Some procurement contracts require a QA test to be performed before accepting a shipment. An operator familiar with the process should be the one to perform the test. |
| Viscosity | Viscosity is a measurement of thickness, or resistance to flow. | Each product will have a specified viscosity range. Instruments are available to measure this parameter. It is useful as a QA aid when checking a new shipment of material but is not a good substitute for a jar test. |
| Fourier transform infra red (FTIR) | FTIR spectra sometimes are offered by suppliers with each batch of material as a means of verification that a received material is indeed what was expected. | FTIR is more sensitive to the vehicle content of a product than to the active ingredient. It is not a good substitute for a jar test when comparing a newly delivered polymer with a reference sample. |

Paul J. Kemp is assistant general manager of the Guam Waterworks Authority (Tamuning, Guam).

Section 4

Residual Solids Management



Sludge Thickening, Digestion, and Dewatering

- or -

Now What Do We Do With It?



1 TDEC - Fleming Training Center

Sludge Types and Characteristics

- Primary sludge is defined as all suspended solids that are removed from the wastestream and that are not a by-product of biological removal of organic matter.
- Secondary sludge is from new bacterial cells that are produced as the bacteria feed on and degrade organic matter
 - Usually these bacterial cells are removed in the secondary clarifier to maintain the proper balance between food and microorganisms (F/M)

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Sludge Types and Characteristics

Primary Sludge

- Coarse and fibrous
- Higher density than water
- 40-80% volatile (organic) solids
- 20-60% nonvolatile (inorganic) solids

Secondary Sludge

- More flocculant, less fibrous
- Specific gravity close to water
- 75-80% volatile (organic) matter
- 20-25% nonvolatile (inorganic) matter

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Primary Sludge Production

- The quantity of primary sludge generated depends on:
 - Influent wastewater flow
 - Concentration of influent settleable suspended solids
 - Efficiency of the primary sedimentation basin

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Secondary Sludge Production

- The quantity of secondary sludge generated depends on:
 - Influent flow to the biological or secondary system
 - Influent organic load to the biological system
 - Efficiency of the biological system in removing organic matter
 - Growth rate of the bacteria in the system, which is highly dependent on:
 - Temperature
 - Nutrient balances
 - Amount of oxygen supplied to the system
 - Ratio between the amount of food supplied (BOD)
 - Mass quantity of biological cells developed within the system
 - Detention time
 - and other factors

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Secondary Sludge Production

- General rule of thumb that operators may use to estimate secondary sludge production is that for every pound of organic matter (soluble 5-day BOD) used by the bacterial cells, approximately 0.30 – 0.70 pounds of new bacterial cells are produced and have to be taken out of the system

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Sludge Thickening, Digestion, and Dewatering

- Thickening
 - Gravity
 - Floatation
 - Gravity belt
- Stabilization
 - Anaerobic digestion
 - Aerobic digestion
- Dewatering
 - Centrifuge
 - Plate and frame
 - Belt filter press
 - Vacuum filter
 - Drying beds

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Sludge Thickening

Main component of sludge is water
~90% or more before treatment

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Thickening

- Settled solids removed from the bottom of the primary clarifier (primary sludge) and settled biological solids removed from the bottom of secondary clarifiers (secondary sludge) contain large volumes of water
- Primary sludge \approx 95-97% water
 - For every pound of primary solids, there are 20-30 pounds of water
- For every pound of secondary solids, approximately 50-150 pounds of water are incorporated in the sludge mass

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Thickening

- The advantages normally associated with sludge thickening include:
 - Improved digester performance due to a smaller volume of sludge
 - Construction cost savings for new digestion facilities due to smaller sludge volumes treated
 - A reduction in digester heating requirements because less water has to be heated

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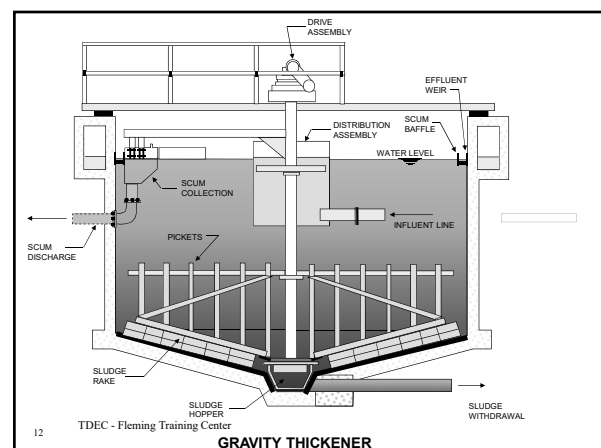
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Gravity Thickening

- Most effective on primary sludge
- Detention time is around 24 hours
- Thickening tank looks like a primary circular clarifier
- Monitored for blanket depth and sludge concentration
- Affected by temperature of sludge
 - Increased temperature will increase biological activity and gas production
- Separates solids into three zones
 - Clear supernatant
 - Sedimentation zone
 - Thickening zone

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GRAVITY THICKENER

Gravity Thickening

- Dilute sludge is fed into center well
- Sludge rake provides for movement of the settled (thickening) sludge.
 - As the rake slowly rotates, the settled solids are moved to the center of the tank where they are deposited in a sludge hopper.
- The vertical steel members (pickets) that are usually mounted on the sludge rake assembly provide for gentle stirring or flocculation of the settled sludge as the rake rotates
 - This gentle stirring action serves 2 purposes
 - Trapped gasses in the sludge are released to prevent rising of the solids
 - Also, stirring prevents accumulation of a large volume of solids (scum) floating on the thickener surface
- Supernatant is returned to primary clarifier or plant headworks
- Thickened sludge is pumped to digester or dewatered

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Factors Affecting Gravity Thickeners

- Type of sludge
- Age of the feed sludge
- Sludge temperature
- Sludge blanket depth
- Solids and hydraulic detention times
- Solids and hydraulic loadings

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Factors Affecting Gravity Thickeners

- Secondary sludges are not as well suited for gravity thickening as primary sludge
- Secondary sludges contain large quantities of bound water that makes the sludge less dense than primary sludge solids
 - Biological solids are composed of approximately 85-90% water by weight within the cell mass
 - The water contained within the cell wall is referred to as "bound water"
 - The fact that biological solids contain large volumes of cell water and are often smaller or finer than primary sludge solids makes them harder to separate by gravity concentration

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Factors Affecting Gravity Thickeners

- If sufficient oxygen is not available in the aeration basin or nutrient imbalances are present, filamentous organisms may grow in the aeration basin
- The predominance of these organisms will decrease the settleability of activated sludge and it will not settle as readily in the secondary clarifiers or compact to its highest degree in gravity thickeners
- Greater compaction can be achieved by the addition of chemicals



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Factors Affecting Gravity Thickeners

- As the temperature of the sludge (primary or secondary) increases, the rate of biological activity is increased and the sludge tends to gasify and rise at a faster rate
- During summertime (warm weather) operation, the settled sludge has to be removed at a faster rate from the thickener than during wintertime operations.

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Gravity Thickening

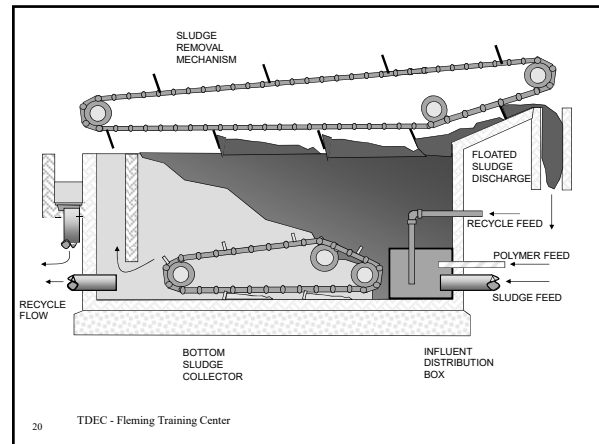
- Normal operating procedures:
 - Monitoring of the influent, effluent and concentrated sludge streams should be done at least once per shift and should include collection of samples for later laboratory analysis
 - Water at the surface should be relatively clear and free from solids and gas bubbles
 - The sludge blanket is usually kept around 5-8 feet
 - The speed of the sludge collectors should be fast enough to allow the settled solids to move toward the sludge collection sump
- On occasion, sludge in primary sedimentation tanks and gravity thickeners can become very thick and resistant to pumping.
 - If this happens, a hole (coning) can develop in the blanket and liquid from above the blanket can be pulled through the pump

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Flotation Thickener

- Treats waste activated sludge
 - Often with added polymers
- Dissolved-air flotation (DAF)
- Small amount of recycled water is aerated under pressure
- Air bubbles attach to the solids and carry them to the surface
- The “Float Cake” is skimmed off the surface
- Cake is 2 – 4% solids without polymer fed, or 3 – 5% solids with polymer fed
- Primary sludges are not easier to treat than biological sludges in a DAF



Flotation Thickener

- The objective of flotation thickening is to separate solids from the liquid phase in an upward direction by attaching air bubbles to particles of suspended solids
 - Dispersed air flotation where bubbles are generated by mixers or diffused aerators
 - Biological flotation where gases formed by biological activity are used to float solids
 - Dissolved air (vacuum) flotation where water is aerated at atmospheric pressure and released under a vacuum
 - Dissolved air (pressure) flotation where air is put into solution under pressure and released at atmospheric pressure
- Flotation by dissolved air (pressure) is the most commonly used procedure for wastewater sludges

Factors Affecting DAF

- Primary sludges are generally heavier than excess biological sludges and are not as easy to treat by flotation concentration
- Gritty or heavy primary sludge particles will settle and be deposited on the floor of the flotation unit and provisions should be made to remove these settled solids
- Sludge age usually does not affect flotation performance as drastically as it affects gravity concentrators.
 - A relatively old sludge has a natural tendency to float due to gasification and this natural buoyancy will have little or no negative effect on the operation of flotation thickeners

Troubleshooting DAF

| Operational Problem | Possible Cause | Check or Monitor | Possible Solution |
|--|----------------------------------|----------------------------------|--|
| 1. Solids carry over with effluent but good float (thickened sludge) | 1. Float blanket too thick | 1a. Flight Speed | 1a. Increase flight speed |
| | | 1b. Solids loading | 1b. Lower flow rate to unit; if possible |
| 2. Good Effluent quality but float thin (dilute) | 2. Float blanket too thin | 2a. Flight speed | 2a. Decrease flight speed |
| | | 2b. Solids loading | 2b. Increase flow rate; if possible |
| | | 3a(1) Air rate (2) Compressor | 3a(1) Increase air input (2) Repair or turn on compressor |
| 3. Poor effluent quality and thin (dilute) float | 3b. Pressure too low or too high | 3b. Pressure gauge | 3b. Open or close valve |
| | 3c. Recycle pump inoperative | 3c. Pressure gauge and pump | 3 c. Turn on recycle pump. |
| | 3d. Reaeration pump inoperative | 3d. Pump pressure | 3d. Turn on reaeration pump |
| | 3e. Chemical addition inadequate | 3e. Chemical system | 3e. Increase chemical dosage |
| | 3f. Loading excessive | 3f. Loading rates | 3f. Lower flow rate |

Gravity Belt Thickener

- Very effective sludge thickening alternative for secondary sludges
- Sludge to be thickened is preconditioned (usually with a polymer) then applied to the gravity belt thickener where free water drains through small openings in the belt and is collected in a trough below the belt.



Gravity Belt Thickener

- Belts are available in a variety of materials (nylon, polypropylene) each with various porosities
 - As the porosity increases, the resistance to flow decreases and larger volumes of water are able to be drained
 - If the porosity is too large, sludge solids may pass through the belt and result in poor filtrate quality
 - If the porosity is too low, the belt may bind or plug, which will produce frequent washouts
 - Washout occurs when a large quantity of free water is unable to be released in the drainage zone and it travels to the discharge end where it is carried out with the thickened sludge.
- With proper operating conditions, secondary sludges can be thickened from concentrations of 0.3-0.6% suspended solids to concentrations of 4-6% suspended solids

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Gravity Belt Thickener

- The belt speed can be varied from approximately 2-10 ft/min
- The speed at which the belt should be operated depends on the sludge flow rate to the belt and the concentration of the influent sludge
- As the belt speed is increased, the rate of belt area contacting the influent sludge also increases and allows for greater volumes of water to drain, belt washout will cause a reduction in the thickened sludge concentration.
 - As the concentration of influent sludge increases, less water is associated with the sludge mass and reduced belt speed can be used.
 - The ideal operating belt speed is the slowest the operator can maintain without washing out the belt.

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Gravity Belt Thickener - Troubleshooting

- The most frequent problem encountered with gravity belt thickeners is washing out
 - Usually this problem is indicated by large volumes of water carrying over with the thickened sludge
 - When this happens check
 - The polymer dosage
 - Hydraulic loading
 - Solids loading
 - Belt speed
 - Belt washing equipment

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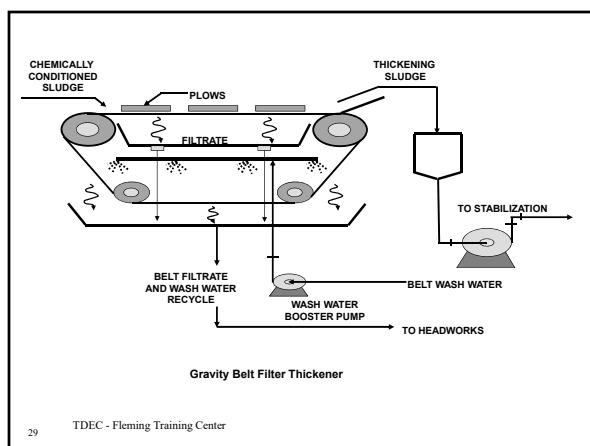
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Gravity Belt Thickener - Troubleshooting

- If the polymer dose is too low, the solids will not flocculate and free water will not be released from the sludge mass
- If the polymer dose is adequate, evidenced by large floc particles and free water, increase the belt speed so as to provide more belt surface area for drainage
- If the belt is already at its maximum setting, check the flow rate to the belt and reduce it if the rate is higher than normal
- If the polymer dose, belt speed and hydraulic loading are set properly but washing out is still occurring, the problem may be related to binding of the belt
 - Check the appearance of the belt as it leaves the washing chamber
 - If the belt appears to be dirtier than normal, increase the wash water rate, turn off the polymer and feed pumps and allow the belt to be washed until it is clean
 - Belt binding often develops because of polymer overdosing

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Biosolids Stabilization (Digestion)

- Reduce volume
- Stabilize organic matter
- Eliminate pathogenic organisms

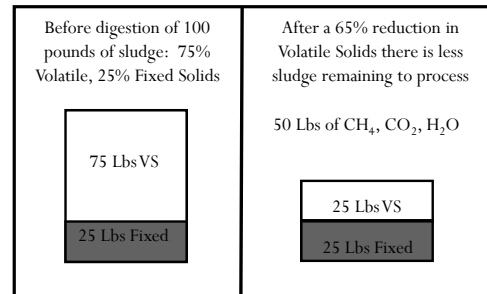
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Stabilization

- Converts the volatile (organic) or odor-causing portion of the sludge solids to
 - Non-odorous end products
 - Prevents the breeding of insects upon disposal
 - Reduces the number of pathogenic (disease-carrying) bacteria content
 - Improves the sludge dewaterability
- Can be done:
 - Anaerobically
 - Aerobically
 - Chemically

General Overview



Biosolids Stabilization

Anaerobic Digestion

Anaerobic Digestion

- The most widely used method of sludge stabilization is anaerobic digestion in which decomposition of organic matter is performed by microorganisms in the absence of oxygen
- Anaerobic digestion is complex biochemical process in which several groups of anaerobic and facultative (survive with or without oxygen) organisms break down organic matter.
 - In the first phase, facultative, acid-forming organisms convert complex organic matter to volatile (organic) acids
 - In the second phase, anaerobic methane-forming organisms convert the acids to odorless end products of methane gas and carbon dioxide

Anaerobic Digestion

- Anaerobic digesters are usually heated to maintain temperatures of 94-97° F (34-36° C).
- If the temperature falls below this range or if the digestion time falls below 15 days, the digester may become upset and require close monitoring and attention

Anaerobic Digestion

- 2-phase process:
 - Acid formers - Facultative bacteria convert organic matter to volatile acids, CO₂, and H₂S
 - SAPROPHYTIC ORGANISMS
 - Methane producers - Anaerobic bacteria convert acids to CH₄ and CO₂
 - The methane producers are not as abundant in raw wastewater as are the acid formers.
 - The methane producers desire a pH range of 6.6 to 7.6 and will reproduce only in that range.
- 28-40% carbon dioxide, 60-72% methane
 - Minimum methane for reuse is 62%
- Sludge retention time is 30-60 days

Psychrophilic Bacteria

- The lowest range (in an unheated digester) utilizes Psychrophilic (cold temperature loving) bacteria.
- The psychrophilic upper range is around 68°F (20°C).
- Digestion in this range requires from 50 to 180 days, depending upon the degree of treatment or solids reduction required.

Mesophilic Bacteria

- Organisms in the middle temperature range are called the Mesophilic (medium temperature loving) bacteria
- Thrive between about 68°F (20°C) and 113°F (45°C).
- The optimum temperature range is 85°F (30°C) to 100°F (38°C), with temperatures being maintained at about 95°F (35°C) in most anaerobic digesters.
- Digestion at 95°F may take from 5 to 50 days or more (normally around 25 to 30 days), depending upon the required degree of volatile solids reduction and adequacy of mixing.

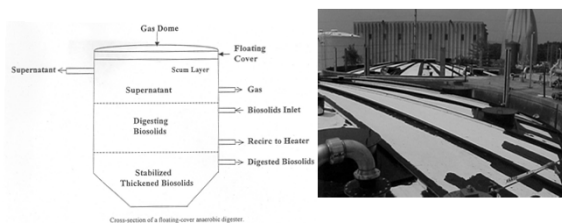
Thermophilic Bacteria

- Organisms in the third temperature range are called Thermophilic (hot temperature loving) bacteria and they thrive above 113 °F (45°C).
- The optimum temperature range is considered 120 °F (49°C).
- The time required for digestion in this range falls between 5 and 12 days, depending upon operational conditions and degree of volatile solids reduction.
- However, the problems of maintaining temperature, sensitivity of the organisms to temperature change, and some reported problems of poor solids - liquid separation are reasons why only a few plants have actually been operated in the thermophilic range.

Changing Temperatures

- You can't change temperature and expect a quick change in bacteria population and therefore a shorter digestion time
- An excellent rule for digestion is never change the temperature more than one degree a day to allow the bacterial culture to become acclimated (adjust to the temperature changes).

Anaerobic Digestion



Anaerobic Digestion – Normal Ranges

| Parameter | Normal Ranges |
|-----------------------------------|--------------------------------------|
| Sludge retention time | 30 – 60 days (Heated) |
| Operating Temperature | 90 – 95 °F (Heated) |
| Volatile Solids Loading | 0.04 – 0.1 lb VM/day/ft ³ |
| % Methane in gas | 60 – 72% |
| % Carbon Dioxide in gas | 28 – 40% |
| pH | 6.8 – 7.2 |
| Volatiles acids: alkalinity ratio | ≤0.1 |
| Volatiles solids reduction | 40 – 60% |

* For every 1 lb. of VM destroyed, 12-18 ft³ of gas is produced.

Anaerobic Digestion

- Volatile Acids to Alkalinity Ratio

$$\text{Ratio} = \frac{\text{volatile acids concentration, mg/L}}{\text{alkalinity concentration, mg/L}}$$

- VA/Alk relationship is the key to successful digester operation
- Must monitor alkalinity
- Can be used to control operation of anaerobic digester
- Very sensitive indicator of process condition
- One of the first indicators that the digester is going sour

Acid-Alkalinity Relationship

| | |
|--------------|------------------------|
| Optimum | VA/ALK = .05 - 0.1 |
| Stress | VA/ALK = 0.3 - 0.4 |
| Deep Trouble | VA/ALK = 0.5 - 0.7 |
| Failure | VA/ALK = 0.8 and above |

- Each treatment plant will have its own characteristic ratio for proper sludge digestion (generally less than 0.1)
 - High buffer capacity exists when VA are low and the Alkalinity is high (120 mg/L VA/2400 mg/L Alk)
 - When the VA/Alk ratio is 0.8 or higher, the pH of the digester will begin to drop.

Acid-Alkalinity Relationship

- When the VA/Alk ratio starts to increase
 - Extend the mixing time of the digester contents
 - Control the heat more evenly
 - Decrease the raw sludge feed rates
 - Decrease the digested sludge withdrawal rates from digesters
- Pumping a thicker sludge to the digester can help prevent a loss of alkalinity

Anaerobic Digestion

- Mixing
 - Puts microorganisms in contact with food
 - Controls pH, distributes buffering alkalinity
 - Distributes heat throughout the tank
 - Mixing combined with heating speeds up the digestion rate

Anaerobic Digestion

- Mechanical mixing is most common method
 - Shaft-driven propeller extended down into sludge
 - Susceptible to wear
 - Cleaning and replacement necessary
- Other methods
 - Propeller with draft tube
 - Bubble-gun type

Anaerobic Digestion

| Anaerobic Digestion – Sludge Parameters | |
|---|--|
| < 4% Solids | Loss of alkalinity |
| | Decreased Sludge retention time |
| | Increased heating requirements |
| 4 – 8% Solids | Decreased volatile acid/alkalinity ratio |
| Normal Operation | |
| > 8% Solids | Poor mixing |
| | Organic overloading |
| | Decreased volatile acid/alkalinity ratio |

Anaerobic Digestion

- A digester can be compared with your own body.
 - Both require food; but if fed too much will become upset.
 - Excess acid will upset both.
- Sour digester?
 - Lime
 - Lime is added at a 1:1 ratio, 1 lb of lime for every 1 lb of volatile acid
 - Soda ash
 - Transfer alkalinity from secondary digester to primary



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Anaerobic Digestion

- Foaming
 - Problems: odors, excess pressure on cover, plugs gas piping system
 - Cause: Gas production at startup with insufficient solids separation
 - Prevention: Adequate mixing before foaming starts



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Neutralizing a Sour Digester

- The recovery of a sour digester can be accelerated by neutralizing the acids with a caustic material such as anhydrous ammonia, soda ash, or lime, by transferring alkalinity in the form of digested sludge from the secondary digester.
- Such neutralization reduces the volatile acid/alkalinity to a level suitable from growth of the methane fermenters and provides buffering material which will help maintain the required volatile acid/alkalinity relationship and pH.
- If digestion capacity and available recovery time are great enough, it is probably preferable to simply reduce loading while heating and mixing so that natural recovery occurs.

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Neutralizing a Sour Digester

- When neutralizing a digester, the prescribed dose must be carefully calculated.
 - Too little will be ineffective, and too much is both toxic and wasteful. In considering dosage with lime, the small plant without laboratory facilities could use a rough guide a dosage of about **one pound of lime added for every 1000 gallons of sludge** to be treated.
 - You must realize that neutralizing a sour digester will only bring the PH to a suitable level, it will not cure the cause of the upset.
- Stuck Digester - A stuck digester does not decompose organic matter properly.
 - The digester is characterized by low gas production, high VA/alk relationship, and poor liquid-solids separation.
 - A digester in a stuck condition is sometimes called a "sour" or "upset" digester.

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Gas Production

- When methane fermentation starts and the methane content reaches around 60%, the gas will be capable of burning.
- Methane production eventually should predominate, generating a gas with 65-70% methane and 30-35% carbon dioxide by volume.
- Digester gas will burn when it contains 56% methane, but is not usable as a fuel until the methane content approaches 62%.
- When the gas produced is burnable, it may be used to heat the digester as well as for powering engines and for providing building heating.

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Biosolids Stabilization

Aerobic Digestion

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Factors Affecting Aerobic Digestion

- Sludge type
- Digestion time
- Digestion temperature
- Volatile solids loading
- Quantity of air supplied
- Dissolved oxygen (DO) concentrations within the digester
 - This is the most important water quality test for an aerobic digester

Aerobic Digestion

- Extended aeration of wastewater
 - Wastes stabilized by long-term aeration of about 10-20 days
 - Check pH weekly and adjust if less than 6.5
 - Lower equipment costs than anaerobic (but higher energy costs)
 - Less noxious odors at $DO \geq 1 \text{ mg/L}$
 - Better on secondary sludge than primary sludge
 - Sludge has higher water content
 - By products: residual solids, CO_2 , H_2O , SO_4 , NO_3

Aerobic Digestion

- Widest application is with secondary sludges
 - Which are made primarily of biological cells that are produced in activated sludge or trickling filter processes as a by-product of degrading organic matter
 - In the absence of an external food source (no new food being introduced), these microorganisms enter the endogenous or death phase of their life cycle.
 - When no new food is available, the biomass begins to self-metabolize (consume its own cellular material), which results in a conversion of biomass to end products of carbon dioxide and water; and a net decrease in the sludge mass

Aerobic Digestion

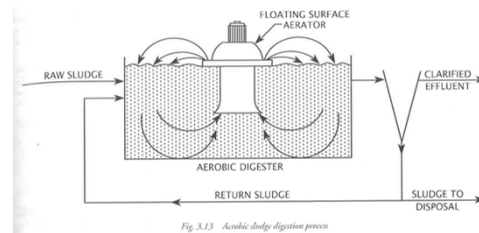


Fig. 3.13 Aerobic sludge digestion process

Aerobic Digestion

- When primary sludge is fed into an aerobic digester, food becomes available to the microorganisms
 - In the presence of an external food source (the primary sludge), the biomass will convert the food to end products of carbon dioxide and water; and will function in the growth phase, the biomass will reproduce, resulting in a net increase in the sludge mass
 - Aerobic digestion times are long enough to allow the food to be depleted and the biomass to eventually enter the endogenous or death phase
 - The main drawback to aerobically digested primary sludge is that more air has to be supplied to maintain a desirable DO level because the bacteria are more active when food is available

Comparison Between Anaerobic and Aerobic Digestion

| Anaerobic Digestion | Aerobic Digestion |
|-------------------------------------|--|
| Does not use aeration | Aeration equipment—oxygenation, mixing |
| Fresh wastes | Partially stabilized solids |
| Putrefaction | Produces fewer odors |
| Concentrates sludge | Higher water content sludge |
| Produces solids, water, etc. | Produces residual solids, water, etc |
| Liquids that are difficult to treat | Liquids that are easier to treat |

Biosolids Stabilization

Chemical Stabilization

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Chemical Stabilization

- Sludges that are not biologically digested or thermally stabilized can be made stable by the addition of large doses of lime or chlorine to destroy pathogenic and nonpathogenic organisms.
- Chemical addition to sludge to prepare it for ultimate disposal is not a common practice
- Chemical addition is usually considered to be a temporary stabilization process and finds application at overloaded plants or at plants experiencing stabilization facility upsets
- The main drawback to chemical stabilization is the cost associated with the large quantities of chemical required.

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Lime Stabilization

- Lime stabilization is accomplished by adding sufficient quantities of lime to the sludge to raise the pH to 11.5 -12.0
- Estimated dosages to achieve a pH of 11.5-12.0 are generally 200-220 pounds of lime per ton for primary sludge solids
- The addition of lime adds to the overall quantity of solids that must be ultimately disposed
- The high pH of the stabilized solids may also reduce the range of beneficial reuse opportunities

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Lime Stabilization

- Lime arrives from the supplier in powder form and can't be added directly to the sludge
- The powdered lime must be made into a slurry with the addition of water prior to blending with the sludge
- The process of lime stabilization produces an unfavorable environment and destroys pathogenic and nonpathogenic bacteria
 - Studies have shown that >99% of the fecal coliforms and fecal streptococci can be destroyed
- If the pH is not adjusted to the 11.5-12.0 range, the goals of stabilization will not be achieved.

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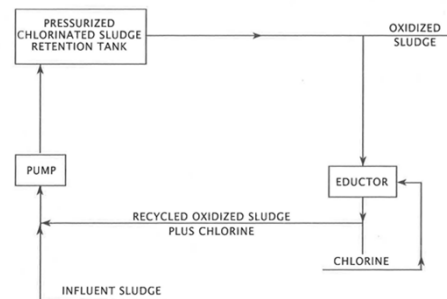
Chlorine Stabilization

- Chlorine stabilization is accomplished by adding sufficient quantities of gaseous chlorine to the sludge to kill pathogenic and nonpathogenic organisms.
- Estimated dosages to achieve disinfection are generally 100-300 lbs chlorine/ton of sludge solids
- Waste activated sludge (WAS) requires higher doses than primary sludge
- The addition of the large quantities of chlorine required for stabilization will result in an acidic (pH less than 3.5) sludge and neutralization with lime or caustic may be required prior to dewatering due to the corrosive condition of the mixture.

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Chlorine Stabilization



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Image: Advanced Waste Treatment, 5th ed.

Sludge Dewatering

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Conditioning

- Pretreatment of sludge to facilitate the removal of water in subsequent treatment processes
- Reduces mutually repelling electrostatic charges on suspended sludge particles
- Decreases the ability of biological sludges to entrain (hold) water
- Promotes coagulation of the sludge solids

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Sludge Conditioning Methods

1. Chemical treatment
2. Thermal treatment
3. Wet oxidation
4. Elutriation
5. Other methods such as freezing, electrical treatment, and ultrasonic treatment

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Chemical Treatment

- Ferric chloride
 - Either alone or in combination with lime
- Polymers
 1. Anionic have a negative charge
 - Normally used as coagulant aids with positively charged alum and ferric chloride
 2. Cationic have a positive charge
 - Can serve as sole coagulant or used in combination with an inorganic coagulant such as alum
 - Most common in sludge dewatering

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Chemical Treatment - Polymers

- Optimum chemical and type of dosage is highly dependent on the characteristics of that sludge
 - On-site experimentation
 - Trial-and-error
 - Jar testing

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Sludge Dewatering

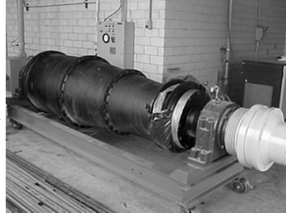
- Dewatering reduces sludge moisture and volume to allow for more economical disposal
- Types:
 - Centrifuge
 - Plate and Frame Press
 - Belt Press
 - Vacuum Filter
 - Drying Beds
 - Composting

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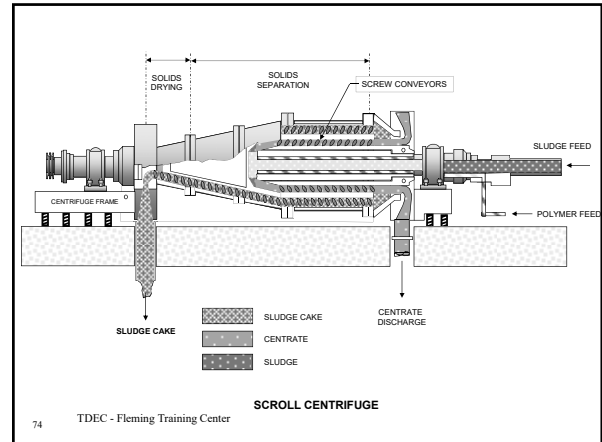
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Centrifuge

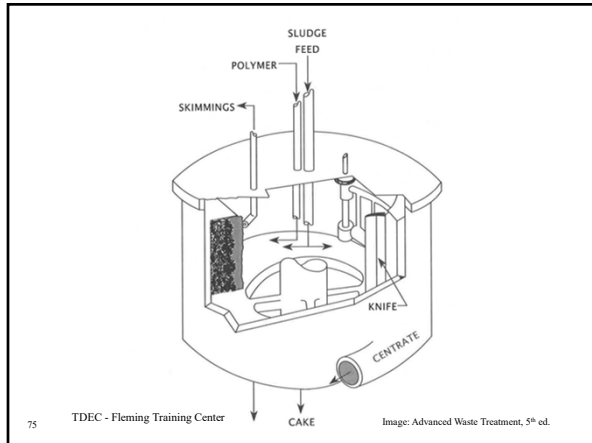
- Used to thicken or dewater secondary sludges
- Sludge fed at constant rate into rotating horizontal bowl
- Solids separated from liquid and compacted by centrifugal force (1000 – 2000 rpm)



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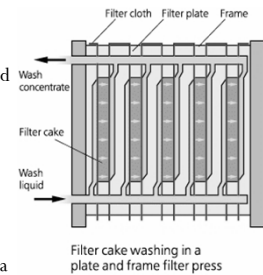
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75 TDEC - Fleming Training Center Image: Advanced Waste Treatment, 5th ed.

Plate-and-Frame

- Solids are pumped in batches into spaces between plates
- 200 – 250 psi pressure applied to squeeze out water
- At end of cycle (1.5 – 4 hours), plates are separated and solid drops out onto conveyor
- Pressure filtration that forces liquid through the filter media



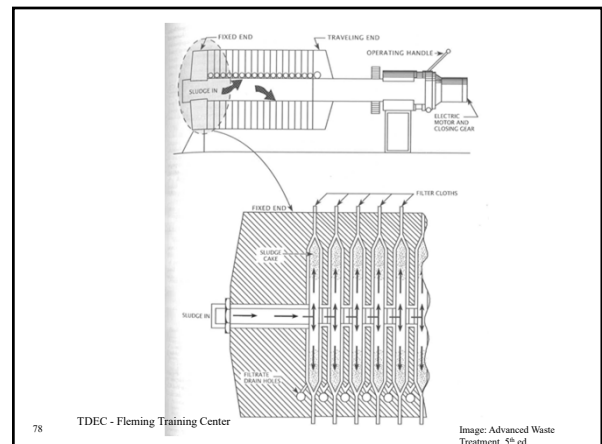
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Plate-and-Frame



- JVAP (US Filter) – Chattanooga
- Modified plate and frame that is vacuum assisted
 - Steam heated at 163.4°F for 30 min
 - Entire process takes about 4 hours

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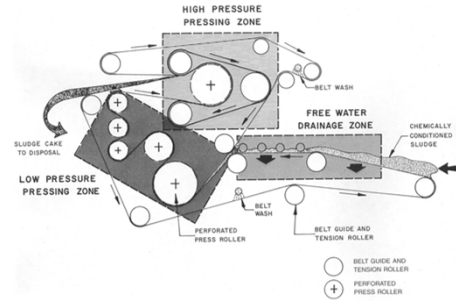
78 TDEC - Fleming Training Center Image: Advanced Waste Treatment, 5th ed.

Belt Filter Press

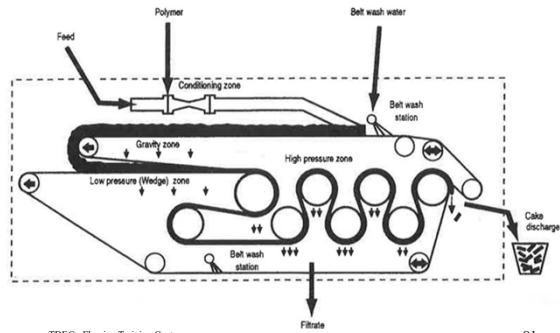
- Low power use
- Reliable
- Continuous operation
- Two long belts that travel over a series of rollers
- Sludge applied to free water zone (much water will drain off here)
- Solids then squeezed between a series of rollers (and more water is removed)
- Remaining solids are scraped from the belt
- Belts are washed and the process repeats



Belt Filter Press



Belt Filter Press

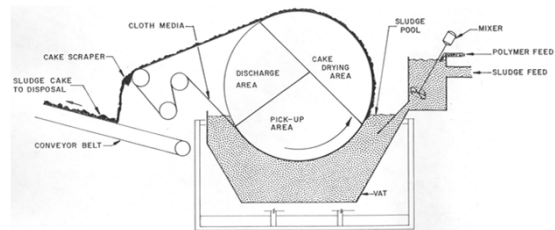


Vacuum Filter

- Sludge pumped into a tank around a partially submerged rotating drum
- Drum rotates, vacuum collects solids on surface
- Vacuum removes excess water
- Vacuum is then released and solids are removed

• [Video](#)

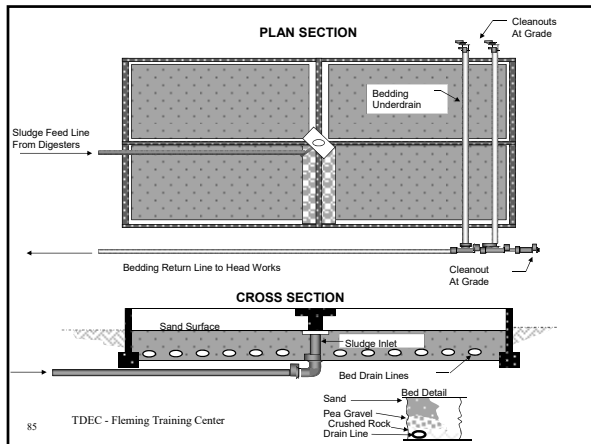
Vacuum Filter



Drying Bed

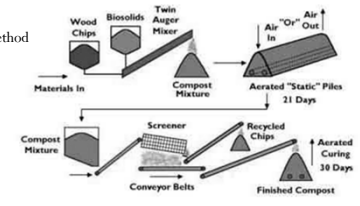
- Simplest of all methods
- Sludge deposited in layer on sand bed or other surface with drain
- Dewatering occurs by drainage and evaporation
- Time required is affected by climate, depth of solids, and type of solids
- Sometimes drying beds are covered while others have vacuum assisted drainage





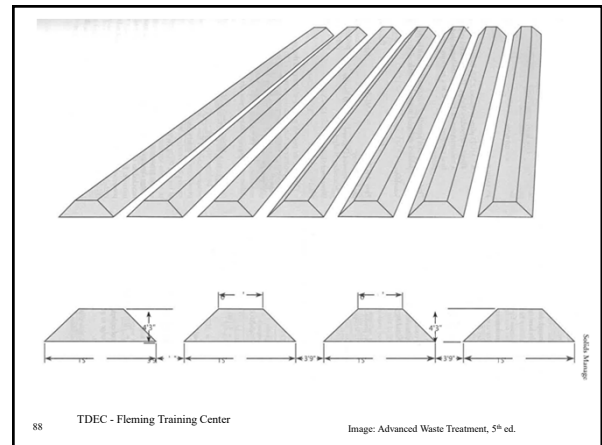
Composting

- Composting results in the decomposition of organic matter by the action of Thermophilic facultative aerobic microorganisms to sanitary, nuisance-free, humus-like material
- Composting generally falls into three categories
 - Windrow
 - Most common method
 - Static pile
 - Mechanical



Composting – Windrow Operation

- Dewater sludge to the highest degree economically practical.
- Blend dewatered sludge with recycled compost or bulking agents to produce a homogenous (evenly blended) mixture with a moisture content of 45-65%.
- Form the windrow piles and turn (aerate) once or twice daily for the first 4-5 days after windrow formation.
- Turn the piles approximately once every two days to once a week to maintain the desired temp. (130-140°F or 55-60°C) until the process is complete.
 - The temperature of the piles should be routinely monitored during this period.
- Load the compost onto trucks for disposal or recycle purposes.



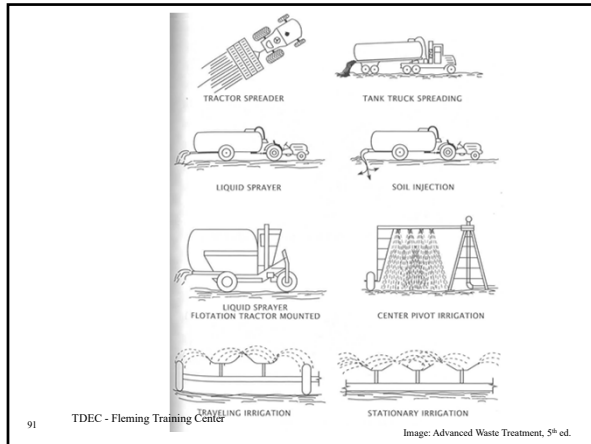
Composting – Windrow Operation

- If stacks are turned too often, excessive heat will be released and the temperature may drop to a point where it is unfavorable for the thermophilic composting bacteria.
- When pathogen destruction is a goal, temperature measurements must be taken and recorded.
- A well-operated windrow compost facility can dry sludge from an initial moisture content of approximately 60% to a moisture content of 30% in about 15-20 days to a final moisture of 20% in approximately 20-30 days.
- The most common problems that arise are anaerobic conditions and reductions in compost temperatures.

Composting – Safety

- Large numbers of spores are released into the atmosphere during certain composting operations (compost screening, dumping and mixing of compost, and wood chip dumping).
- To reduce the exposure to airborne pathogens:
 - Enclose the cabs of heavy equipment
 - Ventilate all enclosed areas properly
 - Provide dust masks to employees working in dusty areas.





503 Regs

- The 40 CFR part 503 Sludge Regulations was published in the Federal Register on February 19, 1993, and became effective on March 22, 1993.
- This regulation requires the generator of sludge to treat the sludge to a certain degree before land applying of the sludge.
- The 503 regulation requires the sludge to be monitored for
 - certain pollutants (metals)
 - disease causing organisms called pathogens
 - and Vector Attraction Reduction, which is the reduction of Volatile organic solids to the degree where vectors (flies, mosquitoes, and other disease-carrying organisms) are not attracted to the sludge or biosolids once it is placed on the land.

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503 Regs

- Now that the 503 regulation is in effect, digesters will have to be efficiently operated to meet the parameters of the regulation.
- If the Sludge is prepared for land application or surface disposal, it must comply with applicable pathogen reduction requirements.
- The part 503 regulation allows nine pathogen reduction alternatives, which are divided into two distinct classes :
 - Class A
 - Class B

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503 Regs

- Class A alternatives produce a sludge that is virtually pathogen free.
- Class B alternatives significantly reduce the pathogen level in sludge.
- Both Class A and B alternatives specify maximum levels of fecal coliform allowed in the sludge.
- Monitoring frequency for the pollutants, pathogen reduction and vector reduction requirements are based on amount of (dry weight tons) disposal per year.
- Records of the results will be kept at the sludge wastewater plant.

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503 Regs

- If your wastewater plant has a design influent flow rate equal to or greater than 1 million gallons per day, or serves a population of 10,000 or more, or Class I Sludge management facilities (State of Tennessee Industrial Pretreatment Program) you must report annually to the permitting authority.
- Annual reports cover information and data collected during the calendar year (January 1 to December 31) and are due February 19, every year and submitted to the permitting authority, which is the EPA Regional 6 in Kansas Office for Tennessee.

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Metals Limits

- The sludge (Biosolids) applied to land must meet the ceiling concentrations for table section 503.13 pollutants at a minimum.
- The Table 3 section 503.13 pollutant concentration limits are the best limits to meet because they are considered exceptional quality required no loading rate limits to the land being applied to.

TABLE 3 OF § 503.13.—POLLUTANT CONCENTRATIONS

| Pollutant | Monthly average concentration (milligrams per kilogram) ¹ |
|----------------|--|
| Arsenic | 41 |
| Cadmium | 39 |
| Copper | 1500 |
| Lead | 300 |
| Mercury | 17 |
| Nickel | 420 |
| Selenium | 100 |
| Zinc | 2800 |

¹ Dry weight basis.

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Pathogen Requirements

- Either Class A or Class B pathogen requirements and site restrictions must be met before the biosolids (sludge) can be land applied; the two classes differ depending on the level of pathogen reduction that has been obtained.
- Aerobic digesters with adequate detention times (40-60 days), maintaining correct dissolved oxygen levels and feeding the digesters correctly will usually be able to have to the sludge tested for class B pathogens and meet it with satisfactory results (**less than 2 million colony** - forming units per gram of total solids - dry weight).

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Pathogen Requirements

- There are a total of 3 options to meet the Class B Reduction:
 - Fecal Coliform Count
 - Processes to Significantly Reduce Pathogens
 - Processes to Significantly Reduce Pathogens Equivalent

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40 CFR 503 - Pathogen Reduction

Class A

- Six alternatives, each must meet following criteria:
 1. Fecal coliform:
Fewer than 1000 MPN (most probable number) per gram of total dry solids
 2. *Salmonella sp.*:
Fewer than 3 MPN per 4 grams of total dry solids

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Class B

- Three alternatives meet the criteria:
 1. Fecal coliform:
Less than 2 million MPN or 2 million cfu per gram of total solids
 - Anaerobically digested:
Minimum mean cell residence time of 15 days in anaerobic digester at 35-55°C

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Vector Attraction Reduction

- Vector attraction reduction is to reduce the attraction of vectors (flies, mosquitoes, and other potential disease - carrying organisms) to the biosolids or sludge.
- 1 of 10 options specified in part 503 to achieve vector attraction reduction must be met when biosolids are applied to land.

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Requirements in one of the following options must be met for vector attraction reduction

- Reduce the mass of volatile solids by a minimum of 38%
- Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit
- Meet a specific oxygen uptake rate for aerobically treated biosolids
- Use aerobic processes at greater than 40°C (avg. temp 45°C) for 14 days or longer (during biosolids composting)
- Add alkaline materials to raise the pH under specified conditions

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Requirements in one of the following options must be met for vector attraction reduction

- Reduce the moisture content of biosolids that do not contain unstabilized solids from other than primary treatment to at least 75% solids
- Reduce the moisture content of biosolids with unstabilized solids to at least 90%
- Inject biosolids beneath the soil surface within a specified time, depending on the level of pathogen treatment
- Incorporate biosolids applied to or placed on the land surface within specified time periods after application to or placement on the land surface

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Any Questions?

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3

Residual Solids Management (Sludge Thickening, Digestion, and Dewatering) – Review Questions

1. Secondary sludge is more difficult to treat than primary sludge.
 - a. True
 - b. False
2. Anaerobic and Aerobic Digestion are both ways of dewatering sludge.
 - a. True
 - b. False
3. Gravity thickening is most effective on primary sludge.
 - a. True
 - b. False
4. What measures should be taken during summertime operation to reduce gas production and rising sludge in gravity thickeners?
 - a. Reduce wasting
 - b. Increase wasting
 - c. Increase detention time
 - d. None of the above
5. Secondary sludges contain large quantities of “bound” water, which makes the sludge less dense than primary sludge solids and therefore, more difficult to thicken.
 - a. True
 - b. False
6. As temperature of the sludge increases, the rate of biological activity is decreased.
 - a. True
 - b. False
7. Secondary sludges are easier (than primary sludges) to treat in a DAF system.
 - a. True
 - b. False
8. If you are producing good effluent quality but a thin float in your DAF system what action could you take to thicken the float?
 - a. Decrease flight speed
 - b. Increase flight speed
 - c. Turn on recycle pump
 - d. None of the above
9. If your belt filter press is producing cake solids that are too wet, what action should you take?
 - a. Increase belt speed
 - b. Reduce belt speed
 - c. Increase belt tension
 - d. Increase wash water rate
 - e. B. or C. are both possible answers
10. What is the most important factor to monitor in an anaerobic digester?
 - a. pH
 - b. Alkalinity

- c. Volatile Acid/Alkalinity ratio
 - d. Temperature
11. An anaerobic digester has a volatile acid concentration of 98 mg/L and an alkalinity of 110 mg/L, what does this tell you?
- a. The digester is operating optimally
 - b. The digester is stressed
 - c. The digester is failing
 - d. You need more information that this to make a decision
12. If your Volatile Acid/Alkalinity ratio is 0.5, what action could you take?
- a. Add polymer
 - b. Add an alkaline material
 - c. Add an acid material
 - d. None of the above
13. Which of the following is an example of a chemical that could be added to fix a sour digester?
- a. Sulfuric acid
 - b. Sodium thiosulfate
 - c. Chlorine
 - d. Lime
14. Lime stabilization is accomplished by adding sufficient quantities of lime to the lower the pH of the sludge to 3.0 – 4.0.
- a. True
 - b. False
15. To reduce exposure to airborne pathogens when working around a composting operation, operators should:
- a. Set up fans in the area
 - b. Keep the doors to the facility closed
 - c. Wear a dust mask
 - d. Hose down the compost
16. In order to meet Class A biosolids requirements, the fecal coliform count must be what?
- a. Less than 2 million MPN
 - b. Less than 1000 MPN
 - c. Less than 126 MPN
 - d. None of the above
17. In order to meet Class B biosolids requirements, the fecal coliform count must be what?
- a. Less than 2 million MPN
 - b. Less than 1000 MPN
 - c. Less than 126 MPN
 - d. None of the above
18. Biosolids are the primarily organic solid product produced by wastewater treatment processes that can be beneficially recycled.
- a. True
 - b. False

19. The term “blinding” refers to the clogging of the filtering medium of a microscreen or a vacuum filter when the holes or spaces in the media become clogged or sealed off due to a buildup of grease or the material being filtered.
- True
 - False
20. Which of the following is **not** a reason why solid particles present in sludge usually require conditioning in order to separate from wastewater:
- They are fine in particle size
 - They are hydrated (combined with water)
 - They may carry an electrostatic charge
 - They increase in volume when exposed to water

Answers:

- B
- B
- A
- B
- A
- B
- A
- A
- E
- C
- C
- B
- D
- B
- C
- B
- A
- A
- A
- D

OPERATOR ESSENTIALS

What every operator should know about anaerobic digestion

Ken Schnaars



| Knowledge | Principle | A practical consideration |
|----------------------|---|--|
| Volatile acid (VA) | <p>VAs are fatty acids (organic acids) that are soluble in water. VA test results are expressed as milligrams of equivalent acetic acid and indicate the health of the digester.</p> <p>In a normal or healthy digester, the VA will be used as the food for the methane formers.</p> | <p>The production of organic acids depends on the volume of solids fed to the digester. The typical range for VAs in a primary digester is between 50 and 300 mg/L.</p> <p>When VA concentrations climb above 300 mg/L, the digester could be overloaded or experiencing other problems.</p> |
| Alkalinity (ALK) | <p>ALK is the buffering capacity of water to neutralize acids. ALK is a measure of carbonates, bicarbonates, hydroxides, and, occasionally, borates, silicates, and phosphates. It is expressed in milligrams of equivalent calcium carbonate per liter.</p> | <p>The methane formers (methanogens) in anaerobic digestion are affected by small pH changes, while the acid producers can function satisfactorily across a wide range of pH.</p> <p>Digestion stability depends on the buffering capacity of the digester contents. Higher ALK values indicate a greater capacity for resisting pH changes. ALK value in an anaerobic digester can range between 1500 and 5000 mg/L.</p> |
| VA/ALK ratio | <p>VA and ALK, when examined together, can measure and control the digestion process. VA and ALK concentrations are used in a formula to provide a single number that provides a snapshot of digester operation.</p> | <p>Maintaining a consistent VA/ALK ratio of less than 0.35 ensures that conditions are correct for proper digester operation.</p> $\text{VA/ALK ratio} = \frac{\text{VA (mg/L)}}{\text{ALK (mg/L)}}$ <p>The ratio in a well-operated digester ranges between 0.1 and 0.35. If the ratio exceeds 0.35, it indicates such issues as increased organic loading, hydraulic overloading, etc.</p> |
| Mesophilic digestion | <p>Mesophilic organisms grow optimally in a temperature range of approximately 30°C to 38°C (85°F to 100°F).</p> | <p>Most anaerobic digestion processes at wastewater treatment plants operate in the mesophilic range. It is important for operators to maintain temperatures within a narrow range – typically, 35°C to 37°C (95°F to 98°F).</p> <p>The temperature within a digester must not be changed more than 0.6°C (1°F) per day.</p> <p>The solids retention time for a mesophilic digestion system ranges between 10 and 30 days.</p> |

| Knowledge | Principle | A practical consideration |
|------------------------|---|--|
| Thermophilic digestion | <p>Thermophilic organisms grow optimally in a temperature range of 50°C to 60°C (122°F to 140°F).</p> <p>Temperature variations are especially hard on thermophilic microorganisms.</p> | <p>A digestion system that operates in the thermophilic temperature range requires a shorter solids retention time than an anaerobic digester operating in the mesophilic temperature range.</p> <p>The solids retention time for a thermophilic digestion system ranges between 5 and 12 days.</p> |
| Organic loading | <p>Anaerobic digesters are fed based on a measurement of mass or weight of volatile solids per unit of digester volume per day.</p> <p>The units kg/m³·d and lb/1000 ft³·d are most common.</p> | <p>Anaerobic digestion systems designed today usually are high-rate systems with loadings of 1.6 to 6.4 kg/m³·d (100 to 400 lb/1000 ft³·d).</p> <p>Digesters should be fed at a consistent and constant rate to operate properly.</p> |
| Gas production | <p>A benefit of anaerobic digestion is the production of methane gas, which can be used as a fuel to heat the digesters or another process, such as a dryer. The gas also can be used to fuel an electrical cogeneration system.</p> <p>Gas production in an anaerobic digester is estimated between 0.8 and 1.1 m³/kg of volatile solids destroyed (13 and 18 ft³/lb of volatile solids destroyed).</p> <p>Digester gas contains approximately 65% methane and 35% carbon dioxide.</p> <p>The heat value of the digester gas is between 19 and 23 MJ/m³ (500 and 600 Btu/ft³).</p> | <p>Operators should visually monitor the color of the flame at the waste-gas burner to determine the quality of gas produced. A predominantly blue flame indicates good methane production; an increase in yellow indicates more carbon dioxide.</p> <p>An increase in carbon dioxide could indicate a digestion process issue. An increase in carbon dioxide also will affect the operation of the equipment using digester gas as a fuel source.</p> |
| Mixing | <p>Anaerobic digesters are mixed to ensure constant temperature and that incoming solids are well dispersed.</p> | <p>One key to successful digester operation is good and thorough mixing.</p> <p>Types of mixing systems used in anaerobic digesters include gas mixing, internal mixing, and external mixing. Internal and external mixing systems are hydraulic and/or mechanical.</p> |
| Foaming | <p>Foaming in an anaerobic digester can result in poor process performance, safety issues, and damaged equipment and/or structures.</p> | <p>Foaming typically results from poor mixing, temperature variations, and/or improper/inconsistent feeding.</p> <p>Sometimes, filaments transferred from the liquid process stream to the digesters can cause foaming.</p> |
| Toxicity | <p>Anaerobic digestion processes cannot tolerate elevated levels of several compounds, including heavy metals, sulfides, volatile acids, alkali/alkalines, and even ammonia–nitrogen.</p> <p>A properly operated digester requires the optimal balance of such parameters as organic loading rate, pH, mixing, and temperature.</p> | <p>Heavy metals, such as copper, inhibit digestion at a soluble concentration greater than 0.5 mg/L. Metals entering a digester may be coming from an industrial user.</p> <p>Ammonia concentrations of 50 to 200 mg/L are beneficial, but ammonia levels of 1500 to 3000 mg/L (pH greater than 7.4) are inhibitory. An ammonia concentration higher than 3000 mg/L is toxic.</p> <p>As an operator, if you notice that the ammonia levels are climbing steadily, you may need to reduce the organic loading rate.</p> |
| Struvite | <p>Struvite, or magnesium ammonium phosphate (MgNH₄PO₄), accumulates in scale deposits in anaerobic digestion systems and in the downstream dewatering system. Typically, it causes maintenance problems by clogging pipes, valves, heat exchangers, etc., with a white residue.</p> | <p>Once struvite deposits have formed, they are difficult to remove. Acid washing is an effective cleaning method but is time consuming, costly, and can be a safety issue.</p> <p>Some facilities feed ferric chloride or ferrous chloride to digester feed lines to reduce the potential of forming struvite deposits.</p> |

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What every operator should know about solid bowl centrifuge dewatering

Ken Schnaars



| Knowledge | Principle | A practical consideration |
|------------------------|--|--|
| Solid bowl centrifuges | <p>Solid bowl centrifuges operate using centrifugal forces to separate solids from water.</p> <p>Conditioned sludge that enters the centrifuge is thrown to the walls on the inside of the bowl. As the solids are spun around, the heavier solids migrate closer to the wall of the bowl while the water (centrate) remains closer to the center of the machine.</p> <p>Any oils would be above the water toward the center of the machine. Basically, the higher the specific gravity of the material, the closer it will be to the bowl wall, and the lower the specific gravity of the material, the further away.</p> | <p>Centrifuges are like clarifiers, except that clarifiers rely on gravity for settling and centrifuges rely on centrifugal forces. Like a clarifier, a centrifuge requires surface area, retention time, and weir length to operate successfully.</p> <p>Centrifuges typically can produce a dewatered product that is between 15% and 30% solids, depending upon the type and condition of the input solids.</p> |
| Solids loading rate | <p>Solids loading rate (SLR) is the quantity of dry solids entering the centrifuge per hour.</p> <p>SLR is calculated using the following formula:</p> $SLR = \frac{\text{feed solids (\%)}}{100} \times \text{feed rate} \left(\frac{\text{gal}}{\text{min}} \right) \times 60 \frac{\text{min}}{\text{h}} \times 8.34 \frac{\text{lb}}{\text{gal}}$ | <p>This is an important parameter because if the rated capacity of the centrifuge is exceeded, it will become overloaded and shut down.</p> <p>Centrifuges never should be operated strictly on flow rate (gal/min). The flow rate needs to be calculated based on the SLR to remain within the centrifuge's design parameters.</p> |
| Bowl | The bowl is the casing around the scroll (conveyor). The bowl is operated by its own motor. | The bowl operates at a constant speed – normally at 2400 to 2600 rpm. The bowl contains a conical section at one end where the dewatered solids are scrolled out of openings near the end of the cone. On the other end, dams act like weirs where the centrate is removed from the centrifuge. |
| Scroll or conveyor | The scroll is the conveyor located inside the bowl. The scroll is used to move the solids to the end of centrifuge where they are removed. | The scroll is tapered at one end so it can push solids up the conical end of the centrifuge. The scroll operates at different speeds and is driven by its own motor separate from the bowl motor. The scroll is operated at different speeds so it can adjust to the process conditions and control the dryness of the dewatered solids. |

| Knowledge | Principle | A practical consideration |
|--------------------------------|---|--|
| Differential or relative speed | Differential or relative speed is a term used by centrifuge manufacturers to explain the difference between the bowl speed and the scroll (conveyor) speed. | <p>Differential or relative speed is an important aspect for operators to understand in controlling a centrifuge. The slower the scroll (conveyor) moves in the bowl, the longer the solids remain in the centrifuge and the drier the dewatered solids. The faster the scroll-speed, the shorter the residence time in the centrifuge and the wetter the dewatered solids.</p> <p>Operating a centrifuge in a differential control mode usually is not recommended by manufacturers because this is considered a manual mode of operation in which the machine will not compensate automatically for changes in feed rate, feed concentration, polymer changes, and other process conditions.</p> |
| Torque (or load) | Torque control is the automatic mode of operation that centrifuge manufacturers use to control the dryness of the solids. | <p>In the torque mode of operation, the centrifuge controls perform a mathematical calculation to adjust the centrifuge scroll automatically to maintain a consistent output.</p> <p>In the automatic torque control mode of operation, the centrifuge constantly will make adjustments to compensate for such process variables as feed solids concentration, feed rate, and polymer dose.</p> |
| Capture rate | Capture rate describes how much solids are dewatered and do not escape in the centrate. Capture rate, basically, is the efficiency of the centrifuge. | <p>Typically, centrifuges have capture rates between 90% and 95%. Capture rates will depend upon the feed solids characteristics, feed sludge age, feed rate, polymer feed rate, polymer condition, and other such factors.</p> $\text{Capture rate} = \frac{\text{cake solids} \times (\text{feed} - \text{centrate})}{\text{feed} \times (\text{cake solids} - \text{centrate})} \times 100$ |
| Centrate | Centrate is the liquid separated from solids in the centrifuge. The centrate exits the centrifuge on the opposite end of the unit from the dewatered solids. | <p>Evaluating the centrate leaving a centrifuge is one of the operating parameters that enables the operator to determine how well the centrifuge is performing.</p> <p>If the centrate is black and dirty, then the unit is performing poorly. If the centrate is white and low in solids, then the centrifuge has a high capture rate. If the centrate is white, slimy, and possibly foaming, then the unit is receiving too much polymer; this wastes polymer, incurs additional operating cost, and should be avoided.</p> |
| Polymer | Polymer (polyelectrolyte) is a chemical used to condition solids prior to entering the centrifuge. | <p>Polymer is the most common chemical used for solids conditioning. Polymer is used to release the bound water so the solids cake can become drier.</p> <p>Polymers are organic chemicals with high molecular weights. Polymer use increases the capture rate of the centrifuge (centrate quality), improves the dewatered cake concentration, and enables a greater sludge feed rate.</p> <p>Typically, centrifuges at treatment facilities use cationic polymer that can be delivered in liquid or dry forms.</p> <p>Polymer solutions usually are mixed to between 0.25% and 0.75% polymer. Depending on the type of feed solids, required polymer dose rates can range from 2.3 to 6.8 kg (5 to 15 lb) of dry polymer needed per ton of solids.</p> |
| Clean-in-place procedure | A clean-in-place (CIP) procedure normally is a step that is conducted on a centrifuge when the unit is shutting down. A CIP flushes solids out of the centrifuge so the unit is clean when it is restarted. | <p>It is important that a CIP be completed when a centrifuge is being shut down to flush solids from the unit. If solids are left inside, they could cause an imbalance condition and vibration issues upon startup.</p> <p>If a centrifuge has been out of service for an extended period, sometimes a CIP is conducted before restarting to ensure any dried material is flushed before starting.</p> <p>Typically, a CIP is performed at a lower speed (600 rpm) and for a preset time. During a CIP the scroll is operated both forward and backward to provide a good cleaning action within the bowl.</p> <p>There are two types of CIPs: dry and wet. Depending upon the configuration of the machine, some manufacturers prefer one over the other. A wet CIP introduces water to the bowl during the CIP phase.</p> |

| Knowledge | Principle | A practical consideration |
|--------------|---|---|
| Pond or pool | Pond or pool refers to the liquid level inside the centrifuge. | <p>The pond depth can be adjusted by raising or lowering the dams (weirs) at the end of the centrifuge. The manufacturer typically determines the pond depth at startup depending on the conditions required for a particular facility.</p> <p>Higher pond depth leads to lower velocities and, therefore, clearer liquid discharge but wetter cake solids. Lower pond depth equals faster velocities and, therefore, cloudier liquid discharge, but drier dewatered solids.</p> <p>Pond depths are set to provide the best cake percentage (dewatered solids) and clearest centrate.</p> |
| Seal or plug | Seal or plug is the condition when the centrifuge has reached speed and is ready to produce dewatered solids. | <p>When a centrifuge initially starts, solids will pour out of the discharge end until the machine is up to speed and the centrifugal forces have pulled the water (pool) below the solids discharge ports.</p> <p>Until seal is achieved, the discharge conveyor (inclined conveyor) below the centrifuge operates in the reverse direction to avoid water and poor solids capture from being discharged into the conveyor system. Once the centrifuge makes seal, the inclined conveyor reverses and the processing of dewatered solids can begin.</p> |

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What every operator should know about biosolids management for land application

Steve Wilson



| Knowledge | Principles | Practical considerations |
|-------------------------|---|--|
| Regulatory requirements | Title 40, <i>Code of Federal Regulations</i> , Part 503 Various state and local rules | The 1993 40 <i>CFR</i> Part 503 Rule and technical support documents serve as the foundation of all regulatory policies. State or local jurisdictions can be more conservative in some cases, but never less stringent. |
| Terminology | <i>Biosolids</i> versus <i>sewage sludge</i> | <i>Biosolids</i> are the primarily organic solid product of wastewater treatment that can be beneficially used. <i>Sludge</i> or <i>sewage sludge</i> is unprocessed (<i>i.e.</i> , unstabilized) and generally unsuitable for beneficial use. The Part 503 rule does not use the term <i>biosolids</i> , but subsequent guidance and state-level policies have recognized the distinction between <i>sludge</i> and <i>biosolids</i> and use this terminology. |
| Product standards | Rules and guidance define acceptable (risk-based) chemical characteristics focusing on metals. Pathogen reduction and stabilization (vector attraction reduction) standards also are defined. | Metal (pollutant) limits are defined in the Part 503 rule. Metals rarely are limiting in beneficial use programs because pretreatment programs have been so effective. But operators always should check data for verification. Pathogen reduction will be to Class A or Class B standards depending on process technology. Class B product reuse has management practice limits to protect operator and public health. Stabilization standards, such as the minimum 38% volatile solids reduction through digestion, minimize odors during product handling and reuse and help minimize complaints. |
| Agronomic rates | Application rates are determined to match the amount of available nitrogen applied to the amount needed by crops. | Available nitrogen is calculated in units of pounds per dry ton. This value is converted to a wet (or as-applied) basis in either wet tons or gallons per acre in line with fertilizer recommendations for the crop being grown. Many guidance documents and even online spreadsheets are available to assist in making these calculations (see below). Spreader equipment then is calibrated to deliver this amount of material per unit of field. |
| Marketability | Class B biosolids generally are delivered at no cost or for a nominal fee; the land owner benefits from the fertilizer value. Class A products may be marketed more aggressively and sometimes are sold to offset production costs. Quality may be more important. | Product quality parameters include <ul style="list-style-type: none"> ■ meeting or exceeding all regulatory requirements, ■ lack of visible trash or foreign material, ■ low odor potential, ■ “soil-like” consistency (<i>i.e.</i>, manufactured topsoil or compost), and ■ dust-free product with uniform particle size (for dried products). |



Steve Wilson



Steve Wilson

| Knowledge | Principles | Practical considerations |
|---------------------------------|---|--|
| Monitoring | Part 503 and state rules dictate sampling frequencies, parameters, and methodology. | <p>Testing generally includes Part 503 metals (arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc), nutrients (total Kjeldahl nitrogen, ammonium–nitrogen, nitrate–nitrogen, and phosphorus), and percent-total and percent-volatile solids.</p> <p>For Class A products, additional testing is required to demonstrate pathogen reduction to minimal (1000 MPN/g dry solids) levels.</p> |
| Reporting | Agencies must report process control details (to verify pathogen and vector attraction reduction), biosolids quantities, pollutant concentrations, nutrient values, and biosolids disposition information on an annual basis. | <p>At a minimum, a biosolids “preparer” must submit an annual report to the U.S. Environmental Protection Agency (EPA) for the previous year by February 19. Where authority has been delegated to states, the report goes to the state regulatory agency. Dual reporting to both state and EPA is not uncommon.</p> <p>The preparer must certify that all regulatory requirements have been met. In some cases, a contract “applier” must submit a separate report certifying land application practices. The preparer always should verify that a separate applier has met all requirements.</p> |
| Resources | Comprehensive guidance and training is available readily from several sources. | <p>A short list of sources includes the following:</p> <ul style="list-style-type: none"> ■ The Water Environment Federation provides access to state regulatory contacts, technical resources, and other documents at www.wef.org/biosolidsnews. ■ EPA lists a wealth of links and information at http://water.epa.gov/polwaste/wastewater/treatment/biosolids. ■ EPA also posts the <i>Plain English Guide to the Part 503 Rule</i> at http://water.epa.gov/scitech/wastetech/biosolids/503pe_index.cfm. |
| Networking | Become active in your regional or local biosolids community. | Regional biosolids communities include the Northwest Biosolids Management Association (Seattle), the North East Biosolids Recycling Association (Tamworth, N.H.), the Mid-Atlantic Biosolids Association (Philadelphia), the California Association of Sanitation Agencies (Sacramento, Calif.), and WEF Member Association biosolids committees. |
| Promoting public support | Share information. | News releases about program successes benefit public understanding by sharing positive biosolids recycling news. |
| Potential for public opposition | Be aware. | An Internet search for “biosolids” reveals the extent of unsupported, unscientific, negative information that is out there for the uninformed to use as the basis for their first impression of biosolids recycling. It’s important to understand what kind of faulty information the public may be exposed to. |
| Research and emerging issues | Support research. | Questions about fundamental biosolids benefits and controls – not to mention emerging constituents, personal care products, and other microconstituents – abound. Consider funding research with local universities directly through your agency or as a regional association member. |

Steve Wilson is a chief scientist in the Portland, Ore., office of Brown and Caldwell (Walnut Creek, Calif.).

Section 5

Phosphorus Removal

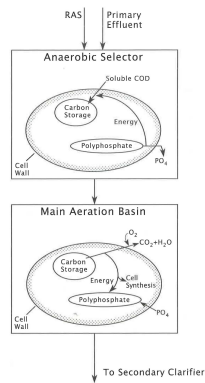


Fig. 5.3 Microorganism cell reactions during phosphorus release and luxury uptake process

PHOSPHORUS REMOVAL

1 **Advanced Wastewater Class**

WHERE DOES PHOSPHORUS COME FROM?

- Fertilizers
- Manure
- Organic wastes in sewage and industrial effluent
- Soil erosion from banks is a major contributor of phosphorus in streams
 - Attaches to soil particles
- Essential element for plant life
 - Usually the limiting nutrient

2

PHOSPHORUS IN WASTEWATER

- Orthophosphate
 - Readily available to organisms
- Polyphosphates (condensed phosphates)
 - Converted to orthophosphates via hydrolysis reactions (slow)
- Organic phosphates (phospholipids and nucleotides)

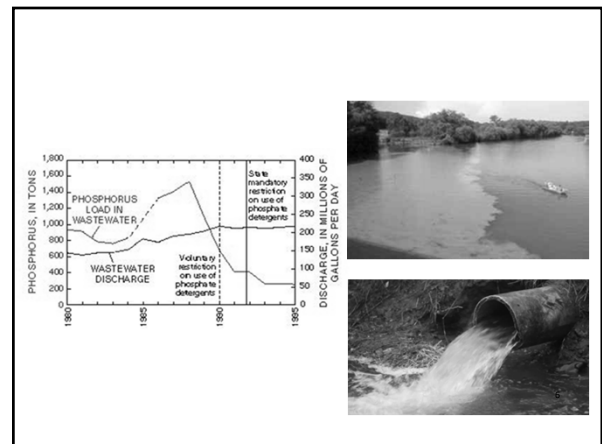
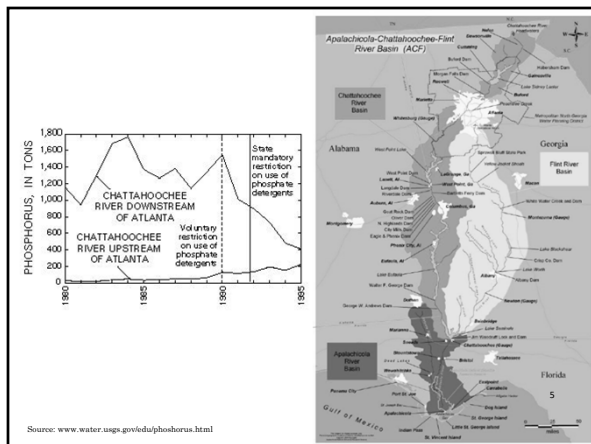
- Phosphate species and their abundance - function of pH
- In conventional WW treatment:
 - TP in raw wastewater typically 4 – 8 mg/L
 - ~5 – 10% P removed during primary setting/secondary clarification
 - ~20 – 25% P taken up in AS process during bacterial growth

3

WHY MUST PHOSPHORUS BE REMOVED?

- Nutrient and food source for algae
- When combined with inorganic Nitrogen = Eutrophication
 - Eutrophication = an increase in chemical nutrients in an ecosystem (on land or in water)
- By removing phosphorus, the receiving stream will have one less nutrient that is essential for algae growth
 - Reduction in essential nutrient = reduction in algae

4



NPDES PERMIT LIMITS

- Plants that discharge into smaller receiving streams already have NPDES permit limits
- Reported as P
- Plants may be required to report, but no limits (yet)
- Some plants monitoring, but no limits (yet)

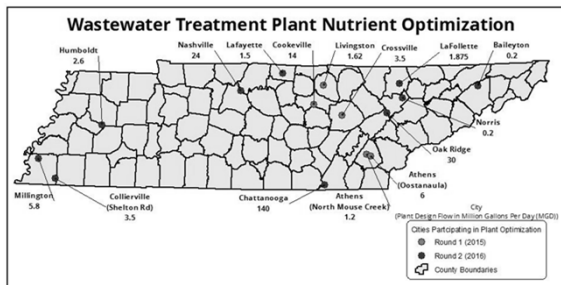
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TENNESSEE NUTRIENT REDUCTION FRAMEWORK

- Prioritize watersheds
 - Set watershed nutrient reduction goals
- Ensure effective point source permits
- Devise effective agricultural BMPs
- Encourage reduction from non MS4s
- Watershed monitoring
- Document and report activities

8

TENNESSEE NUTRIENT REDUCTION FRAMEWORK



TYPES OF PHOSPHORUS REMOVAL SYSTEMS

Most common:

1. Biological Phosphorus Removal
 - Phosphorus contained within cells of microorganisms
 - "Luxury uptake"
2. Lime Precipitation
 - Addition of lime
 - Flocculation and precipitation
3. Filtration following Aluminum Sulfate Flocculation
 - Addition of aluminum sulfate
 - Similar to lime precipitation, with addition of a filter after the clarifier

Other types:

- Bardenpho process
 - Removes both Nitrogen and Phosphorus
 - Modification of the activated sludge process

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BIOLOGICAL PHOSPHORUS REMOVAL

- 2 Elements of all biological treatment systems:
 1. Biomass
 - Suspended Growth - Contained in a reactor/basin
 - Fixed Growth – attached to inert media
 2. Liquid-Solids Separation
- Oxygen level is key
 - Aerobic – dissolved oxygen is present
 - Anoxic – no dissolved oxygen present, "oxygen deficient"
 - Chemically bound oxygen, such as nitrate, is present
 - Anaerobic – no dissolved oxygen or bound oxygen

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BIOLOGICAL PHOSPHORUS REMOVAL

- Selector
 - A reactor or basin that contains compartments
 - Baffles or other devices
 - The environment can be controlled to "select" for microbial populations
 - Environmental conditions (ex: food, lack of dissolved oxygen) are intended to favor the growth of certain organisms over others
- Mean Cell Residence Time (MCRT)
 - The average time a microorganism will spend in the activated sludge process or specific process phase

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BIOLOGICAL PHOSPHORUS REMOVAL

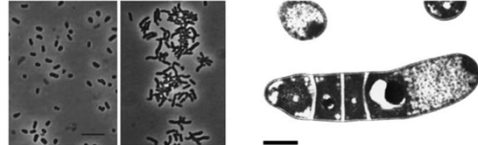
o Types of Microorganisms:

1. Autotrophs
 - Rely on inorganic carbon for growth (Ex: carbon dioxide)
 2. Heterotrophs
 - Rely on organic carbon for growth
- o Both types of organisms can be:
- Obligate aerobes – must have dissolved oxygen to survive
 - Obligate anaerobes – must exist in environment with no dissolved oxygen
 - **Facultative organisms** – able to perform oxic, anoxic, and anaerobic reactions

BIOLOGICAL PHOSPHORUS REMOVAL

o Phosphate-Accumulating Organisms (PAOs)

- Heterotrophic and Facultative
- Through design and operational conditions, they are given selective advantage to grow and function
- *Accumulibacter*
- *Tetrasphaera*



QUIZ

- o What elements do all biological treatment systems have in common?
- o Briefly define the following terms:
 - Aerobic or oxic
 - Anoxic
 - Anaerobic
- o How does an operator “select” the organisms needed to meet a particular processing objective?

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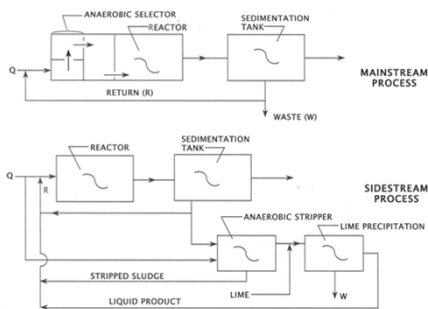
BIOLOGICAL PHOSPHORUS REMOVAL

o 2 General process layouts are used:

1. Mainstream
 - Anaerobic selector at the beginning of the process
 2. Sidestream
 - Sidestream anaerobic stripper and a phosphorus extractor or a clarifier
- o The way the organisms remove the phosphorus is the same in both layouts

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BIOLOGICAL PHOSPHORUS REMOVAL



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Source: Advanced Waste Treatment, 5th ed., p.479

Fig. 5.1 Biological phosphorus removal process layout

BIOLOGICAL PHOSPHORUS REMOVAL – MAINSTREAM LAYOUT

o Advantages:

1. Complete and thorough mixing of entire wastestream with biomass in the anaerobic contactor
2. Relatively simple design

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BIOLOGICAL PHOSPHORUS REMOVAL – SIDESTREAM LAYOUT

Advantages:

- Hydrolysis and volatile acid formation may be better
 - However, this advantage could be offset by incomplete mixing
- Provides for routine phosphorus extraction
 - Less dependent on sludge production and metabolic limits
- Can potentially achieve lower P limits

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BIOLOGICAL PHOSPHORUS REMOVAL – LUXURY UPTAKE

Luxury uptake = the process in which microorganisms take excess P into their bodies

Microbes routinely remove some P

- Required for survival
- They can be forced to remove/uptake more than they actually need
- Aerobic, then anaerobic environment

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BIOLOGICAL PHOSPHORUS REMOVAL – LUXURY UPTAKE

- In aerobic conditions, the microbes will take up and store P in their cells
 - Stored as Polyphosphate
- Once they have stored maximum amount of P in their cells, they are transferred to anaerobic environment
- Microbes chemically convert some of the carbon materials in their cells to get the oxygen they need for metabolism
 - The energy used in this chemical rxn comes from the polyphosphate stored in it's cells
 - As a result, phosphorus is released from the cells

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BIOLOGICAL PHOSPHORUS REMOVAL – LUXURY UPTAKE

- After releasing the P, they are returned to the aeration tank
- Lots of food, oxygen, P
- Since they just used up all the P in their cells, they will take up and store large quantities of P
- "luxury uptake"
- Remain in aerobic phase until they are completely revived
- Sequence is repeated

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BIOLOGICAL PHOSPHORUS REMOVAL

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BIOLOGICAL PHOSPHORUS REMOVAL

Phosphate Accumulating Organism (PAO)

Volatile Fatty Acids (VFA) - produced during digestion/fermentation

- The preferred food for the PAO
- PAO's expend energy to transform VFA's into a chemical form for storage
- That energy comes from breaking P bonds, results in P release

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BIOLOGICAL PHOSPHORUS REMOVAL

- o Lime can be added to supernatant from P stripping tank
 - P precipitates out in clarifier
 - Polymers can be added to improve coag/floc
- o Sludge from stripping tank (contains microbes) is returned to aerobic reactor
 - This is in contrast to the mainstream layout, where microbes are removed entirely from waste stream

Fig. 5.3 Luxury uptake of phosphorus (biological flow diagram)

Source: Advanced Waste Treatment, 5th ed, p.481

BIOLOGICAL PHOSPHORUS REMOVAL

LUXURY UPTAKE (PHOSTRIP®)

PHOSPHORUS SLUDGE TO DEWATERING AND DISPOSAL FACILITIES

BIOLOGICAL PHOSPHORUS REMOVAL

Five-stage Bardenpho process

BIOLOGICAL PHOSPHORUS REMOVAL – LUXURY UPTAKE

o Key Principles:

- Will only occur in very controlled environment
- Strict anaerobic conditions must be maintained in stripping tank at all times!
- Operators must carefully regulate detention time so it is long enough to remove as much P as possible, but not so long that the microbes will die of starvation
- Sludge recycle time is very important

QUIZ

1. What is luxury uptake of phosphorus?
2. What is happening during the aerobic phase?
3. What is happening during the anaerobic phase?
4. What is a PAO?

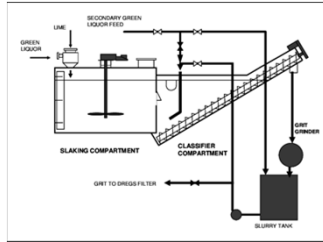
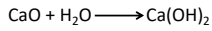
PHOSPHORUS REMOVAL – LIME PRECIPITATION

o 3 general physical or chemical reactions that take place during lime precipitation:

1. Coagulation
 - Coagulant added to reduce electrostatic charges that keep suspended particles apart
 - Electrical charge is altered, P particles come together
 - Floc is formed
2. Flocculation
 - Agglomeration or coming together of suspended particles into larger particles
3. Sedimentation
 - Settling of heavier suspended particles due to gravity
 - Removed from bottom of clarifier

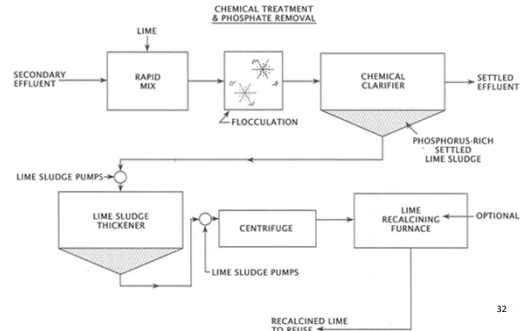
PHOSPHORUS REMOVAL – LIME PRECIPITATION

- o Lime usually comes in a dry form – Calcium oxide (CaO)
- o Must be mixed with water to form a slurry – Calcium hydroxide (Ca(OH)₂)



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PHOSPHORUS REMOVAL – LIME PRECIPITATION



Source: *Advanced Waste Treatment*, 5th ed., p. 402

Fig. 5.5 Lime precipitation process

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PHOSPHORUS REMOVAL – LIME PRECIPITATION

- o Recarbonation = process in which CO₂ is bubbled into the water to lower the pH
 - Effluent from the chemical clarifier will usually have a pH of at least 11
 - Carbon dioxide (CO₂) can be used to neutralize the water
 - o Bring the pH down to ~7
 - This will also produce settleable calcium carbonate that can be recalcined for reuse in the lime treatment procedure
 - o Recalcination = a lime recovery process in which calcium carbonate in sludge is converted to lime by heating to 1,800 °F

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PHOSPHORUS REMOVAL – LIME PRECIPITATION

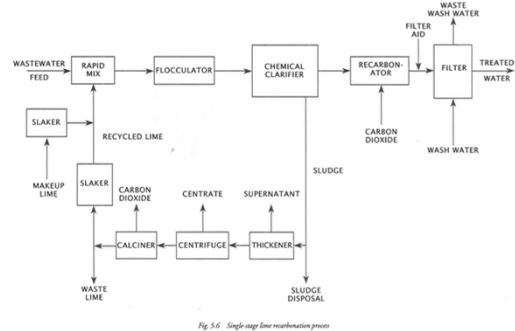


Fig. 5.6 Single-stage lime recarbonation process

PHOSPHORUS REMOVAL –LIME PRECIPITATION

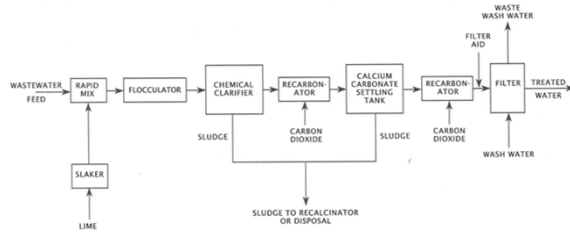


Fig. 5.7 Two-stage lime recarbonation process
Source: *PROCESS DESIGN MANUAL FOR PHOSPHORUS REMOVAL*, EPA-625/1-76-001A

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QUIZ

o What factors could affect phosphorus removal efficiency in the lime precipitation process?

1. Short circuiting
2. Changes in pH
3. Solids loading
4. Small straggler floc
5. Stormwater
6. Industrial discharges
7. Plugged pumps or piping
8. Inadequate lime supply
9. Operational problems with upstream or downstream treatment processes

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PHOSPHORUS REMOVAL – ALUM FLOCCULATION

- Used the same as lime precipitation
 - Same principles of coagulation, flocculation, sedimentation apply
- Aluminum Sulfate is more expensive than lime
- Aluminum Sulfate (Alum) has long been used in water and wastewater treatment
 - Proven ability to coagulate and flocculate suspended particles

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ALUM FLOCCULATION

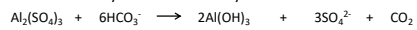
- The compound that is created is aluminum phosphate particles that attach to each other and settle out
 - The alum floc is difficult to settle out and needs to be run through a pressure filter or sand or mixed-media filter to remove any remaining floc that does not settle in the clarifier

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ALUM FLOCCULATION

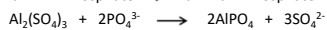
- 2 general reactions occur:
 1. Alum reacts with alkalinity to form aluminum hydroxide floc

Alum + Alkalinity → Aluminum Hydroxide Floc + Sulfate + Carbon Dioxide



2. Alum also reacts with the phosphate present

Alum + Phosphate → Aluminum Phosphate + Sulfate



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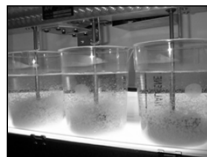
ALUM FLOCCULATION



- Phosphorus removal is achieved by the formation of an insoluble complex precipitate and by adsorption on the aluminum hydroxide floc.
- Dosage of alum depends on alkalinity of the water
 - 200 – 400 mg/L are commonly required to reduce P in effluent down to 0 – 0.5mg/L
 - Optimum P removal is achieved around a pH of 6.0
 - Jar tests can be used to determine optimum pH set point and alum dosage rate

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ALUM FLOCCULATION



- Alum overdose
 - Very common problem
 - Lowers the pH, which will hinder the ability of the alum to coagulate the suspended solids
 - Causes cloudy condition in filter effluent, with higher turbidity and SS
- Operators must rely on jar testing and sampling of influent and effluent from a filter bed to make sure alum dosage is correct for optimum phosphorus and suspended solids removal efficiency

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ALUM FLOCCULATION

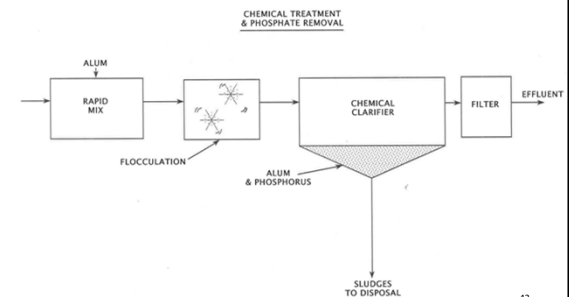
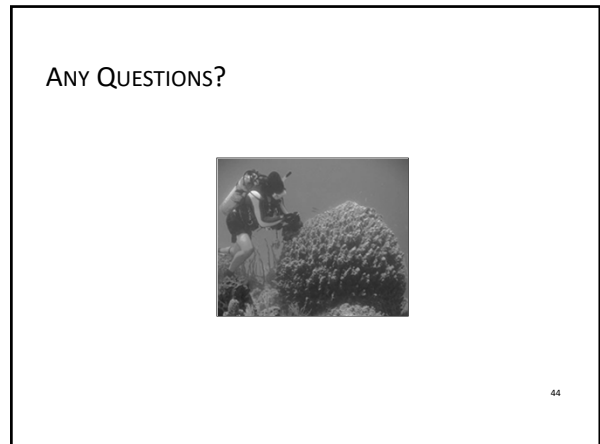
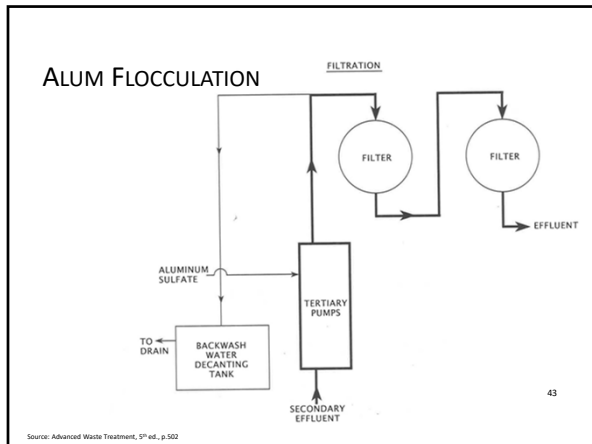


Fig. 5.8 Alum flocculation as used in a clarification process

Source: Advanced Waste Treatment, 5th ed., p. 501

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Phosphorus Removal – Review Questions

1. Phosphorus must be removed from wastewater treatment plant effluent so that it will not combine with nitrogen in the receiving stream to kill algae and cause eutrophication.
 - a. True
 - b. False

2. In the lime precipitation process for phosphorus removal, the pH of the combined wastewater and lime slurry should be _____ or above.
 - a. 5.5
 - b. 9.5
 - c. 7.0
 - d. 11.0

3. During “luxury uptake,” microorganisms are taking up phosphorus into their cell structure under _____ conditions and then they will release it under _____ conditions.
 - a. Aerobic, anaerobic
 - b. Anaerobic, aerobic
 - c. Aerobic, autotrophic
 - d. Anaerobic, anoxic

4. Chemicals used to remove phosphorus from wastewater include all of the following **except**:
 - a. Aluminum sulfate
 - b. Calcium hydroxide
 - c. Chlorine
 - d. Lime

5. Lime feeding equipment should be routinely checked:
 - a. Every hour
 - b. Several times during each shift
 - c. Once each shift
 - d. Once a week

6. Important variables the operator must control in the luxury uptake process include all of the following **except**:
 - a. Detention time in the anaerobic tank
 - b. Dissolved oxygen level in the stripping tank
 - c. Predominance of anaerobic microorganisms in the activated sludge
 - d. Primary effluent supply to the aeration tank
 - e. Stripping tank sludge recycle rate

7. Generally speaking, phosphorus levels in wastewater have dropped due to:
 - a. Changes in drinking water consumption
 - b. Increased phosphorus uptake by plants and aquatic life
 - c. Phosphate detergent bans
 - d. Cutting edge phosphorus removal technology

8. Which of the following is **not** a type of phosphorus removal system?
 - a. Biological phosphorus removal
 - b. Lime precipitation
 - c. Filtration following Aluminum Sulfate Flocculation
 - d. Ammonia Stripping

9. Phosphate-Accumulating Organisms are heterotrophic and facultative.
 - a. True
 - b. False
10. The dosage of alum depends on the _____ of the water.
 - a. pH
 - b. Turbidity
 - c. BOD
 - d. Alkalinity
11. Environmental conditions within a selector can be manipulated to promote the growth of certain bacteria over others.
 - a. True
 - b. False
12. The preferred food of phosphate-accumulating organisms is:
 - a. Volatile fatty acids
 - b. Carbonaceous BOD
 - c. Nitrogen
 - d. Ammonia
13. Strict aerobic conditions must be maintained in the stripping tank during biological phosphorus removal.
 - a. True
 - b. False
14. Which of the following factors is **not** important to control during luxury uptake?
 - a. Strict anaerobic conditions in the stripping tank
 - b. Carefully regulated detention time in stripping tank
 - c. Alum dosage
 - d. Sludge recycle time
15. Recarbonation is the process in which carbon dioxide is bubbled into water to lower the pH
 - a. True
 - b. False
16. The addition of lime to remove phosphorus will result in a pH drop in the wastewater pH.
 - a. True
 - b. False
17. Alum reacts with _____ to form aluminum hydroxide floc.
 - a. Dissolved solids
 - b. Alkalinity
 - c. BOD
 - d. COD
 - e. True
 - f. False
18. Jar tests are used to determine the concentration of volatile fatty acids present for luxury uptake.
 - a. True
 - b. False

19. Alum floc is difficult to settle out and often needs to be run through a pressure filter, sand, or mixed-media filter to remove any remaining floc that does not settle in the clarifier.
- True
 - False
20. The 5-stage Bardenpho system consists of an anaerobic zone and multiple anoxic and aerobic zones that result in nitrogen and phosphorus removal.
- True
 - False

Answers:

- A
- D
- A
- C
- B
- C
- C
- D
- A
- A
- A
- A
- B
- C
- A
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- B
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- A
- A

What every operator should know about biological phosphorus removal



Mike Ross

Biological phosphorus removal (BPR) was first used at a few water resource recovery facilities in the late 1960s. By the 1970s, many engineers developed specific versions of the processes – University of Cape Town; anaerobic/anoxic/oxic; and Modified Ludzack–Ettinger – to remove phosphorus from wastewater. BPR can be a lower-cost alternative to chemical phosphorus removal. As environmental concerns over excess nutrients in receiving streams grew, regulatory agencies in the late 1980s began to require effluent phosphorus limits. Many facilities have made upgrades that included BPR.

| Knowledge | Principle | Practical considerations |
|-------------------------------------|--|--|
| Biological phosphorus removal (BPR) | Phosphorus-accumulating organisms (PAOs) can absorb dissolved phosphorus from wastewater and store it in granules within their cells, doubling the phosphorus content of the solids. | BPR is dependent on maintaining a sufficient population of PAOs. Overall phosphorus removal occurs as the PAOs are wasted from the system. |
| PAO characteristics | PAOs are aerobic and are similar to other activated-sludge bacteria. In an anaerobic environment, PAOs have the ability to sequester readily biodegradable biochemical oxygen demand (BOD). Most other activated sludge bacteria do not. | PAOs require the same environment as found in conventional activated sludge in terms of dissolved oxygen (DO), pH, etc. An anaerobic tank is needed prior to the aeration tank to give PAOs an advantage in absorbing BOD. |
| BPR process | For BPR, a facility must have wastewater and return activated sludge (RAS) flowing into an anaerobic tank, then an aerobic tank (typically an aeration basin). Anoxic zones and appropriate recycle streams often are used for BPR, as well as for nitrate reduction. | Conventional activated sludge facilities usually can be modified for BPR by adding an anaerobic tank prior to the existing aeration basin. Anaerobic basins are smaller, often only 5% to 20% the size of the aeration basin. |
| Anaerobic phosphorus release | The anaerobic uptake of BOD by PAOs requires energy. Since there is no DO, energy cannot be provided by the normal metabolic process. Instead, the PAOs can obtain energy by cleaving a phosphate (PO_4) molecule from the internal polyphosphate granule. This phosphate molecule then passes through the cell membrane into the mixed liquor suspended solids (MLSS). | In the anaerobic zone, there is a decrease in BOD and an increase in phosphorus. For BPR, a release of 5 to 50 mg/L is expected. Only soluble BOD will decrease through the anaerobic zone. The plant influent phosphorus concentration should not be used to determine release, since it will be affected by the recycle streams and RAS. Collect samples from the beginning and end of the anaerobic basin to determine release. Zero or low release can be due to insufficient BOD or low PAO population. Phosphorus release problems can be investigated in the lab using a settleometer and adding acetic acid as a food source. |



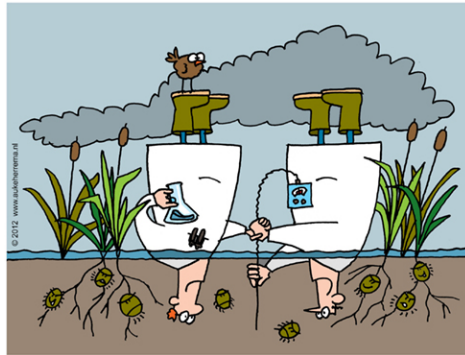
| Knowledge | Principle | Practical considerations |
|-------------------------------------|---|---|
| Aerobic luxury uptake of phosphorus | <p>During the aerobic cycle, PAOs absorb phosphate ions from the bulk MLSS and transport them into the cell. Each phosphate ion is added to polyphosphate granules scattered through the cell.</p> <p>Creating the granules requires energy, which is provided by metabolism of the BOD absorbed in the anaerobic zone.</p> | <p>Soluble phosphorus will decrease through the length of the aeration basin.</p> <p>If DO is low in the aeration basin, uptake of phosphorus may be incomplete.</p> <p>Insufficient BOD in the feed to the anaerobic basin also may result in low phosphorus uptake.</p> <p>Specific laboratory staining techniques can highlight the phosphorus granules.</p> |
| Phosphorus chemistry | <p>Phosphorus almost always is bound to oxygen as phosphate. It can be found as a single ion with a -3 charge, commonly called "orthophosphate." Phosphate ions can form a chain called "polyphosphate." Phosphate also may be bound to an organic molecule as organic phosphorus.</p> | <p>Untreated wastewater contains phosphorus in many forms.</p> <p>Anaerobic and aerobic processes tend to convert most phosphorus to phosphate.</p> <p>PAOs can only take up phosphate.</p> <p>Polyphosphate and organic phosphorus must be broken down to the orthophosphate form for BPR.</p> |
| Phosphorus element | <p>Unlike BOD, phosphorus cannot be destroyed. Phosphate is soluble.</p> | <p>If phosphorus is not taken up by the PAOs, it will remain in solution and be discharged in effluent.</p> <p>It is relatively easy to calculate a mass balance of total phosphorus through a facility.</p> |
| Phosphorus measurements | <p>Because of the many forms of phosphate, care must be used when performing lab analyses.</p> <p>Total phosphorus analyses measure every atom of phosphorus, whether in the liquid or solid fraction.</p> <p>Reactive phosphorus generally measures all orthophosphate, as well as some simple organic and polyphosphate. Samples can be filtered or allowed to settle so that aliquots for soluble fractions can be analyzed.</p> <p>Phosphorus commonly is reported as mg/L P. Some instruments can display results as either mg/L P or mg/L phosphate. Verify the procedures and display settings to prevent confusion.</p> | <p>Most contract labs should be able to perform phosphorus analyses on liquids and solids.</p> <p>Total phosphorus analysis requires strong oxidizers and digestion at an elevated temperature.</p> <p>Reactive phosphorus testing can be performed quickly using prepared reagent packets or tubes. The resulting blue color is measured in a colorimeter or spectrometer to determine phosphorus concentration. Read the procedures carefully to ensure that proper sample sizes and dilutions are used for the particular packet or tube. Verify that the proper container size is being used in the colorimeter and that the wavelength setting is correct.</p> <p>For operational purposes, samples can be collected from the settleometer or other supernatant rather than filtering, but this must be done soon after collecting the sample.</p> |

| Knowledge | Principle | Practical considerations |
|---------------------------------|--|--|
| Phosphorus removal drivers | <p>Assuming that there are sufficient PAOs, a specific amount of BOD is needed for the net uptake of a specific amount of phosphorus loading.</p> <p>This is commonly expressed as the BOD to phosphorus ratio (BOD:P) of the feed to the anaerobic zone.</p> | <p>Influent BOD is an acceptable measurement, since recycle streams generally are low in BOD.</p> <p>Include recycle streams in phosphorus sampling or mathematically to determine total phosphorus to the anaerobic reactor.</p> <p>A BOD:P value of less than 20 is unlikely to allow BPR. Ratios greater than 40 should produce good BPR. However, remember that all BOD is not equal for BPR. These ratios are useful for typical municipal wastewater. For treatment of significant industrial contributions, more-detailed BOD analyses should be performed.</p> |
| BOD type | PAOs can only absorb simple organic molecules, known as "volatile fatty acids" (VFAs), under anaerobic conditions. The BOD test does not differentiate organic molecules. Readily biodegradable BOD is a precursor for VFAs. | A soluble BOD or flocced and filtered chemical oxygen demand test is a better measure of food for PAOs. A ratio of either of these to total BOD can be established but may fluctuate seasonally. |
| Collection system effects | Under anaerobic and septic conditions, organic material generally will break down to simpler molecules, increasing the amount that could be used by PAOs. Long, slow, and septic collection systems will help BPR. | <p>Rainy periods causing influx and infiltration may lead to a decrease in BPR performance.</p> <p>Seasonal changes in BPR performance may be due to changes in the collection system environment, rather than temperature changes in the basins.</p> |
| Nitrate poisoning | PAOs grow best when there is no other competition for BOD in the anaerobic zone. When RAS containing nitrates enters the anaerobic zone, it creates anoxic conditions. Denitrifying bacteria can then grow, which compete with the PAOs for the BOD. | <p>Measure RAS nitrate weekly and adjust the process to encourage denitrification.</p> <p>RAS nitrate levels less than 5 mg/L should be acceptable. Results greater than 10 mg/L may lead to PAO competition.</p> |
| Non-PAO phosphorus removal | Phosphorus is an essential element for all living cells. All bacteria will consume some phosphorus for cell maintenance and growth. | Even when no PAOs are present, there will be a net reduction of phosphorus through the aeration basin. Non-PAO solids will have a phosphorus concentration of about 2% (by weight). |
| Undesirable phosphorus release | <p>Phosphorus can be released from the solids back into the liquid either as bulk granules from the supernatant and decanter liquor from waste activated sludge thickening and dewatering or slowly as the PAOs release stored phosphorus for energy.</p> <p>For example, as PAO cells in septic waste activated sludge at the bottom of a gravity thickener die and lyse (break apart), the polyphosphate granules also decompose and become part of the bulk liquid.</p> | <p>Soluble phosphorus will be 0.5 mg/L or less at the end of the aeration basin when BPR is working well.</p> <p>Increased effluent phosphorus might be due to release in secondary clarifiers with deep blankets or sludge removal problems.</p> <p>Digestion processes increase soluble phosphorus, which can be returned to the process through supernating or decanting.</p> <p>Dewatering processes following digestion also may generate high phosphorus recycle streams.</p> |
| Other anaerobic considerations | <p>Anaerobic activity produces desirable BOD. This occurs in the anaerobic zone, but the solids retention time (SRT) typically is short.</p> <p>Fermentation is an anaerobic process that can be performed using primary sludge. Biodegradable BOD produced in the sludge blanket or in a thickener is elutriated back to the headworks.</p> | <p>Anaerobic SRT typically is less than 0.5 days. Hydraulic retention time typically is less than 2 hours.</p> <p>Fermentation occurs in primary clarifiers or primary sludge thickeners. Anaerobic digesters do not work well as fermenters, because the biodegradable BOD is consumed by the methanogens in the digester.</p> |
| Effluent particulate phosphorus | Effluent total suspended solids generally are biomass that escaped the secondary clarifier. The phosphorus in the biomass will contribute to effluent total phosphorus but can be removed through a filtration process. | If effluent total suspended solids were 10 mg/L, the contribution to effluent total phosphorus would be about 0.6 mg/L. |

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Section 6

Nitrogen Removal



NITROGEN REMOVAL

1

Advanced Wastewater Class

WHERE DOES NITROGEN COME FROM?

- Most abundant compound in the atmosphere
 - N_2 : 79% of air volume
 - Key component of proteins and nucleic acids
- Major sources:
 - Plant, animal, human origin – decaying matter
 - Protein and nucleic acids – ammonia formation
 - Volatile organic nitrogen released during plant decay
 - Industrial and agricultural origin
 - Nitrous oxides and nitric acid
 - Fertilizers – urea, ammonium phosphate, ammonium sulfate, ammonium nitrate
 - Atmospheric origin

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NITROGEN IN WASTEWATER

- Most common forms:
 - Ammonia (NH_3)
 - Ammonium ion (NH_4^+)
 - Nitrogen gas (N_2)
 - Nitrite (NO_2^-)
 - Nitrate (NO_3^-)
 - Organic Nitrogen

} Inorganic forms

} Oxidized forms
- Municipal – NH_4^+ and organic nitrogen
 - Domestic wastewater TKN - ~60% NH_4^+ , ~40% organic
 - Organic N converted to NH_4^+ via ammonification

3

NITROGEN IN WASTEWATER

- Total Nitrogen (TN) = Ammonia + Organic + Nitrite + Nitrate
 - $TN = TKN + \text{Oxidized forms}$
- TKN in raw wastewater typically 25 – 45 mg/L

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WHY MUST NITROGEN BE REMOVED?

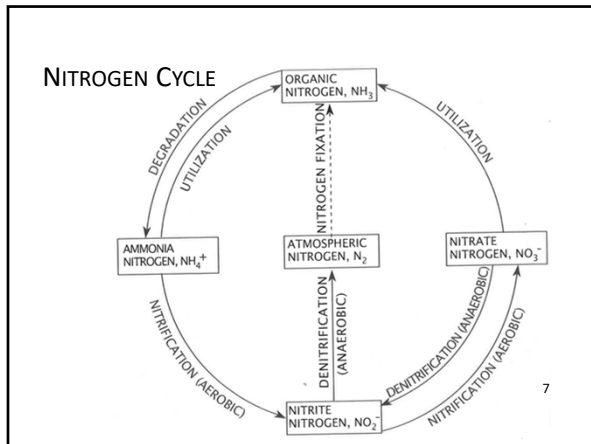
- Inorganic nitrogen provides a nutrient or food source for algae
 - Combination of nitrogen and phosphorus in receiving waters = rapid algal growth
- Dead and decaying algae = oxygen depletion problems
 - Fish kills
 - Taste and odor issues in drinking water
- By removing nitrogen, the receiving stream will have one less nutrient essential for algal growth

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NPDES PERMIT LIMITS

- EPA requires that wastewater plants remove nitrogen in effluent to eliminate nutrient from plant food chain
 - Sensitive waters
- Nitrogenous compounds must be controlled in plant effluent to prevent:
 - Ammonia toxicity – impact on fish
 - Reduction in chlorine disinfection efficiency
 - Increase in dissolved oxygen depletion in receiving waters
 - Adverse public health effects – nitrates in groundwater
 - Reduction in water's suitability for reuse

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NPDES PERMIT LIMITS

- o Most nitrogen limits expressed as Total Nitrogen (TN)
 - 3 tests: TKN, nitrite, nitrate
- o Nitrate+Nitrite (mostly industrial)
- o Nitrate limits (ex: explosives manufacturers)
- o Many facilities required to report, but no limits (yet)
- o Some plants monitoring, but no limits (yet)

- ### TYPES OF NITROGEN REMOVAL SYSTEMS
1. Nitrification
 2. Denitrification
 3. Modified Activated Sludge
 4. Overland Flow
 5. Ammonia Stripping
 6. Breakpoint Chlorination
 7. Ion Exchange

NITRIFICATION

BIOLOGICAL NUTRIENT REMOVAL - NITRIFICATION

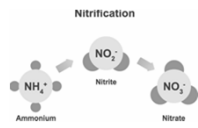
- o Nitrification = the conversion of ammonia to nitrate
- o Accomplished primarily by 2 types of microorganisms*:
 1. Nitrosomonas
 2. Nitrobacter
- o Autotrophic – use inorganic materials for energy and growth
 - Derive carbon for their cellular growth from inorganic sources (Ex: CO₂ and bicarbonate alkalinity (HCO₃⁻))

GENERA OF NITRIFYING BACTERIA

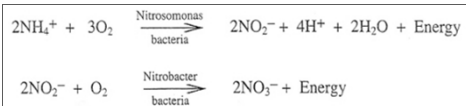
- o Ammonia Oxidizers
- o "AOB's"
 - Nitrosomonas
 - Nitrosococcus
 - Nitrospira
 - Nitrosorbio
- o Nitrite Oxidizers
- o "NOB's"
 - Nitrobacter
 - Nitrospira
 - Nitrococcus
 - Nitrospina

C - Ammonia oxidizers appear red and Nitrospira appear green

BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION



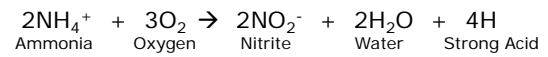
- First step: Conversion of Ammonia (NH₃) or Ammonium (NH₄⁺) to Nitrite (NO₂⁻) by *Nitrosomonas*
- Second step: Conversion of Nitrite to Nitrate (NO₃⁻) by *Nitrobacter*



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NITRIFICATION

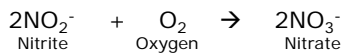
- Step 1 – Ammonia (NH₃) or ammonium (NH₄⁺) gets converted to nitrite (NO₂⁻) by the *Nitrosomonas* bacteria.



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NITRIFICATION

- Step 2 – The second step is conversion of nitrite to nitrate (NO₃⁻) by the *Nitrobacter* bacteria.



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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- Can be accomplished in either
 1. Suspended growth reactors – aeration basin
 - Basin must be large enough and MCRT long enough
 2. Attached growth reactors (fixed film)
 - Trickling Filters, RBCs, and Packed Bed or Packed Tower reactors
 - Media surface - contact time between the microbes and the wastewater
 - Supply of oxygen (natural draft or forced draft) and sufficient pretreatment to reduce BOD load
 - Recycling or recirculation of reactor effluent is important

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- Factors affecting biological nitrification:
 1. Dissolved Oxygen
 2. pH
 3. Wastewater temperature
 4. Nitrogenous food
 5. Detention time
 6. MCRT, F:M, or Sludge Age
 7. Toxic materials (Inhibition)

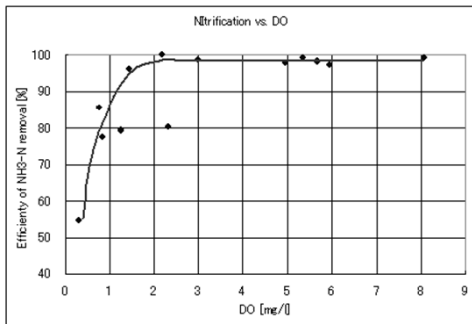
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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

1. Dissolved Oxygen
 - Nitrification exerts a substantial oxygen requirement
 - Each pound ammonium-nitrogen that is nitrified requires ~4.6 pounds of oxygen
 - Can increase required oxygenation by 30 – 40%
 - 1.0 – 4.0 mg/L
 - Never fall below 1.0 mg/L (Sacramento manual)
 - At least 0.5 mg/L, typically 2 – 3 mg/L (WEF, Activated Sludge OM-9)
 - *Add in modifications on p. 141

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EFFECT OF DISSOLVED OXYGEN ON THE RATE OF NITRIFICATION



BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- pH
 - There must be sufficient alkalinity in the wastewater to balance the acid produced by nitrification
 - 7.5 - 8.5 considered optimal
 - Rates rapidly depressed as pH is reduced below 7.0
 - ~ 7.2 pounds of alkalinity are destroyed per pound of ammonia-nitrogen oxidized
 - Caustic or lime addition may be required to supplement alkalinity
 - Maintain min. effluent alkalinity of at least 50 mg/L

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EFFECT OF PH ON THE RATE OF NITRIFICATION

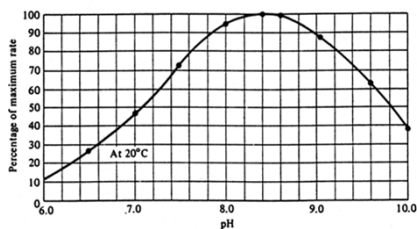


FIGURE 13-18 Rate of nitrification versus pH at constant temperature. [Source: H. E. Wild, Jr., C. N. Sawyer, and T. C. McMahon, "Factors Affecting Nitrification Kinetics," *J. Water Poll. Control Fed.* 43, no. 9 (1971): 1852.]

BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- Temperature
 - 60 - 90°F (15 - 35°C) considered optimal
 - Nitrification rate doubles for every 8 -10°C rise
 - Nitrification is inhibited at low temps
 - Up to 5x as much detention time may be needed to accomplish "complete nitrification" in the winter
 - Growth rate of nitrifiers increases as temp increases (and vice versa)
 - Operational controls: increasing MLVSS conc, MCRT, etc. to compensate

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EFFECT OF TEMPERATURE ON THE RATE OF NITRIFICATION

- Growth rate increases exponentially with temperature
 - Maximum at 30-35°C
 - Declines at 40°C
- Process variables that an operator does can adjust to compensate for slower winter growth rates in the nitrification process
 - Adjust pH to higher levels
 - Increase the MCRT
 - Increase the MLVSS

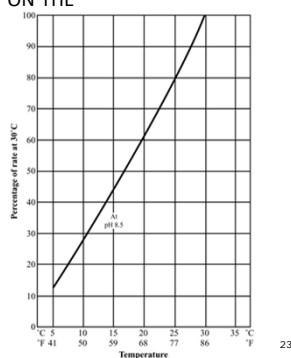
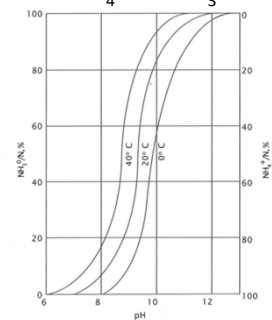


FIGURE 13-17 Rate of nitrification at all temperatures compared to the rate at 30°C. [Source: H. E. Wild, Jr., C. N. Sawyer, and T. C. McMahon, "Factors affecting Nitrification Kinetics," *J. Water Poll. Control Fed.* 43, no. 9 (1971): 1852.]

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EFFECTS OF PH AND TEMPERATURE ON EQUILIBRIUM BETWEEN NH₄⁺ AND NH₃



Source: Advanced Waste Treatment, 6th ed., p. 537

Fig. 6.11 Effect of pH and temperature on equilibrium between ammonium ion (NH₄⁺) and ammonia gas (NH₃)

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

4. Nitrogenous Food
- Population of nitrifiers will be limited by amount of nitrogenous food in influent
 - Organic N and Phosphorus-containing compounds
 - Trace elements
 - 100:5:1 (BOD:Nitrogen:Phosphorus)
 - Perform TKN and P in lab
 - Supplemental nutrient if necessary

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

5. Detention Time
- Time required for nitrification is directly proportional to the amount of nitrifiers in the system
 - Rate of oxidation of $\text{NH}_3\text{-N}$ is essentially linear or constant, so short circuiting must be prevented.
 - Flow should follow plug-flow model
 - Detention time of at least 4 hours, preferably 8 hours
 - Not all AS process mode modifications are appropriate for nitrification

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- Activated sludge process modes that are suitable for nitrification:
 - ✓ Plug Flow or Conventional
 - Long, narrow aeration tank provides adequate detention time
 - pH level may drop during DT since nitrification destroys alkalinity
 - ✓ Extended Aeration
 - Long aeration time and long sludge age
 - ✓ Step-Feed Aeration
 - Can accomplish partial nitrification
 - Addition of influent at various points along aeration basin means the contact time is not long enough for complete nitrification to occur

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

6. MCRT, F:M, or Sludge Age
- MCRT must be long enough to allow nitrifiers sufficient time to grow
 - Usually at least 4 days
 - Nitrification can only be maintained when rate of growth of nitrifying bacteria is rapid enough to replace organisms lost through sludge wasting
 - If they can't keep pace with carbonaceous bacteria, ability to nitrify decreases

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- When reviewing performance of your plant for the selection of optimum MCRT, F:M, or Sludge Age:
 - Oxygen requirements of carbonaceous bacteria should be considered along with nitrification requirements
 - If $\text{NH}_3\text{-N}$ permit limit is exceeded: MCRT or Sludge Age should be increased
 - Will increase MLSS and decrease F:M
 - Growth of cell mass from the oxidation of NH_3 is ~0.5 lb per lb of $\text{NH}_3\text{-N}$ oxidized
 - Thus, degree of nitrification will have little effect on the net sludge yield and WAS rates

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

7. Toxic Materials
- Halogen-substituted phenolic compounds, 0.0 mg/L
 - Halogenated solvents, 0.0 mg/L
 - Heavy metals, 10 – 20 mg/L
 - Pretreatment program is important
 - Lime primary treatment is very effective in removing heavy metals

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- o Alkalinity and pH
- Alkalinity changes in the nitrification process stream and the final effluent reliably indicate what is happening in the plant
 - Alkalinity tests are one of the best process control tests
- Hydrogen ions produced in some reactors may reduce buffering capacity
 - The measure of a solution to neutralize acids or bases (resistance to changes in pH)

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BIOLOGICAL NUTRIENT REMOVAL – NITRIFICATION

- o Alkalinity and pH
- o At a pH of 7, nitrification may be inhibited since little buffer capacity remains
- o If alkalinity drops so low that the low pH interferes with nitrification
 - Add lime, soda ash, etc
 - Overdosing with alkaline materials can also cause nitrification inhibition due to ammonia toxicity
 - o Shifts the NH_4^+ toward NH_3

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NITRIFICATION

o Troubleshooting Example:

- You ran tests on your effluent and you have the following results:
 - o Ammonia – 3 mg/L
 - o Nitrate – 4 mg/L
 - o Nitrite – 21 mg/L
- What do you think is happening here?

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+$$

Ammonia
Oxygen
Nitrite
Water
Strong Acid

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

Nitrite
Oxygen
Nitrate

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DENITRIFICATION

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BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION

- o Denitrification = process by which microorganisms reduce nitrate (NO_3^-) to nitrogen gas (N_2) that is released to the atmosphere
- o Denitrifiers are heterotrophic
 - Several species
- o When placed in anoxic environment containing a carbon food source, denitrifiers will reduce NO_3^- to N_2 by breaking down the nitrate to obtain the oxygen
 - Waste products: primarily N_2 , minor amounts of nitrous oxide (N_2O) or nitric oxide (NO)

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BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION

- o Step 1 – Nitrate (NO_3^-) is reduced to nitrite (NO_2^-)
- o Step 2 – Nitrite is reduced to nitric oxide (NO), nitrous oxide (N_2O) or nitrogen gas (N_2)

Denitrification

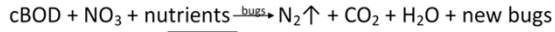
Created by J. Stock, University of Minnesota

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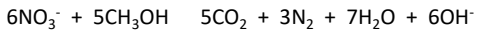
BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION

- Denitrifiers (heterotrophic) require organic carbon

Anoxic Denitrification (no free dissolved oxygen, but using Nitrate as an oxygen source)



- Using methanol as the carbon source, the overall energy reaction is:



- Methanol to nitrogen ratio 3:1

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BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION

- This nitrogen gas is then released to the atmosphere once it gets to an aerated tank



- This can also occur in primary or secondary clarifiers

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BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION

- Attached growth reactors
 - Fixed-film denitrification such as trickling filters or rotating biological contactors processes)
- Modified activated sludge process
 - Known as suspended growth denitrification

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BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION

- Affected by:
 - Nitrate
 - Carbon source
 - Dissolved oxygen concentrations

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NITRIFICATION VS DENITRIFICATION

- Nitrification
 - $\text{NH}_4 + \text{O}_2 \rightarrow \text{NO}_2 + \text{acid}$
 - $\text{NO}_2 + \text{O}_2 \rightarrow \text{NO}_3$
 - Uses 4.6 mg of O_2 and 7.1 mg of Alk
- Denitrification
 - $\text{NO}_3 + \text{cBOD} \rightarrow \text{N}_2 \uparrow$
 - Get back 2.9 mg of O_2 and 3.6 mg Alk

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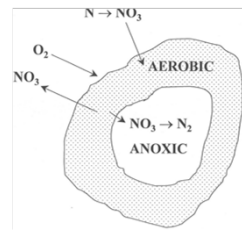
DENITRIFICATION METHODS

- Pre-anoxic zone with nitrate recycle from aeration tank
- On-Off aeration
- Low D.O. operation
 - D.O. of 0.1 - 0.4 mg/L
 - D.O. of 0.4 mg/L appears below that required by obligate aerobic low D.O. filaments
 - Typical D.O. for low D.O. filaments is 0.5 – 1.0 mg/L

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FACTORS EFFECTING SIMULTANEOUS NITRIFICATION/DENITRIFICATION (SNdN)

- o Organic carbon source with TCOD:TKN 7:1; 9:1 if P removal also.
- o Dissolved oxygen concentration: optimal N removal when rate of nitrification equals rate of denitrification at 0.5 mg/L
- o Floc size produces separate zones within the floc



- D.O. penetrates floc, theoretically to the center at 2.0 mg/L
- Less D.O. provides anaerobic center; anoxic if NO₃⁻ is available

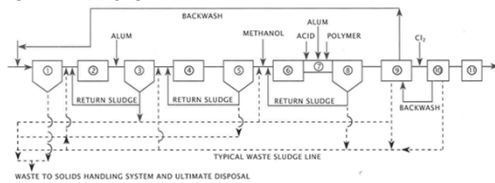
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BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION USING A SUSPENDED GROWTH REACTOR

- o Nitrified wastewater flows through a vessel without free oxygen but with a carbon food source
- o Microbes feed on organic carbon
- o Since no free oxygen available, they break down the NO₃⁻ to obtain oxygen portion of the ion
- o Nitrogen gas is released as byproduct

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NITRIFICATION-DENITRIFICATION USING SUSPENDED GROWTH REACTOR



| PRIMARY TREATMENT | HIGH RATE ACTIVATED SLUDGE | NITRIFYING ACTIVATED SLUDGE | DENITRIFYING ACTIVATED SLUDGE | POST TREATMENT |
|----------------------|---|---|---|--|
| ① SEDIMENTATION TANK | ① AERATION TANK ② SEDIMENTATION TANK | ① AERATION TANK ② SEDIMENTATION TANK | ① ANOXIC REACTORS* ② AERATED CHANNEL ③ SEDIMENTATION TANK | ① MIXED MEDIA FILTERS ② CHLORINE CONTACT ③ POST AERATION |

*ANOXIC: Oxygen deficient or lacking sufficient dissolved molecular oxygen.

Fig. 6-9 Nitrification-denitrification flow chart using modifications of the activated sludge process
Source: Advanced Waste Treatment, 5th ed., p. 533
From PROCESS DESIGN MANUAL FOR NITROGEN CONTROL, US Environmental Protection Agency

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BIOLOGICAL NUTRIENT REMOVAL PROCESSES

- o There are many processes that incorporate activated sludge
- o There are many classifications, but the simplest are
 1. Single Sludge Process – use only one biological sludge for the entire process
 - o Solids separation occurs only once
 - o RAS is returned to the entire process
 2. Multiple Sludge Process – may involve 2 or 3 separate sludges
 - o Isolate sludges for separate treatment tasks (ex: CBOD removal and nitrification)

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BIOLOGICAL NUTRIENT REMOVAL PROCESSES

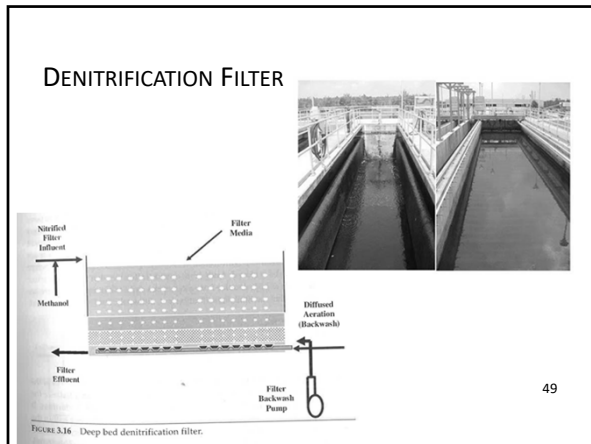
- o Biological Phosphorus Removal Processes:
 - Cycle the activated sludge through anaerobic zone and then aerobic zone
- o Biological Nitrification Systems:
 - Conversion between carbonaceous and nitrification treatment modes depends on the system used
 - Single-stage: both carbonaceous and nitrogenous uptake occur in the same tank
 - Two-stage: 2 complete activated sludge processes in series
 - o First stage has its own intermediate clarifiers and provides carbonaceous removal
 - o Second stage provides ammonia oxidation

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BIOLOGICAL NUTRIENT REMOVAL PROCESSES

- o Biological Denitrification – Denitrification Filter
 - Combo attached-growth and effluent filter
 - Supplemental carbon source added to nitrified effluent entering system
 - Heterotrophic bacteria (denitrifiers) in media produce N₂
 - Periodic backwash “bumps” N₂ – released to atmosphere

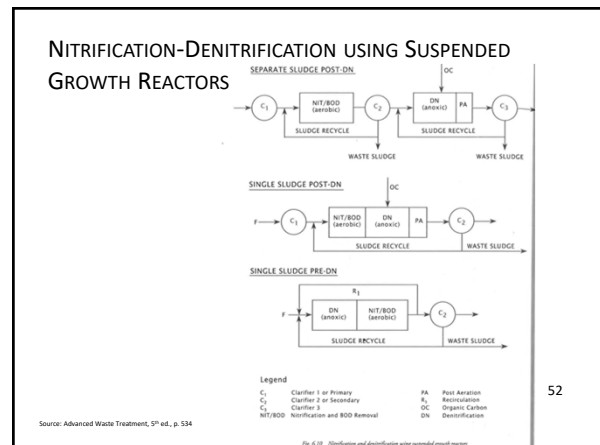
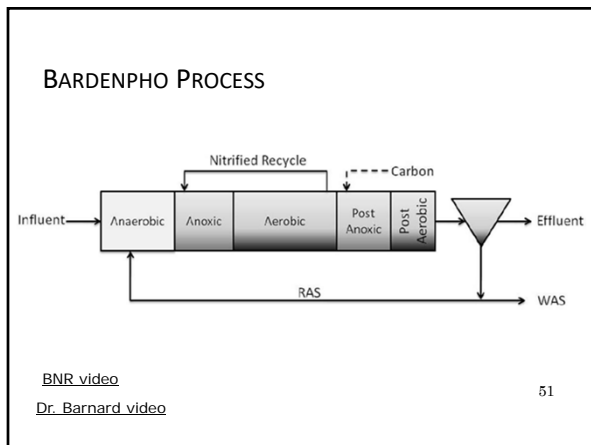
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BIOLOGICAL NUTRIENT REMOVAL – MODIFIED ACTIVATED SLUDGE SYSTEMS

- Capable of removing both N and P
- Include separate tanks (or zones within the tanks) with/without aeration to create a sequence of anaerobic → anoxic → aerobic zones
 - Ex: Bardenpho system

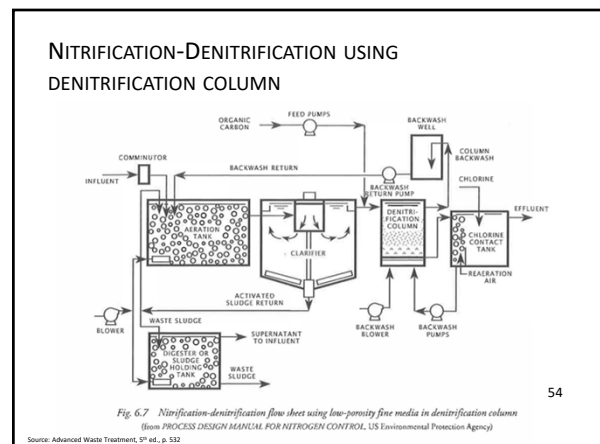
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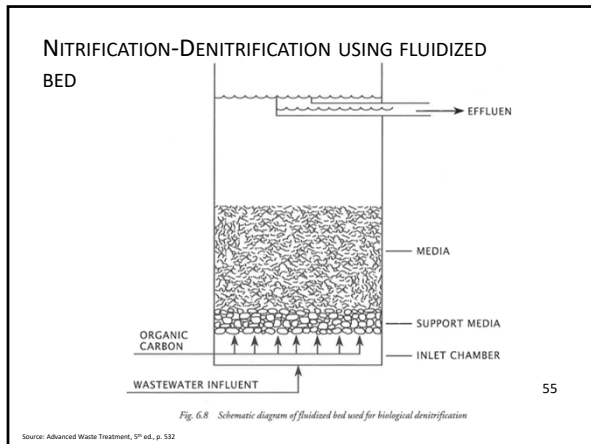


BIOLOGICAL NUTRIENT REMOVAL – DENITRIFICATION USING FIXED FILM REACTOR

- Biological Fluidized Bed Process
- Wastewater flows upward through a bed of fine sand at a velocity sufficient for the sand to float or “fluidize”
 - Allows for entire surface area of sand to be available for biological growth
- Organic carbon food source is added
 - Methanol (wood alcohol), methane gas, primary effluent, or other sources of high-carbon food
- Attached bacteria feed on organic carbon and break down NO_3^- ion to get oxygen, release N_2 as byproduct

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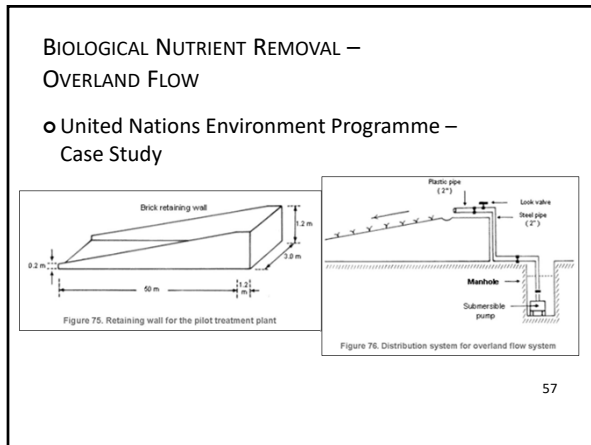


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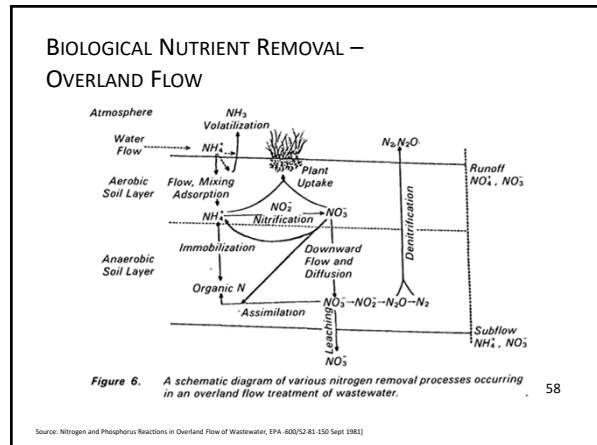
BIOLOGICAL NUTRIENT REMOVAL – OVERLAND FLOW

- Wastewater is applied to grass-covered slips by sprinklers or to the land surface through ports in pipes at evenly spaced intervals
- Water flows or trickles as a sheet through grasses and into a collection ditch
- Microorganisms in grass/soil surface reduce BOD and cause both nitrification and denitrification

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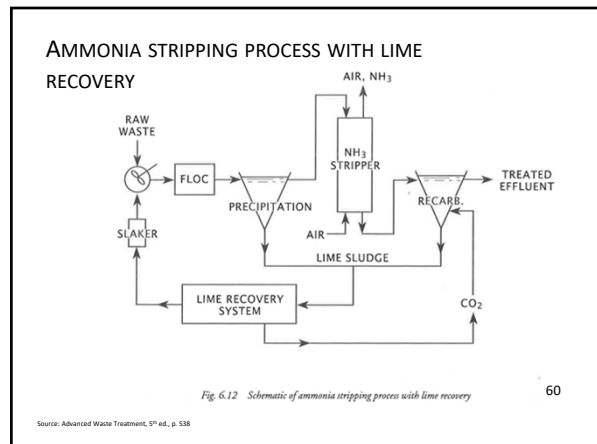


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PHYSICAL - AMMONIA STRIPPING

- Ammonia nitrogen in the gaseous ammonia form (NH_3) will naturally leave wastewater
- Ammonium (NH_4^+) is converted to gaseous form
 - Add chemicals to increase pH to 10.5 – 11.5
 - At pH 11, percentage of NH_3 is ~98%
- Ammonia stripping tower
 - High pH water falls over mixed media while a blower continuously forces fresh air into the mixture to strip off more ammonia

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CHEMICAL – BREAKPOINT CHLORINATION

- Breakpoint chlorination = the oxidation of NH₃-N into N₂ through the use of chlorine
- Requires relatively large amount of chlorine per unit of ammonia removed
 - Expense and danger makes it prohibitive for large quantities
 - Chlorine:NH₃-N ratio is 10:1
- Used primarily to remove small amounts of NH₃-N remaining after ww has been treated with other N removal processes

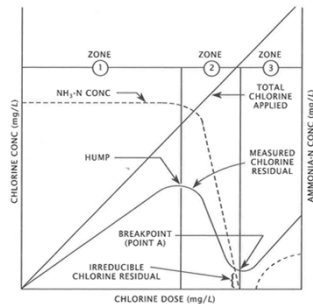
61

CHEMICAL – BREAKPOINT CHLORINATION

- When chlorine is added to water, it first reacts with the inorganic reducing materials (Ex: H₂S)
- When chlorine is added to waters containing ammonia, the ammonia reacts with hypochlorous acid (HOCl) to form:
 - Monochloramine
 - Dichloramine
 - Trichloramine
- Addition of further chlorine results in the destruction of chloramines and chlororganics
 - The oxidation of these compounds produces nitrous oxide (N₂O), nitrogen gas (N₂), and chlorine

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BREAKPOINT CHLORINATION REACTION CURVE



Source: Advanced Waste Treatment, 5th ed., p. 540

Fig. 6.13 Typical breakpoint chlorination reaction curve illustrating destruction of the ammonia molecule

(From PROCESS DESIGN MANUAL FOR NITROGEN CONTROL, US Environmental Protection Agency)

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CHEMICAL – ION EXCHANGE

- Passing ammonia-laden wastewater down through a series of columns packed with natural or synthetic ion exchange resins
 - Naturally occurring resin “clinoptilolite” commonly used
- When first column loses its ammonium ion adsorptive capacity, it is removed and washed with lime water
 - Converts the captured ammonium ions into ammonia gas
 - Released to atmosphere by mixing heated air in wastewater stream
 - Similar to ammonia stripping

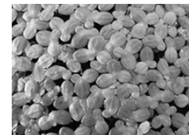
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SYSTEMS FOR NITROGEN REMOVAL

| System | Operation Considerations |
|--|--|
| Physical Treatment Methods | Expensive |
| • Sedimentation | |
| • Gas Stripping | |
| Chemical Treatment Methods | Expensive |
| • Breakpoint Chlorination | |
| • Ion Exchange | |
| Biological Treatment Methods | |
| • Activated Sludge Process | • Operational control. |
| • Trickling Filter Process | • Additional cost for oxygen to produce nitrification. |
| • Rotating Biological Contactor Process | |
| • Oxidation Pond Process | |
| • Land Treatment Process (Overland Flow) | • Land Requirements. |
| • Wetland Treatment Systems | • Suitable Temperatures. |
| | • Control of plants. |

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LEMNA DUCKWEED SYSTEM



- Use of aquatic duckweed plants for wastewater treatment
- Used effectively as a polishing pond after a conventional wastewater treatment pond
- The duckweed cover the polishing pond's surface, preventing sunlight to get to the algae and the algae die off
- Duckweed are capable of removing phosphorus and nitrogen from the water

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LAGOON EFFLUENT POLISHING WITH DUCKWEED

- Duckweed covers surface of polishing pond
- Prevents sunlight penetration, killing green algae

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QUIZ

1. List the harmful effects that could result from the discharge of nitrogenous compounds from wastewater plants.
2. Algal growth is caused mainly by what 2 nutrients in receiving waters?
3. List the steps of Nitrification.
4. List the steps of Denitrification.
5. What is the recommended use of breakpoint chlorination for removing nitrogen?

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OXIDATION REDUCTION POTENTIAL

- Allows evaluation of biological conditions with or without DO available
- Simple and cheap
 - Portable pH meter
 - ORP probe
 - Immerse probe in tank and read
- Responds to chemical ion concentrations

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ORP CONTROL (GORONZY, 1992)

| Process | Range, mV | e ⁻ Acceptor |
|-------------------|--------------|---|
| cBOD oxidation | +50 to +200 | O ₂ |
| Poly-P production | +40 to +250 | O ₂ |
| Nitrification | +150 to +350 | O ₂ |
| Denitrification | -50 to +50 | NO ₃ ⁻ |
| Poly-P breakdown | -40 to -175 | NO ₃ ⁻ , SO ₄ ⁼ |
| Sulfide formation | -50 to -250 | SO ₄ ⁼ |
| Acid formation | -40 to -200 | Organics |
| Methane formation | -200 to -350 | Organics |

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| ORP (mV) | Process | Electron acceptors | Conditions |
|----------|---------|------------------------------|----------------------|
| +300 | 1, 2, 3 | O ₂ | Oxic or aerobic |
| +200 | | | |
| +100 | | NO ₃ ⁻ | Anoxic or anaerobic |
| 0 | 4 | | |
| -100 | 5, 6, 7 | SO ₄ ⁼ | Fermentive anaerobic |
| -200 | | | |
| -300 | 8 | Carbonaceous organics | Fermentive anaerobic |
| -400 | | | |

1. Organic carbon oxidation 2. Polyphosphate development
 3. Nitrification 4. Denitrification
 5. Polyphosphate breakdown 6. Sulfide formation
 7. Acid formation 8. Methane formation

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ANY QUESTIONS?

NITROGEN GAS

Fly little ones!
You're free!

Denitrifying bacteria

72

Nitrogen Removal – Review Questions

1. Nitrification is the process by which bacteria reduce nitrate to gaseous nitrogen forms, primarily nitrogen gas and nitrous oxide.
 - a. True
 - b. False
2. All of the following are major sources of nitrogen **except**:
 - a. Decaying matter (plant, animal, or human origin)
 - b. Fertilizers
 - c. Drinking water chemical additions
 - d. Atmospheric origin
3. Which of the following are oxidized forms of nitrogen?
 - a. Ammonia
 - b. Nitrite
 - c. Nitrate
 - d. Organic nitrogen
 - e. Both b. and c.
4. The best water quality indicator to monitor an enhanced nitrogen oxidation process is:
 - a. pH
 - b. ORP
 - c. Alkalinity
 - d. Temperature
5. Nitrifiers such as *Nitrosomonas* and *Nitrobacter* are:
 - a. Autotrophic
 - b. Heterotrophic
 - c. Photosynthetic
 - d. Synthetic
6. Denitrification is the process by which microorganisms reduce nitrate to nitrogen gas that is then released to the atmosphere.
 - a. True
 - b. False
7. What is the primary factor in the speed of denitrification?
 - a. Dissolved Oxygen
 - b. BOD
 - c. Suspended Solids
 - d. Temperature
8. pH levels may increase during nitrification because nitrification destroys alkalinity.
 - a. True
 - b. False
9. Which of the following is **not** a limiting factor in the biological nitrification process?
 - a. Dissolved oxygen
 - b. Nitrifying bacteria
 - c. Temperature

- d. Alkalinity
 - e. Phosphorus
10. Nitrifying bacteria in the process of nitrifying ammonia consume _____ lbs of oxygen per pound of ammonia nitrogen oxidized.
- a. 1.0
 - b. 2.2
 - c. 4.6
 - d. 7.1
11. What is the best (most efficient) way to remove nitrate from your system?
- a. Nitrification
 - b. Carbonaceous BOD removal
 - c. Denitrification
 - d. Luxury uptake
12. To compensate for slower winter growth rates, operators have to adjust process variables to ensure the nitrification process continues. Which of the following process adjustments would **not** be needed to improve nitrification rates?
- a. Reduce DO levels
 - b. Raise the pH
 - c. Increase the MCRT
 - d. Increase the MLVSS
13. Nitrification results in the destruction of _____ mg alkalinity for every 1 mg ammonia nitrogen oxidized.
- a. 10.0
 - b. 7.1
 - c. 5.2
 - d. 4.6
14. When operating an attached growth nitrification process, the ratio of BOD:N:P is:
- a. 100:10:1
 - b. 100:5:2
 - c. 200:5:2
 - d. 100:5:1
15. The denitrification process will replace about 3.6 mg/L of the alkalinity that was lost during nitrification.
- a. True
 - b. False
16. Which of the following are ways that ammonia nitrogen can be removed from wastewater?
- a. Ammonia stripping
 - b. Biological nitrification
 - c. Breakpoint chlorination
 - d. Ion exchange
 - e. All of the above
17. The recommended dissolved oxygen level for nitrification in a suspended growth reactor is 2.0 to 4.0 mg/L.
- a. True
 - b. False

18. An anoxic reactor is lacking in free dissolved molecular oxygen, but may contain chemically bound oxygen.
- True
 - False
19. For nitrogen to be completely removed using biological processes, the system must consist of both nitrification and denitrification.
- True
 - False
20. If an operator notices that there are elevated levels of nitrite in the secondary effluent, but the ammonia levels are still within the normal range, which of the following could be a possible explanation?
- Denitrification is inhibited
 - Partial nitrification is occurring
 - Nitrobacter* are inhibited
 - Both b. and c.
21. Nitrification is inhibited at low/cold wastewater temperatures.
- True
 - False
22. Some of the harmful effects of discharging treatment plant effluent containing nitrogen include all of the following **except**:
- Ammonia toxicity to fish in receiving waters
 - Increased dissolved oxygen depletion in receiving waters
 - Potential health hazards to newborn infants living in a home with well water
 - Reduction in nutrients available to algae
 - Reduction of chlorine disinfection efficiency
23. Which of the following activated sludge process modes is best suited for nitrification in a suspended growth reactor?
- Complete mix
 - Contact stabilization
 - Conventional or plug flow
 - Modified aeration
 - Step-feed aeration
24. Which of the following could **not** be used as a carbon food source in an attached growth (fixed film) reactor?
- Methane gas
 - Methanol
 - Primary effluent
 - Secondary effluent
25. Which of the following **must** be present in order to create an anoxic zone within a reactor?
- Ability to completely drain basin for inspection and maintenance
 - Provisions for the buildup of an adequate sludge blanket
 - Sufficient mixing of contents to maintain the microbial solids in suspension without transferring oxygen to the biomass
 - Recycling facilities to automatically control the MCRT
26. Lime primary treatment is very effective in removing heavy metals that are toxic to the nitrifying bacteria.
- True
 - False

27. At a pH of 11, about 98% of ammonia is in the gaseous form (NH_3).
- True
 - False
28. Breakpoint chlorination uses only a small amount of chlorine per unit of ammonia removed, therefore it is recommended for large systems that need to remove high levels of ammonia.
- True
 - False
29. Total Kjeldahl Nitrogen (TKN) is a measure of what form(s) of nitrogen?
- Oxidized forms
 - Total nitrogen
 - Ammonia nitrogen
 - Organic nitrogen
 - Both c. and d.
30. Nitrification is an aerobic process.
- True
 - False

Answers:

- B
- C
- E
- C
- A
- A
- A
- B
- E
- C
- C
- A
- B
- D
- A
- E
- A
- A
- A
- D
- A
- D
- C
- D
- C
- A
- A
- B
- E
- A

OPERATOR ESSENTIALS

What every operator should know about nitrification

Woodie Mark Muirhead

| Knowledge | Principle | A practical consideration |
|--------------------|---|--|
| Definition | <p>Nitrification is the oxidation of ammonia to nitrate by two separate groups of organisms.</p> <p>Ammonia-oxidizing bacteria (AOB) oxidize ammonia to nitrite.</p> $\text{NH}_4^+ + 1.5 \text{O}_2 \rightarrow 2\text{H}^+ + \text{H}_2\text{O} + \text{NO}_2^-$ <p>Nitrite-oxidizing bacteria (NOB) oxidize nitrite to nitrate.</p> $\text{NO}_2^- + 0.5 \text{O}_2 \rightarrow \text{NO}_3^-$ | <p>Nitrosomonas and Nitrobacter historically have been associated (including certification exams) with the oxidation of ammonia to nitrite and the oxidation of nitrite to nitrate, respectively. Now, it is known that more genera of nitrifying organisms are involved and the terms used are ammonia-oxidizing bacteria and nitrite-oxidizing bacteria.</p> |
| Environmental need | <p>Ammonia can be toxic and also create oxygen deficiency in receiving waters.</p> <p>Nitrite and nitrate in drinking water can affect health.</p> <p>All forms of inorganic nitrogen can serve as nutrients for undesirable biological growth, such as algal blooms.</p> | <p>It is important to understand the basis for effluent ammonia (and other nitrogen) limits, because other parameters in effluent and receiving water (e.g., pH for ammonia toxicity) can be critical for compliance.</p> |
| Respiration | <p>Nitrifying organisms are obligate aerobes that require oxygen for metabolism. Approximately 4.6 mg/L of oxygen is required to oxidize 1.0 mg/L of ammonia-nitrogen to nitrate-nitrogen.</p> | <p>The oxygen demand of 22 mg/L ammonia-nitrogen is equal to approximately 100 mg/L of carbonaceous biochemical oxygen demand (cBOD).</p> <p>Nitrification requires significant energy commitments associated with aeration (e.g., blowers) for suspended growth systems.</p> |
| Energy source | <p>Nitrifying organisms are autotrophic. They use inorganic compounds as an energy source. AOB use ammonia (NH₄⁺), and NOB use nitrite (NO₂⁻).</p> | <p>Nitrifying organisms do not need or use organic carbon — cBOD substances — for metabolism.</p> <p>Post-secondary nitrification processes (which follow cBOD removal) can be used to accomplish nitrification.</p> |
| Alkalinity | <p>The oxidation of 1 mg/L ammonia-nitrogen to nitrite-nitrogen consumes 7.12 mg/L of alkalinity.</p> <p>The alkalinity is consumed during nitrification almost exclusively by the AOB.</p> | <p>If wastewater alkalinity is not sufficient to support full nitrification and other alkalinity-consuming processes, pH depression can occur and result in a permit violation and even inhibition of NOB, which results in an accumulation of nitrite.</p> |

| | | |
|--|---|--|
| <p>Growth rate</p> | <p>Nitrifying organisms are slow-growing, and their growth rate increases and decreases with wastewater temperature.</p> | <p>The solids retention time (SRT) needed for nitrification is higher than needed for cBOD removal and is critical to ensure that a sufficient population of nitrifying organisms can be established.</p> <p>Though environmental conditions influence the required SRT, an approximate SRT of 7 days is needed at 15°C. An SRT of 2 days is needed at 26°C.</p> |
| <p>Suspended and fixed-film systems</p> | <p>Nitrifying organisms are not floc formers. They consequently depend on being “trapped” in heterotrophic floc to prevent being washed out of suspended growth systems. However, they are able to attach to fixed media effectively.</p> | <p>Experience has shown that nitrifying organisms can attach and grow in effluent sample lines. Then the organisms slough off and seed the effluent samples. This contamination can accelerate nitrification in the biochemical oxygen demand (BOD) test and result in higher than normal BOD results. Routine sample line cleaning or replacement can prevent this.</p> |
| <p>Inhibition</p> | <p>Nitrifying organisms are more sensitive to changes in environmental conditions (e.g., temperature, pH, dissolved oxygen) than heterotrophic organisms.</p> <p>NOB are more sensitive to these conditions than AOB.</p> <p>NOB grow faster than AOB under environmental conditions typically found in domestic wastewater and oxidize nitrite as soon as it is produced by AOB.</p> | <p>When NOB are inhibited, increased concentrations of nitrite can occur in secondary effluent.</p> <p>Nitrite–nitrogen reacts with chlorine in a 5:1 ratio. So, elevated nitrite can suddenly increase chlorine demand to a level that hinders proper disinfection.</p> |

Woodie Mark Muirhead is a vice president and operations specialist in the Honolulu office of Brown and Caldwell (Walnut Creek, Calif.).

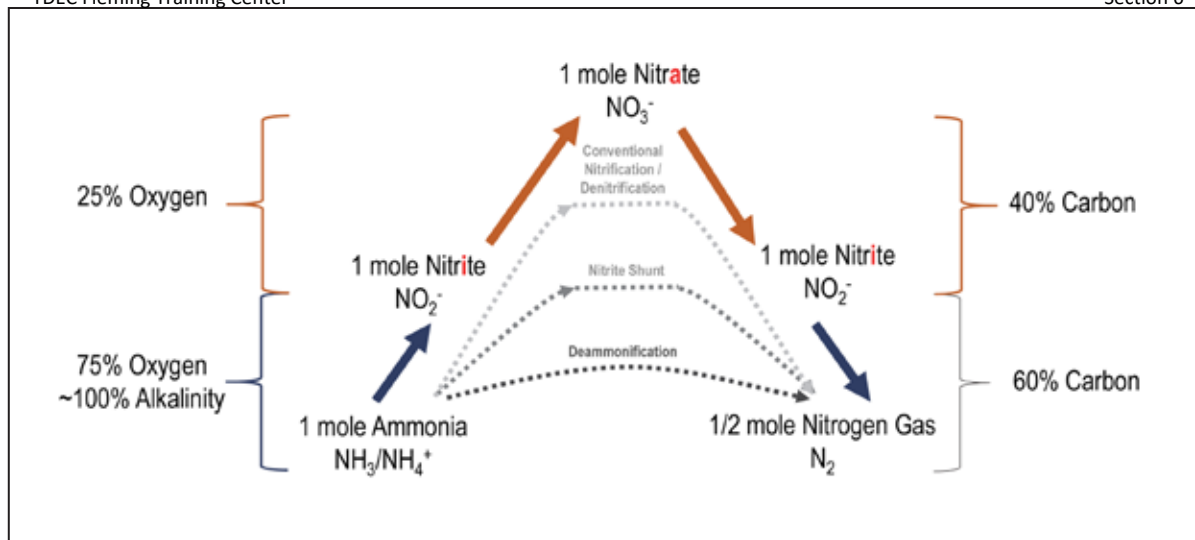
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What every operator needs to know about shortcut nitrogen removal

Adam Rogensues



| Knowledge | Principal | Practical considerations |
|------------------|--|---|
| Processes | <p>Nitrification</p> <p>Denitrification</p> <p>Nitritation is the conversion of ammonia only to nitrite.</p> <p>Denitrification is the conversion of nitrite to nitrogen gas.</p> | <p>This is the biological oxidation of ammonia (NH_4) to nitrite (NO_2) and nitrate (NO_3).</p> <p>This is the reduction of NO_3 or NO_2 to nitrogen gas.</p> <p>This is the oxidation of ammonia to nitrite. This process reduces operating costs by reducing oxygen consumption by about 25% by stopping the nitrification process at nitrite.</p> <p>This process is the reduction of nitrite to nitrogen gas. This process reduces operating costs by reducing the supplemental carbon requirement by 40%.</p> |
| Dissolved oxygen | <p>Conventional biological nitrification is oxygen-intensive.</p> <p>Conversely, low dissolved oxygen conditions are necessary to successfully denitrify.</p> | <p>Biological oxidation of ammonia (nitrification) stoichiometrically requires 4.57 lb of oxygen per lb of $\text{NH}_4\text{-N}$ oxidized. Nitritation (see below) constitutes 75% of the overall oxygen demand required to convert ammonia to nitrate.</p> <p>Comparatively, biological oxidation of biochemical oxygen demand (BOD) requires 1.0 to 1.5 lb of oxygen per lb of BOD. Generally, dissolved oxygen concentrations equal to or greater than or equal to 1.5 mg/L are necessary for complete nitrification.</p> <p>The general rule is to maintain a dissolved oxygen concentration less than 0.3 mg/L to achieve denitrification.</p> |
| Alkalinity | <p>Alkalinity, usually measured as calcium carbonate (CaCO_3) concentration, is the measure of the capacity of water to neutralize acids. Conventional biological nitrification requires a great deal of alkalinity.</p> <p>Denitrification produces alkalinity.</p> | <p>Biological oxidation of ammonia (nitrification) stoichiometrically requires 7.14 lb of CaCO_3 per lb of nitrogen oxidized.</p> <p>In a conventional denitrifying activated sludge process, alkalinity produced as a part of the denitrification process is considered "recovered" from the alkalinity spent in the nitrification process (see above). Alkalinity is produced at a rate of 3.57 lb as CaCO_3 per lb of nitrate-nitrogen denitrified.</p> |

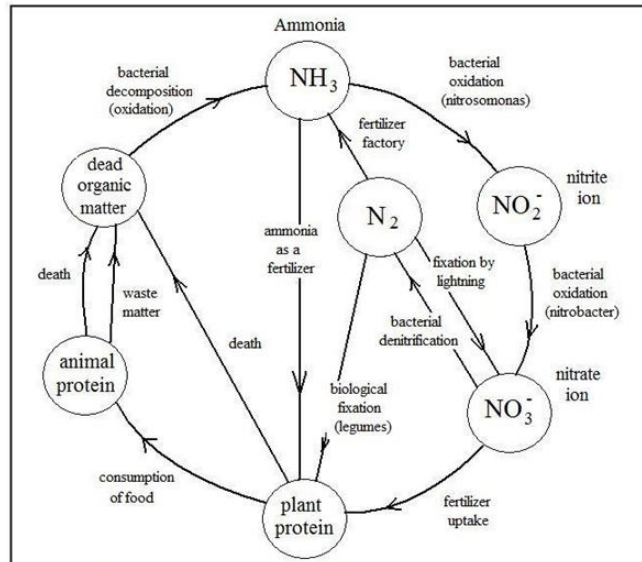


| Knowledge | Principal | Practical considerations |
|--|--|--|
| Carbon | Denitrifying bacteria require an adequate supply of carbon as they break down nitrate or nitrite to nitrogen gas. | Methanol or glycerin are used commonly as a supplemental carbon source for biological denitrification. |
| Advancements | The nitrite shunt or shortcut nitrogen removal can skip some of the steps in the traditional nitrification/denitrification processes described above. See figure above. | The nitrite shunt shortcut skips two steps: conversion of nitrite to nitrate and the conversion of nitrate back to nitrite. (See figure above.) This shortcut saves 25% in oxygen demand, 40% in carbon demand, and 40% in biomass production. Deammonification skips four steps; anaerobic ammonia oxidizing bacteria convert ammonia directly to nitrogen gas. This process saves 63% in oxygen demand, 100% in carbon cost, and 80% in biomass production. |
| Aerobic ammonia oxidizing bacteria (AerAOB) | AerAOB are autotrophic bacteria – that is, bacteria that take in inorganic chemicals (e.g., CO ₂) in the synthesis of organic compounds – capable of oxidizing ammonia to nitrite for energy production. | Autotrophic organisms take inorganic substances into their bodies and transform them into organic nourishment. This is the first step in traditional two-step nitrification. |
| Anaerobic ammonia oxidizing bacteria (AnAOB) | AnAOB are autotrophic bacteria capable of oxidizing ammonia for energy production. | These bacteria often are called <i>anammox</i> bacteria, though the term AnAOB is preferred. |
| Nitrite-oxidizing bacteria (NOB) | NOBs are autotrophic bacteria capable of oxidizing nitrite to nitrate for energy production. | This is the second step in traditional two-step nitrification. |
| Process fundamentals of nitrite shunt | Nitrite shunt requires conditions to enable AerAOB to thrive and out-select NOB. | Process operation at short sludge retention times (SRT) along with control of the DO setpoint are commonly used selection mechanisms. |
| Process fundamentals of deammonification | Deammonification is not yet widely accepted for mainstream treatment process. However, the process has been implemented successfully and controlled for sidestream treatment, such as ammonia-laden sidestreams from anaerobically digested solids. Deammonification requires AnAOB to be favored in the system and out-select NOB. | There are three important fundamental process objectives associated with all available sidestream deammonification technologies: <ul style="list-style-type: none"> ■ Reactor design and operation must selectively retain and concentrate the slow-growing AnAOB. ■ The reactor design and operation must provide a partitioned aerobic/anaerobic environment. ■ The AnAOB process is designed to out-select NOB and includes provisions to counter NOB growth, if it were to occur. |

Adam Rogensues is an engineer and O&M specialist in the Centennial, Colo., office of Burns & McDonnell (Kansas City, Mo.).

Section 7

Nutrient Removal



Wastewater Nutrient Removal

Prepared by: Brett Ward
The University of Tennessee
Municipal Technical Advisory Service

1

Class Agenda

- What's New
 - Tennessee Nutrient Reduction Framework
 - Grant Weaver: Projects, training, case studies
- Nitrogen Removal
- Phosphorus Removal

2

Tennessee Nutrient Reduction Framework

Introduction

Nutrients are naturally occurring and essential components of healthy aquatic systems. However, excessive amounts of nutrients can impact water quality. We have over 3000 miles of streams and over 15,000 acres of lake in Tennessee that are impaired due to nutrients. Tennessee has developed the Tennessee Nutrient Reduction Framework as part of our efforts to accomplish long-term nutrient reduction in our water resources. The documents below outline Tennessee's framework as well as implementation.

Framework

- Tennessee's Nutrient Reduction Framework (rev. 03/02/15)

For more information please contact Dr. Sherry Wang at Sherry.Wang@tn.gov or 615-532-0656.

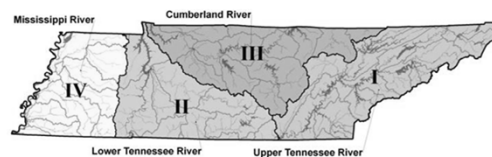
Implementation

- Wastewater Treatment Plant Optimization
 - Nitrogen & Phosphorus Removal at the Cookeville, Crossville & Livingston Wastewater Treatment Plants" (8/24/15)

For more information please contact Karina Bynum at Karina.Bynum@tn.gov or 931-432-7634.

3

Tennessee Nutrient Reduction Framework



4

Tennessee Nutrient Reduction Framework

- Nutrient enrichment and eutrophication
 - EPA states 5.5% of the TN and 5.3% of TP in the Gulf of Mexico is from Tennessee
- But, streams need nutrient to be healthy
- Tenn, is trying to avoid the “blanket” limits some states have attempted
- \$ where their mouth is with Grant Weaver

5

Tennessee Nutrient Reduction Framework

- Prioritize Watersheds
- Set watershed nutrient reduction goals
- Ensure effective point source permits
- Dev. Effective Agricultural BMP's
- Encourage reductions from non-MS4s
- Watershed monitoring
- Document and report activities

6

TDEC as Assistance Provider

- Nutrient Assistance- Grant Weaver Project
 - Training: Webinars, regional, on-site
 - Target Plants
 - 5 in 2015
 - 10 in 2016
 - Call Karina Bynum
- G.Weaver training-“Its all about Operators”

7

Empowered, Effective Operators



- Plant Operations
 - BOD removal
 - Nutrient removal
 - Solids handling
- Regulations
- Explain these to EO's
- Communicate with Regulators and Engineers

8

Success of New Equipment/Plant

- Many focus entirely on the tools and not on the people or processes.
- New equipment must work!
 - Function as designed.
 - Produce the intended results!
- Don't pay for it if it does not work.
 - May need better training, integration, or application....

9

Nutrient Removal

- More Complex: Advanced Treatment, Tertiary Treatment
 - Chemical/Physical Treatment
 - Biological Treatment
 - Traditional Treatment-Oxidation Process
 - Nitrogen Removal-Oxidation then Reduction
 - Phosphorus- Reduction then Oxidation
- Complex and often a delicate processes

10

Lots of Chemistry/Biochemistry

Periodic Table of Elements

- Organic compounds
- Alkalinity
- Oxidation
- Reduction
- Chemical equations

11

Organic Matter

- Materials/molecules made up of Carbon, Hydrogen and Oxygen:
 - CHO, C₆H₁₂O₆- glucose- simple sugar
 - Add nitrogen & sulfur and we have proteins
 - Other molecules have phosphorus
 - Biomass~ C₅H₇O₂NP_{0.083}
- Materials of animal and vegetable origin.
- Plant bacteria are small chemical factories

12

Inorganic Matter

- Do not contain C, H, O, like organic matter does.
- Minerals, metals, gases
- Ammonia is inorganic, NH_3 , a gas at pH 10
- Ammonium, NH_4^+ , liquid at pH <6.0
- Carbon Dioxide, CO_2 - inorganic gas form of carbon that will dissolve in water.
- Alkalinity- CO_2 , HCO_3 , CO_3

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Alkalinity

- Titration test reported as Calcium Carbonate (CaCO_3) or dip strips (not regulatory approved)
- Forms:
 - CO_2 -Carbon dioxide
 - HCO_3^{1-} -Bicarbonate
 - CO_3^{2-} - Carbonate
 - OH^- ~ Hydroxide
- They change with pH (low CO_2 - high CO_3)
- Alkalinity is important part of nutrient removal

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Oxidation / Reduction

- Oxidation- add oxygen, releases energy
 - We oxidize BOD, NH_3 to treat sewage, removing the high energy oxygen demanding pollutants.
- Reduction- removes oxygen from NO_2 and NO_3 , reactions that occur when DO is at or near zero.
- PAO's must have both conditions

15

Bacterial Habitat



Three Different Habitats

- Make the treatment bacteria do what we want them to by manipulating and controlling their habitat or environment.
- Operators must control the bacteria!

16

Current Situation

- Many plants nitrify
- Some denitrify
- Most are monitoring effluent nutrient levels
- What are you doing?



17

Nutrient Removal Outline

- Nitrogen then Phosphorus
 - What are nutrients?
 - Why remove nutrient?
 - Who must remove nutrients?
 - How do you remove nutrients?




18

What are Nutrients? Think Fertilizer

- Nutrients
 - Nitrogen and Phosphorus
 - Two main fertilizer elements needed for growing green plants.
 - They contribute to aquatic plant growth,
 - Excess plant growth clogs streams and,
 - When they die add a BOD and nutrient load back onto the stream

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Fertilizer Labels



- 20-5-10
- 20% nitrogen
- 5% phosphoric acid P₂O₅
- 10% Potash K₂O
- N&P are of concern

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Why Nutrient Removal in TN

- Regulations- Permit Required
 - To meet Tennessee Water Quality Standards
 - Ammonia Toxicity
 - Impaired Streams, 303d listed for nutrient enrichment
 - EPA’s demand that TN reduce nutrient loading to the Gulf of Mexico
 - TN Strategy~ Optimization of existing plants

21

Other Reasons Why!

- Improve water Quality
- Improve plant performance
- Save money
- Recycle nutrients to land



22

Who Must Remove Nutrients?

- Permit Limits
 - Ammonia Toxicity~ small streams
 - Impaired Stream, 303d listed for nutrient enrichment
 - Expanded volume on small stream
- Nutrient Monitoring, does not mean that you will soon have limits!

23

How do you remove nutrients?

- Nitrogen
 - Biologically- nitrification followed by denitrification
 - Chemically- ammonia stripping, breakpoint Cl₂
- Phosphorus
 - Biologically-to ~ 1.0 mg/L
 - Chemically-with or without biological removal

24

Quiz

- What are the two nutrients we're most concerned with removing?
- Why?

25

Forms of Nitrogen in the Environment

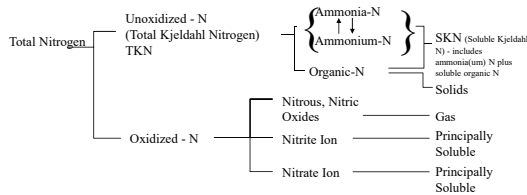
Unoxidized Forms of Nitrogen

- Nitrogen Gas (N₂)
Air is 78 % N₂
- Ammonia (NH₄⁺, NH₃)
• pH 9.0 50%/50%
- Organic Nitrogen (urea, amino acids, peptides, proteins, etc...)

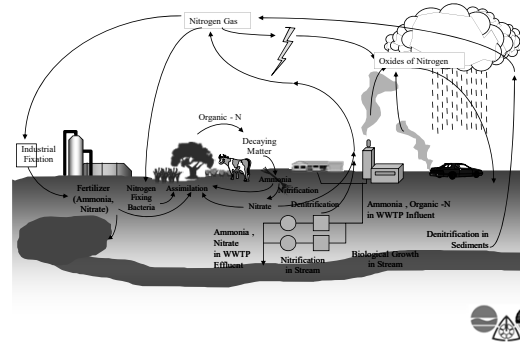
Oxidized Forms of Nitrogen

- Nitrite (NO₂⁻)
- Nitrate (NO₃⁻)
- Nitrous Oxide (N₂O)
NOS, O₂ fin 21% to 33% anesthetic
- Nitric Oxide (NO)
Impt. in cell communication, precursor of NO₂
- Nitrogen Dioxide (NO₂)
•Brown toxic gas & pollutant

Forms of Nitrogen



The Nitrogen Cycle



Soluble vs Particulate



- Soluble is dissolved in the water
- Particulate is part of the solids.
- Soluble goes through the filter.
 - BOD-SBOD
 - Kjeldahl Nitrogen SKN
 - Organic Nitrogen SON
 - Ortho-Phosphorus

29

Processes to Meet Limits

- | Limits | Process | Products |
|------------------------|-----------------|-----------------|
| - Ammonia | Nitrification | Nitrite/Nitrate |
| - Total Nitrogen | | |
| • Organic Rem. | Ammonification | Ammonia |
| • Ammonia Rem. | Nitrification | Nitrite/Nitrate |
| • Nitrite/Nitrate Rem. | Denitrification | Nitrogen Gas |
- Keep effluent BOD and TSS low!

30


Typical Concentrations of Nitrogen in Influent & Effluent

| | Raw Municipal Influent | Primary Effluent | Secondary Effluent (No Nitrification) | Secondary Effluent (Nitrified) |
|---------------------------------|------------------------|------------------|---------------------------------------|--------------------------------|
| NH ₄ ⁺ -N | 15 | 16 | 12 | 1.0 |
| TKN | 30 | 25 | 15 | 2.2 |
| NO ₂ ⁻ -N | 0 | 0 | 0 | 0.1 |
| NO ₃ ⁻ -N | 0 | 0 | 0 | 17 |

Typical Nitrogen Concentrations in Municipal & Industrial Wastewaters

| | Municipal Wastewater | | | Industrial Wastewater | | |
|---|----------------------|---------|---------|--------------------------|-----------------------|-------------------|
| | High I/I | Low I/I | Septage | Vegetable Based Industry | Animal Based Industry | Landfill Leachate |
| NH ₄ ⁺ -N | 10 | 25 | 150 | <5 | 10-1000 | 150-1000 |
| TKN | 15 | 45 | 300 | <5 | 100-1000 | 500-1000 |
| NO ₂ ⁻ -N/ NO ₃ ⁻ -N | 0 | 0 | 0 | 0 | 0 - 500 | 0 |
| BOD ₅ | 80 | 200 | 1000 | 1000 | — | 500-2000 |
| COD | 160 | 450 | 2000 | 2500 | — | 1500-5000 |

Other Ammonia Sources




- Anaerobic Digester – 500-1000 mg/L
- Aerobic Digester that is anaerobic, 200mg/L
- Interstate Rest Area – 100mg/L
- RV & Porta Pottie – 100-3000 mg/L
- Schools, Factories
- Ammonia Refrigeration
- STEP or Grinder CS

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1st, Organic Nitrogen Removal,

BOD Bugs Convert Organic Nitrogen (amino acids, proteins in BOD & TSS)(ammonification) to NH₃

BOD + BOD_{Bugs} + O₂ = More BOD_{Bugs} + CO₂ + H₂O + NH₃



34


Elevated Effluent Soluble BOD Elevated Soluble Organic Nitrogen

- Need Oxidative Pressure
 - More time in the aerobic basin
 - More Biomass
 - Complete Mix Mode
 - If low, more DO
- More time for bugs to stabilize the BOD, or less food for each bug.

35

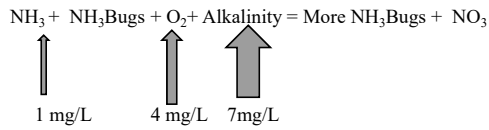
2nd, Ammonia(NH₃) Removal

- Nitrification- Biological oxidation of NH₃ to NO₂ then NO₃
- Removal Factors
 - Dissolved Oxygen
 - Microorganisms
 - Alkalinity
 - Temperature
 - No Toxics



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Ammonia Removal Chemistry



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Dissolved Oxygen

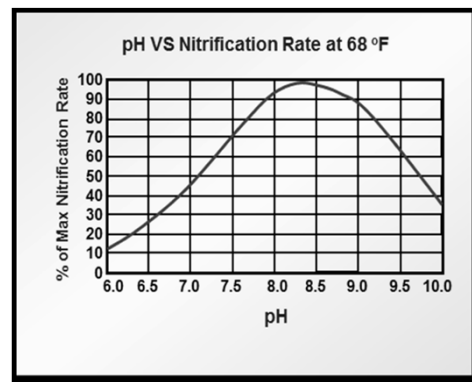
- For each mg/L NH_3 four times as much oxygen is needed as for BOD removal
 - Books say D.O. > 2.0 mg/L is needed,
 - The most common reason for poor nitrification is low D.O.
 - But, plants will fully nitrify at lower D.O. levels, even as low as 0.5 mg/L
 - If $\text{DO} < 1.5$ additional DO may be helpful
 - Hydraulic Detention Time affects

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Alkalinity

- If Alkalinity is low, pH may soon follow
- Check influent and effluent alkalinity
 - If effluent Alk. < 50mg/L, add alkalinity
 - Influent Alk. < $(\text{Influent NH}_4 * 7.14) + 50$, add alkalinity
 - If there is a pH drop across the aerator or digester, add alkalinity.
 - Optimum pH is 8.3 s.u.

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Increase Influent pH

- Add high pH materials
 - Caustic, NaOH, Sodium Hydroxide
 - Liquid, very caustic, need feed equipment, cheap
 - Hydrated Lime, $\text{Ca}(\text{OH})_2$, Calcium Hydroxide
 - Dry powder, very dusty, 50lbs bags, or truckloads
 - Does not dissolve well
 - $\text{Mg}(\text{OH})_2$, Magnesium Hydroxide, Max pH<9
 - Soda Ash, Na_2CO_3 , Sodium Carbonate
 - NaHCO_3 , Sodium Bicarbonate, very good but \$

Adjust aerator or digester alkalinity

- Use same products used to raise pH
 - Alkalinity needed and lbs of product
 - Lbs of alk needed * 0.76 = lbs of lime
 - Lbs of alk needed * 0.8 = lbs of NaOH
 - Lbs of alk needed * 1.08 = lbs of soda ash
 - Lbs of alk needed * 1.72 = lbs of Sodium Bicarbonate

Nitrification-Microorganisms

- Are there sufficient microorganisms?
 - What is MLSS, or Mean Cell Residence Time (MCRT)
 - $MCRT = \frac{\text{Total solids in system}}{\text{Solids Wasted}}$
 - Generally want MCRT > 2 days, >5 in winter
- AOB's- Ammonia Oxidizing Bacteria
- NOB's- Nitrite Oxidizing Bacteria

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Temperature impacts Nitrification

- Temperature impacts the rate of oxidation
 - 100% at 29°
 - 55% at 25°
 - 38 % at 20°
 - 25% at 15°
 - 17% at 10°
- Need more bugs and longer MCRT in Winter
- Starting Nitrification at 4° C is ~ impossible

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Toxicity



- Toxics
 - The nitrifying bacteria are wimps!
 - They often are the first to die with a toxic dump
 - Especially the NOB's
 - Quaternary Ammonia compounds
 - "ammonium chloride"....

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Compounds that Inhibit Nitrification

- Organic Compounds:
 - Acetone
 - Carbon Disulfide
 - Chloroform
 - Ethanol
 - Monoethanolamine
 - Phenol
 - Ethylenediamine
 - Hexamethylene Diamine
 - Aniline
-
- Metals and Inorganic Compounds:
 - Zinc
 - Free Cyanide
 - Perchlorate
 - Copper
 - Mercury
 - Chromium
 - Nickel
 - Silver
 - Cobalt
 - Thiocyanate
 - Sodium Cyanide
 - Sodium Azide
 - Hydrazine
 - Sodium Cyanate
 - Potassium Chromate
 - Cadmium
 - Arsenic (trivalent)
 - Fluoride
 - Lead
 - Quaternary Ammonia Compounds

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High Effluent Ammonia NH₃

- Oxidative Pressure
 - More Bugs, longer solids detention time in the aerator, more Air- oxidation rate highest at 2.0 mg/L D.O.
- Longer Hydraulic Detention in Aerator
- Alkalinity additions if needed
- Absence of Toxic impacts
- Temperature

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Biological Ammonia Oxidation

- Highest rate of oxidation (removal) is at DO of 2.0 mg/L, Temp of 29°, pH of 8.3, and high reactor ammonia concentrations.
- Treatment is always a compromise,
- Longer HDT and MCRT makes for the various non-optimum conditions.

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Chemical Removal of NH₃

- Ammonia Stripping
 - At pH 11 and 25° C, 98% of ammonia is in the gas form and will evaporate to the air.
- Breakpoint chlorination
 - Cl₂:NH₃ ration of 10:1
- Ion Exchange



49

Quiz

- What are the four forms of nitrogen that we are most concerned with removing?
- Which lab test quantifies these?

50

Denitrification, removal of NO₃



- 1st organic N removed
- 2nd ammonia removed
- 3rd nitrite/nitrate removed
- This should give low Total Nitrogen
- TSS ~ 12% N

51

Why Denitrify?

- Required
 - New NPDES Permit Limits
 - Total Nitrogen
 - Nitrite/Nitrate
- Desired
 - Activated Sludge Improvements
 - Reduced Electrical Usage, to 30 %

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Denitrification Benefits

- Meet the Permit
- Recycle Oxygen
- Recover Alkalinity/pH
- Improve Effluent
- Select against Filaments
- Improved Solids Proc.
- Save Dollars



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Total Nitrogen Limits

- Total Nitrogen
 - TN = TKN + NO₂ + NO₃
 - TKN = Organic Nitrogen + Ammonia
 - Organic Nitrogen to Ammonia
 - Ammonia to Nitrite and to Nitrate
 - NO₂: generally low
 - Organic Nitrogen ~ TSS/BOD
- Nitrate, NO₃ parameter of concern

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Removing Nitrate Through Biological Denitrification

- Create the needed environment
 - Nitrate must be present
 - Anoxic Zone, Dissolved Oxygen < 0.3 mg/L
 - BOD or food must be available
 - BOD organisms must be present
 - ORP to -100mV

55

Denitrification

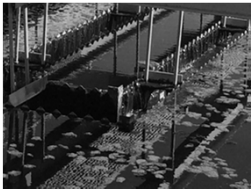

- $BOD + BOD_{Bugs} + O_2 = \text{More } BOD_{Bugs} + CO_2 + H_2O + NH_3$
- $NH_3 + NH_3Bugs + O_2 + \text{Alkalinity} = \text{More } NH_3Bugs + NO_3^-$
- $BOD + BOD_{Bugs} + \cancel{NO_3^-} = \text{more } BOD_{Bugs} + CO_2 + H_2O + N_2 \uparrow + \text{Alk.}$

NO_3^-
 \swarrow

$Nitrogen\ gas$
 \uparrow

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Denitrification

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Denitrification Efficiency

- $BOD + BOD_{Bugs} + O_2 = \text{More } BOD_{Bugs} + CO_2 + H_2O + NH_3$
 1mg/L 1-1.5 mg/L
- $NH_3 + NH_3Bugs + O_2 + \text{Alkalinity} = \text{More } NH_3Bugs + NO_3^-$
 1 mg/L 4mg/L 7mg/L
- $BOD + BOD_{Bugs} + \cancel{NO_3^-} = \text{more } BOD_{Bugs} + CO_2 + H_2O + N_2 \uparrow + \text{Alk.}$

NO_3^-
 \swarrow

$Nitrogen\ gas$
 \uparrow

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Speed of Denitrification

Fast

- DO = 0.0 mg/L
- Soluble BOD available

Slow

- DO > 0.3 mg/L
- Little Food
 - Endogenous Respiration
 - Extended Aeration
 - Digester

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Speed of Denitrification

- Dissolved Oxygen vs Denitrification Rate
- 0.0 mg/L--100%
- 0.1 mg/L--40%
- 0.2 mg/L--20%
- 0.3 mg/L--10%

- BOD bacteria
 - Soluble BOD vs Particulate BOD
 - pH 6.5-8.5
 - Temperature
 - Slower when cold
 - Faster when warm
 - 2x/10° C increase

60

Removing Nitrate Through Biological Denitrification

- Create the needed environment
 - Nitrate must be present
 - Anoxic Zone, Dissolved Oxygen < 0.3 mg/L
 - BOD or food must be available
 - BOD organisms must be present
 - ORP to - 100mV


61

Making Your Plant Denitrify

- Locate the basin which best meets the denitrification requirements.
 - Primary clarifier, depends of piping
 - Aeration basin, perhaps
 - Final clarifier, no way!
 - Other basins, what do you have?

62

Aerator is Common Choice



- Turn the air “OFF”,
- Denitrify
- Turn the air back “ON”

63

#1 Activated Sludge Myth

- Aeration basin Dissolved Oxygen must be maintained at a set levels continuously. Dan Miklos, Advanced Treatment Science, Columbus, Ohio
- Biological treatment is more flexible than this!
 - Treatment and odor prevention will continue as long as there is O₂ or NO₃

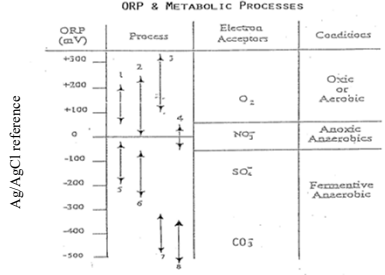
64

Oxygen Usage Hierarchy

| | |
|---|---|
| Free Dissolved Oxygen | Aerobic or Oxidic Treatment “D” |
| Little or No free Oxygen, but NO ₃ present | Anoxic Treatment “N” |
| Sulfate, SO ₄ is the next choice of the Bugs | Anaerobic conditions are beginning. ODORS, from H ₂ S, “r” |
| Carbon/Oxygen, CO ₂ , HCO, CO ₃ | Anaerobic conditions are strong. CH ₄ “R” |

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ORP & METABOLIC PROCESSES



1- Organic Carbon Oxidation 2- Polyphosphate Breakdown
 3- Nitrification 4- Denitrification
 5- Sulfide Formation 6- Sulfate Reduction
 7- Acid Fermentation 8- Methane Formation

GUMBRICH, et al 1992
 CHARPENTIER, et al 1986
 BLAND & HOLZ 1973

66

Nitrogen Sources & Fate

| | |
|---|---|
| <p>Sources</p> <ul style="list-style-type: none"> • Sewage <ul style="list-style-type: none"> – Organic – Inorganic- Ammonia • Industrial <ul style="list-style-type: none"> – Process wastewater – Refrigeration • Other <ul style="list-style-type: none"> – Trucked in waste – Water processing | <p>Fate of Nitrogen</p> <ul style="list-style-type: none"> • Leaves the plant in one of three ways. <ul style="list-style-type: none"> – Effluent <ul style="list-style-type: none"> • NH₃, NO₃, Organic – Biosolids or sludge <ul style="list-style-type: none"> • Organic, NO₃, Ammonia – Atmosphere <ul style="list-style-type: none"> • Nitrogen gas |
|---|---|

67

Quiz!

- What are the limiting factors in the biological nitrification process?

68

“Off – On” Aeration

also called
Cyclical Nitrogen Removal (CNR)
Pulsed Aeration
Multiphase Cyclical Aeration


Wastewater Treatment Plant Examples

69

Prison Wastewater Treatment


Operational Problems

- Low pH
- Bloodworms
- 1 Caustic feed added
- 2 OFF/ON
 - 3hr ON/ 3hr Off
 - Recycled alkalinity
 - pH maintained
 - Caustic eliminated
 - Bloodworms gone
- \$600/mo. savings



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Prison Wastewater Treatment



- Current Data, EFF.
 - BOD ~1-2 mg/L
 - TSS ~1-2 mg/L
 - NH₄ ~0.3 mg/L
 - NO₃, 1-4 mg/l
 - pH ~7.0
- Aerator
 - pH 6.2-6.8
 - Alkalinity ~80 mgL

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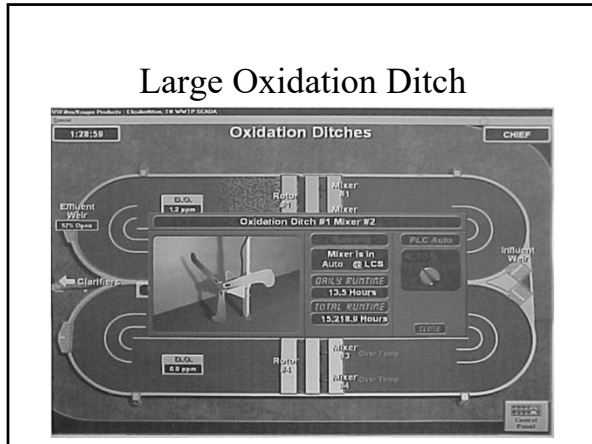
Small Oxidation Ditch



- 30 min. Settler = 1000
- Microscopic evaluation = filaments
- History of low eff. pH
- Eff Alkalinity ~ 0.0mg/L
- Off/ On
 - 5hr ON/ 3hr off
- Best effluent ever and 30% electricity savings

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Large Oxidation Ditch



Large Oxidation Ditch

- Kruger system
- Computer controlled Dissolved Oxygen Range
 - 0.2 to 1.5 mg/L
- NO₃ < 1.0 mg/L
- TSS ~ 1.0 mg/L
- BOD < 5.0 mg/L

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Extreme Cycles



- Complete Mix /Plug Flow AS
- Basic Cycle
 - Off 2-6 pm
 - Off 12-6 am
- BOD ~ 3.0
- TSS ~ 1.0
- NH₄ < 0.2
- NO₃ ~ 5.0

75

Determine “Off” Time

- ORP, Oxidation Reduction Potential
 - Common cycle
 - Aerate to + 200 mV
 - Air “off” to - 100 mV
 - Theoretical beginning of Sulfate reduction
 - -50 mV, Goronszy
 - -100 to -200mV Optimum range for H₂S creation
 - Odors will depend on concentration of H₂S & pH
 - Measure in the settled Biomass

76

Determine “Off” Time

- Oxygen Uptake Rate, OUR
 - $\frac{O_2 \text{ mg/L} + (2.86 * NO_3 \text{ mg/L})}{OUR \text{ mg/L/ Hr}}$ = Hours “Off”
- Monitor
 - pH, Alkalinity, Nitrate
 - Enzyme Fluorescence, more direct measure of biological metabolism.
- Trial and Error, DO = 0.0mg/L + more time

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Items of Concern

- Aeration Capacity to raise DO after “Off” cycle.
- Diffuser Type
- Mixing
- Switch Control
 - Manual, Timers, Computer
- Different Flows & Loads



78

If you nitrify, Why not denitrify?

- Benefits
 - Meet permit limits
 - Save money
 - Recycle oxygen and alkalinity
 - Select against filaments
 - Be a better operator!



79

Quiz!

- What is nitrification?
- Why is it important?
- What is denitrification?
- When is it important?

80

PHOSPHORUS REMOVAL

81

Phosphorus Importance

- Essential element of life
- Essential nutrient in crop production
- Maury Co, Tenn. was once a world leader in the production of phosphorus fertilizer



82

Phosphorus Removal

- Influent Concentrations:
 - 6-20 mg/L common levels
- Common Effluent Levels
 - Secondary treatment ~ 3-4 mg/L
 - With phosphorus removal ~ 1.0- 0.01mg/L
- Common Tennessee Limits ~ 0.5 mg/L
- Limits from other states ~ 0.1 mg/L

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Phosphorus Sources




- Sewage
- Soaps & Detergents
- Corrosion control:
 - Water distribution
 - Boiler feed water
- Industrial Sources
 - Food Processing
 - Fertilizer mfg.
 - Metal processing

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Fate of Phosphorus

- Effluent
 - Organic P in BOD & TSS
 - Dissolved in the water
- Sludge or Biosolids
 - Organic P in the solids
 - Dissolved in the water

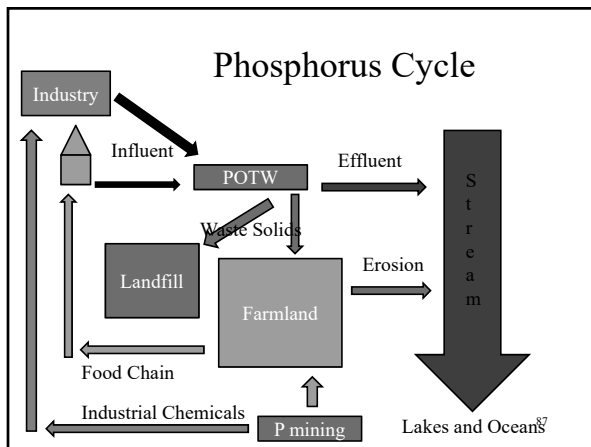


85

Phosphorus Forms

- Influent Total Phosphorus 6-20 mg/L
- Organic Phosphorus ~ 2-5 mg/L
 - Essential element in all plant and animal life
 - Acid digestion converts this to Orthophosphorus for testing.
- Inorganic Phosphorus ~ 4-15 mg/L
 - Orthophosphorus, PO_4^{3-} (reactive phosphorus)

86



Quiz!

- What type of conditions are needed for denitrification?

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Biological Removal

- PAO- phosphorus accumulating organisms
- First identified and researched in 1960's
- Process includes:
 - Anaerobic zone (anoxic needed to remove NO_3)
 - Aerobic zone- Luxury Uptake of Phosphorus
- There are many variations of this basic flow

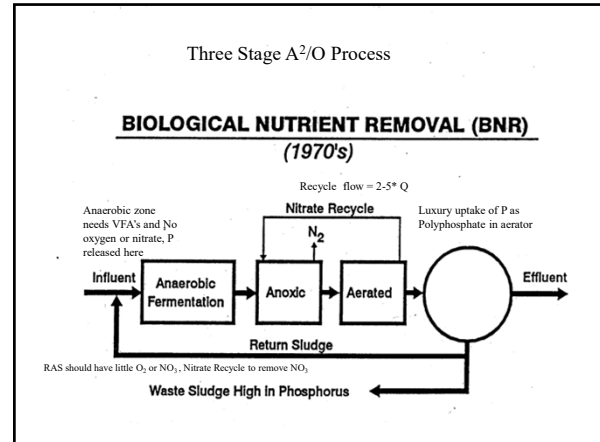
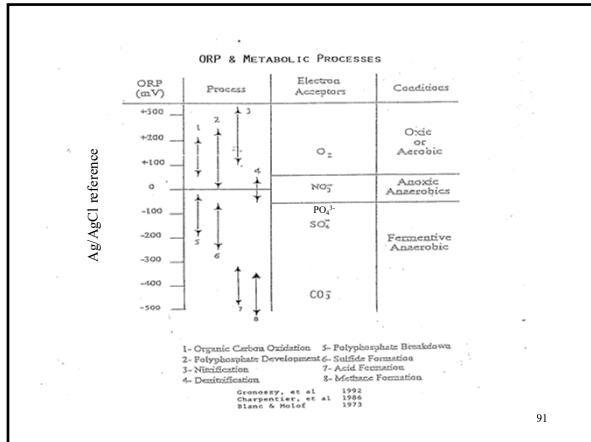
89

Oxidation Reduction Potential

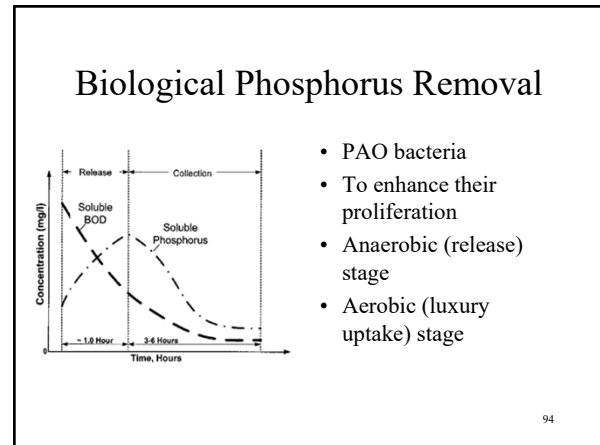
- ORP
- Redux Potential
- Ratio of Oxidized chemical species vs. Reduced
- Indicates the type of biological activity when there is no DO.



90



- ### Other Phos Removal Processes
- Three Stage A²/O
 - Five Stage Bardenpho
 - University of Cape Town (UCT)
 - Also UCT with Virginia Initiative Process
 - Johannesburg and Modified Johannesburg processes
 - All have some pattern of Anaerobic/Aerobic
- 93



- ### Biological Phosphorus Removal
- Anaerobic zone
 - ~ 2 hours HDT
 - Readily available BOD needed such as VFA's
 - Reducing environment
ORP, -50 to -250 mV
-
- Anaerobic Zone
- 95

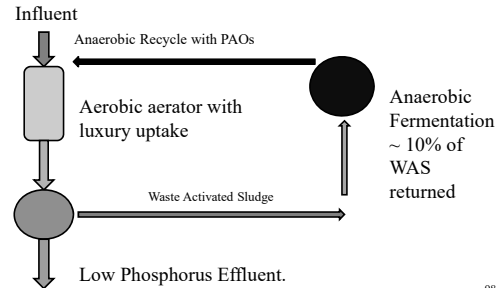
- ### Biological Phosphorus
-
- LaFollette, Tenn.
 - Oxidation Ditch
 - Off/On cycles
 - 90 on, DO~2 ORP ~300
 - 60 off, ORP ~ -100mV
 - Subsurface mixing
 - DO controlled and ORP monitored
 - Limits TN=8, TP=2
- 96

Other Technology and Methods

- Many proprietary nutrient removal methods
- Side stream treatment processes
 - Treat part of the flow to develop PAO's then add them to the full flow
 - Treat internal flows such as digester supernatant

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Side Stream Anaerobic System



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Athens Utility Board, 2016

- Always used chemicals
- Grants guidance for bioP removal
- WAS recycle to old clarifiers, then to ditch
- 2nd trial, to middle ring
- Success with no Chem.



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Chemical Phosphorus Removal

- Common Chemicals
 - Aluminum & Ferric
 - Lime, pH>11
 - Proprietary Products
- Need feed equipment
- Mixing
- Alkalinity
- Effluent filters improve removal



Alum Feed System 100

Chemical Phosphorus Removal



Ferric Sulfate Tank

- Alum dose ~ 1.75gallons alum/lbs P
- Ferric Sulfate ~1.3 gallons ferric sulfate /lbs P
- Varies with:
 - Alkalinity, pH
 - Limit to meet

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Chemical Phosphorus Removal

- Fairview: Ferric Sulfate, 24 gpd in 0.24MGD, fed into influent interceptor, meeting a 0.5 mg/L limit
- Lawrenceburg: SBR with BioP removal to ~1.0 mg/L then alum @ 60 gpd into 1.5MGD to reach 0.5 mg/L limit.

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Athens Utility Board



- Limits
 - TN=5mg/L, TP= 1mg/L
- Ditch Rings
 - Outer- anoxic
 - Middle, DO~1.0
 - Inner, DO ~2.0
- Ferric Chloride added to clarifier center well
 - 60-120 gpd into 2.0 MGD

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Phosphorus Removal



Floc. basin and filters

- Filters
 - TSS will contain 2% Phosphorus
 - Effluent filters improve removal with or without chemical addition
 - Plants constructed to remove P will have filters.
- Flow Equalization

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Phosphorus Removal

- May be a limited parameter in the future.
- Two main removal methods.
- Phosphorus leaves the plant in effluent or sludge only.
- Retrofits probably chemical but may be biological.
- Operator Knowledge in Key.

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Summary

- Nutrient Removal is here!
- It will challenge operators and owners.
 - Processes are complex, and varied,
 - They have many interferences,
 - And they will be more costly.

106

Operator Advice

- Don't get nutrient limits!
- Keep a stable process.
- Do extra process control tests.
- Talk to those who are already doing it.
- Hold vendors, engineers, programmers feet to the fire!

107

Optimization

- Know the basics of Nutrient Removal!
- Plants are very different!
 - Develop a strategy
 - Ask for help
 - Contact TDEC- they are promising “enforcement digression” if you create a violation
 - Document everything!

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Questions,
Comments,
Discussion




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Section 8

Reclamation and Reuse



TDEC - Fleming Training Center 1



WASTEWATER RECLAMATION AND REUSE

Advanced Wastewater Treatment

Wastewater Reclamation and Reuse

2

- Recycled
 - Water or wastewater is used within a facility before it is discharged to a treatment system
- Reclamation
 - Operation or process of changing the condition or characteristics of water so that improved uses can be achieved.
- Reuse
 - Water is discharged and then withdrawn by another user

TDEC - Fleming Training Center

Wastewater Reclamation and Reuse

3

- Water agencies forced to seek new water sources
 - Population growth
 - Contamination of surface or groundwater
 - Droughts
 - Uneven water distribution
- Water reuse common in many areas
 - In US, especially in arid and semi-arid areas
 - Mostly restricted to non-potable reuse, like irrigation
- Other alternatives
 - Water conservation
 - More efficient use
 - Development of new water resource and management

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Water Reuse: Historical Perspective

4

| | | |
|------|---------------------------------|--|
| 1912 | San Francisco, CA | First small urban reuse begins with the irrigation of Golden Gate Park |
| 1942 | Baltimore, MD (Bethlehem Steel) | Metals cooling and steel processing |
| 1960 | Colorado Springs, CO | Landscape irrigation of golf courses, cemeteries and freeways |
| 1984 | Tokyo, Japan | Water recycling for toilet flushing in 19 high-rise buildings in congested metropolitan area |
| 1987 | Monterey, CA | Agricultural irrigation for food crops eaten uncooked (celery, broccoli, lettuce, cauliflower, etc.) |

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Wastewater Reuse Categories

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- Agricultural irrigation
- Landscape irrigation
- Industrial recycling and reuse
- Groundwater recharge
- Recreational and environmental uses
- Non-potable urban uses
- Potable reuse

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Agricultural Irrigation

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- Largest use in US
- Uses:
 - Crop irrigation
 - Commercial nurseries
- Issues/Constraints:
 - Surface and groundwater contamination if not managed properly
 - Marketability of crops and public assistance




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Landscape Irrigation

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- Uses:
 - Parks
 - School yards
 - Golf courses
 - Greenbelts
 - Cemeteries
 - Freeway medians
 - Residential
- Issues/Constraints:
 - Effect of water quality, particularly salts, on soils and crops
 - Public health concerns related to pathogens
 - Restrictions on area use, including buffer zone may result in higher costs



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Industrial Recycling and Reuse

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- Uses:
 - Cooling water
 - Process water
 - Boiler feed
 - Heavy construction
- Issues/Constraints:
 - Constituents in reclaimed water related to scaling, corrosion, biological growth and fouling
 - Possible aerosol transmission or pathogens in cooling water
 - Cross-connection of potable and reclaimed water lines

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Groundwater Recharge

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- Uses:
 - Groundwater replenishment
 - Spreading basins
 - Saltwater intrusion control
 - Direct injection
 - Subsidence control
- Issues/Constraints:
 - Possible contamination of groundwater aquifer used as potable water source
 - Organic chemicals in reclaimed water and their toxicological effects
 - Total dissolved solids, nitrates and pathogens




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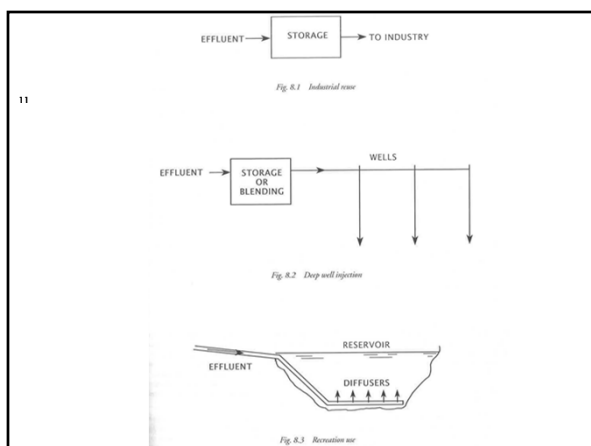
Recreational and Environmental Uses

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- Uses:
 - Development of lakes and ponds
 - Marsh enhancement
 - Stream flow augmentation
 - Fisheries
 - Snowmaking
- Issues/Constraints:
 - Health concerns about pathogens
 - Eutrophication due to nitrogen and phosphorus in receiving water
 - Toxicity to aquatic life




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Non-potable Urban Uses

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- Minimal use in US
- Uses:
 - Fire protection
 - Air conditioning
 - Toilet flushing
 - Flushing of sanitary sewers
- Issues/Constraints:
 - Health concern over possible aerosol transmission of pathogens
 - Effects of water quality on scaling, corrosion, biological growth and fouling
 - Cross-connection of potable and reclaimed water lines



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Potable Reuse

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- Minimal use in US
- Uses:
 - ▣ Blending in water supply reservoirs
 - ▣ Pipe-to-pipe water supply
- Issues/Constraints:
 - ▣ Constituents in reclaimed water (especially trace organic chemicals and their toxicological effects)
 - ▣ Aesthetics and public acceptance
 - ▣ Health concerns about pathogen transmission

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Effluent Disposal

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- Dilution
 - ▣ Lakes
 - ▣ Rivers
 - ▣ Streams
- Wastewater Reclamation
 - ▣ Land application
 - ▣ Underground disposal



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Disposal by Dilution

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- Treatment required prior to discharge:
 - ▣ Stabilize waste
 - ▣ Protect public health
 - ▣ Meet discharge requirements
- Site specific
- Most common method of effluent disposal
- How does one evaluate the effect of a WWTP's effluent upon the receiving stream?
 - ▣ Sample water in stream above and below the plant's outfall location
 - ▣ Perform a DO profile of the stream

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Disposal by Dilution

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- Diffusers
- Cascading outfalls
 - ▣ Increase D.O.
 - ▣ Remove chlorine
 - ▣ Remove sulfur dioxide
- Surface discharge



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Land Treatment Systems

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- When high-quality effluent or even zero-discharge is required, land treatment offers a means of reclamation or ultimate disposal

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Land Treatment Systems

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- Simulate natural pathways of treatment
- Use soil, plants, and bacteria to treat and reclaim wastewater
- Treatment is provided by natural processes as effluent moves through soil and plants
- Some of wastewater is lost by evaporation and transpiration
- Remainder returns to hydrologic cycle through surface runoff or percolation to groundwater

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Hydrologic Cycle

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The diagram illustrates the hydrologic cycle with various processes labeled: Precipitation (rain falling from clouds), Solar Energy (powering evaporation and transpiration), Transpiration from Plants (water vapor rising from vegetation), Evaporation from Land and Water (water vapor rising from surfaces), Surface Runoff (water flowing over the ground), Infiltration (water seeping into the ground), and Ground Water (water stored underground). A water table is also indicated.

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Land Application System

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- Treatment prior to application
- Transmission to the land treatment site
- Storage
- Distribution over the site
- Runoff recovery system
- Crop systems

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Land Application System

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The flowchart shows the process of land application: Treated Plant Effluent flows into a Storage Reservoir, then to a Land Disposal Site. From the Land Disposal Site, Evapotranspiration occurs upwards, Percolation occurs downwards, and Surface Runoff occurs to the right.

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Site Considerations

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- Control of ponding problems
 - Percolation
 - Crop selection
 - Drainage tiles
- Install PVC laterals below ground
- Potential odor release with spray systems
- Routine inspection of equipment
- Plan "B" in case system fails

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Wastewater Reclamation: Land Application

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- Land Disposal:
 1. Irrigation most common:
 - Ridge and furrow
 - Sprinklers
 - Surface/drip systems
 2. Overland flow
 3. Infiltration - percolation

Wastewater Treatment Plant & Poplar Tree Reuse System; Woodburn, Oregon

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Irrigation

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- Method depends on crop grown
 1. Forage crops (ex: grasses and alfalfa)
 2. Field crops (ex: corn)
 3. Forests
 - Silage / hay
 - Parks / golf courses
 - Horticulture / timber / turf grass
- Water & nutrients enhance plant growth for beneficial use.
- Water removed by:
 - Surface evaporation & plant transpiration
 - Deep percolation to subsoil

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Irrigation

(*) IRRIGATION

- Irrigation application of wastewater over relatively flat area, usually by spray (sprinklers) or surface spreading
- Water and nutrients are absorbed by plants and soil
- In soil, organic matter is oxidized by bacteria

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Irrigation

- Most common land treatment in US
- Spray: fixed or moving
- Surface spreading: controlled flooding or ridge & furrow
- Climate affects efficiency
 - If ground freezes, subsurface seepage is greatly reduced.
 - Therefore storage of treated wastewater may be necessary
- Ex: lawns, parks, golf courses, pastures, forests, fodder crops (corn, alfalfa), fiber crops, cemeteries

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Irrigation - Spray Systems

- Fixed
 - Buried or on surface
 - Cultivated crops or woodlands
- Moving - center pivot
- Minimum slope 2 – 3%
 - Promotes lateral drainage and reduces ponding
- Maximum slope in TN:

| | |
|----------------|-----|
| ■ Row crops | 8% |
| ■ Forage crops | 15% |
| ■ Forests | 30% |

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Irrigation - Spray Systems

Center pivot, moving spray irrigation

Fixed spray irrigation on risers

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Irrigation – Ridge & Furrow

- Ridge and Furrow = a series of interconnected ditches (furrows) which allow for the distribution, infiltration, and treatment of wastewater
- Wastewater flows through furrows between rows of crop
- Wastewater slowly percolates into soil
- Wastewater receives partial treatment before it is absorbed by plants

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Irrigation – Ridge & Furrow

Gated pipe applying flow to furrows

Irrigation ditch in foreground supplying water to furrows

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Irrigation – Removal Efficiencies

| Parameter | % Removal |
|------------------|-----------|
| BOD | 98 |
| COD | 80 |
| Suspended Solids | 98 |
| Nitrogen | 85 |
| Phosphorus | 95 |
| Metals | 95 |
| Microorganisms | 98 |

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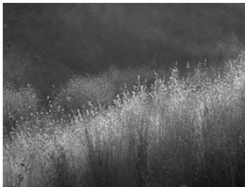
Irrigation – Removal Efficiencies

- Under normal circumstances:
 - Water and nitrogen are absorbed by crops
 - Phosphorus and metals are adsorbed by soil particles
 - Bacteria is removed by filtration
 - Viruses are removed by adsorption
- Nitrogen cycle
 - Secondary effluent contains ammonia, nitrate and organic nitrogen
 - Ammonia and organic nitrogen are retained in soil by adsorption and ion exchange, then oxidized to nitrate
 - Major removal mechanisms are ammonia volatilization, crop uptake and denitrification

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Overland Flow




- Spray or surface application
 - 6-12 hours/day
 - 5-7 days/week
- 2-8% slope
- Slow surface flow treats wastewater
- Water removed by evaporation & percolation
- Runoff collection

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Overland Flow



Wastewater application by surface spray or sprinkler methods

Slope 2-8%

Water tolerant grasses

Sheet flow

Limited percolation

Overland flow terrace

Collection ditch

Terrace back slope

Terrace front slope

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Overland Flow

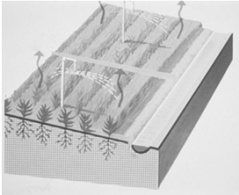
- Wastewater is applied intermittently at top of terrace
- Runoff collected at bottom (for further treatment)
- Treatment occurs through direct contact with soil

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Overland Flow

- Low pressure sprays
 - <20 psi
 - Low energy costs
 - Good wastewater distribution
 - Nozzles subject to plugging
- Surface distribution
 - Generate minimal aerosols
 - Higher energy costs
 - Hard to maintain uniform distribution



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Surface Methods

Distribution Methods

| Methods | Advantages | Limitations |
|----------------------------|--|---|
| General | Low energy costs Minimize aerosols and wind drift Small Buffer zones | Difficult to achieve uniform distribution Moderate erosion potential |
| Gated Pipe | Same as General, plus: Easy to clean Easiest to balance hydraulically | Same as General, plus: Potential for freezing and settling |
| Slotted or Perforated Pipe | Same as General | Same as Gated Pipe, plus: Small openings clog Most difficult to balance hydraulically |
| Bubbling Orifices | Same as General, plus: Not subject to freezing/settling Only the orifice must be leveled | Same as General, plus: Difficult to clean when clogged |
| Low-pressure Sprays | Better distribution than surface methods Less aerosols than sprinkler Low energy costs | Nozzles subject to clogging More aerosols and wind drift than surface methods |
| Sprinklers | Most uniform distribution TDEC - Fleming Training Center | High energy costs Aerosol and wind drift potential Large buffer zones |

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Suitable Grasses

| Common Name | Perennial or Annual | Rooting Characteristics | Method of Establishment | Growing Height (cm) |
|--------------------------|---------------------|-------------------------|-------------------------|---------------------|
| Cool Season Grass | | | | |
| Reed canary | Perennial | sod | seed | 120-210 |
| Tall fescue | Perennial | bunch | seed | 90-120 |
| Rye grass | Annual | sod | seed | 60-90 |
| Redtop | Perennial | sod | seed | 60-90 |
| KY bluegrass | Perennial | sod | seed | 30-75 |
| Orchard grass | Perennial | bunch | seed | 15-60 |
| Warm Season Grass | | | | |
| Common Bermuda | Perennial | sod | seed | 30-45 |
| Coastal Bermuda | Perennial | sod | sprig | 30-60 |
| Dallis grass | Perennial | bunch | seed | 60-120 |
| Bahia | Perennial | sod | seed | 60-120 |

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- ### Suitable Grasses
- ❑ Well established plant cover is essential for efficient performance of overland flow
 - ❑ Primary purpose of plants is to facilitate treatment of wastewater
 - ❑ Planting a mixture of different grasses usually gives best results
 - ❑ Ryegrass used as a nurse crop; grows quickly until other grasses are established
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- ### Suitable Grasses
- ❑ Cool Season Grass – plant from Spring through early Summer or early Fall to late Fall
 - ❑ Warm Season Grass – generally should be planted from late Spring through early Fall
 - ❑ Planting time affected by expected rainfall, location, climate, grass variety, etc
 - ❑ Amount of seed required to establish cover depends on:
 - Expected germination
 - Type of grass
 - Water availability
 - Time available for crop development
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Overland Flow – Removal Efficiencies

| Parameter | % Removal |
|------------------|-----------|
| BOD | 92 |
| Suspended Solids | 92 |
| Nitrogen | 70-90 |
| Phosphorus | 40-80 |
| Metals | 50 |

- ❑ Treatment by oxidation and filtration
 - SS removed by filtration through vegetative cover
 - BOD oxidized by microorganisms in soil and on vegetative debris
 - Nitrogen removal by denitrification and plant uptake

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Rapid Infiltration


- ❑ Primary objective is to recharge the groundwater
- ❑ Wastewater is applied to spreading basins or seepage basins and allowed to percolate through the soil
- ❑ No plants are used or desired

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Rapid Infiltration

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- Top— Picture of a seepage basin in Nevada
- Bottom - Large volumes of reclaimed water, which have undergone advanced secondary treatment, are reused through land-based applications in a 40-square-mile area near Orlando, Florida.



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Rapid Infiltration


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- Effluent is discharged into a basin with a porous liner
- No plants needed or desired
- Primary objective is groundwater recharge
- Not approved in Tennessee
 - Due to Karst topography – cracks in limestone provide direct route of infiltration to groundwater and therefore no treatment achieved and groundwater may become contaminated

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Land Treatment Limitations

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- Sealing soil surface due to high SS in final effluent
 - More common in clay soils
 - Three possible solutions:
 - Remove SS from the effluent
 - Disk or plow field to break mats of solids
 - Apply water intermittently and allow surface mat to dry and crack
- Build up salts in soil
 - Salts are toxic to plants
 - Leach out the salts by applying fresh water (not effluent)
 - Rip up the soil 4 – 5 ft deep to encourage percolation

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Land Treatment Limitations

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- The severity of both soil sealing due to suspended solids and salinity problems due to dissolved solids depends on the type of soil in the disposal area.
- These problems are more difficult to correct in clay soils than in sandy soils.
- Excessive nitrate ions can reach groundwater if irrigation or rapid infiltration are overloaded or not properly operated.
 - Rapid infiltration systems have no crops to remove nitrogen so they must be operated in wet/dry cycles in order to first nitrify the ammonium (dry) and then denitrify the nitrate (wet) to form nitrogen gas (N₂), which is released to the atmosphere.

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Land Treatment Limitations

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- Excessive nitrate ions reach groundwater
 - Rain can soak soil so that no treatment is achieved
 - Do not apply nitrate in excess of crop's nitrogen uptake ability
 - Excessive nitrate in groundwater can lead to methyloglobenemia (blue baby syndrome)
 - Too much nitrate consumed by child leads to nitrate in stomach and intestines where nitrogen is absorbed into bloodstream and it bonds to red blood cells preventing them from carrying oxygen.
 - Baby becomes oxygen deprived, turns blue and suffocates

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Monitoring Requirements


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| Area | Test | Frequency |
|-------------------------------------|--|---------------------|
| Effluent and groundwater or seepage | BOD | Two times per week |
| | Fecal coliform | Weekly |
| | Total coliform | Weekly |
| | Flow | Continuous |
| | Nitrogen | Weekly |
| | Phosphorus | Weekly |
| | Suspended solids | Two times per week |
| | pH | Daily |
| | Total dissolved solids (TDS) | Monthly |
| | Boron | Monthly |
| | Chloride | Monthly |
| Vegetation | - - - variable depending on crop - - - | |
| Soils | Conductivity | Two times per month |
| | pH | Two times per month |
| | Cation Exchange Capacity (CEC) | Two times per month |

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Any Questions?

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Reclamation and Reuse – Review Questions

1. What is the most commonly used form of reclamation or reuse in the US?
 - a. Agricultural Irrigation
 - b. Potable Reuse
 - c. Groundwater Recharge
 - d. None of the above

2. What is the most common form of effluent disposal used in the US?
 - a. Dilution
 - b. Land application
 - c. Underground disposal
 - d. Deep well injection

3. If water or wastewater is used again within a facility before it is discharged to a treatment system, it is considered:
 - a. Recycled
 - b. Reused
 - c. Reclamation
 - d. Potable

4. Cascading outfalls are beneficial because they can do all of the following except what?
 - a. Increase DO
 - b. Remove chlorine
 - c. Decrease BOD
 - d. Remove sulfur dioxide

5. If wastewater effluent is discharged and then withdrawn by another user, it is considered:
 - a. Recycled
 - b. Reused
 - c. Reclamation
 - d. Potable

6. The nutrients contained in wastewater can enhance plant growth when land applied.
 - a. True
 - b. False

7. The operation or process of changing the condition or characteristics of water so that improved uses can be achieved is known as:
 - a. Recycling
 - b. Reuse
 - c. Reclamation
 - d. None of the above

8. Ground temperature is an important factor to take into consideration when planning for adequate storage of wastewater that is to be used for irrigation.
 - a. True
 - b. False

9. Overland flow method does not require runoff collection.
 - a. True
 - b. False

10. Rapid Infiltration is a common method in Tennessee.
 - a. True
 - b. False
11. Toxic salts can build up in soils where wastewater is being sprayed or distributed.
 - a. True
 - b. False
12. Methylmoglobinemia is caused by an excessive amount of _____ in groundwater?
 - a. Nitrite
 - b. Ammonia
 - c. Nitrate
 - d. Metals
13. In order to monitor the effect of your effluent on the receiving stream, what actions should be taken?
 - a. Ensure your DMR is submitted to the State by the 15th of the month
 - b. Increase the speed at which the water is being discharged
 - c. Monitor both Influent and Effluent flow
 - d. Collect samples upstream and downstream and compare the results
14. Which of the following is **not** a component of a land application system?
 - a. Treatment before application
 - b. Transmission to land treatment site
 - c. Storage
 - d. Distribution over site
 - e. Polishing pond
15. The following are all methods of land disposal of wastewater **except**:
 - a. Irrigation
 - b. Dilution
 - c. Infiltration
 - d. Overland flow

Answers:

1. A
2. A
3. A
4. C
5. B
6. A
7. C
8. A
9. B
10. B
11. A
12. C
13. D
14. E
15. B

What every operator should know about water reclamation and reuse

Craig Riley

| Knowledge | Principle | A practical consideration |
|-----------------------------|---|--|
| Reclaimed or recycled water | Wastewater that has gone through specific treatment processes to meet specific water quality criteria with the intent of being used in a beneficial manner as a water supply | Water reclamation projects often start as a means to reduce wastewater flows and loads discharged to the environment. Reclaimed or recycled water is a water supply that should be considered as an integral component of water resources management in water-scarce areas. |
| Graywater | Wastewater, excluding toilet/urinal wastewater – and in most cases – dishwasher and kitchen sink wastewaters | Graywater use generally is limited to onsite, subsurface irrigation; if treatment is provided in accordance with state and local codes for other uses, the water can become reclaimed or recycled water. |
| Beneficial uses | The many ways reclaimed water can be used | Examples of beneficial uses include irrigation, industrial applications, toilet and urinal flushing, wildlife enhancement, aesthetic and recreational impoundments, and municipal water supply. |
| End user | The final customer, either wholesale or retail | End users can range from public entities such as cities purchasing reclaimed water wholesale to industry purchasing reclaimed water commercially to individual homeowners buying water for lawn irrigation. |
| Use area | An area of reclaimed water use with defined boundaries or limits, such as a building or site permitted to use reclaimed water | Use areas range from large sites, such as golf courses and parks, to residential lawns or city median strips. Permits may be required for individual sites or sites grouped by different types of use. |
| End-user agreement | A legally binding agreement between the supplier and reclaimed water user that (among other things) establishes terms and conditions of service; describes reclaimed water supply availability, quality, and cost; and lists responsibilities of both parties for signage, use control, and compliance monitoring | Agreements define the responsibilities of both the supplier and user of the reclaimed water. They are intended to ensure that water users are aware of and trained in the proper use of reclaimed water and that utilities are protected from permit violations that are beyond their control. |
| Dual distribution system | The system of pipes used to distribute reclaimed water to end users | Dual distribution systems utilize separate piping systems for reclaimed and potable water. Special pipe separation standards are often required for construction. |



| Knowledge | Principle | A practical consideration |
|--------------------------|---|---|
| Purple pipe | The color code specifically designated for reclaimed water distribution systems and appurtenances | Color shade Pantone 522 or 512 is required in several states. Pipes, valves, or hydrants can be colored or painted purple; marked with purple identification tags; or wrapped in purple polyethylene wrap or identification tape. |
| Reclaimed water storage | A reclaimed water impoundment or conventional steel/concrete storage tank to facilitate the distribution and use of the water | Storage of reclaimed water may be needed for several uses, including fire protection equivalent to potable water distribution systems, landscape or crop irrigation, recreation, and industrial process water. |
| Cross connection control | Preventing a physical connection between a potable water system and any potential source of contamination through a physical connection in a plumbing system through which a potable water supply could be contaminated by nonpotable water | Cross connection protection for water reclamation projects involves the protection of potable water systems from cross contamination from reclaimed water. It also includes protection of reclaimed water systems from contamination by lower-quality water. |
| Nonpotable reuse | Use of reclaimed water for nonpotable uses in buildings, industries, lawn and turf irrigation, and nonpotable municipal needs | Nonpotable water use within communities constitutes the majority of the water system demand. Uses include toilet and urinal flushing, cooling and heating, street cleaning, sewer flushing, ship ballast, fountains, and watering residential lawns and gardens as well as cemeteries, parks, and golf courses. |
| Indirect potable reuse | Augmentation of a drinking water source (surface water or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment | Indirect potable reuse can occur via groundwater recharge, discharge to a raw water reservoir, or discharge to a watercourse where water is subsequently withdrawn for treatment and potable use. |
| Direct potable reuse | The introduction of highly treated reclaimed water either directly into the potable water supply distribution system downstream of a water treatment plant, or into the raw water supply immediately upstream of a water treatment plant | Direct potable reuse does not include passage of reclaimed water through an environmental buffer. |

| Knowledge | Principle | A practical consideration |
|------------------------------------|---|---|
| Environmental buffer | <p>For surface water discharge, a natural waterbody, such as a reservoir, river, or lake, that physically separates reclaimed water from the intake to a drinking water plant</p> <p>For groundwater recharge, the soil and aquifer that physically separate the reclaimed water recharge site from a potable water extraction well</p> | <p>An environmental buffer may or may not improve the quality of the reclaimed water. In fact, the reclaimed water is almost always of a higher quality than the water it mixes with in an environmental buffer.</p> <p>The main advantage of an environmental buffer is that it provides time to respond to situations where the reclaimed water introduced into the environmental buffer is found to not meet all appropriate standards.</p> |
| Aquifer storage and recovery (ASR) | Use of reclaimed water to recharge local aquifers through either surface spreading or direct injection | Reclaimed water ASR can function exactly like potable water ASR, storing reclaimed water underground for use during peak demand periods. |
| Environmental uses | Reclaimed water use to enhance the environment | Environmental uses include wetland creation, replacement, or augmentation, as well as stream augmentation to maintain or supplement minimum streamflows. |
| Reliability | The ability of a treatment system or component(s) to perform a required function under stated conditions for a stated period of time | <p>Reclaimed water systems must produce reclaimed water of defined quality at all times. Unless reclaimed water continuously meets all water quality limits while all required treatment processes are on-line and functioning properly, the water cannot be sent to the end user. Reliability is based on applying multiple protective barriers for microbial and chemical contaminants.</p> |
| Reliability assessment | A formal determination and review of the reliability of reclaimed water system components and equipment | <p>The assessment should list and describe operating standards, maintainability, critical operating conditions, spare parts requirements and availability, and any other factors that affect the reliability or the treatment performance of the reclamation facility.</p> <p>It is impossible to plan to be "fail safe," but it is possible to plan to fail safely.</p> <p>Reliability assessments involve assessing individual equipment as well as complete process trains, and must ensure adequate sensors, alarms, controllers, transmitters, and receivers to ensure continuous process operation and product quality. Reliability includes production, distribution, and storage facilities, as well as use area notifications and protections.</p> |

Craig Riley is reuse program lead at the Washington State Department of Health and chairman of the Water Environment Federation (Alexandria, Va.) Water Reuse Committee.

The author would like to thank Water Reuse Committee members Jim Crook, Alan Rimer, and Don Vandertulip for their assistance with this article.

Section 9

Fats, Oils and Grease



Fats, Oil and Grease Control

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BEWARE of the GREASE MONSTER

COLLECT KITCHEN GREASE. DISPOSE IN TRASH.

When sewer pipes get clogged with kitchen grease, the wastewater can back up into sinks, tubs and other drains. These backups can cause serious public health and environmental problems, as well as costly maintenance bills for you.

How can sewer backups be prevented?
 • Pour cooled cooking grease into a disposable container.
 • Never pour fats, oils or cooking grease down sinks, tubs or toilets.
 • Rinse these simple steps in mind to avoid a visit from the Grease Monster.

Introduction

- Review information presented in Tennessee Oil and Grease Control Document, June 2002, TDEC.
- Editors: Jennifer Peters Dodd and Roger D. Lemasters, TDEC.
- Purpose: Tool for municipalities to create regulations and enforcement plans dealing with oil and grease on a local level.

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Background

- Oil and grease in sewers causing problems for many TN cities.
- Contributing factors:
 - increase in restaurants
 - aging collection system
 - decrease in disposal options

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Background

- Federal pretreatment regulations (40 CFR 403.5(b)(6)) specifically prohibit petroleum oil, non-biodegradable cutting oil, or products of mineral origin in amounts that will cause interference or pass through.
- Few cities have regulations that specify limits and enforcement of oil and grease discharges from restaurants.

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Background

- Minimizing oil and grease discharges to collection system will reduce sewer blockages and sewage backup into service laterals.
- Guidance document focuses on edible oil and grease from restaurants and other food processors (prisons, churches, schools, etc.)

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Contents

- Introduction
- Fats, Oil, and Grease Limits
- Preventing Grease from Entering the Sewer Collection System
- Grease Separation Devices
- Disposal Options
- Education
- Appendices

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Characteristics of Oil & Grease

- Found in wastewater as an emulsion or free-floating agglomerates.
- WEF's Pretreatment of Industrial Wastes, Manual of Practice FD-3 defines grease as: "fats, oils, waxes, and soaps according to their effect on wastewater collection and treatment systems and their physical (semisolid) forms".
- FOG: general term for fats, oil, and grease.

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Characteristics of Oil & Grease

- Due to its structure, grease collects on cool internal surfaces of sewers
 - blockages
 - grease logs
- Grease also accumulates due to cooling and dilution of surfactants, that allows grease to separate and collect on pipes and wet wells
 - fouling of controls
 - prevent proper operation of pumps



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Characteristics of Oil & Grease

- Grease blockages may lead to sewage backup at service laterals or manholes.
- Sewer agency is responsible for any damage that occurs.
- If the damage results in a violation of a permit issued by TDEC-DWR, enforcement action against the sewer agency is possible.

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9

Fats, Oil and Grease Limits

- When setting FOG limits, cities must consider:
 - protection of CS and WWTP
 - practicality of monitoring and enforcement
 - cost and manpower needed for enforcement



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Numerical Limits

- Most commonly used limit is 100 mg/L.
- Some cities specify different FOG limits for FOG from different sources.
- Limits may vary due to:
 - number of wet wells
 - sewer type, slope, and flow
 - sewer O & M
 - history of grease related clogs

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Numerical Limits

- EPA suggested influent to biological treatment contain less than 50 mg/L of FOG and that dilution in CS would reduce any 100 mg/L discharges to acceptable levels for the WWTP.
- Use of numerical limits allow uniform regulation of local restaurants.
- FOG analysis is somewhat costly and some restaurants resist paying for sampling.

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Numerical Limits

- Instead, may use temperature limit for grease trap effluent.
- Grease traps are not effective if temperature is too high (85°F).
- Numerical temperature limits can aid in applying and enforcing limits.
- Can easily be monitored.
- Cannot guarantee grease trap is properly maintained and operated.

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Best Management Practices (BMP)

- Effective tool in controlling FOG without requiring extensive monitoring
 - dry wiping pots, pans, and dishware
 - discontinue use of garbage grinders
 - routine cleaning of grease traps
 - retain copies of grease trap hauler manifests
 - place oil recycle container in convenient location

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Numerical Limits vs. BMP

- Cities may consider surcharging restaurants for high-strength BOD and suspended solids.
- Whether numerical limits or BMPs are used, authority for the FOG program is based on the local sewer use ordinance.
- Should not conflict with local building codes, plumbing codes, and health department regulations.

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Sampling

- Collect as grab samples
- Specially cleaned 1 L **wide-mouth glass container**
- Preserve with HCl or H₂SO₄ to pH < 2
- **Refrigerate at 6°C or less up to 28 days**
- Sample at peak flows to determine adequacy of equipment
- For surcharge purposes, sample at average flow

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Sampling

- Frequency depends on the need for data
- Perform surcharge monitoring monthly
- When scheduling compliance monitoring consider:
 - staff availability
 - cost of sampling
 - compliance history of the facility
- May be scheduled or unannounced

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Analysis

- New EPA-approved FOG method is Method 1664
- Uses hexane instead of freon
- More labor intensive than Method 413.1
- Average price for analysis is similar

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Preventing Grease From Entering Sewers

- The most economical and prudent method is proper pretreatment of waste streams to reduce or eliminate grease.
- Since waste streams vary, consider several options.

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Zero Discharge of FOG

- Scrape food into solid waste container
- Scrape cookware before washing
- No garbage grinders
- Train restaurant managers and employees in disposal of cooking oil in recycling containers



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Grease Removal Devices

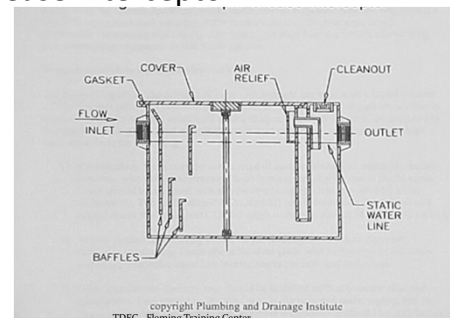
- Must remove emulsified and free-floating FOG
- Three types:
 - passive under-sink devices
 - large outside passive devices
 - mechanical devices



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Grease Interceptor



copyright Plumbing and Drainage Institute
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Preventing Grease from Entering Sewers

- Remember, multiple sources of FOG in restaurant kitchens
- Commercial/residential sources of FOG:
 - food manufacturers and processors
 - food providers
 - normal cooking and cleaning in homes



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Use of Additives by Facilities

- Should be regulated by the Control Authority.
- Solvents, caustics, and acids dissolve FOG, but can harm WWTP and its workers.
- Enzymes and detergents dissolve FOG, but this reaction is often reversible. This benefits the restaurant, but causes accumulation in downstream areas.
- Bacteria consume grease-must use proper microorganisms; often more effective in CS.

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Grease Separation Devices

- Grease trap or interceptor consists of enclosed chamber, designed to separate and retain oil and grease from wastewater.
- Fats and greases have lower specific gravity than water and rise to surface.
- Wastewater passes through to sewer.
- Periodic cleaning needed to remove accumulated grease and settled solids, restoring separation volume.

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Criteria to Ensure Separation

- Time: retention time to allow emulsified grease and oil to separate and float.
- Temperature: adequate volume to allow wastewater to cool, allowing FOG to separate.
- Turbulence: during high discharge rates, ensure solids and grease are not kept in suspension.

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Passive Separation Devices

- Small Point-of-Use Interceptors:
 - installed near wastewater source
 - under the counter or in the floor adjacent to the source of the wastewater, such as a sink or dishwasher
 - fabricated steel
 - sized by storage capacity and flow

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Passive Separation Devices

- Precast In-Ground Traps:
 - concrete with min. 2 compartments separated by full width baffle
 - 2 manholes for cleaning/inspection
 - Above inlet and outlet
 - min. 2 hrs detention time at design flow, modified by a loading factor
 - inspect and clean regularly
 - Generally not less than monthly
 - sampling ports in inlet and outlet piping

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Automatic Separation Devices

- Trap and remove free-floating grease and oils (and sometimes accumulated solids)
- Stainless steel enclosure, internal baffles, removable solids separator screen, grease level sensing probe, electric heater element, and skimmer or dipper.

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Automatic Separation Devices

- Heat accumulated grease to 115-130°F so it melts and can be dipped or skimmed off to a separate storage container.
- Typically not located after dishwashers since detention times are inadequate to break hot, detergent-laden grease and water emulsions.

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Disposal Options: Pumping

- Ultimate disposal of FOG is important part of a FOG control program.
- Traps should generally be pumped when grease and solids combined measure 30% of the depth of the tank.
- TDEC recommends pumping the entire contents of the trap, followed by cleaning with a scraper. Tees, baffles and bottom are then inspected.

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Disposal Options: Recycling

- Encourage facility managers stress waste cooking oil be placed only in recycle container
- Recycled grease trap uses: dust suppressant, manufacturing lubricant, and binder for pesticides and fertilizers to help them stick to plants when sprayed on fields.
 - Fuel substitute for natural gas

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Disposal Options: WWTP

- Some sewage treatment plants have the ability to treat grease trap waste hauled to the plant.
- Animal and vegetable FOG is degradeable by wastewater microorganisms, but there are problems associated with this treatment.
 - BOD level of FOG is 10,000 – 30,000 mg/L
- Aeration basin
 - Longer solids detention time
 - More biomass
 - FOG will contribute to filamentous growth
 - Nocardia, M. parvicella

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Disposal Options: Land Application

- To landfill, must pass paint filter test.
- Most grease trap waste contains free water, so must therefore be dewatered:
 - add absorbent (sawdust, straw, etc.)
 - mechanical drying or drying bed
 - mechanical dewatering (JEA uses gravity draining and vacuum filtration with polymer)

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Education

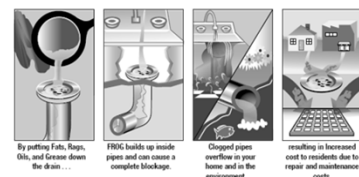
- To ensure your FOG control program is successful, you must educate:
 - public officials
 - restaurants and other facilities
 - recyclers
 - public (civic and environmental groups, scouts, local media, etc.)

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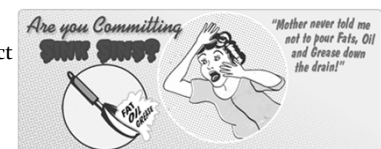
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Education

- Coral Springs, FL



- West Valley Sanitation District



- City of Franklin, TN "Grease Busters"

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Information Sources

- Tennessee Oil and Grease Control Guidance Document
 - <https://www.tn.gov/content/dam/tn/environment/water/documents/GuidanceCover2.pdf>
- EPA National Pretreatment Program (40 CFR 403)
 - <https://www.epa.gov/npdes/part-403-general-pretreatment-regulations-existing-and-new-sources-pollution>
- North Carolina Dept. of Environmental Quality
 - <https://deq.nc.gov/conservation/recycling/recyclable-materials/fats-used-cooking-oils-grease>

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Any Questions?



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Review Questions – Fats, Oil, and Grease

1. Which of the following is not a contributing factor to FOG problems in cities throughout the country?
 - a. Restaurants
 - b. Aging Collection Systems
 - c. Larger hogs being bred
 - d. Lack of disposal options

2. Which federal document prohibits petroleum oils, non-biodegradable cutting oils, or products of mineral origin from being disposed of in the sewer system?
 - a. 40 CFR 136
 - b. 40 CFR 403
 - c. 40 CFR 503
 - d. 40 CFR 129

3. Cities do not need regulatory documents that allow them to specify limits and enforce FOG discharges because the EPA monitors these discharges.
 - a. True
 - b. False

4. Grease blockages may lead to sewage backup at service laterals or manholes.
 - a. True
 - b. False

5. Grease traps are not effective if temperature is too high.
 - a. True
 - b. False

6. Instead of numerical limits, cities may use temperature limits for grease trap effluent.
 - a. True
 - b. False

7. Preventing FOG buildup in the collection system is the main goal of FOG control measures.
 - a. True
 - b. False

8. Best Management Practices are an effective tool in controlling FOG. Some of these practices include
 - a. Dry wiping pots, pans, and dishware
 - b. Discontinuing use of garbage grinders/disposals
 - c. Placing oil recycle containers in convenient locations so that restaurant employees can easily use them

- d. All of the above
9. A composite sample should be used for FOG laboratory analysis.
 - a. True
 - b. False
 10. FOG samples should be collected in a wide-mouth plastic container.
 - a. True
 - b. False
 11. What is the hold time for a FOG sample that is being refrigerated at 6 degrees C?
 - a. 8 hours
 - b. 36 hours
 - c. 24 hours
 - d. 28 days
 12. Which of the following is not a type of grease removal devices?
 - a. Passive under sink devices
 - b. Large outside passive devices
 - c. In-sink mesh drain screens
 - d. Mechanical devices
 13. Which of the following is not a factor that is required to ensure separation of FOG and wastewater?
 - a. Adequate Retention Time
 - b. Proper Temperature
 - c. Proper pH
 - d. Turbulence
 14. Grease traps should be pumped completely and then cleaned with a scraper.
 - a. True
 - b. False
 15. FOG in an aeration basin does not contribute to the growth of filamentous bacteria.
 - a. True
 - b. False
 16. To dispose of FOG from a grease trap in a landfill, it must first pass the paint filter test.
 - a. True
 - b. False
 17. Public education is of key importance in ensuring your FOG control program is successful.
 - a. True
 - b. False

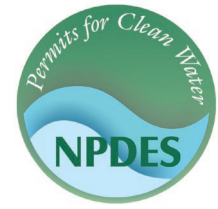
Answers:

1. C
2. B
3. B
4. A
5. A
6. A
7. A
8. D
9. B
10. B
11. D
12. C
13. C
14. A
15. B
16. A
17. A



National Pretreatment Program

(40 CFR 403)



Controlling Fats, Oils, and Grease Discharges from Food Service Establishments

Summary

The National Pretreatment Program implements Clean Water Act requirements to control pollutants that are introduced into POTWs. As part of this program, EPA has promulgated General Pretreatment Regulations that require the establishment of State and local pretreatment programs to control pollutants which pass through or interfere with POTW treatment processes or may contaminate POTW sewage sludge. Meeting these requirements may require elimination of interference caused by the discharge to POTWs of Fats, Oils, and Grease (FOG) from food service establishments (FSE). More specifically, the Pretreatment Program regulations at 40 CFR 403.5(b)(3) prohibit "solid or viscous pollutants in amounts which will cause obstruction" in the POTW and its collection system.

What is the environmental problem with FOG discharges into sewers?

EPA's Report to Congress on combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) identified that "grease from restaurants, homes, and industrial sources are the most common cause (47%) of reported blockages. Grease is problematic because it solidifies, reduces conveyance capacity, and blocks flow." See Impacts and Controls of CSOs and SSOs, EPA-833-R-04 001, August 2004.

Controlling FOG discharges will help POTWs prevent blockages that impact CSOs and SSOs, which cause public health and water quality problems. Controlling FOG discharges from FSEs is an essential element in controlling CSOs and SSOs and ensuring proper operations for many POTWs. The interference incidents identified in CSO/SSO Report to Congress may indicate the need for additional oversight and enforcement of existing regulations and controls. See 71 FR 76660 (21 December 2006).

What is the source of FOG at Food Service Establishments?

FOG wastes are generated at food service establishments (FSEs) as byproducts from food preparation activities. FOG captured on-site is generally classified into two broad categories: yellow grease and grease trap waste. Yellow grease is derived from used cooking oil and waste greases that are separated and collected at the point of use by the food service establishment.

The annual production of collected grease trap waste and uncollected grease entering sewage treatment plants can be significant and ranges from 800 to 17,000 pounds/year per restaurant.

What is the legal authority for POTWs to require FSEs to control FOG discharges?

The National Pretreatment Program already provides the necessary regulatory tools and authority to local pretreatment programs for controlling interference problems. Under the provisions of Part 403.5(c)(1) & (2), a POTW must establish and enforce specific local limits for industrial users to prevent interference with the operation of the municipally-owned treatment works in the following circumstances:

- (1) POTWs with approved pretreatment programs;
 - (2) POTWs that have experienced Interference or Pass-Through and such violation is likely to recur.
- See also 46 FR 9406 (28 January 1981).

Consequently, pretreatment oversight programs should include activities designed to identify and control sources of potential interference and, in the event of actual interference, enforcement against the violator.

How do POTWs determine whether they have FOG issues and how to address them?

POTWs should base their FOG programs on knowledge of their systems and a suite of best practices that have proven to reduce FOG discharges and related backups in their collection systems. These efforts are often best implemented through a Capacity, Management, Operations, and Maintenance (CMOM) or an Asset Management program which provides a framework for addressing FOG and other collection system challenges.

The use of Geographic Information System (GIS) mapping to inventory and locate entities that produce FOG constituents, paired with a complaint database that notes when FOG is responsible for blockages, can be a powerful tool in assessing problems and developing solutions. With knowledge of the sources and of

problems areas, a number of steps can then be taken to ensure that FOG does not impact the smooth functioning of the system. A POTW may work towards amending or putting in place a FOG ordinance to be followed in the community, or establish design requirements for grease traps or other structures to prevent FOG from entering the collection system. POTWs should establish an enforcement program to ensure compliance with FOG related policies and ordinances, including an inspection program to ensure that related equipment is working properly. In addition, POTWs may target or prioritize cleaning of the distribution systems based on discharges due to FOG or other root causes. For examples of controls, local limits, and/or pollution prevention measures, see “Where can I get more information?” below).

How can CMOM help control FSE FOG discharges?

EPA expects that blockages from FOG discharges will decrease as POTWs incorporate FOG reduction activities into their Capacity, Management, Operations, and Maintenance (CMOM) program and daily practices. CMOM programs are comprehensive, dynamic, utility specific programs for better managing, operating and maintaining sanitary sewer collection systems, investigating capacity constrained areas of the collection system, and responding to SSOs.

Collection system owners or operators who adopt FOG reduction activities as part of their CMOM program activities are likely to reduce the occurrence of sewer overflows and improve their operations and customer service.

What can FSEs do to control FOG discharges?

Food service establishments can adopt a variety of best management practices or install interceptor/collector devices to control and capture the FOG material before discharge to the POTW collection system. For example, instead of discharging yellow grease to POTWs, food service establishments often accumulate this material for pick up by consolidation service companies for re-sale or re-use in the manufacture of tallow, animal feed supplements, fuels, or other products.

Additionally, food service establishments can install interceptor/collector devices (e.g., grease traps) in order to accumulate grease on-site and prevent it from entering the POTW collection system.

How should FSEs design and maintain their FOG controls?

Proper design, installation, and maintenance procedures are critical for these devices to control and capture the FOG. For example,

- ◆ Interceptor/collector devices must be designed and sized appropriately to allow FOG to cool and separate in a non-turbulent environment.
- ◆ FSE must be diligent in having their interceptor/collector devices serviced at regular intervals.

The required maintenance frequency for interceptor/collector devices depends greatly on the amount of FOG a facility generates as well as any best management practices (BMPs) that the establishment implements to reduce the FOG discharged into its sanitary sewer system.

In many cases, an establishment that implements BMPs will realize financial benefit through a reduction in their required grease interceptor and trap maintenance frequency.

What are some POTWs doing today to control FOG discharges from FSEs?

A growing number of control authorities are using their existing authority (e.g., general pretreatment standards in Part 403 or local authority) to establish and enforce more FOG regulatory controls (e.g., numeric pretreatment limits, best management practices including the use of interceptor/collector devices) for food service establishments to reduce interferences with POTW operations (e.g., blockages from fats, oils, and greases discharges, POTW treatment interference from *Nocardia filamentous* foaming, damage to collection system from hydrogen sulfide generation).

For example, since identifying a 73% non-compliance rate with its grease trap ordinance among restaurants, New York City has instituted a \$1,000-per-day fine for FOG violations.

Likewise, more and more POTWs are addressing FOG discharges by imposing mandatory measures of assorted kinds, including inspections, periodic grease pumping, stiff penalties, and even criminal citations for violators, along with 'strong waste' monthly surcharges added to restaurant sewer bills. Surcharges are reportedly ranging from \$100 to as high as \$700 and

more, the fees being deemed necessary to cover the cost of inspections and upgraded infrastructure. Pretreatment programs are developing and using inspection checklists for both food service establishments and POTW pretreatment inspectors to control FOG discharges. Additionally, EPA identified typical numeric local limits controlling oil and grease in the range of 50 mg/L to 450 mg/L with 100 mg/L as the most commonly reported numeric pretreatment limit.

Where can I get more information?

Report to Congress: Impacts and Controls of CSOs and SSOs, EPA-833-R-04 001, August 2004, http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm

Local Limits Development Guidance, EPA-833-R-04-002A, July 2004, and EPA's Pretreatment Web site, http://cfpub.epa.gov/npdes/home.cfm?program_id=3

CMOM information is located in the following document, Guide for Evaluating Capacity, Management, Operation, and Maintenance (CMOM) Programs at Sanitary Sewer Collection Systems, EPA-305-B-05-002, January 2005, http://www.epa.gov/npdes/pubs/cmom_guide_for_collection_systems.pdf

Additional information is also available from your state or EPA Region.

OPERATOR ESSENTIALS

What every operator should know about fats, oils, and grease

Rhonda Harris



| Knowledge | Principles | A practical consideration |
|---------------------------|--|--|
| What is FOG? | FOG, which generally refers to “fats, oils, and grease,” is not a single compound with a single set of distinctive features. It is a family of chemicals with a common link of solubility in hexane, and various other features. | <p>FOG is</p> <ul style="list-style-type: none"> • congealable – solidifies at room temperature; • floatable – specific gravity is less than 1 g/mL; • soluble – dissolves in water; and • emulsive – forms oil–water emulsions. <p>FOG also can be</p> <ul style="list-style-type: none"> • animal or vegetable in origin – usually biodegradable; • petroleum or mineral in origin – may carry volatile organics or other contaminants; • biodegradable – consumed by organisms as food; • nonbiodegradable – inert and not consumed as food; and • foaming – may be caused by surfactants and surface attractive agents. |
| Where does FOG come from? | <p>FOG typically enters the municipal sewers from residential, commercial, and industrial establishments. These dischargers dump their waste FOG down the drain. This is most common for residences, either single-family or multifamily.</p> <p>Restaurants and other commercial and industrial establishments typically fall under a pretreatment program for their community and are not allowed to discharge their FOG wastes directly to the municipal sewer.</p> | Commercial and industrial establishments usually have grease traps or other collection systems, which are then pumped out and disposed of by a contractor. Many municipal or regional water resource recovery facilities accept this waste. This practice, at least, keeps FOG out of the sewers, where it can accumulate, plug pipes, and cause overflows. However, FOG still must be dealt with at the facility. |

| Knowledge | Principles | A practical consideration |
|--|---|--|
| When and where does FOG show up? | <p>FOG will show up in the collection system.</p> <p>FOG also will show up at the treatment facility.</p> <p>Some utilities accept FOG as a hauled waste at a specific location within the facility.</p> | <p>There is a direct correlation in many cities between the amount of FOG in the collection system and the number of restaurants in a specific area, even though most restaurants have grease traps.</p> <p>FOG can build up in pipes, reducing the capacity of lines and even causing blockages and overflows, which must be handled on an emergency basis. This incurs extra expense for the utility, as well as the problem of dealing with regulatory agencies regarding the overflow.</p> <p>FOG can interfere with the influent pumps and wet wells or enter primary clarifiers as floating scum.</p> <p>This can work well if the FOG is used as a booster in the anaerobic digestion system for generating gas production.</p> <p>If this is the case, the facility may want to use a dual equalization tank for accepting FOG to allow time for separation, as well as allow for a continuous low rate feed to the digesters.</p> |
| Why is FOG a problem for operators? | <p>FOG can coat equipment and walls in the influent pump station, creating a nuisance that must be removed manually from the wet wells.</p> <p>If FOG is petroleum-based, it may contain some levels of benzene, toluene, ethylbenzene, xylene, and/or other volatile organic compounds.</p> | <p>FOG may have entrapped materials that are toxic to the microorganisms in the biological treatment system.</p> <p>In this case, FOG can pose an explosion hazard to the sewer system and lift stations, so this type of FOG should be regulated and/or prohibited.</p> |
| How do we as operators deal with FOG? | <p>Most municipalities have regulations that help minimize FOG in the sewer, but some FOG always will make its way down to the treatment facility.</p> | <p>It is helpful for the collection system operations staff to keep a map updated with the problem-prone areas for blockages and reduced capacity so that the appropriate authorities can go out to inspect and monitor these areas for "bad actors" – restaurants with overflowing grease traps, industries not disposing of their wastes properly, etc.</p> <p>This way, the operators hopefully can minimize the effects of FOG and reduce the number of sewer-plugging and overflow incidents.</p> <p>At the treatment facility, operators must minimize the effects by trapping FOG as early as possible and removing it from the process.</p> |
| What are some of the operational issues? | <p>When FOG reaches the treatment facility, if it does not congeal and is biodegradable, the only issues are excess biochemical oxygen demand loading and oxygen demand.</p> <p>Emulsified FOG and surfactants raise more questions and require additional investigation before being accepted.</p> | <p>Operators always should determine FOG's composition, how it is made, and whether it has any other special properties.</p> <p>If FOG is hauled in for introduction to an anaerobic digester, it can produce revenue, but only if the digester is designed to handle the FOG. This dosing must be monitored closely.</p> |

Asking the right questions and being aware of the types of FOG coming into a system and treatment facility enables municipalities and/or utilities to begin to see FOG as an opportunity rather than a problem. The key to success in managing a FOG program is due diligence in this process. The bottom line: "Know your FOG!"

Rhonda Harris is an "A" Operator, as well as director of consulting and training services, in the CH2M Hill (Englewood, Colo.) Operations Management Business Group in Dallas and Vancouver, British Columbia.

Section 10

Tennessee Regulations



**RULES
OF THE
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION**

**CHAPTER 0400-40-03
GENERAL WATER QUALITY CRITERIA**

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0400-40-03-.01 TENNESSEE BOARD OF WATER QUALITY, OIL AND GAS.

The Water Quality Control Act, T.C.A., § 69-3-101, et seq., makes it the duty of the Board of Water Quality, Oil and Gas to study and investigate all problems concerned with the pollution of the Waters of the State and with its prevention, abatement, and control; and to establish such standards of quality for any Waters of the State in relation to their reasonable and necessary use as the Board shall deem to be in the public interest; and establish general policies relating to pollution as the Board shall deem necessary to accomplish the purposes of the Act. The following general considerations and criteria shall be used to determine the permissible conditions of waters with respect to pollution and preventative or corrective measures required to control pollution in various waters or in different sections of the same waters.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.02 GENERAL CONSIDERATIONS.

- (1) Tennessee water quality standards shall consist of the General Water Quality Criteria and the Antidegradation Statement found in Chapter 0400-40-03, and the Use Classifications for Surface Waters found in Chapter 0400-40-04.
- (2) Waters have many uses which in the public interest are reasonable and necessary. Such uses include: sources of water supply for domestic and industrial purposes; propagation and maintenance of fish and other aquatic life; recreation in and on the waters including the safe consumption of fish and shellfish; livestock watering and irrigation; navigation; generation of power; propagation and maintenance of wildlife; and the enjoyment of scenic and aesthetic qualities of waters.
- (3) The rigid application of uniform water quality is not desirable or reasonable because of the varying uses of such waters. The assimilative capacity of a stream for sewage and waste varies depending upon various factors and including the following: volume of flow, depth of channel, the presence of falls or rapids, rate of flow, temperature, natural characteristics, and the nature of the stream.
- (4) In order to permit the reasonable and necessary uses of the Waters of the State, existing pollution should be corrected as rapidly as practicable, and future pollution prevented through the best available technology economically achievable or that greater level of technology necessary to meet water quality standards; i.e., modeling and stream survey assessments, treatment plants or other control measures.

(Rule 0400-40-03-.02, continued)

- (5) Since all Waters of the State are classified for more than one use, the most stringent criteria will be applicable. In cases where criteria for protection of more than one use apply at different stream flows (e.g., aquatic life versus recreation), the most protective will also be applicable.
- (6) Waters identified as wet weather conveyances according to the definition found in Rule 0400-40-03-.04, shall be protective of humans and wildlife that may come in contact with them and shall not adversely affect the quality of downstream waters. Applicable water quality standards will be maintained downstream of wet weather conveyances.
- (7) Where general water quality criteria are applied on a regional, ecoregional, or subecoregional basis, these criteria will be considered to apply to a stream if eighty percent (80%) of its watershed or catchment is contained within the unit upon which the criterion is based.
- (8) All fish and aquatic life metals criteria are expressed as total recoverable, except cadmium, copper, lead, nickel, silver, and zinc which are expressed as dissolved. Translators will be used to convert the dissolved fraction into a total recoverable permit limit. One of three approaches to metals translation will be used: (1) translator is the same as the conversion factor, (2) translator is based on relationships derived from STORET data, (3) a site-specific translator is developed. Where available, a site-specific translator is preferred. For assessing whether criteria for cadmium, copper, lead, nickel, silver, and zinc are exceeded by ambient water quality conditions, the dissolved criteria will also be translated in order to allow direct comparison to the ambient data, if total recoverable.
- (9) Site-specific criteria studies may be conducted on any appropriate fish and aquatic life criteria.
 - (a) Site-specific criteria studies based on a Water Effects Ratio (WER) calculated from the documented toxicity of a parameter in the stream in which it will be introduced may supersede the adopted criteria at a site. The Division shall approve a site-specific criteria developed by others provided that the WER methodology [Interim Guidance on Determination and Use of Water-effect Ratios for Metals (EPA-823-B-94-001)] is used, both the study plan and results are approved by the Department, and the U.S. Environmental Protection Agency has concurred with the final site specific criterion value(s).
 - (b) Any site specific criterion based on methodologies other than the WER methodology which recalculate specific criterion, such as the Resident Species Method or the Recalculation Method, must be adopted as a revision to Tennessee water quality standards into this Chapter, and following EPA approval, can be used for Clean Water Act purposes.

References on this subject include, but are not limited to: Technical Support Document for Water Quality-based Toxics Control (EPA - 505/2-90-001); Technical Guidance Manual for Performing Waste Load Allocations: Book VIII (EPA/600/6-85/002a/002b/002c); MinteqA2, An Equilibrium Metal Speciation Model (EPA/600/3-87/012); Water Quality Standards Handbook, Second Edition (EPA-823-B-93-002); The Metals Translator: Guidance for Calculating a Total Recoverable Permit Limit From a Dissolved Criteria (EPA-823-B-96-007); Interim Guidance on Determination and Use of Water-effect Ratios for Metals (EPA-823-B-94-001).

- (10) Interpretation and application of narrative criteria shall be based on available scientific literature and EPA guidance and regulations.

(Rule 0400-40-03-.02, continued)

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.03 CRITERIA FOR WATER USES.

- (1) The criteria for the use of Domestic Water Supply are the following.
 - (a) Dissolved Oxygen - There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.
 - (b) pH - The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.
 - (c) Hardness or Mineral Compounds - The hardness of or the mineral compounds contained in the water shall not appreciably impair the usefulness of the water as a source of domestic water supply.
 - (d) Total Dissolved Solids - The total dissolved solids shall at no time exceed 500 mg/l.
 - (e) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as may impair the usefulness of the water as a source of domestic water supply.
 - (f) Turbidity or Color - There shall be no turbidity or color in amounts or characteristics that cannot be reduced to acceptable concentrations by conventional water treatment processes (See definition).
 - (g) Temperature - The maximum water temperature change shall not exceed 3°C relative to an upstream control point. The temperature of the water shall not exceed 30.5°C and the maximum rate of change shall not exceed 2°C per hour. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet or mid-depth, whichever is less, and the temperature in flowing streams shall be measured at mid-depth.
 - (h) Coliform - The concentration of the E. coli group shall not exceed 630 per 100 ml as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purpose of determining the geometric mean, individual samples having an E. coli group concentration of less than 1 per 100 ml shall be considered as having a concentration of 1 per 100 ml.
 - (i) Taste or Odor - The waters shall not contain substances which will result in taste or odor that prevent the production of potable water by conventional water treatment processes.
 - (j) Toxic Substances - The waters shall not contain toxic substances, whether alone or in combination with other substances, which will produce toxic conditions that materially affect the health and safety of man or animals, or impair the safety of conventionally treated water supplies. Available references include, but are not limited to: Quality Criteria for Water (Section 304(a) of Public Law 92-500 as amended); Federal Regulations under Section 307 of Public Law 92-500 as amended; and Federal Regulations under Section 1412 of the Public Health Service Act as amended by the Safe Drinking Water Act, (Public Law 93-523). Limits set for some of the most commonly occurring toxic substances are as follows:

(Rule 0400-40-03-.03, continued)

| Compound | Criteria (µg/L) | Compound | Criteria (µg/L) |
|--|--------------------|----------------------------|--------------------|
| Antimony | 6 | Diquat | 20 |
| Arsenic | 10 | Endothall | 100 |
| Beryllium | 4 | Glyphosate | 700 |
| Barium | 2000 | Hexachlorobenzene | 1 |
| Cadmium | 5 | Hexachlorocyclopentadiene | 50 |
| Chromium, total | 100 | Oxamyl (Vydate) | 200 |
| Lead | 5 | Picloram | 500 |
| Cyanide (as free cyanide) | 200 | Simazine | 4 |
| Mercury | 2 | 2,3,7,8 TCDD (Dioxin) | 0.00003 |
| Nickel | 100 | Benzene | 5 |
| Selenium | 50 | Carbon tetrachloride | 5 |
| Thallium | 2 | 1,2-Dichloroethane | 5 |
| Alachlor | 2 | 1,1-Dichloroethylene | 7 |
| Atrazine | 3 | 1,1,1-Trichloroethane | 200 |
| Carbofuran | 40 | Trichloroethylene | 5 |
| Chlordane | 2 | Vinyl chloride | 2 |
| Dibromo chloropropane | 0.2 | para-Dichlorobenzene | 75 |
| 2,4 Dichlorophenoxyacetic Acid | 70 | cis 1,2-Dichloroethylene | 70 |
| Ethylene dibromide | 0.05 | 1,2-Dichloropropane | 5 |
| Heptachlor | 0.4 | Ethyl benzene | 700 |
| Heptachlor epoxide | 0.2 | Monochlorobenzene | 100 |
| Lindane | 0.2 | ortho-Dichlorobenzene | 600 |
| Methoxychlor | 40 | Styrene | 100 |
| Polychlorinated biphenyls | 0.5 | Tetrachloroethylene | 5 |
| 2,4,5 Trichlorophenoxy xyprionic acid | 50 | Toluene | 1000 |
| Pentachlorophenol | 1 | trans 1,2-Dichloroethylene | 100 |
| Benzo(a)pyrene | 0.2 | Xylenes, total | 10000 |
| Dalapon | 200 | Dichloromethane | 5 |
| Di(2-ethylhexyl) adipate | 400 | 1,2,4-Trichlorobenzene | 70 |
| Di(2-ethylhexyl) phthalate | 6 | 1,1,2-Trichloroethane | 5 |
| Dinoseb | 7 | Endrin | 2.0 |
| | | Toxaphene | 3 |
| | | Nitrate | 10000 |

(k) Other Pollutants - The waters shall not contain other pollutants in quantities that may be detrimental to public health or impair the usefulness of the water as a source of domestic water supply.

(2) The criteria for the use of Industrial Water Supply are the following.

(a) Dissolved Oxygen - There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

(b) pH - The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

(c) Hardness or Mineral Compounds - The hardness of or the mineral compounds contained in the water shall not appreciably impair the usefulness of the water as a source of industrial water supply.

(d) Total Dissolved Solids - The total dissolved solids shall at no time exceed 500 mg/l.

(Rule 0400-40-03-.03, continued)

- (e) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as may impair the usefulness of the water as a source of industrial water supply.
 - (f) Turbidity or Color - There shall be no turbidity or color in amounts or characteristics that cannot be reduced to acceptable concentrations by conventional water treatment processes.
 - (g) Temperature - The maximum water temperature change shall not exceed 3°C relative to an upstream control point. The temperature of the water shall not exceed 30.5°C and the maximum rate of change shall not exceed 2°C per hour. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet or mid-depth, whichever is less, and the temperature in flowing streams shall be measured at mid-depth.
 - (h) Taste or Odor - The waters shall not contain substances which will result in taste or odor that would prevent the use of the water for industrial processing.
 - (i) Toxic Substances - The waters shall not contain toxic substances whether alone or in combination with other substances, which will adversely affect industrial processing.
 - (j) Other Pollutants - The waters shall not contain other pollutants in quantities that may adversely affect the water for industrial processing.
- (3) The criteria for the use of Fish and Aquatic Life are the following.
- (a) Dissolved Oxygen - The dissolved oxygen shall not be less than 5.0 mg/l with the following exceptions.
 1. In streams identified as trout streams, including tailwaters, dissolved oxygen shall not be less than 6.0 mg/L.
 2. The dissolved oxygen concentration of trout waters designated as supporting a naturally reproducing population shall not be less than 8.0 mg/L. (Tributaries to trout streams or naturally reproducing trout streams should be considered to be trout streams or naturally reproducing trout streams, unless demonstrated otherwise. Additionally, all streams within the Great Smoky Mountains National Park should be considered naturally reproducing trout streams.)
 3. In wadeable streams in subcoregion 73a, dissolved oxygen levels shall not be less than a daily average of 5.0 mg/L with a minimum dissolved oxygen level of 4.0 mg/L.
 4. The dissolved oxygen level of streams in ecoregion 66 (Blue Ridge Mountains) not designated as naturally reproducing trout streams shall not be less than 7.0 mg/L.

Substantial and/or frequent variations in dissolved oxygen levels, including diurnal fluctuations, are undesirable if caused by man-induced conditions. Diurnal fluctuations shall not be substantially different than the fluctuations noted in reference streams in that region.

(Rule 0400-40-03-.03, continued)

In lakes and reservoirs, the dissolved oxygen concentrations shall be measured at mid-depth in waters having a total depth of ten feet or less, and at a depth of five feet in waters having a total depth of greater than ten feet and shall not be less than 5.0 mg/L.

- (b) pH - The pH value shall not fluctuate more than 1.0 unit over a period of 24 hours and shall not be outside the following ranges: 6.0 – 9.0 in wadeable streams and 6.5 – 9.0 in larger rivers, lakes, reservoirs, and wetlands.
- (c) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character that may be detrimental to fish and aquatic life.
- (d) Turbidity, Total Suspended Solids, or Color - There shall be no turbidity, total suspended solids, or color in such amounts or of such character that will materially affect fish and aquatic life. In wadeable streams, suspended solid levels over time should not be substantially different than conditions found in reference streams.
- (e) Temperature - The maximum water temperature change shall not exceed 3°C relative to an upstream control point. The temperature of the water shall not exceed 30.5°C and the maximum rate of change shall not exceed 2°C per hour. The temperature of recognized trout waters shall not exceed 20°C. There shall be no abnormal temperature changes that may affect aquatic life unless caused by natural conditions. The temperature in flowing streams shall be measured at mid-depth.

The temperature of impoundments where stratification occurs will be measured at mid-depth in the epilimnion (see definition in Rule 0400-40-03-.04) for warm water fisheries and mid-depth in the hypolimnion (see definition in Rule 0400-40-03-.04) for cold water fisheries. In the case of large impoundments (100 acres or larger) subject to stratification and recognized as trout waters, the temperature of the hypolimnion shall not exceed 20°C.

A successful demonstration as determined by the Department conducted for thermal discharge limitations under Section 316(a) of the Clean Water Act, (33 U.S.C. §1326), shall constitute compliance with this paragraph.

- (f) Taste or Odor - The waters shall not contain substances that will impart unpalatable flavor to fish or result in noticeable offensive odors in the vicinity of the water or otherwise interfere with fish or aquatic life. References include, but are not limited to: Quality Criteria for Water (section 304(a) of Public Law 92-500 as amended).
- (g) Toxic Substances - The waters shall not contain substances or a combination of substances including disease - causing agents which, by way of either direct exposure or indirect exposure through food chains, may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), physical deformations, or restrict or impair growth in fish or aquatic life or their offspring. References on this subject include, but are not limited to: Quality Criteria for Water (Section 304(a) of Public Law 92-500 as amended); Federal Regulations under Section 307 of Public Law 92-500 as amended. The following criteria are for the protection of fish and aquatic life:

| Compound | Criterion Maximum Concentration µg/L (CMC) | Criterion Continuous Concentration µg/L (CCC) |
|----------------|--|---|
| Arsenic (III)* | 340 | 150 |
| Cadmium** | 2.0 | 0.25 |

(Rule 0400-40-03-.03, continued)

| | | |
|------------------------|-------|--------|
| Chromium, III** | 570 | 74 |
| Chromium, VI* | 16 | 11 |
| Copper** | 13 | 9.0 |
| Lead** | 65 | 2.5 |
| Mercury* (b) | 1.4 | 0.77 |
| Nickel** | 470 | 52 |
| Selenium | 20 | 5 |
| Silver** | 3.2 | --- |
| Zinc** | 120 | 120 |
| Cyanide*** | 22 | 5.2 |
| Chlorine (TRC) | 19 | 11 |
| Pentachlorophenol **** | 19 | 15 |
| Aldrin | 3.0 | --- |
| g-BHC – Lindane (b) | 0.95 | --- |
| Chlordane (b) | 2.4 | 0.0043 |
| 4-4'-DDT (b) | 1.1 | 0.001 |
| Demeton | ---- | 0.1 |
| Diazinon | 0.1 | 0.1 |
| Dieldrin (b) | 0.24 | 0.056 |
| a-Endosulfan | 0.22 | 0.056 |
| b-Endosulfan | 0.22 | 0.056 |
| Endrin | 0.086 | 0.036 |
| Guthion | ---- | 0.01 |
| Heptachlor | 0.52 | 0.0038 |
| Heptachlor epoxide | 0.52 | 0.0038 |
| Malathion | ---- | 0.1 |
| Methoxychlor | ---- | 0.03 |
| Mirex (b) | ---- | 0.001 |
| Nonylphenol | 28.0 | 6.6 |
| Parathion | 0.065 | 0.013 |
| PCBs, total (b) | --- | 0.014 |
| Toxaphene (b) | 0.73 | 0.0002 |
| Tributyltin (TBT) | 0.46 | 0.072 |

(b) Bioaccumulative parameter.

* Criteria for these metals are expressed as dissolved.

** Criteria for these metals are expressed as dissolved and are a function of total hardness (mg/L). Hardness-dependent metals criteria may be calculated from the following (values displayed above correspond to a total hardness of 100 mg/l and may have been rounded):

$$\text{CMC (dissolved)} = \exp\{mA[\ln(\text{hardness})]+bA\} \text{ (CF)}$$

$$\text{CCC (dissolved)} = \exp\{mC [\ln(\text{hardness})]+bC\} \text{ (CF)}$$

| Chemical | MA | bA | MC | BC | Freshwater Conversion Factors (CF) | |
|--------------|--------|--------|--------|--------|--|--|
| | | | | | CMC | CCC |
| Cadmium | 1.0166 | -3.924 | 0.7409 | -4.719 | $1.136672-[(\ln \text{hardness})(0.041838)]$ | $1.101672-[(\ln \text{hardness})(0.041838)]$ |
| Chromium III | 0.8190 | 3.7256 | 0.8190 | 0.6848 | 0.316 | 0.860 |

(Rule 0400-40-03-.03, continued)

| | | | | | | |
|--------|--------|--------|--------|--------|-----------------------------------|-----------------------------------|
| Copper | 0.9422 | -1.700 | 0.8545 | -1.702 | 0.960 | 0.960 |
| Lead | 1.273 | -1.460 | 1.273 | -4.705 | 1.46203-[(ln hardness)(0.145712)] | 1.46203-[(ln hardness)(0.145712)] |
| Nickel | 0.8460 | 2.255 | 0.8460 | 0.0584 | 0.998 | 0.997 |
| Silver | 1.72 | -6.59 | | | 0.85 | |
| Zinc | 0.8473 | 0.884 | 0.8473 | 0.884 | 0.978 | 0.986 |

If criteria are hardness-dependent, the Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) shall be based on the actual stream hardness. When an ambient hardness of less than 25 mg/L is used to establish criteria for cadmium or lead, the hardness dependent conversion factor (CF) shall not exceed one. When ambient hardness is greater than 400 mg/L, criteria shall be calculated according to one of the following two options: (1) calculate the criterion using a default Water Effects Ratio (WER) of 1.0 and a hardness of 400 mg/L in the hardness based equation; or (2) calculate the criterion using a WER and the actual ambient hardness of the surface water in the hardness based equation. For information concerning metals translation and site-specific criteria, see paragraph (9) of Rule 0400-40-03-.02.

*** If Standard Methods 4500-CN I (Weak Acid Dissociable), 4500-CN G (Cyanides Amenable to Chlorination after Distillation), or OIA-1677 are used, this criterion may be applied as free cyanide.

**** Criteria for pentachlorophenol are expressed as a function of pH. Values displayed above correspond to a pH of 7.8 and are calculated as follows:

$$\text{CMC} = \exp(1.005(\text{pH}) - 4.869) \quad \text{CCC} = \exp(1.005(\text{pH}) - 5.134)$$

- (h) Other Pollutants - The waters shall not contain other pollutants that will be detrimental to fish or aquatic life.
- (i) Iron – The waters shall not contain iron at concentrations that cause toxicity or in such amounts that interfere with habitat due to precipitation or bacteria growth.
- (j) Ammonia – The one-hour average concentration of total ammonia nitrogen (in mg N/L) shall not exceed the CMC (acute criterion) calculated using the following equations:

Where salmonid fish are present:

$$\text{CMC} = \frac{0.275}{1 + 10^{7.204-\text{pH}}} + \frac{39.0}{1 + 10^{\text{pH}-7.204}}$$

Or where salmonid fish are not present:

$$\text{CMC} = \frac{0.411}{1 + 10^{7.204-\text{pH}}} + \frac{58.4}{1 + 10^{\text{pH}-7.204}}$$

The thirty-day average concentration of total ammonia nitrogen (in mg N/L) shall not exceed the CCC (chronic criterion) calculated using the following equations:

(Rule 0400-40-03-.03, continued)

When fish early life stages are present:

$$CCC = \left[\frac{0.0577}{1 + 10^{7.688 - \text{pH}}} + \frac{2.487}{1 + 10^{\text{pH} - 7.688}} \right] \cdot \text{MIN} (2.85, 1.45 \cdot 10^{0.028 \cdot (25 - T)})$$

When fish early life stages are absent:

$$CCC = \left[\frac{0.0577}{1 + 10^{7.688 - \text{pH}}} + \frac{2.487}{1 + 10^{\text{pH} - 7.688}} \right] \cdot 1.45 \cdot 10^{0.028 \cdot (25 - \text{MAX} (T, 7))}$$

In addition, the highest four-day average within the 30-day period shall not exceed 2.5 times the CCC.

- (k) Nutrients - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and/or the biological integrity fails to meet regional goals. Additionally, the quality of downstream waters shall not be detrimentally affected. Examples of parameters associated with the criterion include but are not limited to: nitrogen, phosphorus, potassium, calcium, magnesium, and various forms of each.

Interpretation of this provision may be made using the document Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion and/or other scientifically defensible methods.

- (l) Coliform - The concentration of the E. coli group shall not exceed 630 per 100 ml as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli group concentration of less than 1 per 100 ml shall be considered as having a concentration of 1 per 100 ml. In addition, the concentration of the E. coli group in any individual sample shall not exceed 2,880 per 100 ml.
- (m) Biological Integrity - The waters shall not be modified through the addition of pollutants or through physical alteration to the extent that the diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or, in the case of wadeable streams, substantially different from conditions in reference streams in the same ecoregion. The parameters associated with this criterion are the aquatic biota measured. These are response variables.

Interpretation of this provision for any stream which (a) has at least 80% of the upstream catchment area contained within a single bioregion and (b) is of the appropriate stream order specified for the bioregion and (c) contains the habitat (riffle or rooted bank) specified for the bioregion, may be made using the most current revision of the Department's Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys and/or other scientifically defensible methods.

Interpretation of this provision for all other wadeable streams, lakes, and reservoirs may be made using Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA/841-B-99-002) or Lake and Reservoir Bioassessment and Biocriteria (EPA 841-B-98-007), and/or other scientifically defensible methods. Interpretation of this

(Rule 0400-40-03-.03, continued)

provision for wetlands or large rivers may be made using scientifically defensible methods. Effects to biological populations will be measured by comparisons to upstream conditions or to appropriately selected reference sites in the same bioregion if upstream conditions are determined to be degraded.

- (n) Habitat - The quality of stream habitat shall provide for the development of a diverse aquatic community that meets regionally-based biological integrity goals. Examples of parameters associated with this criterion include but are not limited to: sediment deposition, embeddedness of riffles, velocity/depth regime, bank stability, and vegetative protection. Types of activities or conditions which can cause habitat loss include, but are not limited to: channel and substrate alterations, rock and gravel removal, stream flow changes, accumulation of silt, precipitation of metals, and removal of riparian vegetation. For wadeable streams, the in stream habitat within each subcoregion shall be generally similar to that found at reference streams. However, streams shall not be assessed as impacted by habitat loss if it has been demonstrated that the biological integrity goal has been met.
 - (o) Flow – Stream or other waterbody flows shall support the fish and aquatic life criteria.
- (4) The criteria for the use of Recreation are the following.
- (a) Dissolved Oxygen - There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.
 - (b) pH - The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.
 - (c) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character that may be detrimental to recreation.
 - (d) Total Suspended Solids, Turbidity or Color - There shall be no total suspended solids, turbidity or color in such amounts or character that will result in any objectionable appearance to the water, considering the nature and location of the water.
 - (e) Temperature - The maximum water temperature change shall not exceed 3°C relative to an upstream control point. The temperature of the water shall not exceed 30.5°C and the maximum rate of change shall not exceed 2°C per hour. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.
 - (f) Coliform - The concentration of the E. coli group shall not exceed 126 colony forming units per 100 ml, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 ml shall be considered as having a concentration of 1 per 100 ml.

Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, Exceptional Tennessee Water or ONRW (0400-40-03-.06) shall not exceed 487 colony forming units per 100 ml. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 ml.

(Rule 0400-40-03-.03, continued)

- (g) Taste or Odor - The waters shall not contain substances that will result in objectionable taste or odor.
- (h) Nutrients - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that the public's recreational uses of the waterbody or other downstream waters are detrimentally affected. Unless demonstrated otherwise, the nutrient criteria found in subparagraph (3)(k) of this rule will be considered adequately protective of this use.
- (i) Nutrient Response Criteria for Pickwick Reservoir: those waters impounded by Pickwick Dam on the Tennessee River. The reservoir has a surface area of 43,100 acres at full pool, 9,400 acres of which are within Tennessee. Chlorophyll a (corrected, as described in Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998): the mean of the photic-zone (See definition) composite chlorophyll a samples collected monthly April through September shall not exceed 18 µg/L, as measured over the deepest point, main river channel, dam forebay.
- (j) Toxic Substances - The waters shall not contain toxic substances, whether alone or in combination with other substances, that will render the waters unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish, or will propose toxic conditions that will adversely affect man, animal, aquatic life, or wildlife. Human health criteria have been derived to protect the consumer from consumption of contaminated fish and water. The water and organisms criteria should only be applied to those waters classified for both recreation and domestic water supply. The criteria for recreation are as follows:

(Rule 0400-40-03-.03, continued)

| Compound | Water & Organisms Criteria * (µg/L) | Organisms Only Criteria (µg/L) |
|-------------------|-------------------------------------|--------------------------------|
| <u>INORGANICS</u> | | |
| Antimony | 5.6 | 640 |
| Arsenic (c) | 10.0 | 10.0 |
| Mercury (b) | 0.05 | 0.051 |
| Nickel | 610 | 4600 |
| Thallium | 0.24 | 0.47 |
| Cyanide | 140 | 140 |
| Selenium | 170 | 4200 |
| Zinc | 7400 | 26000 |
| Dioxin ** (b) | 0.000001 | 0.000001 |

| | | |
|-------------------------------|------|-------|
| <u>VOLATILES</u> | | |
| Acrolein | 6 | 9 |
| Acrylonitrile (c) | 0.51 | 2.5 |
| Benzene (c) | 22 | 510 |
| Bromoform (c) | 43 | 1400 |
| Carbon tetrachloride (c) | 2.3 | 16 |
| Chlorobenzene | 130 | 1600 |
| Chlorodibromomethane (c) | 4.0 | 130 |
| Chloroform (c) | 57 | 4700 |
| Dichlorobromomethane (c) | 5.5 | 170 |
| 1,2-Dichloroethane (c) | 3.8 | 370 |
| 1,1-Dichloroethylene | 330 | 7100 |
| 1,2-Dichloropropane (c) | 5.0 | 150 |
| 1,3-Dichloropropene (c) | 3.4 | 210 |
| Ethylbenzene | 530 | 2100 |
| Methyl bromide | 47 | 1500 |
| Methylene chloride (c) | 46 | 5900 |
| 1,1,2,2-Tetrachloroethane (c) | 1.7 | 40 |
| Tetrachloroethylene (c) | 6.9 | 33 |
| Toluene | 1300 | 15000 |
| 1,2-Trans-Dichloroethylene | 140 | 10000 |
| 1,1,2-Trichloroethane (c) | 5.9 | 160 |
| Trichloroethylene (c) | 25 | 300 |
| Vinyl chloride (c) | 0.25 | 24 |

| Compound | Water & Organisms Criteria * (µg/L) | Organisms Only Criteria (µg/L) |
|--------------------------|-------------------------------------|--------------------------------|
| <u>ACID EXTRACTABLES</u> | | |
| 2-Chlorophenol | 81 | 150 |
| 2,4-Dichlorophenol | 77 | 290 |
| 2,4-Dimethylphenol | 380 | 850 |

(Rule 0400-40-03-.03, continued)

| | | |
|--|---------|---------|
| 2-Methyl-4,6-dinitrophenol | 13 | 280 |
| Dinitrophenols | 69 | 5300 |
| Pentachlorophenol (c) (pH) | 2.7 | 30 |
| Phenol | 10000 | 860000 |
| 2,4,6-Trichlorophenol (c) | 14 | 24 |
| BASE NEUTRALS | | |
| Acenaphthene | 670 | 990 |
| Anthracene | 8300 | 40000 |
| Benidine (c) | 0.00086 | 0.0020 |
| Benzo(a)anthracene (c) | 0.038 | 0.18 |
| Benzo(a)pyrene (c) | 0.038 | 0.18 |
| Benzo(b)fluoranthene (c) | 0.038 | 0.18 |
| Benzo(k)fluoranthene (c) | 0.038 | 0.18 |
| Bis(2-Chlorethyl)ether (c) | 0.30 | 5.3 |
| Bis(2-Chloro-isopropyl)ether | 1400 | 65000 |
| Bis(2-Ethylhexyl)phthalate (c) | 12 | 22 |
| Bis(Chloromethyl)ether (c) | 0.0010 | 0.0029 |
| Butylbenzyl Phthalate | 1500 | 1900 |
| 2-Chloronaphthalene | 1000 | 1600 |
| Chrysene (c) | 0.038 | 0.18 |
| Dibenz(a,h)Anthracene (c) | 0.038 | 0.18 |
| 1,2-Dichlorobenzene | 420 | 1300 |
| 1,3-Dichlorobenzene | 320 | 960 |
| 1,4-Dichlorobenzene | 63 | 190 |
| 3,3-Dichlorobenzidine (c) | 0.21 | 0.28 |
| Diethyl phthalate | 17000 | 44000 |
| Dimethyl phthalate | 270000 | 1100000 |
| Di-n-butyl phthalate | 2000 | 4500 |
| 2,4-Dinitrotoluene (c) | 1.1 | 34 |
| 1,2-Diphenylhydrazine (c) | 0.36 | 2.0 |
| Fluoranthene | 130 | 140 |
| Fluorene | 1100 | 5300 |
| Hexachlorobenzene (b)(c) | 0.0028 | 0.0029 |
| Hexachlorobutadiene (b)(c) | 4.4 | 180 |
| Hexachlorocyclohexane- Technical (b)(c) | 0.123 | 0.414 |
| Hexachlorocyclopentadiene | 40 | 1100 |
| Hexachloroethane (c) | 14 | 33 |
| Ideno(1,2,3-cd)Pyrene (c) | 0.038 | 0.18 |
| Isophorone (c) | 350 | 9600 |
| Nitrobenzene | 17 | 690 |
| Nitrosamines | 0.0008 | 1.24 |
| Nitrosodibutylamine (c) | 0.063 | 2.2 |
| Nitrosodiethylamine (c) | 0.008 | 12.4 |
| Nitrosopyrrolidine (c) | 0.16 | 340 |
| N-Nitrosodimethylamine (c) | 0.0069 | 30 |
| N-Nitrosodi-n-Propylamine (c) | 0.05 | 5.1 |
| N-Nitrosodiphenylamine (c) | 33 | 60 |

(Rule 0400-40-03-.03, continued)

| Compound | Water & Organisms Criteria * (µg/L) | Organisms Only Criteria (µg/L) |
|--------------------------------|-------------------------------------|--------------------------------|
| Pyrene | 830 | 4000 |
| Pentachlorobenzene (b) | 1.4 | 1.5 |
| 1,2,4,5-Tetrachlorobenzene (b) | 0.97 | 1.1 |
| 1,2,4-Trichlorobenzene | 35 | 70 |
| 2,4,5-Trichlorophenol | 1800 | 3600 |

PESTICIDES

| | | |
|------------------------|---------|---------|
| Aldrin (c) | 0.00049 | 0.00050 |
| a-BHC (c) | 0.026 | 0.049 |
| b-BHC (c) | 0.091 | 0.17 |
| g-BHC - Lindane (b) | 0.98 | 1.8 |
| Chlordane (b)(c) | 0.0080 | 0.0081 |
| 4-4'-DDT (b)(c) | 0.0022 | 0.0022 |
| 4,4'-DDE (b)(c) | 0.0022 | 0.0022 |
| 4,4'-DDD (b)(c) | 0.0031 | 0.0031 |
| Dieldrin (b)(c) | 0.00052 | 0.00054 |
| a-Endosulfan | 62 | 89 |
| b-Endosulfan | 62 | 89 |
| Endosulfan Sulfate | 62 | 89 |
| Endrin | 0.059 | 0.06 |
| Endrin Aldehyde | 0.29 | 0.30 |
| Heptachlor (c) | 0.00079 | 0.00079 |
| Heptachlor epoxide (c) | 0.00039 | 0.00039 |
| PCB, total (b)(c) | 0.00064 | 0.00064 |
| Toxaphene (b)(c) | 0.0028 | 0.0028 |

(b) Bioaccumulative parameter.

(c) 10-5 risk level is used for all carcinogenic pollutants.

* These criteria are for protection of public health due to consumption of water and organisms and should only be applied to these waters designated for both recreation and domestic water supply.

** Total dioxin is the sum of the concentrations of all dioxin and dibenzofuran isomers after multiplication by Toxic Equivalent Factors (TEFs). Following are the TEFs currently recommended by EPA (subject to revision):

| DIOXIN ISOMERS | TEF | FURAN ISOMERS | TEF |
|-----------------------|-----|-----------------------|------|
| Mono-, Di-, & TriCDDs | 0.0 | Mono-, Di-, & TriCDFs | 0.0 |
| 2,3,7,8 TCDD | 1.0 | 2,3,7,8 TCDF | 0.1 |
| Other TCDDs | 0.0 | Other TCDFs | 0.0 |
| 2,3,7,8 PeCDD | 0.5 | 1,2,3,7,8 PeCDF | 0.05 |
| Other PeCDDs | 0.0 | 2,3,4,7,8 PeCDF | 0.5 |
| | | Other PeCDFs | 0.0 |
| 2,3,7,8 HxCDD | 0.1 | Other PeCDFs | 0.0 |

(Rule 0400-40-03-.03, continued)

| | | | |
|---------------|-------|-------------------------------|------------|
| Other HxCDDs | 0.0 | 2,3,7,8 HxCDF Other HxCDFs | 0.1 0.0 |
| 2,3,7,8 HpCDD | 0.01 | 2,3,7,8 HpCDF | 0.01 |
| Other HpCDDs | 0.0 | Other HpCDFs | 0.0 |
| OCDD | 0.001 | OCDF | 0.001 |

- (k) Other Pollutants - The waters shall not contain other pollutants in quantities which may have a detrimental effect on recreation.
- (l) Fish Consumption Advisories - A public fishing advisory will be considered when the calculated risk of additional cancers exceeds 10⁻⁴ for typical consumers or 10⁻⁵ for atypical consumers (See definition). A "do not consume" advisory will be issued for the protection of typical consumers and a "precautionary advisory" will be issued for the protection of atypical consumers. The following formula will be used to calculate the risk of additional cancers:

$$R = qE$$

where:

R= Plausible-upper-limit risk of cancer associated with a chemical in a fisheries species for a human subpopulation.

q = Carcinogenic Potency Factor for the chemical (mg kg⁻¹ day⁻¹)⁻¹ estimated as the upper 95% confidence limit of the slope of a linear dose-response curve. Scientifically defensible Potency Factors will be used.

E = Exposure dose of the chemical (mg kg⁻¹ day⁻¹) from the fish species for the human subpopulation in the area. E is calculated by the following formula:

$$E = \frac{C \times I \times X}{W} \quad \text{where:}$$

C = Concentration of the chemical (mg/kg) in the edible portion of the species in the area. The average levels from multiple fillet samples of the same species will be used. Catfish will be analyzed skin-off with the belly flap included in the sample. Gamefish and carp will be analyzed skin-on with the belly flap included in the sample. Sizes of fish collected for analysis will represent the ranges of sizes likely to be collected and consumed by the public. References on this subject include, but are not limited to: EPA's Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories.

I = Mean daily consumption rate (g/day averaged over 70 year lifetime) of the fish species by the human subpopulation in the area. 6.5 g/day will be used unless better site-specific information is available.

X = Relative absorption coefficient, or the ratio of human absorption efficiency to test animal absorption efficiency of the chemical. Assumed to be 1.0 unless better information is available.

W = Average human mass (kg). 75 kg will be used.

(Rule 0400-40-03-.03, continued)

For substances for which the public health concern is based on toxicity, a "do not consume" advisory will be considered warranted when average levels of the substance in the edible portion of fish exceed U.S. Food and Drug Administration (FDA) Action Levels or EPA national criteria. Based on the rationale used by FDA or EPA for their levels, the Commissioner may issue precautionary advisories at levels appropriate to protect sensitive populations.

- (m) Flow – Stream flows shall support recreational uses.
- (5) The criteria for the use of Irrigation are the following.
- (a) Dissolved Oxygen - There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.
 - (b) pH - The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.
 - (c) Hardness or Mineral Compounds - The hardness of or the mineral compounds contained in the water shall not impair its use for irrigation.
 - (d) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as may impair the usefulness of the water for irrigation purposes.
 - (e) Temperature - The temperature of the water shall not interfere with its use for irrigation purposes.
 - (f) Toxic Substances - The waters shall not contain toxic substances whether alone or in combination with other substances which will produce toxic conditions that adversely affect the quality of the waters for irrigation.
 - (g) Other Pollutants - The waters shall not contain other pollutants in quantities which may be detrimental to the waters used for irrigation.
- (6) The criteria for the use of Livestock Watering and Wildlife are the following.
- (a) Dissolved Oxygen - There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.
 - (b) pH - The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.
 - (c) Hardness or Mineral Compounds - The hardness of or the mineral compounds contained in the water shall not impair its use for livestock watering and wildlife.
 - (d) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as to interfere with livestock watering and wildlife.
 - (e) Temperature - The temperature of the water shall not interfere with its use for livestock watering and wildlife.
 - (f) Toxic Substances - The waters shall not contain substances whether alone or in combination with other substances, which will produce toxic conditions that adversely affect the quality of the waters for livestock watering and wildlife.

(Rule 0400-40-03-.03, continued)

- (g) Other Pollutants - The waters shall not contain other pollutants in quantities which may be detrimental to the water for livestock watering and wildlife.
- (7) The criteria for the use of Navigation are the following.
 - (a) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as to interfere with navigation.
 - (b) Other Pollutants - The waters shall not contain other pollutants in quantities which may be detrimental to the waters used for navigation.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.04 DEFINITIONS.

In addition to the meanings provided in the Water Quality Control Act (T.C.A. § 69-3-103), terms used in these rules shall mean the following:

- (1) Atypical consumers - Those persons in the vicinity of a stream or lake who due to physiological factors or previous exposure are more sensitive to specific pollutants than is the population in general. Examples of atypical consumers may include, but are not limited to: children; pregnant or nursing women; subsistence fishermen; frequent purchasers of commercially harvested fish; and agricultural, industrial, or military personnel who may have had previous occupational exposure to the contaminant of concern.
- (2) Conventional Water Treatment - Conventional water treatment as referred to in the criteria denotes coagulation, sedimentation, filtration, and chlorination or disinfection.
- (3) Degradation - The alteration of the properties of waters by the addition of pollutants, withdrawal of water, or removal of habitat, except those alterations of a short duration.
- (4) De Minimis degradation – Degradation of a small magnitude, as provided in this paragraph.
 - (a) Discharges and withdrawals
 - 1. Subject to the limitation in part 3 of this subparagraph, a single discharge other than those from new domestic wastewater sources will be considered de minimis if it uses less than five percent of the available assimilative capacity for the substance being discharged.

(Note: Consistent with T.C.A. § 69-3-108, special consideration will be given to bioaccumulative substances to confirm the effect is de minimis, even if they are less than five percent (5%) of the available assimilative capacity.)
 - 2. Subject to the limitation in part 3 of this subparagraph, a single water withdrawal will be considered de minimis if it removes less than five percent of the 7Q10 flow of the stream.
 - 3. If more than one activity described in part 1 or 2 of this subparagraph has been authorized in a segment and the total of the authorized and proposed impacts uses no more than 10% of the assimilative capacity, or 7Q10 low flow, they are presumed to be de minimis. Where the total of the authorized and proposed impacts uses 10% of the assimilative capacity, or 7Q10 low flow, additional

(Rule 0400-40-03-.04, continued)

degradation may only be treated as de minimis if the Division finds on a scientific basis that the additional degradation has an insignificant effect on the resource.

- (b) Habitat alterations authorized by an Aquatic Resource Alteration Permit (ARAP) are de minimis if the Division finds that the impacts, individually and cumulatively are offset by impact minimization and/or in-system mitigation, provided however, in ONRWs the mitigation must occur within the ONRW.
- (5) Ecoregion - A relatively homogeneous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.
- (6) Epilimnion – The upper layer of water in a thermally stratified lake or reservoir. This layer consists of the warmest water and has a fairly uniform (constant) temperature.
- (7) Ground water – Water beneath the surface of the ground within the zone of saturation, whether or not flowing through known and definite channels.
- (8) Ground water table – The upper surface of the zone of saturation by ground water.
- (9) Hypolimnion - The lowest layer in a thermally stratified lake or reservoir. This layer consists of colder, more dense water, has a constant temperature and no mixing occurs. The hypolimnion of a eutrophic lake is usually low or lacking in oxygen.
- (10) Interflow – The runoff infiltrating into the surface soil and moving toward streams as shallow, perched water above the main ground-water level.
- (11) Measurable degradation, as used in the context of discharges or withdrawals – Changes in parameters of waters that are of sufficient magnitude to be detectable by the best available instrumentation or laboratory analyses.
- (Note: Because analytical techniques change, the Department may consider either the most sensitive detection method needed to comply with state standards or any biological, chemical, physical, or analytical method, conducted in accordance with U.S. EPA approved methods as identified in 40 C.F.R. part 136. Consistent with T.C.A. § 69-3-108, for scenarios involving cumulative, non-measurable activities or parameters that are managed by a narrative criterion, the Department will use mathematical models and ecological indices to ensure no degradation will result from the authorization of such activities, consistent with the state's mixing zone policy.)
- (12) Mixing Zone - That section of a flowing stream or impounded waters in the immediate vicinity of an outfall where an effluent becomes dispersed and mixed.
- (13) Multiple populations – Two or more individuals from each of two or more distinct taxa, in the context of obligate lotic aquatic organisms.
- (14) Normal weather conditions – Those within one standard deviation of the cumulative monthly precipitation means for at least the three months prior to the hydrologic determination investigation, based on a 30-year average computed at the end of each decade. Precipitation data shall come from National Oceanographic and Atmospheric Agency's National Climatic Data Center, National Resources Conservation Service's National Climatic Data Center, National Resources Conservation Service's National Water and Climate Center, or other well-established weather station.
- (15) Obligate lotic aquatic organisms - Organisms that require flowing water for all or almost all of the aquatic phase of their life cycles.

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- (16) Parameter – A biological, chemical, radiological, bacteriological, or physical property of water that can be directly measured. Some criteria are expressed in terms of a single parameter; others, such as habitat, nutrients, and biological integrity are not directly measured, but are derived from measurements of parameters.
- (17) Perched water – Water that accumulates above an aquitard that limits downward migration where there is an unsaturated interval below it, between the aquitard and the zone of saturation.
- (18) Photic Zone - the region of water through which light penetrates and where photosynthetic organisms live.
- (19) Reference condition - A parameter-specific set of data from regional reference sites that establish the statistical range of values for that particular substance at least-impacted streams.
- (20) Reference Site - Least impacted waters within an ecoregion that have been monitored to establish a baseline to which alterations of other waters can be compared.
- (21) Response Variable – a characteristic of water quality that can be measured and changes as a result of an alteration of habitat, water withdrawal, or discharge of pollutants, as distinguished from agents that cause changes in aquatic systems.
- (22) Stratification – The tendency in lakes and reservoirs for distinct layers of water to form as a result of vertical change in temperature and, therefore, in the density of water. During stratification, dissolved oxygen, nutrients, and other parameters of water chemistry do not mix well between layers, establishing chemical as well as thermal gradients.
- (23) Stream - A surface water that is not a wet weather conveyance.
- (24) Subecoregion - A smaller, more homogenous area that has been delineated within an ecoregion.
- (25) Thermocline – The middle layer in a thermally stratified lake or reservoir. In this layer there is a rapid decrease in temperature with depth. Also called the metalimnion.
- (26) Wadeable streams - Streams that can be sampled using a hand held, one meter square or smaller kick net without water and materials escaping over the top of the net.
- (27) Watercourse - A man-made or natural hydrologic feature with a defined linear channel which discretely conveys flowing water, as opposed to sheet-flow.
- (28) Wet weather conveyance - Man-made or natural watercourses, including natural watercourses that have been modified by channelization:
 - (a) That flow only in direct response to precipitation runoff in their immediate locality;
 - (b) Whose channels are at all times above the ground water table;
 - (c) That are not suitable for drinking water supplies; and
 - (d) In which hydrological and biological analyses indicate that, under normal weather conditions, due to naturally occurring ephemeral or low flow there is not sufficient water to support fish, or multiple populations of obligate lotic aquatic organisms whose life cycle includes an aquatic phase of at least two months.

(Rule 0400-40-03-.04, continued)

- (29) Wet weather conveyance determination - The decision based on site specific information of whether a particular watercourse is a stream or a wet weather conveyance. It is synonymous with "stream determination" and "hydrologic determination."
- (30) Zone of saturation – A subsurface zone below the ground water table in which all of the interconnected voids and pore spaces are filled with water.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03. Amendments filed January 6, 2015; effective April 6, 2015.

0400-40-03-.05 INTERPRETATION OF CRITERIA.

- (1) Interpretation of the above criteria shall conform to any rules and regulations or policies adopted by the Board of Water Quality, Oil and Gas.
- (2) The effect of treated sewage or waste discharge on the receiving waters shall be considered beyond the mixing zone except as provided in this paragraph. The extent to which this is practicable depends upon local conditions and the proximity and nature of other uses of the waters. Such mixing zones (See definition) shall be restricted in area and length and shall not (a) prevent the free passage of fish or cause aquatic life mortality in the receiving waters; (b) contain materials in concentrations that exceed acute criteria beyond the zone immediately surrounding the outfall; (c) result in offensive conditions; (d) produce undesirable aquatic life or result in dominance of a nuisance species; (e) endanger the public health or welfare; or (f) adversely affect the reasonable and necessary uses of the area; (g) create a condition of chronic toxicity beyond the edge of the mixing zone; (h) adversely affect nursery and spawning areas; or (i) adversely affect species with special state or federal status.
- (3) The technical and economical feasibility of waste treatment, recovery, or adjustment of the method of discharge to provide correction shall be considered in determining the time to be allowed for the development of practicable methods and for the specified correction, to the extent allowable under paragraph (5) of Rule 0400-40-03-.06.
- (4) Water quality criteria for fish and aquatic life and livestock watering and wildlife set forth shall generally be applied on the basis of the following stream flows: unregulated streams - stream flows equal to or exceeding the 7-day minimum, 10-year recurrence interval; regulated streams - all flows in excess of the minimum critical flow occurring once in ten years as determined by the Division. However, criteria that are wholly or partially based on measurements of ambient aquatic community health, such as the nutrient, biological integrity, and habitat criteria for the fish and aquatic life use, shall support the designated use. These criteria should be considered independent of a specified minimum flow duration and recurrence. All other criteria shall be applied on the basis of stream flows equal to or exceeding the 30 day minimum 5 year recurrence interval.
- (5) In general, deviations from normal water conditions are undesirable, but the frequency, magnitude and duration of the deviations shall be considered in interpreting the above criteria. When interpreting pathogen data, samples collected during or immediately after significant rain events may be treated as outliers unless caused by point source dischargers. Such outlier data may be given less weight in assessment decisions than non-rain event sampling results.
- (6) The criteria and standards provide that all discharges of sewage, industrial waste, and other waste shall receive the degree of treatment or effluent reduction necessary to comply with water quality standards, or state or federal laws and regulations pursuant thereto, and where

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appropriate will comply with the "Standards of Performance" as required by the Tennessee Water Quality Control Act, (T.C.A., §§ 69-3-101, et seq.).

- (7) Where naturally formed conditions (e.g., geologic formations) or background water quality conditions are substantial impediments to attainment of the water quality standards, these natural or background conditions shall be taken into consideration in establishing any effluent limitations or restrictions on discharges to such waters. For purposes of water quality assessment, exceedances of water quality standards caused by natural conditions will not be considered the condition of pollution.
- (8) There are cases in which the in-stream criteria as established by this rule are less than current chemical technological capabilities for analytical detection. In instances where permit limits established through implementation of these criteria are below analytical capabilities, compliance with those limits will be determined using the following reporting limits, unless in specific cases other reporting limits are demonstrated to be the best achievable because of the particular nature of the wastewater being analyzed. Such a demonstration shall be made at the time results are submitted and shall affirm that using methods, personnel, training, and equipment appropriate to reach applicable RRLs, the laboratory was unable to do so due to the nature of the sample. The methods, equipment, and general nature of the interference shall be provided. Inability to accurately quantify the level of a contaminant shall not be acceptable grounds for a higher reporting level if the permit requirement is based on detection/non-detection.

REQUIRED REPORTING LEVELS [RRL] (µg/L)
Approved EPA Methods Must Be Used)

| <u>INORGANICS</u> | RRL | <u>BASE NEUTRALS</u> | RRL |
|--------------------------|---------|-------------------------------|------|
| Antimony | 3.0 | Acenaphthylene (c) | 2.3 |
| Arsenic, total (c) | 1.0 | Anthracene | 0.7 |
| Arsenic (III) (c) | 1.0 | Benzo(a)anthracene (c) | 0.3 |
| Beryllium (c) | 1.0 | Benzo(a)pyrene (c) | 0.3 |
| Cadmium | 1.0 | 3,4-Benzofluoranthene (c) | 0.3 |
| Chromium, total | 1.0 | Benzo(k)fluoranthene (c) | 0.3 |
| Chromium (III) | 1.0 | Bis(2-Chloroethyl)ether (c) | 1.0 |
| Chromium (VI) | 10.0 | Bis(2-Ethylhexyl)phthalate(c) | 2.5 |
| Copper | 1.0 | Chrysene | 2.5 |
| Lead | 1.0 | 1,2-Dichlorobenzene | 2.0 |
| Mercury | 0.2 | 1,3-Dichlorobenzene | 2.0 |
| Nickel | 10.0 | 1,4-Dichlorobenzene - | |
| Selenium | 2.0 | para-Dichlorobenzene | 4.4 |
| Silver | 1.0 | Diethyl phthalate | 1.9 |
| Zinc | 1.0 | Dimethyl phthalate | 1.6 |
| Cyanide | 5.0 | Di-n-Butyl phthalate | 2.5 |
| | | 2,4-Dinitrotoluene (c) | 1.0 |
| Dioxin | 0.00001 | Fluoranthene | 2.2 |
| <u>INORGANICS</u> | RRL | <u>BASE NEUTRALS</u> | RRL |
| <u>VOLATILES</u> | | Fluorene | 0.3 |
| Acrolein | 1.0 | Hexachlorobenzene (c) | 1.9 |
| Acrylonitrile (c) | 1.0 | Hexachlorobutadiene (c) | 5.0 |
| Benzene (c) | 1.0 | Hexachloroethane (c) | 0.5 |
| Bromoform - | | Nitrobenzene | 10.0 |
| Tribromomethane (c) | 1.0 | Phenanthrene | 0.7 |
| Carbon tetrachloride (c) | 1.0 | Pyrene | 0.3 |

(Rule 0400-40-03-.05, continued)

| | | | |
|-------------------------------|------|------------------------|------|
| Chloroform - | | <u>PESTICIDES</u> | |
| Trichloromethane (c) | 0.5 | Aldrin (c) | 0.5 |
| Dichlorobromomethane (c) | 1.0 | g-BHC - Lindane (c) | 0.5 |
| 1,2-Dichloroethane (c) | 1.0 | Chlordane (c) | 0.1 |
| 1,1-Dichloroethylene (c) | 1.0 | 4-4'-DDT (c) | 0.1 |
| 1,3-Dichloropropylene | 1.0 | 4,4'-DDE (c) | 0.1 |
| Ethylbenzene | 1.0 | 4,4'-DDD (c) | 0.1 |
| Methyl chloride - | | Dieldrin (c) | 0.05 |
| Chloromethane (c) | 1.0 | a-Endosulfan | 0.1 |
| Methylene chloride - | | b-Endosulfan | 0.05 |
| Dichloromethane (c) | 1.0 | Endrin | 0.1 |
| 1,1,2,2-Tetrachloroethane (c) | 0.5 | Heptachlor (c) | 0.05 |
| Tetrachloroethylene (c) | 0.5 | Heptachlor epoxide (c) | 0.08 |
| Toluene | 1.0 | PCB-1242 (c) | 0.5 |
| 1,1,1-Trichloroethane | 1.0 | PCB-1254 (c) | 0.5 |
| 1,1,2-Trichloroethane (c) | 0.2 | PCB-1221 (c) | 0.5 |
| Trichloroethylene (c) | 1.0 | PCB-1232 (c) | 0.5 |
| Vinyl chloride (c) | 2.0 | PCB-1248 (c) | 0.5 |
| | | PCB-1260 (c) | 0.5 |
| <u>ACID EXTRACTABLES</u> | | PCB-1016 (c) | 0.5 |
| 2-Methyl-4,6-dinitrophenol- | | PCB, total (c) | 0.5 |
| 4,6-Dinitro-o-cresol | 24.0 | Toxaphene (c) | 0.5 |
| 2,4-Dinitrophenol | 42.0 | | |
| Pentachlorophenol | 5.0 | | |
| 2,4,6-Trichlorophenol (c) | 2.7 | | |

(c) carcinogen

(9) Standard operating procedures for making stream and wet weather conveyance determinations (hydrologic determinations)

(a) General

1. Because a primary purpose of the Water Quality Control Act is to protect the Waters of the State for the public, and since streams receive a higher level of protection than wet weather conveyances, anyone desiring to alter a watercourse who wishes to avoid unnecessary expense and delay, may request the department to process a permit application or issue an authorization under a general permit with the presumption that the watercourse is a stream. In that instance, a full hydrologic determination would not be performed under these rules. However, nothing shall preclude an applicant from subsequently seeking a wet weather conveyance determination.
2. The procedures detailed in this rule are intended to be used in situations where there is some question whether a watercourse is a stream or wet weather conveyance. In situations where it is obvious that a watercourse is a stream, such as named rivers or streams with watersheds larger than a square mile, or spring-fed streams with consistent flow greater than one cubic foot per second, it is not necessary to conduct a detailed hydrologic determination.
3. It is the purpose of this rule to set out the framework for making stream and wet weather conveyance determinations taking into consideration all relevant and necessary information on the biology, geology, geomorphology, precipitation, hydrology, and other scientifically based principles. Staff of the Department and certified hydrologic professionals not employed by the Department who are

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making a submission pursuant to T.C.A. § 69-3-108(r) shall follow these rules and the Guidance for Making Hydrologic Determinations (Guidance) which contains the instructions and examples for proper application of these rules to situations in the field that has been developed pursuant to T.C.A. § 69-3-107(25) in making these determinations.

4. The format for documenting these determinations is provided in the Hydrologic Determination Field Data Sheet (Data Sheet) in the Guidance. All available field characteristics necessary to make an accurate determination shall be evaluated, and all evidence utilized in making a determination shall be documented using the Data Sheet or as an addendum. Applicants may choose to submit additional hydrological or geotechnical data not included in the standard procedure in support of a hydrologic determination. Any additional relevant information submitted to the Department shall be considered by the Division in its determination.
5. Any significant revision to the Data Sheet or Guidance shall be subject to a 30-day public comment period prior to adoption. The Department shall advertise its intent to modify the Data Sheet or Guidance by posting notice of proposed changes on the Department's internet web site and by sending to the permit mailing list. Significant modifications include the addition or deletion or substantive modification of either the primary or secondary indicators or a change in the scoring system. The Department shall consider the need for modifications to the Data Sheet and Guidance periodically and whenever a significant comment is submitted in regard to them.
6. To be classified as a wet weather conveyance, a watercourse must meet all four elements of the definition in T.C.A. § 69-3-103. Therefore, if it is determined that any one of the four elements does not apply to a watercourse, the watercourse is a stream.
7. Because natural variation and human activities can alter hydrologic conditions over time, hydrologic determination will only be considered valid for a maximum of five years or the term of a permit based on it.
8. Because there can be considerable variability within a given reach of a watercourse, wet weather conveyance determinations should not be made on a single point but must also investigate up and down channel and consider the watercourse's landscape context.
9. All of the indicators referred to in these rules and the Guidance are evidence relevant to the presence or absence of one or more of the four elements of the wet weather conveyance definition. The difference between the primary and secondary indicators is that each of the primary indicators is considered presumptive evidence alone regarding one or more of the four elements, and will allow for an immediate hydrologic determination to be made in most cases. Some of the primary indicators involve direct observations of the presence or absence of one or more of the elements. The primary indicators of wet weather conveyances are:
 - (i) hydrologic feature exists solely due to a process discharge,
 - (ii) defined bed and bank absent, watercourse dominated by upland vegetation/ grass,

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- (iii) watercourse dry anytime during February through April 15th under normal precipitation/ ground water conditions, and
 - (iv) daily flow and precipitation records showing feature only flows in direct response to rainfall.
10. Primary indicators of streams are:
- (i) presence of multiple populations of obligate lotic organisms with two months or longer aquatic phase,
 - (ii) presence of fish (except *Gambusia*),
 - (iii) presence of naturally occurring ground water table connection,
 - (iv) flowing water in channel seven days or more since the last precipitation in the local watershed, and
 - (v) evidence watercourse has been used as a supply of drinking water.
11. When primary indicators cannot be observed or documented, then the investigator must evaluate the watercourse using secondary indicators. The secondary indicators are an aggregate set of observations that in total are used to evaluate the presence or absence of one or more of the elements of a wet weather conveyance. Secondary indicators are:
- (i) continuous bed and bank,
 - (ii) sinuous channel,
 - (iii) in-channel structure, riffle-pool sequences,
 - (iv) sorting of soil textures or other substrate,
 - (v) active/relic floodplain,
 - (vi) depositional bars or benches,
 - (vii) braided channel,
 - (viii) recent alluvial deposits,
 - (ix) natural levees,
 - (x) headcuts,
 - (xi) grade controls,
 - (xii) natural valley draingeway,
 - (xiii) at least second order channel on United States Geological Survey or Natural Resources Conservation Service map,
 - (xiv) subsurface flow/discharge into channel,
 - (xv) water in channel more than forty-eight hours since rain,

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- (xvi) leaf litter in channel,
 - (xvii) sediment on plants or on debris,
 - (xviii) organic debris lines or piles (wrack lines),
 - (xix) hydric soils in channel bed or sides,
 - (xx) fibrous roots in channel,
 - (xxi) rooted plants in channel,
 - (xxii) crayfish in channel (exclude in floodplain),
 - (xxiii) bivalves/mussels,
 - (xxiv) amphibians,
 - (xxv) macrobenthos,
 - (xxvi) filamentous algae, periphyton,
 - (xxvii) iron-oxidizing bacteria/fungus, and
 - (xxviii) wetland plants in channel.
12. The secondary indicators shall be scored in accordance with the instructions in the Guidance. Hydrologic determinations will often be made on the basis of secondary indicators because none of the primary indicators is present at the time of investigation. Any of the primary indicators contained in these rules and the Guidance may be considered conclusive after consideration of appropriate background information including recent weather and precipitation, in the absence of any directly contradictory evidence. However, since hydrologic determinations are required to be made at all times of year, secondary indicators of hydrologic status will be used, in accordance with the Guidance and these rules, as determinant evidence in the absence of primary indicators. The secondary indicators used in the Guidance shall be based on sound scientific principles.
13. Watercourses in which flow is solely a result of process or wastewater discharge or other non-natural sources shall not be regulated as streams even though they may exhibit characteristics of a stream rather than a wet weather conveyance.
- (b) The specific procedures outlined herein are intended to consider each of the four elements necessary for a watercourse to be classified as a wet weather conveyance.
- 1. Because the duration of the flow in a watercourse is the central inquiry of hydrologic determinations, all of the primary and secondary indicators are relevant to evaluating it. Although other factors may also be relevant, at a minimum the following procedures shall be used to determine if a watercourse flows only in direct response to precipitation runoff in its immediate vicinity.
 - (i) Prior to conducting a field evaluation, the investigator should review recent precipitation patterns for the local area, the longer-term seasonal precipitation trends, and any other available information such as historic

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- land use, regional geology and soil types, or previous hydrologic determinations near the site to be investigated.
- (ii) The investigator must decide if the determination is being conducted under “normal weather conditions.” The procedure for determining if weather conditions are normal, or either wetter or drier than normal, is contained in the Guidance. If conditions are either wetter or drier than normal the investigator must take this into consideration in making a hydrologic determination.
 - (iii) The vast majority of wet weather conveyances will generally cease to flow within 48 hours of almost all except some of the largest rain events. This is especially true in urbanized, impervious areas, or other areas with low infiltration rates, such as mowed lawns. The investigator shall document the presence or absence of flow within the watercourse. If in-stream surface flow is observed within the evaluated reach, and it has been at least seven days since the last rainfall event in the upstream watershed, the flow will not be considered a direct storm response, and the investigator shall conclude that the feature is a stream. The investigator shall document the source of the precipitation data. The source used shall be as close as feasible to the watercourse.
 - (iv) When subsurface water discharges such as seeps, interstitial flow, perched water, or interflow are observed and used as indicators of hydrology, investigators shall consider the influence of recent precipitation events and localized soil and geologic conditions on these features to determine if these features provide adequate hydrology such that the watercourse flows more than in direct response to precipitation. For example, since some such features have more flow when there has been significant recent precipitation, if they are flowing when there has not been much recent precipitation, it is more likely that they flow for sustained periods. In some instances, there may be observable outcroppings of a confining layer such as shale or clay that causes interstitial flow to discharge to a watercourse. In this situation, the capacity of up-gradient conditions such as the permeability and volume of the soils above the confining layer to sustain extended periods of surface flow should be considered. These types of sustained discharges should not be considered a direct response to rainfall. In other instances, such as in areas with a highly karst geology, observed seeps into a watercourse may be not be able to sustain extended periods of flow, and may be considered a more direct response to rainfall.
 - (v) Field investigations for hydrologic determinations should not be conducted if a one-inch precipitation event in 24 hours has occurred in the area of investigation within the previous 48 hours.
2. The following procedures are to determine if the channel is above the ground water table at all times. Under the definition of wet weather conveyance in T.C.A. § 69-3-103, if there are any times that the channel is not above the ground water table, it is a stream.
- (i) Since larger streams and rivers are frequently in contact with the ground water table, the investigator shall review topographic maps to determine if the watercourse is within the floodplain of, or within 20 feet in elevation of a larger stream or river known to carry perennial flow. Flow in such a watercourse should not be considered conclusive evidence of a ground

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water table connection, but is contributing evidence to be considered in the determination. Therefore further investigation into additional factors including those listed below is necessary to determine that the watercourse in question is in contact with the ground water table.

- (ii) Since the presence of wetlands often indicates a shallow depth to the ground water table, the investigator shall search for the presence of wetlands in the immediate vicinity of the watercourse both on topographic maps and in the field. The presence of wetlands in the vicinity of the watercourse being examined should not be considered conclusive evidence of a ground water table connection, but is contributing evidence to be considered in the determination. Therefore further investigation into other factors including those listed below is necessary to determine that the watercourse in question is in contact with the ground water table.
 - (iii) The investigator shall review United States Department of Agriculture soil surveys. Their soil descriptions often contain information on depth to water table. For watercourses whose channels are at a depth that indicates contact with the ground water table for the soil type in which they are formed, the investigator can conclude that the watercourse is in contact with the water table, absent contradicting field information.
 - (iv) The investigator shall review site geological characteristics affecting the elevation of the ground water table with respect to the elevation of the channel, including the presence of karst bedrock features, erodibility of watershed soils, thickness of regolith and channel alluvium, depth to bedrock or laterally persistent silt or clay horizons, land-use disturbances, and other watershed conditions controlling or contributing to the presence or absence of channel base flow.
 - (v) If data are available from water wells within one mile of and in similar landscape position to a watercourse under investigation, and if the surface elevation of standing water in the well is at or above the elevation of the bottom of the channel of the watercourse, then the investigator can conclude that the watercourse is in contact with the ground water table.
 - (vi) The observed emergence of water from the ground is not necessarily water from the ground water table and should not be considered as conclusive for the purpose of this element. Therefore further investigation into factors including those listed above is necessary to determine the source of the emergent water.
3. The following procedures are to determine if a watercourse is suitable for drinking water supplies. The investigator should note spring boxes, water pipes to carry water from the watercourse to a residence, or other observable evidence the watercourse is being used as a household water supply upstream of or within the segment being evaluated. When these features are noted, the investigator can conclude that the watercourse is a stream absent contradicting information.
4. The following procedures are to determine if a watercourse, under normal weather conditions, due to naturally occurring ephemeral or low flow does not have sufficient water to support fish, or multiple populations of obligate lotic aquatic organisms whose life cycle includes an aquatic phase of at least two months.

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- (i) The presence of the requisite aquatic life is a primary indicator that the watercourse supports that aquatic life. In order to find that the requisite aquatic life is present, the investigator must document more than one individual of at least two qualifying taxa in the evaluated reach under normal weather conditions. Unhatched eggs or any other stage of a taxon's life cycle that could be found in a wet weather conveyance or lentic habitat (such as a deceased winged adult) should not be considered as a primary indicator that a watercourse is a stream. The specific taxa found should be noted on the Data Sheet. Representative individuals of the taxa used to make this determination should be collected for confirmation of identification. All aquatic life observed should be noted, even if some do not qualify as primary indicators. These organisms may also be relevant as secondary field indicators.
- (ii) Indigenous members of taxa within the benthic macroinvertebrate groups listed below are obligate lotic aquatic organisms and thus are primary indicators that a watercourse is a stream when two or more specimens of two or more taxa are documented under normal weather conditions.
 - (I) Gastropoda: Pleuroceridae, Viviparidae, Valvatidae
 - (II) Bivalvia: Unionidae
 - (III) Coleoptera: Dryopidae, Elmidae, Psephenidae, Ptilodactylidae, Staphylinidae
 - (IV) Diptera: Athericidae, Blephariceridae, Chironomidae (except: Chironomini or red midges), Empididae, Ptychopteridae, Tanyderidae, and some Tipulidae (Antocha, Rhabdomastix, Dicranota, Hexatoma, Limnophila, Tipula)
 - (V) Ephemeroptera: all members, except: Siphonuridae, and some Ephemeridae (Hexagenia)
 - (VI) Megaloptera: all members, except: Chauliodes
 - (VII) Odonata: Aeshnidae, Calopterygidae, Cordulegastridae, Gomphidae, some Coenagrionidae (Argia, Chromagrion, Amphigrion), some Libellulidae (Perithemis) and some Corduliidae (Epiteca, Helocordulia, Neurocordulia)
 - (VIII) Plecoptera: all members
 - (IX) Trichoptera: all members, except: Molannidae, some Leptoceridae (Nectopsyche, Triaenodes), and some Limnephilidae (Ironoquia, Limnephilus, Hesperophylax)
 - (X) Oligochaetes: Branchiobdellidae, Lumbriculidae, Sparganophilidae, some Tubificidae (subfamily Naidinae, Ilyodrilus, Rhyacodrilus, Varichaetadrilus), and some Lumbricidae (Eiseniella tetraedra only).
- (iii) The presence of any indigenous fish species, other than the Mosquitofish (*Gambusia*), documented under normal weather conditions, is also a primary indicator that the watercourse is a stream, and constitutes support of the requisite aquatic life.

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- (iv) There are conditions in which a stream may be dry for a period of weeks or even months, but supports multiple populations of lotic aquatic organisms or fish at other times during a year. In such conditions, an investigator could appropriately determine that there is sufficient water on an annual basis to support such populations even though there were not any present on a particular date. In addition, manmade pollution or other water quality issues may preclude support of these organisms. Therefore, the absence of lotic aquatic organisms at the time of the investigation cannot be the sole basis for a determination that a watercourse meets the fourth element of the definition. When multiple populations of lotic aquatic organisms or fish cannot be documented to occur in a watercourse, then the investigator must consider the hydrologic and biologic factors referred to as secondary indicators in these rules and the Guidance to make a hydrologic determination.
- (v) Under normal weather conditions, if the investigator documents the absence of water due to naturally occurring conditions in a watercourse between February 1 and April 15, then the investigator can conclude the watercourse is unable to support fish or multiple populations of obligate lotic aquatic organisms whose life cycle includes an aquatic phase of at least two months and is therefore a wet weather conveyance.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.06 ANTIDegradation Statement.

(1) General

- (a) It is the purpose of Tennessee's standards to fully protect existing uses of all surface waters as established under the Act. Existing uses are those actually attained in the waterbody on or after November 28, 1975. Additionally, the Tennessee Water Quality Standards shall not be construed as permitting the degradation (see definition) of high quality surface waters. Where the quality of Tennessee waters is better than the level necessary to support propagation of fish, shellfish, and wildlife, or recreation in and on the water, that quality will be maintained and protected unless the Department finds, after intergovernmental coordination and public participation, that lowering water quality is necessary to accommodate important economic or social development in the area in which the waters are located. Sources exempted from permit requirements under the Water Quality Control Act should utilize all cost-effective and reasonable best management practices. Where new or increased temperature alterations are proposed, a successful demonstration as determined by the Department under Section 316(a) of the Clean Water Act, 33 U.S.C. §1326, shall be considered to be in compliance with this rule.
- (b) To apply this antidegradation statement in the permitting context, the Department shall first determine if the application is complete. Absent extraordinary circumstances, the Department shall notify the applicant that an application is complete or of any deficiencies within 30 days of receipt of the application.
 - 1. A complete application will include all of the information requested on the forms provided by the Department. For activities other than new domestic wastewater discharges, a complete application will include the applicant's basis for concluding that the proposed activity:
 - (i) will not cause measurable degradation, or

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- (ii) will only cause de minimis degradation, or
 - (iii) will cause more than de minimis degradation.
2. If the proposed activity will cause degradation above a de minimis level or if it is a new discharge of domestic wastewater, a complete application will:
- (i) analyze all reasonable alternatives and describe the level of degradation caused by each of the feasible alternatives;
 - (ii) discuss the social and economic consequences of each alternative; and
 - (iii) demonstrate that the degradation will not violate the water quality criteria for uses existing in the receiving waters and is necessary to accommodate important economic and social development in the area.
3. Such alternatives analyses shall include, at a minimum, completed and accurate Worksheets A and B for public sector applicants or Worksheets A and G for private system applicants, or shall provide alternative information subject to approval by the Department. Additionally, to provide information to the Department regarding the applicant's claim of economic or social necessity, public sector applicants shall provide the relevant information from Forms O, P, Q, S, T, U, and AA, found in the EPA guidance document (Economic Guidance); private sector applicants shall provide the relevant information from Forms O, R, V, W, X, Y, Z, and AB, found in the EPA guidance document (Economic Guidance). Either type of applicant shall submit alternative or additional information regarding economic or social necessity as directed by the Department. These forms are found in the EPA guidance document entitled Interim Economic Guidance for Water Quality Standards: Workbook (EPA 823/B-95-002) (Economic Guidance). Reasonable alternatives for the various activities include, but are not limited to the following actions.
- (i) Alternatives for discharges include connection to an existing collection system, land application, water reuse, water recycling, or other treatment alternatives. For small domestic discharges, connection to an existing system or land application will be considered preferable.
 - (ii) For water withdrawals, alternatives include water conservation, water reuse or recycling, off-stream impoundments, water harvesting during high flow conditions, regionalization, withdrawing water from a larger waterbody, use of ground water, connection to another water supply with available capacity, and pricing structures that encourage a reduction in consumption.
 - (iii) For activities that cause habitat alterations, alternatives that avoid or minimize degradation should be explored and explained by the applicant. These avoidance or minimization activities could include maintaining or enhancing buffer zones, bridging a stream rather than culverting it, altering the footprint of a project instead of relocating a stream, or using a culvert without a bottom, instead of one that is fully concreted.
- (c) When the Department determines that a permit application is complete, it shall notify the applicant by letter or email and shall notify the public and the state and federal agencies with jurisdiction over fish, wildlife, shellfish, plant and wildlife resources, parks, and historic preservation by posting a notice on the Department's web site and sending email to persons who have asked to be notified of permit actions. In the case

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of habitat alterations or water withdrawals this notice shall be a part of the public notice of a permit application under paragraph (4) of Rule 0400-40-07-.04 and shall contain the information required by that paragraph of the rules. For a discharge, the notice shall summarize the information given by the applicant pursuant to subparagraph (b) of this paragraph.

- (d) Next, the Department shall determine the level of degradation that would occur as a result of the proposed activity. Not all activities cause an addition of pollutants, diminish flows, or impact habitat.
 1. In the case of discharges, if the department determines that no measurable degradation will occur as a result of the activity, no further review under this rule is required regardless of the antidegradation classification of the receiving stream, unless the activity:
 - (i) is a new domestic wastewater discharge, or
 - (ii) introduces a parameter identified as bioaccumulative, or
 - (iii) introduces a parameter with a criterion below the current method detection level for that substance, or
 - (iv) is proposed to occur in an ONRW.
 2. In the case of water withdrawals requiring permits from waters other than ONRWs, if the Department determines that no measurable degradation will occur, no further review under this rule is required regardless of the antidegradation classification of the receiving stream.
 3. In the case of habitat alterations, if the department determines that no degradation or only de minimis degradation will occur, no further review under the rule is required regardless of the antidegradation classification of the receiving stream.
- (e) If the steps described in subparagraphs (b), (c) and (d) of this paragraph do not conclude the review under this rule, the Department shall determine whether the waters impacted by the activity are ones with available parameters, unavailable parameters, Exceptional Tennessee Waters, or Outstanding National Resource Waters, or if they are in more than one category. For example, a stream segment may be unavailable for one parameter and be available for others and Exceptional Tennessee Waters may also be unavailable for certain parameters. If an activity is proposed in a waterbody that is in more than one category, it must meet all of the applicable requirements.
 - (2) Waters with unavailable parameters

Unavailable parameters exist where water quality is at, or fails to meet, the levels specified in water quality criteria in Rule 0400-40-03-.03. In the case of a criterion that is a single response variable or is derived from measurement of multiple responsible variables, the unavailable parameters shall be the agents causing water quality to be at or failing to meet the levels specified in criteria. For example, if the biological integrity criterion (derived from multiple response variables) is violated, the unavailable parameters shall be the pollutants causing the violation, not the response variables.

 - (a) In waters with unavailable parameters, new or increased discharges that would cause measurable degradation of the parameter that is unavailable shall not be authorized.

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Nor will discharges be authorized in such waters if they cause additional loadings of unavailable parameters that are bioaccumulative or that have criteria below current method detection levels.

- (b) In waters with unavailable parameters, no new or expanded water withdrawals that will cause additional measurable degradation of the unavailable parameter shall be authorized.
 - (c) Where one or more of the parameters comprising the habitat criterion are unavailable, activities that cause additional degradation of the unavailable parameter or parameters above the level of de minimis shall not be authorized.
- (3) Waters with available parameters

Available parameters exist where water quality is better than the levels specified in water quality criteria in Rule 0400-40-03-.03.

- (a) In waters with available parameters, new or increased discharges that would cause degradation above the level of de minimis for any available parameter for any criterion will only be authorized if the applicant has demonstrated to the Department that reasonable alternatives to degradation are not feasible and the degradation is necessary to accommodate important economic or social development in the area and the degradation will not violate the water quality criteria for uses existing in the receiving waters.
 - (b) In waters with available parameters, new or expanded water withdrawals that would cause degradation above the level of de minimis will only be authorized if the applicant has demonstrated to the Department that reasonable alternatives to degradation are not feasible and the degradation is necessary to accommodate important economic or social development in the area and will not violate the water quality criteria for uses existing in the receiving waters.
 - (c) In waters with available parameters, an activity that would cause degradation of habitat above the level of de minimis will only be authorized if the applicant has demonstrated to the Department that reasonable alternatives to degradation are not feasible and the degradation is necessary to accommodate important economic or social development in the area and will not violate the water quality criteria for uses existing in the receiving waters.
- (4) Exceptional Tennessee Waters

- (a) Exceptional Tennessee Waters are waters that are in any one of the following categories:
 - 1. Waters within state or national parks, wildlife refuges, forests, wilderness areas, or natural areas;
 - 2. State Scenic Rivers or Federal Wild and Scenic Rivers;
 - 3. Federally-designated critical habitat or other waters with documented non-experimental populations of state or federally-listed threatened or endangered aquatic or semi-aquatic plants, or aquatic animals;
 - 4. Waters within areas designated as Lands Unsuitable for Mining pursuant to the federal Surface Mining Control and Reclamation Act where such designation is based in whole or in part on impacts to water resource values;

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5. Waters with naturally reproducing trout;
 6. Waters with exceptional biological diversity as evidenced by a score of 40 or 42 on the Tennessee Macroinvertebrate Index (or a score of 28 or 30 in subcoregion 73a) using protocols found in TDEC's 2011 Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys, provided that the sample is considered representative of overall stream conditions; or
 7. Other waters with outstanding ecological, or recreational value as determined by the Department. When application of this provision is a result of a request for a permit, such preliminary determination is to be made within 30 days of receipt of a complete permit application.
- (b) The Department will maintain a list of waterbodies that have been reviewed and are known to have one or more of the above characteristics on its website and will make paper copies of that list available upon request.
- (c) Authorization of Activities in Exceptional Tennessee Waters
1. In waters identified as Exceptional Tennessee Waters new or increased discharges that would cause degradation of any available parameter above the level of de minimis and discharges of domestic wastewater will only be authorized if the applicant has demonstrated to the Department that reasonable alternatives to degradation are not feasible and the degradation is necessary to accommodate important economic or social development in the area and will not violate the water quality criteria for uses existing in the receiving waters. At the time of permit renewal, previously authorized discharges, including upstream discharges, which presently degrade Exceptional Tennessee Waters above a de minimis level, will be subject to a review of updated alternatives analysis information provided by the applicant, but not to a determination of economic/social necessity. Public participation for these existing discharges will be provided in conjunction with permitting activities. Sources exempted from permit requirements under the Water Quality Control Act should utilize all cost-effective and reasonable best management practices.
 2. In waters identified as Exceptional Tennessee Waters, new or increased water withdrawals that would cause degradation of any available parameter above the level of de minimis will only be authorized if the applicant has demonstrated to the Department that reasonable alternatives to degradation are not feasible and the degradation is necessary to accommodate important economic or social development in the area and will not violate the water quality criteria for uses existing in the receiving waters.
 3. In waters identified as Exceptional Tennessee Waters, an activity that would cause degradation of habitat above the level of de minimis will only be authorized if the applicant has demonstrated to the Department that reasonable alternatives to degradation are not feasible and the degradation is necessary to accommodate important economic or social development in the area and will not violate the water quality criteria for uses existing in the receiving waters.
- (d) Determination of Economic/Social Necessity - The Department's determination that degradation of Exceptional Tennessee Waters resulting from a proposed discharge, habitat alteration or water withdrawal is, or is not, necessary to accommodate important economic and social development in the area shall be subject to review by the Board of Water Quality, Oil and Gas under the following procedures.

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1. If the Department determines that an activity that would cause degradation above a de minimis level of Exceptional Tennessee Waters is necessary to accommodate important economic or social development in the area, it shall give notice to the applicant, the public, and federal and state agencies with jurisdiction over fish, wildlife, shellfish, plant and wildlife resources, parks, and advisory councils for historic preservation. In the case of an application for a discharge, this notice may be combined with the notice of a draft permit under this rule. In the case of an application for a habitat alteration or water withdrawal, this notice shall be given by being posted on the Department's web site and by sending email to persons who have asked to be notified of permit actions. Within 30 days after the date of the notification, any affected intergovernmental coordination agency or affected third person may petition the Board for a declaratory order under T.C.A. § 4-5-223, and the Board shall convene a contested case. After the Board has convened a contested case in response to a declaratory order petition under this part, the Department shall within 5 business days thereafter transmit the petition to the Administrative Procedures Division of the Secretary of State so the contested case may be docketed and an administrative law judge may be assigned to the case. If a declaratory order petition is timely filed, the Department shall not proceed further in processing the permit application until the petition has been resolved before the Board. In the contested case, the petitioner shall have the burden of proof, and the Department's determination shall carry no presumption of correctness before the Board. The applicant is a necessary party to the declaratory order contested case, and if the applicant does not participate in the contested case, the Board shall render a decision that degradation is not necessary to accommodate important economic or social development in the area. If no intergovernmental coordination agency or third person petitions for a declaratory order within 30 days of the notification date, or if one is filed after the 30 days expires, then the Department shall proceed with processing the permit application.
2. A declaratory order contested case conducted under this subparagraph shall be subject to the following procedures. Mediation may occur if all the parties agree. Any proposed agreed order resulting from mediation shall be subject to approval by the Board. In order to provide for an expedited proceeding, the contested case is subject to the following time limitations. The time periods specified in this part shall commence on the day after the contested case has been docketed by the Administrative Procedures Division of the Secretary of State and an administrative law judge has been assigned to the case. Any alteration of the time periods set out in this part shall be granted only upon agreement of all the parties, or when there have been unforeseen developments that would cause substantial prejudice to a party, or when the parties have agreed to mediation. Within 20 days, the parties shall confer to try and develop a proposed agreed scheduling order. If the parties are unable to agree, then each party shall submit a proposed scheduling order, and the administrative law judge, after a hearing, shall enter a scheduling order. All discovery shall be completed no later than 20 days prior to the date the hearing before the Board is to begin. Within 120 days, the hearing before the Board shall begin, but the Board on its own initiative may exceed 120 days to complete the hearing and render its final decision. In order for degradation of Exceptional Tennessee Waters to proceed pursuant to these rules, the Board must make a finding approving degradation by a majority vote of the members of the Board present and voting.
3. If the Department determines that degradation is not necessary to accommodate important economic or social development in the area, it will notify the applicant, the federal and state agencies with jurisdiction over fish, wildlife, shellfish, plant

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and wildlife resources, parks, and advisory councils for historic preservation, and third persons who have asked to be notified of permit actions. The Department also will issue a tentative decision to deny the permit because degradation is not necessary. In accordance with paragraph (4) of this rule, the Department will provide the public with notice of and an opportunity to comment on its tentative denial decision. If no public hearing is requested within the 30 day public comment period, and if the Department does not alter its tentative decision to deny, the Department shall notify the applicant of its final decision to deny the permit because degradation is not necessary. Within 30 days after receiving notice of the final decision to deny the permit, the applicant may seek review of the decision that the degradation is not necessary to accommodate important economic or social development in the area in a contested case before the Board in accordance with T.C.A. § 69-3-105(i). Within 5 business days after the Department receives an applicant's written request for a contested case hearing before the Board, the Department shall transmit the written request to the Administrative Procedures Division of the Secretary of State so the contested case may be docketed and an administrative law judge may be assigned to the case. In the contested case, the applicant shall have the burden of proof, and the Department's determination shall carry no presumption of correctness before the Board. The federal and state intergovernmental coordination agencies, and third persons who requested notification of the Department's degradation determination will be notified by the Department of the applicant's permit appeal. The intergovernmental coordination agencies and third persons may seek to intervene in the contested case in accordance with T.C.A. § 4-5-310.

(5) Outstanding National Resource Waters

(a) The following streams or portions of streams are designated as ONRW:

| | <u>WATERBODY</u> | <u>PORTION DESIGNATED AS ONRW</u> |
|----|--|---|
| 1. | Little River | Portion within Great Smoky Mountains National Park. |
| 2. | Abrams Creek | Portion within Great Smoky Mountains National Park. |
| 3. | West Prong Little Pigeon River | Portion within Great Smoky Mountains National Park upstream of Gatlinburg |
| 4. | Little Pigeon River | From the headwaters within Great Smoky Mountains National Park downstream to the confluence of Mill Branch. |
| 5. | Big South Fork Cumberland | Portion within Big South Fork National RiverRiver and Recreation Area. |
| 6. | Reelfoot Lake | Tennessee portion of the lake and its associated wetlands. |
| 7. | The portion of the Obed River that is designated as a federal wild and scenic river as of June 22, 1999 is designated as ONRW, provided however, that if the current search for a regional water supply by the Cumberland Plateau Regional Water Authority results in a determination that it is necessary to utilize the Obed River as its source of drinking water, for that purpose the Obed shall be designated as an Exceptional Tennessee Water and any permit issued for that | |

(Rule 0400-40-03-.06, continued)

project, whether state, federal, or otherwise, shall be considered under the requirements for Exceptional Tennessee Waters.

- (b) The Department may recommend to the Board of Water Quality, Oil and Gas that certain waterbodies be designated as Outstanding National Resource Waters (ONRWs). These shall be high quality waters which constitute an outstanding national resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance. Designation of ONRWs must be made by the Board of Water Quality, Oil and Gas and will be accomplished in accordance with T.C.A. § 69-3-105(a)(1) of the Tennessee Water Quality Control Act and through the appropriate rulemaking process.
1. In surface waters designated by the Board of Water Quality, Oil and Gas as ONRWs, no new discharges, expansions of existing discharges, water withdrawals or mixing zones will be permitted unless such activity will not result in either measurable degradation or discernible effect. At the time of permit renewal, previously authorized discharges, including upstream discharges and withdrawals, which presently degrade an ONRW, will be subject to alternatives analysis. Public participation for these existing discharges will be provided in conjunction with permitting activities.
 2. In waters designated by the Board of Water Quality, Oil and Gas as ONRWs, no new or increased habitat alteration that would cause degradation of habitat above the level of de minimis or degrade water chemistry for more than a short duration will be authorized.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.07 GROUND WATER CLASSIFICATION.

(1) Purpose and Intent

- (a) It is one of the primary goals of the Tennessee Water Quality Control Act, T.C.A. §§ 69-3-101 et seq. (the "Act") to protect our valuable ground water resource. This rule classifies ground water across the state based on the factors stated in T.C.A. § 69-3-105(a)(2) of the Act and establishes ground water quality criteria. The quality of ground water varies in Tennessee. Some ground water is sufficient to be used by our citizens directly as a drinking water supply with limited or no treatment. Other ground water would require more extensive treatment before it could be used as a water supply. Further, some ground water may be of such value as to warrant special protection. The board recognizes that some water below the surface of the ground may be present in a zone of aeration between ground surface and the water table. The zone of aeration is where treatment from household septic systems occurs and water in the zone of aeration is not classified as ground water in these regulations. Perched water above the zone of saturation may, in some areas, be used as a water supply or may migrate to either ground water or surface water and is included in these regulations to protect for its direct use or impact on ground water or surface water. Additionally, some ground water has levels of naturally occurring constituents that make the resource unusable as a drinking water supply.
- (b) The board recognizes these rules apply to both permitting activities and response actions that involve water beneath the surface of the ground. The permitting of underground injection is governed by Chapter 0400-45-06.

(Rule 0400-40-03-.07, continued)

- (c) These rules provide appropriate flexibility in the regulatory process to protect our ground water resource and to allow the productive use of land. Reuse of brownfield areas is encouraged and reduces the use of greenfield areas.
- (d) The board recognizes that several divisions within the department have a role in protecting ground water resources. It is not the intent of these rules to change the responsibilities of those programs. It is, however, the intent of these rules to provide a basis for decisions involving ground water that may be applied by all divisions of the department. The board does not intend these rules to affect in any way the ability of the State to seek natural resource damages from responsible parties when ground water has been contaminated by human activity.
- (e) Ground water that enters a stream or other water classified as surface water becomes surface water and is subject to respective criteria applicable to that water. The board expects that the department will use prudent judgment where ground water mixes with water on the surface of the ground.

(2) Definitions

- (a) "Area of Control" means a volume designated by the commissioner underlying or surrounding a site, including the zone of aeration and the zone of saturation, containing water, some of which the commissioner has determined not to meet applicable criteria.
- (b) "Ground Water" means water beneath the surface of the ground within the zone of saturation, whether or not flowing through known and definite channels.
- (c) "Perched water" means water that accumulates above an aquitard that limits downward migration where there is an unsaturated interval below it, between the aquitard and the zone of saturation.
- (d) "Point of Classification Change" means the boundary of the volume within which ground water is classified as Site Specific Impaired as established under Rule 0400-40-03-.09.
- (e) "Response action" means a clean up, remedial action, remedy, remedial investigation or other action taken by the department to address the presence of contaminants at levels that have been determined by the Department to require an appropriate response.
- (f) "Zone of Aeration" means a subsurface zone extending from the water table to the surface of the land.
- (g) "Zone of Saturation" means a subsurface zone below the water table in which all of the interconnected voids and pore spaces are filled with water.

(3) Water in the Zone of Aeration

Water in the zone of aeration is not defined as ground water in this rule, but it may occur as perched water. This perched water may be above ground water of any of the classifications used in this rule. Perched water is protected under this rule in accordance with its use as follows:

- (a) Perched water that is used for drinking water or reasonably anticipated to be used as a drinking water supply shall meet the criteria listed for General Use in paragraph (2) of Rule 0400-40-03-.08. Other perched water shall not contain constituents, other than of natural origin, that cause or are reasonably likely to cause a violation of criteria of

(Rule 0400-40-03-.07, continued)

underlying ground water or surface water where the perched water enters those waters.

- (b) Except for naturally occurring levels, perched water shall contain no other constituents at levels and conditions that pose an unreasonable risk to public health or the environment.
 - (c) If perched water, such as in a cave system, is habitat for fish and aquatic life, it shall contain no constituents except for naturally occurring substances at levels and concentrations that violate the criteria of paragraph (3) of Rule 0400-40-03-.03 for fish and aquatic life.
- (4) Water below the surface of the ground is classified as follows:

(a) Special Source Waters

This is ground water or perched water with exceptional quality or quantity, which may serve as a valuable source for water supply or which is ecologically significant.

When the board finds water to be Special Source Water, then through the rulemaking process, the board will amend these rules to include the specific location and the boundaries of ground water or perched water designated as Special Source Water. To initiate this process, a petition shall address the factors listed below for board consideration. Any cost involved in making the petition shall be borne by the petitioner. In making this decision, the board may consider the following factors and relevant public input:

1. The vulnerability of the water in the proposed area to contamination due to hydrogeologic characteristics;
2. The number of persons or the proportion of the population using the water as a drinking water supply;
3. Existing water quality in the proposed Special Source Water area;
4. An evaluation of the ecological and environmental impact should the quality of the Special Source Water be compromised; and
5. Other pertinent information as deemed necessary by the petitioner, department, or board. Because such action is a rulemaking procedure, public input may be made as provided in the Uniform Administrative Procedures Act, T.C.A. §§ 4-5-201 et seq., but not as a contested case under T.C.A. §§ 4-5-301 et seq.

(b) General Use Ground Water

Except for ground water in areas that have been designated as Special Source Water, Site Specific Impaired Ground Water, or meet the definition of Unusable Ground Water, all ground water is designated General Use Ground Water.

(c) Site Specific Impaired Ground Water

This is ground water that has been contaminated by human activity and the board finds that either it is not technologically feasible to remediate the ground water to the criteria required by other classifications or it is not reasonable to remediate to that criteria based on information provided in accordance with Rule 0400-40-03-.09. Ground water shall be classified as Site Specific Impaired upon approval of a petition to the Board of

(Rule 0400-40-03-.07, continued)

Water Quality, Oil and Gas and completion of the rulemaking process to amend these rules to identify the reclassified ground water. When ground water is reclassified to Site Specific Impaired the areal extent of the Site Specific Impaired Ground Water shall be delineated. The boundaries of the Site Specific Impaired Ground Water cannot extend beyond the perimeter and depth investigated with an appropriate safety factor as determined under Rule 0400-40-03-.09. Figures which clearly depict the horizontal and vertical boundaries of the Site Specific Impaired Ground Water must be submitted to the department in the plans/reports required by Rule 0400-40-03-.09.

(d) Unusable Ground Water

Ground water in the following areas are classified as Unusable Ground Water:

1. A "High Dissolved Solids Zone" is an area in which ground water has naturally occurring total dissolved solids of more than 10,000 ppm.
2. A "Historical Injection Zone" is an area in which the ground water and the injection zone designated to receive fluids and other substances from deep well injection initiated prior to September 1985 and operated under compliance with the Department at the time of injection is no longer subject to injection. The certification as a historical injection zone subclass of Unusable Ground Water does not provide authorization for future injection activities and shall not be construed as Class I zone designation under Chapter 0400-45-06, Underground Injection Control. The zone may be subsequently considered for Class I zone designation under that Chapter provided it meets the criteria based on naturally occurring conditions and not from changes as a result of the previously injected fluids.
3. A "Class I Injection Zone" is an area in which ground water has been demonstrated by a permit applicant as a part of a Class I operation under Chapter 0400-45-06, Underground Injection Control, to be suitable for Class I injection.
4. A "Class II or III Injection Zone" is an area in which ground water is mineral, hydrocarbon or geothermal energy producing, or has been demonstrated by a permit applicant as a part of a permit application for a Class II or III operation under Chapter 0400-45-06 Underground Injection Control to contain minerals or hydrocarbons that, considering their quality and location, are expected to be commercially producible. The designation as Class II or III injection zone subclass of Unusable Ground Water shall not be construed as a Class I zone designation under Chapter 0400-45-06, Underground Injection Control.
5. An "Acid Production Zone from Mining Activities" is an area in which ground water occurs within an excavated area where reaction with naturally occurring minerals generates acid rock drainage or acid mine drainage. An excavated area may be a surface or underground mined area as well as a subsidence area whether or not the mined area is backfilled. Ground water beyond the excavated area is classified as described elsewhere in this rule.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.08 CRITERIA.

The water quality criteria for the different classes are as follows:

(Rule 0400-40-03-.08, continued)

(1) Special Source Water

The board will consider the special protection needs of any water identified as Special Source Water and promulgate criteria at the time of designation.

(2) General Use Ground Water

Except for naturally occurring levels, General Use Ground Water:

- (a) shall not contain constituents that exceed those levels specified in subparagraphs (1)(j) and (k) of Rule 0400-40-03-.03; and
- (b) shall contain no other constituents at levels and conditions which pose an unreasonable risk to the public health or the environment.

(3) Site Specific Impaired Ground Water

Except for naturally occurring levels, Site Specific Impaired Ground Water:

- (a) shall contain no substances, whether alone or in combination with other substances, that are toxic, carcinogenic, mutagenic or teratogenic, other than those of natural origin, at levels and conditions which pose an unreasonable risk to public health or the environment;
- (b) shall contain no other constituents at levels and conditions which pose an unreasonable risk to the public health or the environment;
- (c) shall contain no constituents at levels that will prevent ground waters beyond the point of classification change from meeting the classification and criteria for those waters; and
- (d) other criteria established by the board as appropriate to the site.

(4) Unusable Ground Water

Except for naturally occurring levels, Unusable Ground Water:

- (a) shall contain no substances, whether alone or in combination with other substances, that are toxic, carcinogenic, mutagenic or teratogenic, other than those of natural origin, at levels and conditions which pose an unreasonable risk to the public health;
- (b) shall contain no other constituents at levels and conditions which pose an unreasonable risk to the public health;
- (c) shall not discharge to surface water causing a violation of surface water quality criteria or biological integrity; and
- (d) naturally occurring levels as used in subparagraph (a) of this paragraph shall include the natural minerals, mining wastes, and the reaction products of oxidation and reduction associated with these materials in Unusable Ground Water in an Acid Production Zone from Mining Activities. These substances shall not pose an unreasonable public health or safety risk to the public. Physical barriers and institutional controls satisfy that requirement.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.09 SITE SPECIFIC IMPAIRED CLASSIFICATION PETITION PROCESS.

- (1) Any person who encounters ground water that may meet the requirements for Site Specific Impaired, may petition the board to adopt a rule reclassifying that ground water as Site Specific Impaired, using the process set forth in this rule. Any costs involved in making the petition shall be borne by the petitioner. The petition shall include the following, unless it is determined by the department in writing that the site conditions render any of them unnecessary:
 - (a) An assessment of the horizontal and vertical extent of the contamination;
 - (b) An evaluation of the hydrogeology of the area including but not limited to the ground water flow rate and direction, permeability, recharge area, ground water classification and location of local water wells, springs and seeps;
 - (c) An evaluation of the area geology including, but not limited to, soil type, soil permeability, soil porosity, depth to bedrock, and identification of geologic formations;
 - (d) A description of the corrective actions or response actions taken or proposed;
 - (e) The chemical characteristics of the constituents(s) including, but not limited to, the constituent's solubility, mobility, toxicity, and carcinogenicity, the nature of and the level of constituents to remain or be present in the ground water and the calculations and rationale used in the determination;
 - (f) A feasibility study, which evaluates clean-up alternatives, the cost, and the time to complete each alternative;
 - (g) An evaluation of current and reasonably anticipated future ground water use within the proposed site specific impaired area and within a one-half ($\frac{1}{2}$) mile radius of the proposed Site Specific Impaired area; the impact of conduit flow shall be evaluated in karst areas;
 - (h) An evaluation of current and reasonably anticipated future land uses within the proposed Site Specific Impaired area and within a one-half ($\frac{1}{2}$) mile radius of the proposed Site Specific Impaired area;
 - (i) An evaluation of the potential of the constituent to migrate through soil and ground water to:
 1. homes;
 2. buildings;
 3. surface waters;
 4. subsurface utilities; and
 5. adjacent properties.
 - (j) A description of any existing or proposed monitoring program to observe constituent levels in soil and ground water;
 - (k) Evaluation of the existing or anticipated actual exposure pathways (inhalation, ingestion, dermal contact, etc.) of the constituents and an assessment of the human

(Rule 0400-40-03-.09, continued)

- health risks presented by exposure to the constituents as well as the impact, if any, of the constituents on fish and aquatic life pursuant to this Chapter;
- (l) Consideration of the classification in Rule 0400-40-03-.07 that would apply to the ground water at the site if it were not contaminated;
 - (m) Analysis of the benefits of the restored resource;
 - (n) A description of how and when the contamination occurred, if known;
 - (o) A plat map with the proposed site-specific ground water area superimposed on it that shows all property owners for properties included in the Site Specific Impaired classification with contact information for owners of each property and identification and contact information for the parties paying property taxes on each property in the proposed Site Specific Impaired classification area; and
 - (p) Other items as requested by the department associated with the evaluation of the petition.
- (2) Because Site Specific Impaired classification is a rulemaking procedure, public input may be made as provided in the Uniform Administrative Procedures Act, T.C.A. §§ 4-5-201 et seq., but not as a contested case under T.C.A. §§ 4-5-301 et seq. In addition to the requirements for public input under the Uniform Administrative Procedures Act, T.C.A. §§ 4-5-201 et seq., the petitioner shall, at a minimum, notify the party of record paying property taxes for each property subject to the Site Specific Impaired classification of the petition and the process for submitting comments on said petition. The petitioner shall provide a copy of such notification to the department.
- (3) In the evaluation of a petition to classify ground water as Site Specific Impaired, the board may consider the following:
- (a) the extent of any threat to human health or safety;
 - (b) the extent of damage to the environment;
 - (c) technology commercially available to accomplish restoration;
 - (d) a comparison of the environmental and economic costs and benefits to be derived from ground water quality restoration with the environmental and economic costs and benefits to be derived from classification as Site Specific Impaired;
 - (e) analysis of the restored resource;
 - (f) the point of classification change;
 - (g) contaminant or pollution source identification and cleanup;
 - (h) public comments; and
 - (i) other appropriate information presented in the petition.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.10 REMEDIATION OF GROUND WATER OR PERCHED WATER.

- (1) When a release or other event occurs that causes subsurface water to not meet the criteria in these rules, the commissioner has authority under a number of statutes to cause remediation of the water. These statutes include the Solid Waste Disposal Control Act, T.C.A. §§ 68-211-101 et seq., the Hazardous Waste Management Act, parts 1 and 2, T.C.A. §§ 68-212-101 et seq., and §§ 68-212-201 et seq., the Petroleum Underground Storage Tank Act, T.C.A. §§ 68-215-101 et seq., and the Drycleaner Environmental Response Act, T.C.A. §§ 68-217-101 et seq. The goals of all such remediation actions are:
 - (a) to return waters to meeting standards when practicable by such methods as source removal, bioremediation, pump and treat, and natural attenuation; and
 - (b) to protect the public from exposure to water that does not meet standards through such methods as physical and institutional controls.
- (2) In order to accomplish these goals the Commissioner may establish an Area of Control when contamination has caused water to exceed the standards in these rules. In establishing an Area of Control, the Commissioner shall use the authorities of the remediation statutes and rules to:
 - (a) describe the extent of an Area of Control; and
 - (b) protect the public from exposure to the water in the Area of Control.

Where the Commissioner identifies the source of pollution or water of sufficient contamination as to warrant contaminant mass reduction, he may further prescribe the actions to be taken to reduce the levels of contamination within the Area of Control.
- (3) The Commissioner may establish such an Area of Control for water contaminated by human activity prior to November 19, 1980 if there are no liable parties as defined in T.C.A. § 68-212-202(3)(B), (C), or (D) and the current property owner did not cause the water contamination. This could be done in conjunction with imposing land use restrictions to protect the public from any harm caused by the site whether or not the department expends funds to remediate the site. In establishing such an Area of Control, the Commissioner may use the authorities of the remediation statutes and rules to:
 - (a) describe the extent of an Area of Control;
 - (b) prescribe the actions to be taken to reduce the levels of contamination within the Area of control; and
 - (c) protect the public from exposure to the water in the Area of Control.
- (4) Any current or future “alternate concentration limit” or “ground water protection standard” established within a Tennessee Hazardous Waste Management enforceable document in accordance with Rule 0400-12-01-.06 identifies an Area of Control in accordance with this rule. Compliance with the enforceable document constitutes compliance with the remediation actions identified in paragraph (1) of this rule.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.11 CLASSIFIED SITE SPECIFIC IMPAIRED GROUND WATER AND RESPECTIVE CRITERIA.

The following ground water is classified as site specific impaired ground water with the respective criteria:

(1) Porter Cable

(a) Description of the site

The area of ground water classified is the ground water within the boundaries of the Porter Cable/Rockwell facility that is within the rectangle with the following boundary points to a depth equivalent to 250 feet mean sea level.

Northwest boundary point...35°44'27.5"N, 88°51'19.8"W

Northeast boundary point ...35°44'27.5"N, 88°51'05.7"W

Southwest boundary point...35°44'13.8"N, 88°51'19.8"W

Southeast boundary point... 35°44'13.8"N, 88°51'05.7"W

A solvent plume under the western edge of the building is moving very slowly to the north-northwest. Since the plant began operation in the mid-1970's, the plume has migrated approximately 400 feet, with the property boundary another 1500 feet down gradient. Sampling has shown that the plume is degrading to a certain extent by natural and biologic processes, and this process can be enhanced with the addition of nutrients to fuel the biologic activity in the contaminated zone.

(b) Criteria

Nutrient addition is allowed to promote enhanced natural attenuation of the plume in accordance with the remediation remedy being used at the site. Deed restrictions will insure the site will not be used as residential and that ground water will not be used for potable purposes. The point of classification change is totally within the boundaries of the Porter-Cable facility. The plume shall not cross the point of classification change at levels exceeding general use criteria.

(2) Isabella Mine Pit

(a) Description of the site

The area of ground water classified is the ground water in mined areas of the former Isabella/Eureka Mine, the connected Isabella pit, ground water between the Isabella pit and North Potato Creek, and an approximate 500 foot buffer around the mined areas. This ground water classification applies to part of the land that was previously abandoned by the bankruptcy court and is now either under control of a court-appointed receiver or trustee for the Irrevocable Trust of the Tennessee Chemical company (receiver or trustee). If the 500 foot buffer boundary would extend beyond a property line, then the property line shall be the point of classification change. The depth of ground water classification is from ground surface to 1400 feet. The mined areas are delineated as shown on the former mining company's mine maps. The point of classification change for this area is the outer boundary of the area classified as described above and a depth of 1400 feet.

(Rule 0400-40-03-.11, continued)

There is a bulkhead or plug between the Isabella/Eureka Mine and the Burra Burra Mine and this Site Specific Impaired classification includes the drift between the Isabella and Burra Burra Mines on the Isabella side of the drift plug but does not apply to water in the Burra Burra Mine. The drift does not require a 500-foot wide buffer zone.

(b) Criteria

The Site Specific Impaired Ground Water criteria for the water in the Isabella pit, associated Isabella/Eureka mine workings, and ground water between the Isabella pit and North Potato Creek shall be:

1. Any concentration of inorganic constituents or elements associated with acid mine drainage and any pH or other physical standard associated with acid mine drainage;
2. Any concentration of inorganic constituents or elements associated with approved backfilling or addition of ore, waste rock, calcine, concentrate, granulated slag, tailings, or other acid-generating materials from historic mining and ore beneficiation processes in the Copper Basin;
3. Criteria for other constituents are those required for General Use Ground Water as of November 3, 2004;
4. The continued use of institutional controls to avoid the potential for human contact with this ground water; and
5. Institute a monitoring program, acceptable to TDEC, that monitors the water level in the pit and is sufficient to assure protection of human health and the environment.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

0400-40-03-.12 REPORTING REQUIREMENT.

- (1) The Board acknowledges that the General Assembly has given it the authority to promulgate rules for the prevention, control, and abatement of pollution in T.C.A. § 69-3-105(b). The board finds a necessary first step toward controlling and abating pollution is becoming aware of the situation. This is especially needed in the case of ground water, as it is not in plain view as surface water often is. Furthermore, once the department has documents relating to an instance of pollution, they are generally going to be open to the public. Making the public aware of pollution both increases the likelihood that the pollution will be abated and that the public will be able to take appropriate action to reduce harmful exposure. These findings, in addition to the provision of T.C.A. § 69-3-114(b) making it unlawful to refuse to furnish any information required by the Board, are the basis for the requirement stated in paragraph (2) of this rule.
- (2) Owners or prospective purchasers of property used for commercial or industrial purposes who test the ground water or perched water on the property shall notify the Commissioner of any contamination of such water if it is currently used as potable water and it exceeds general use criteria or if an environmental professional engaged by such owner or prospective purchaser reasonably concludes that it poses some other substantial risk to health or safety, including but not limited to, situations in which vapors released from the water are causing an explosion hazard or a current inhalation hazard with a hazard quotient of greater than 1 or a cancer risk of greater than 1×10^{-6} .

(Rule 0400-40-03-.12, continued)

- (3) Routine sampling and reporting of ground water or perched water data required by an agency of the Department as part of a regulatory program obligation shall constitute reporting for the purposes of this rule.

Authority: T.C.A. §§ 69-3-101 et seq. and 4-5-201 et seq. **Administrative History:** Original rule filed September 17, 2013; effective December 16, 2013. Rule originally numbered 1200-04-03.

**RULES
OF THE
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
WATER RESOURCES DIVISION**

**CHAPTER 0400-40-05
PERMITS, EFFLUENT LIMITATIONS AND STANDARDS**

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0400-40-05-.01 PURPOSE.

A permit is designed to allow the holder thereof to conduct activities listed in T.C.A. § 69-3-108 only after strict compliance with conditions and applicable effluent limitations. T.C.A. § 69-3-108(a), (b) and (c) explicitly state when a permit is required, and what activities shall be unlawful without a permit.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.02 DEFINITIONS.

All terminology not specifically defined herein shall be defined in accordance with the Water Quality Control Act, T.C.A. §§ 69-3-101 et seq. When used in Rules 0400-40-05-.01 through .14, the following terms have the meanings given below unless otherwise specified:

- (1) "Act" means the Water Quality Control Act (TWQCA), T.C.A. §§ 69-3-101 et seq.
- (2) "Administrator" means the administrator of the United States Environmental Protection Agency, or an authorized representative.
- (3) An "Agricultural stormwater discharge" refers to a precipitation-related discharge of manure, litter or process wastewater from land areas under the control of a CAFO where the manure, litter, or process wastewater has been applied in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of the nutrients in the manure, litter, or process wastewater, as specified in parts (10)(a)7. through 10. of Rule 0400-40-05-.14.
- (4) "Ammonia (as N)" means ammonia reported as nitrogen.
- (5) An "Animal Feeding Operation" (AFO) is a facility that (1) stables, confines and feeds or maintains animals (other than aquatic animals) for a total of 45 days or more in any 12-month period and (2) does not sustain crops, vegetation, forage growth, or post-harvest residues in the normal growing season over any portion of the facility. Two or more AFOs under common ownership are considered to be a single AFO for the purposes of determining the number of animals at an operation, if they adjoin each other or if they use a common area or system for the disposal of wastes.

(Rule 0400-40-05-.02, continued)

- (6) An "AFO overflow" means the discharge of manure or process wastewater resulting from the filling of wastewater or manure storage structures beyond the point at which no more manure, process wastewater, or storm water can be contained by the structure.
- (7) An "AFO production area" includes the animal confinement area, the manure storage area, the raw materials storage area and the waste containment areas.
 - (a) The animal confinement area includes but is not limited to open lots, housed lots, feedlots, confinement houses, stall barns, free stall barns, milk rooms, milking centers, cowyards, barnyards, medication pens, walkers, animal walkways associated with barns or barnyards, and stables.
 - (b) The manure storage area includes but is not limited to lagoons, runoff ponds, storage sheds, stockpiles, under house or pit storages, liquid impoundments, static piles, and composting piles. If an AFO stores manure in the field (i.e., manure or litter piled for more than several days before land application occurs), the field storage is considered to be a production area. Note that manure or litter stored uncovered for more than two weeks is not considered to be short-term or temporary storage, and is included in the definition of production area.
 - (c) The raw materials storage area includes but is not limited to feed silos, silage bunkers, and organic bedding materials.
 - (d) The waste containment area includes but is not limited to settling basins and areas within berms and diversions which separate uncontaminated storm water.
 - (e) The production area also includes any on-farm egg washing or egg processing facility, and any area used in the storage, handling, treatment, or on-farm disposal of mortalities.
- (8) "Animal Waste Management System" means any system used for the collection, storage, treatment, handling, transport, distribution, land application, or disposal of agricultural wastes, animal waste/wastewater, waste product, and dead animals generated by an AFO that meets or exceeds USDA-NRCS technical standards and guidelines.
- (9) "Area-wide waste treatment management plan" means a plan that has been approved by the administrator pursuant to § 208 (33 U.S.C. § 1288) of the CWA, Public Law 92-500.
- (10) The term "BATEA" (or "BAT") means the best available technology economically achievable as defined by EPA regulations. Effluent limitations established by this designation shall be effective in accordance with the requirements of Section 301(B)(2)(A), Federal Water Pollution Control Act, PL 92-500.
- (11) The term "biological monitoring" shall mean the determination of the effects on aquatic life, including accumulation of pollutants in tissue, in receiving waters due to the discharge of pollutants (a) by techniques and procedures, including sampling of organisms representative of appropriate levels of the food chain appropriate to the volume and the physical, chemical, and biological characteristics of the effluent, and (b) at appropriate frequencies and locations.
- (12) "Board" means the Board of Water Quality, Oil and Gas.
- (13) "BOD₅" means 5-day biochemical oxygen demand.
- (14) The term "BPTCA" means the best practicable control technology currently available, as defined by EPA regulations.

(Rule 0400-40-05-.02, continued)

- (15) A “bypass” is defined as the intentional diversion of waste streams from any portion of a treatment facility.
- (16) A “calendar day” is defined as the 24-hour period from midnight to midnight or any other 24-hour period that reasonably approximates the midnight to midnight time period.
- (17) “CBOD₅” means 5-day carbonaceous biochemical oxygen demand.
- (18) A “closure plan” is a description of the steps taken after a permissible activity has ceased to prevent contamination of surface waters from the inactive site.
- (19) “Commencement of construction” is the initial disturbance of soils associated with clearing, grading, or excavating activities or other construction activities.
- (20) “Commissioner” means the Commissioner of the Department of Environment and Conservation or the Commissioner’s duly authorized representative and, in the event of the Commissioner’s absence or a vacancy in the office of Commissioner, the Deputy Commissioner.
- (21) A “composite sample” is a combination of not less than 8 influent or effluent portions, of at least 100 ml, collected over a 24-hour period. Under certain circumstances a lesser time period may be allowed, but in no case, less than 8 hours.
- (22) A “concentrated animal feeding operation” (CAFO) is an AFO that either meets the large (Class I) CAFO size criteria of paragraph (2) of Rule 0400-40-05-.14, the medium (Class II) criteria of paragraph (3) of Rule 0400-40-05-.14, or has otherwise been designated as a CAFO by the Director.
- (23) “Construction” means any placement, assembly, or installation of facilities or equipment (including contractual obligations to purchase such facilities or equipment) at the premises where such equipment will be used, including preparation work at such premises.
- (24) The “daily maximum amount” is a limitation on the total amount of any pollutant in the discharge by weight during any calendar day.
- (25) The “daily maximum concentration” is a limitation on the average concentration, in units of mass per volume, of the discharge during any calendar day. When a proportional-to-flow composite sampling device is used, the daily concentration is the concentration of that 24-hour composite; when other sampling means are used, the daily concentration is the arithmetic mean of the concentrations of equal volume samples collected during any calendar day or sampling period.
- (26) The meaning of “degradation” shall be the same as defined in Rule 0400-40-03-.04.
- (27) “Department” means the Department of Environment and Conservation.
- (28) “Director” means the director of the Division of Water Resources.
- (29) “Discharge” or “discharge of a pollutant” refers to the addition of pollutants to waters from a source.
- (30) “Division” means the Division of Water Resources.
- (31) A “dry weather overflow” is a type of sanitary sewer overflow and is defined as one day or any portion of a day in which unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall occurs and is not directly related to

(Rule 0400-40-05-.02, continued)

- a rainfall event. Discharges from more than one point within a 24-hour period shall be counted as separate overflows.
- (32) "Effluent limitation" means any restriction, established by the Board or the Commissioner, on quantities, rates or concentrations of chemical, physical, biological, or other constituents which are discharged into waters or adjacent to waters.
- (33) "Fecal coliform" means fecal coliform bacteria, an indicator of pathogenic organisms.
- (34) The "geometric mean" of any set of values is the n^{th} root of the product of the individual values where n is equal to the number of individual values. The geometric mean is equivalent to the antilog of the arithmetic mean of the logarithms of the individual values. For the purposes of calculating the geometric mean, values of zero shall be considered to be one.
- (35) A "grab sample" is a single influent or effluent sample collected at a particular time.
- (36) "Hydrologic connection" means the interflow and exchange between surface impoundments or containment structures and groundwater or surface water through an underground corridor or pathway. In the context of this Chapter, the purpose of prevention/reduction of hydrologic connection is to prevent/ reduce groundwater flow contact resulting in the transfer of pollutants into groundwater.
- (37) "IC₂₅" refers to the inhibition concentration in which at least a 25% reduction in reproduction and/or growth in test organisms occurs.
- (38) "Industrial user" means those industries identified in the standard industrial classification manual, Bureau of the Budget, 1987, as amended and supplemented, under the category "Division D - Manufacturing" and such other classes of significant waste producers as the board or commissioner deems appropriate.
- (39) "Industrial wastes" means any liquid, solid, or gaseous substance, or combination thereof, or form of energy including heat, resulting from any process of industry, manufacture, trade, or business or from the development of any natural resource.
- (40) The "instantaneous maximum concentration" is a limitation on the concentration, in units of mass per volume (where appropriate), of any pollutant contained in the wastewater discharge determined from a grab sample taken of the discharge at any point in time.
- (41) The "instantaneous minimum concentration" is the minimum allowable concentration, in units of mass per volume (where appropriate), of a pollutant parameter contained in the wastewater discharge determined from a grab sample taken from the discharge at any point in time.
- (42) "Land application area" means the land under the control of an AFO owner or operator to which manure, litter or process wastewater from the AFO production area is or may be applied.
- (43) A "large CAFO" (Class I CAFO) is an AFO that confines greater than or equal to the number of animals specified in TABLE 0400-40-05-.14.1.
- (44) "LC₅₀" refers to the concentration that causes at least 50% lethality of the test organisms.
- (45) "Major facility" refers to a municipal or domestic wastewater treatment plant with a design capacity of 1 million gallons per day or greater; or any other facility or activity classified as such by the Commissioner.

(Rule 0400-40-05-.02, continued)

- (46) The term “manure” is defined to include manure, bedding, compost and raw materials or other materials comingled with manure or set aside for disposal.
- (47) “Mature dairy cow” refers to a cow that has previously given birth to a calf.
- (48) A “medium CAFO” (Class II CAFO) is an AFO that falls within the size threshold for the animals specified in column 3 of TABLE 0400-40-05-.14.1 and also meets the criteria of paragraph (3) of Rule 0400-40-05-.14.
- (49) “Minor facility” refers to any facility or activity that is not a major facility.
- (50) The “monthly average amount”, is the arithmetic mean of all the measured daily discharges by weight during the calendar month when the measurements were made.
- (51) The “monthly average concentration”, a limitation on the discharge concentration in units of mass per volume, of any pollutant, other than bacteria, is the arithmetic mean of all the composite or grab samples collected in a one calendar-month period.
- (52) “Multi-year phosphorus application” means phosphorus applied to a field in excess of crop needs and/or crop removal rates when there is no soil test recommendation for phosphorus and the Tennessee Phosphorus Index indicates manure, litter or process wastewater should be applied at the crop phosphorus removal rate. Subsequent phosphorus application is prohibited until the applied phosphorus has been removed via harvest and/or crop removal or a subsequent soil test indicates phosphorus is required. Crop phosphorus removal rates are set by University of Tennessee Extension technical guidance documents for nutrient management.
- (53) “National Pollutant Discharge Elimination System (NPDES)” means the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the federal CWA. The term includes an “approved program.”
- (54) A “natural riparian buffer” is a permanent strip of natural vegetation adjacent to a stream that contains dense vegetation made up of grass, shrubs and trees. The purpose of a natural riparian buffer is to maintain existing water quality by minimizing the risk of any potential nutrients or pollutants from leaving the field and reaching adjacent surface waters and to further prevent negative water quality impacts by providing canopy over adjacent waters.
- (55) The term “new source” means any building, structure, facility, area or installation from which there is or may be a “discharge of pollutants,” the construction of which commenced after the publication of state or federal regulations prescribing a standard of performance.
- (56) “Nitrate (as N)” means nitrate reported as nitrogen.
- (57) “Non-contact cooling water” in general practice, refers to cooling water that does not contact raw materials, materials being produced, finished product, by-products or process wastewater. For some industrial categories, other, more specialized definitions related to non-contact cooling water may also apply.
- (58) “Nonpoint source pollution” occurs when precipitation moves over and through the ground, picks up and carries away pollutants and deposits them into waters of the state.
- (59) The term “1-hour average maximum” is a limitation on the concentration in units of mass per volume, of a composite consisting of any three equal volume grab samples collected consecutively at 30 minute intervals.

(Rule 0400-40-05-.02, continued)

- (60) A “one week period” (or “calendar-week”) is defined as the period from Sunday through Saturday. For reporting purposes, a calendar-week that contains a change of month shall be considered part of the latter month.
- (61) “Owner or operator” means any person who owns, leases, operates, controls or supervises a source.
- (62) A “quarter” is defined as any one of the following three-month periods: January 1 through March 31, April 1 through June 30, July 1 through September 30, and/or October 1 through December 31.
- (63) “Permit” means an authorization, license, or equivalent control document issued by the Division of Water Resources which implements the requirements of the TWQCA. “Permit” includes an NPDES “general permit.”
- (64) “Permit action” refers to the issuance, reissuance, revocation, denial or modification of an individual permit.
- (65) “Point source” means any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.
- (66) “Person” means an individual, association, partnership, corporation, municipality, state or federal agency, or an agent or employee thereof.
- (67) “Pollutant” means sewage, industrial wastes, or other wastes.
- (68) “Pollution” means such alteration of the physical, chemical, biological, bacteriological, or radiological properties of the waters of this state including, but not limited to, changes in temperature, taste, color, turbidity, or odor of the waters that will:
- (a) Result or will likely result in harm, potential harm or detriment of the public health, safety, or welfare;
 - (b) Result or will likely result in harm, potential harm or detriment to the health of animals, birds, fish, or aquatic life;
 - (c) Render or will likely render the waters substantially less useful for domestic, municipal, industrial, agricultural, recreational, or other reasonable uses; or
 - (d) Leave or likely leave the waters in such condition as to violate any standards of water quality established by the board.
- (69) “Process wastewater” for operations other than AFOs means any water which, during manufacturing or processing, comes into direct contact with or results from the production or use of any raw material, intermediate product, finished product, byproduct, or waste product.
- (70) “Process wastewater” for AFOs means water directly or indirectly used in the operation of the AFO for any or all of the following: spillage or overflow from animal or poultry watering systems; washing, cleaning, or flushing pens, barns, manure pits, or other AFO facilities; direct contact swimming, washing, or spray cooling of animals; or dust control. Process wastewater also includes any water which comes into contact with any raw materials, products, or byproducts including manure, litter, feed, milk, eggs, or bedding.

(Rule 0400-40-05-.02, continued)

- (71) A “rainfall event” is defined as any occurrence of rain, preceded by 10 hours without precipitation that results in an accumulation of 0.01 inches or more. Instances of rainfall occurring within 10 hours of each other will be considered a single rainfall event. Ten-year, 24-hour rainfall event, 25-year, 24-hour rainfall event, and 100-year, 24-hour rainfall event are mean precipitation events with a probable recurrence interval of once in 10 years, or 25 years, or 100 years, respectively, as defined by the National Weather Service in Technical Paper No. 40, “Rainfall Frequency Atlas of the United States,” May, 1961, or equivalent regional or state rainfall probability information developed from this source.
- (72) A “rationale” (or “fact sheet”) is a document that is prepared when drafting an NPDES permit or permit action. It provides the technical, regulatory and administrative basis for an agency’s permit decision.
- (73) A “sanitary sewer overflow (SSO)” is defined as an unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall.
- (74) “Schedules of compliance” means a schedule of remedial measures including an enforceable sequence of actions or operations leading to compliance with an effluent limitation, condition of a permit, other limitation, prohibition, standard, or regulation.
- (75) “Setback” means a specified distance from surface waters or potential conduits to surface waters where manure, litter, and process wastewater may not be land applied. Examples of conduits to surface waters include but are not limited to: open tile line intake structures, sinkholes, and wells.
- (76) “Severe property damage” when used to consider the allowance of a bypass or SSO means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass or SSO. Severe property damage does not mean economic loss caused by delays in production.
- (77) “Sewage” means water-carried waste or discharges from human beings or animals, from residences, public or private buildings, or industrial establishments, or boats, together with such other wastes and ground, surface, storm, or other water as may be present.
- (78) “Sewerage system” means the conduits, sewers, and all devices and appurtenances by means of which sewage and other waste is collected, pumped, treated, or disposed.
- (79) “Source” means any activity, operation, construction, building, structure, facility, or installation from which there is or may be the discharge of pollutants.
- (80) “Standard of performance” means a standard for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the commissioner determines to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.
- (81) “Stream” means a surface water that is not a wet weather conveyance.
- (82) “Total coliform” means all coliform bacteria.
- (83) “Total dissolved solids (TDS)” means nonfilterable residue.
- (84) “Toxic effluent limitation” means an effluent limitation on those pollutants or combinations of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or

(Rule 0400-40-05-.02, continued)

indirectly by ingestion through food chains, will, on the basis of available information, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring.

- (85) "Upset" means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.
- (86) "USDA-NRCS" means the Natural Resources Conservation Service, an agency within the U.S. Department of Agriculture.
- (87) "Variance" means an authorization issued to a person by the Commissioner, which would allow that person to cause a water quality standard to be exceeded for a limited time period without changing the standard.
- (88) "Vegetated buffer" means a narrow, permanent strip of dense perennial vegetation established parallel to the contours of and perpendicular to the dominant slope of the field for the purposes of slowing water runoff, enhancing water infiltration, and minimizing the risk of any potential nutrients or pollutants from leaving the field and reaching surface waters.
- (89) The term, "washout" is applicable to activated sludge plants and is defined as loss of mixed liquor suspended solids (MLSS) of 30.00% or more from the aeration basin(s).
- (90) "Watercourse" means a man-made or natural hydrologic feature with a defined linear channel which discretely conveys flowing water, as opposed to sheet-flow.
- (91) "Waters" means any and all water, public or private, on or beneath the surface of the ground, which are contained within, flow through, or border upon Tennessee or any portion thereof except those bodies of water confined to and retained within the limits of private property in single ownership which do not combine or effect a junction with natural surface or underground waters.
- (92) The term "water quality limited segment" means any segment where it is known that water quality does not meet applicable water quality standards, and/or is not expected to meet applicable water quality standards, even after the application of the technology-based effluent limitations required by sections 301(b) and 306 of the federal CWA.
- (93) The "weekly average amount", is the arithmetic mean of all the measured daily discharges by weight during the calendar week when the measurements were made.
- (94) The "weekly average concentration", a limitation on the discharge concentration in units of mass per volume of any pollutant, is the arithmetic mean of all the concentrations measured in a calendar week.
- (95) "Wet weather conveyance" means, notwithstanding any other law or rule to the contrary, man-made or natural watercourses, including natural watercourses that have been modified by channelization:
- (a) That flow only in direct response to precipitation runoff in their immediate locality;
 - (b) Whose channels are at all times above the groundwater table;
 - (c) That are not suitable for drinking water supplies; and

(Rule 0400-40-05-.02, continued)

- (d) In which hydrological and biological analyses indicate that, under normal weather conditions, due to naturally occurring ephemeral or low flow there is not sufficient water to support fish, or multiple populations of obligate lotic aquatic organisms whose life cycle includes an aquatic phase of at least two months.
- (96) A “wet weather overflow” is a type of sanitary sewer overflow and defined as an unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall that is directly related to a specific rainfall event. Discharges occurring from multiple locations within a single rainfall event are considered separate, wet-weather overflows.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.03 EXCLUSIONS.

- (1) The following discharges do not require NPDES permits:
 - (a) Any introduction of pollutants from non point-source agricultural and silvicultural activities, including storm water runoff from orchards, cultivated crops, pastures, range lands, and forest lands; and
 - (b) Return flows from irrigated agriculture.
- (2) Discharges into a septic tank connected only to a subsurface drain field do not require a state issued permit under T.C.A. § 69-3-108.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.04 PROHIBITIONS.

- (1) No permits shall be issued authorizing any of the following discharges:
 - (a) The discharge of any radiological, chemical, or biological warfare agent;
 - (b) The discharge of radioactive waste into waters (though this does not prohibit radioactivity from authorized discharges provided such discharge is in accordance with state water quality standards);
 - (c) Any discharge which the Secretary of the Army acting through the chief of engineers finds would substantially impair anchorage and navigation;
 - (d) Any discharge to which the regional administrator has objected in writing in a timely fashion according to Section 402(d)(2), federal Clean Water Act (CWA);
 - (e) Any discharge from a source with effluent limitations less stringent than those included in an approved area-wide waste treatment management plan;
 - (f) When the conditions of the permit do not provide for compliance with the applicable requirements of either the federal CWA, or the Tennessee Water Quality Control Act (TWQCA); or
 - (g) To a new source or a new discharger, if the discharge from its construction or operation will cause or contribute to the violation of water quality standards.

(Rule 0400-40-05-.04, continued)

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.05 PERMIT APPLICATION, ISSUANCE.

- (1) Any person who plans to engage or is engaging in any of the activities outlined in T.C.A. § 69-3-108(b) or (c) shall make application in writing to the Commissioner for a permit, or for modification of an existing permit; except where a person discharges into a publicly owned sewerage system or into a septic tank connected only to a subsurface drain field.
- (2) Applicants shall complete and submit standard application forms supplied by the Commissioner together with such engineering reports, plans and specifications as are required. The Commissioner may subsequently request additional reasonable information as required in order to make the permit decision. If an environmental impact statement is required by federal regulation, the Commissioner may require the applicant to pay for its preparation. Processing of an application shall not be completed until all requested information has been supplied. The applicant will be provided notice of completeness of the application and re-submitted material within 30 days of a determination that such material constitutes a complete application. This provision does not preclude the Commissioner from later requesting additional material that subsequent to the notice of completeness is determined to be necessary for permit processing.
- (3) Completed applications for new source discharges or for substantial changes in the nature, volume or frequency of existing permitted discharges shall be submitted:
 - (a) For state permits, no later than 180 days in advance of the date on which the operation is to commence or change, unless permission for a later application date has been granted by the Commissioner. Persons proposing a new operation are encouraged to submit their applications well in advance of the 180-day requirement to avoid delay.
 - (b) For NPDES permits, no later than 180 days in advance of the date on which the discharge is to commence or change, unless permission for a later application date has been granted by the Commissioner. Persons proposing a new discharge are encouraged to submit their applications well in advance of the 180-day requirement to avoid delay.
- (4) All permittees with currently effective permits shall submit a new application 180 days before the existing permit expires, except that the Commissioner may grant permission to submit an application later than the deadline for submission otherwise applicable, but no later than the permit expiration date.
- (5) For facilities eligible for coverage under any state-issued general permit, notices of intent shall be submitted in accordance with timeframes established in the applicable general permit.
- (6) Applications shall be submitted in accordance with the following:
 - (a) For a corporation:
 1. By a responsible corporate officer, i.e., a president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy- or decision-making functions for the corporation;

(Rule 0400-40-05-.05, continued)

2. By a manager of one or more manufacturing, production, or operating facilities, provided, the manager is authorized to make management decisions which govern the operation of the regulated facility to assure long term environmental compliance with environmental laws and regulations; or
 3. By a person in a corporate position to which signatory authority has been delegated by a corporate officer.
- (b) For a partnership or sole proprietorship: by a general partner or the proprietor, respectively.
- (c) For a municipality, state, federal, or other public agency:
1. A principal executive officer (i.e., the chief executive officer of the agency, or a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency); or
 2. Ranking elected official.
- (7) The Commissioner may agree with the regional administrator on the exchange of completed applications and other information.
- (8) The Commissioner will not authorize construction related to any such application as described in paragraphs (1) through (6) of this rule until after the end of the public comment period as outlined in Rule 0400-40-05-.06.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.06 NOTICE AND PUBLIC PARTICIPATION.

- (1) For an individual application for a new or expanded discharge, the applicant shall notify the public of the application by posting a sign near the point of entrance to such facility and within view of a public road. The sign shall contain provisions as specified by the Commissioner. The sign shall be of such size that is legible from the public road. Also, the sign shall be maintained for at least 30 days following submittal of the application to the division.
- (2) Each completed application (or request for permit action) shall be evaluated and a tentative determination of whether to issue or deny a permit action shall be made. If a tentative determination is made to issue a permit, then a draft permit shall be prepared that includes proposed effluent limitations, a proposed schedule of compliance, including interim dates and requirements, and a brief description of any other proposed special conditions. A rationale, as defined in paragraph (3) of this rule, shall also be provided along with the draft permit. The Commissioner may attach other relevant information as necessary.
- (3) For each application, the Commissioner shall prepare a rationale that includes or considers as appropriate:
 - (a) The type and quantity of wastes, fluids, or pollutants which are proposed to be or are being treated, stored, disposed of, injected, emitted, or discharged;
 - (b) A brief summary of the basis for the draft permit conditions including references to applicable statutory or regulatory provisions and appropriate supporting references to the administrative record;

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- (c) Reasons why any requested variances or alternatives to required standards do or do not appear justified;
- (d) The location of the discharge or activity described in the application;
- (e) A quantitative and qualitative description of the discharge described in the application which includes at least the following:
 - 1. The rate or frequency of the proposed discharge; if the discharge is continuous, the average and maximum daily flow in gallons per day or million gallons per day;
 - 2. For thermal discharges subject to limitation, the average and maximum summer and winter temperature;
 - 3. The average and maximum daily discharge in pounds per day and concentrations in units of mass per volume of any pollutants which are present in significant quantities or which are subject to limitations or prohibition under described provisions of T.C.A. §§ 69-3-101 et seq. or this rule; and
 - 4. Other parameters for which control may be required by the Commissioner;
- (f) Any calculations or other necessary explanation of the derivation of specific effluent limitations and conditions including a citation to the applicable effluent limitation guideline, performance standard, reasons why they are applicable or an explanation of how the alternate effluent limitations were developed;
- (g) When the draft permit contains any of the following conditions, an explanation of the reasons why such conditions are applicable:
 - 1. Technology-based limitations to control toxic pollutants;
 - 2. Limitations on internal waste streams;
 - 3. Limitations on indicator pollutants; or
 - 4. Limitations set on a case-by-case basis;
- (h) The tentative determination regarding the discharge;
- (i) A brief citation, including a brief identification of the uses for which the receiving waters have been classified, of the water quality standards and effluent standards and limitations applied to the proposed discharge;
- (j) A fuller description of the procedures for the formulation of final determinations than that given in the public notice including:
 - 1. The beginning and ending dates of the 30-day comment period required by this rule;
 - 2. The address where comments will be received;
 - 3. Procedures for requesting a public hearing and the nature thereof; and

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4. Any other procedures by which the public may participate in the formulation of the final determinations; and
 - (k) Name and telephone number of a person to contact for additional information;
- (4) The Commissioner shall ensure that the public is notified that the following actions have occurred:
 - (a) A permit application has been tentatively denied;
 - (b) A draft permit has been prepared;
 - (c) A hearing has been scheduled; or
 - (d) An appeal has been granted.
- (5) No public notice is required:
 - (a) When a request for permit modification, revocation and reissuance, or termination is denied based on the Commissioner's determination that the request was not justified (written notice of that denial shall be given to the requester and to the permittee); or
 - (b) For minor permit modifications which include corrections of typographical errors, requiring more frequent monitoring or reporting, changing an interim compliance date or allowing a change of ownership.
- (6) Public notices may describe more than one permit or permit actions.
- (7) Public notice of the preparation of a draft permit (including a notice of intent to deny a permit application) required under this rule shall allow at least 30 days for public comment.
- (8) Public notice of a public hearing shall be given at least 30 days before the hearing. (Public notice of the hearing may be given at the same time as public notice of the draft permit, and the two notices may be combined.)
- (9) In order to inform interested and potentially interested persons of the proposed discharge/activity and of the tentative determinations regarding it, public notice shall be circulated within the geographical area of the proposed discharge by the following means:
 - (a) For new, major NPDES or general permits and public hearings, publishing in local daily or weekly newspapers and periodicals, or, if appropriate, in a daily newspaper of general circulation;
 - (b) For all permits, by mailing (either electronically and/or physically) a copy of the notice to the following persons:
 1. The applicant (except general permits when there is no applicant);
 2. Any other agency which the Director knows has issued or is required to issue other permits for the same facility or activity;
 3. Federal and state agencies with jurisdiction over fish and wildlife resources and historic preservation;
 4. Any affected states and Indian Tribes;

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5. For NPDES only:
 - (i) Any state agency responsible for plan development under CWA section 208(b)(2), 208(b)(4) or 303(e) and the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service;
 - (ii) Any user identified in the permit application of a privately owned treatment works;
 6. Persons on a mailing list developed by:
 - (i) Including those who request in writing to be on the list;
 - (ii) Soliciting persons for "area lists" from participants in past permit proceedings in that area;
 - (iii) Notifying the public of the opportunity to be put on the mailing list through periodic publication in the public press, newsletters, environmental bulletins, or state law journals; (The Commissioner may update the mailing list from time to time by requesting written indication of continued interest from those listed. The Commissioner may delete from the list the name of any person who fails to respond to such a request.)
 7. To any unit of local government having jurisdiction over the area where the facility is proposed to be located;
 8. To each state agency having any authority under state law with respect to the construction or operation of such facility; and
 - (c) If determined necessary by the commissioner, any other method reasonably calculated to give actual notice of the action in question to the persons potentially affected by it, including press releases, website postings or any other forum or medium to elicit public participation.
- (10) Public notice of applications shall include the following:
- (a) Name, address, phone number of the Division;
 - (b) Name and location address of each applicant;
 - (c) Brief description of each applicant's activities or operations which result in the discharge described in the application or are adjacent to waters (e.g.: municipal waste treatment plant, steel manufacturing, drainage from mining activities);
 - (d) Name of waterway to which each discharge is made or to which each activity is adjacent and a short description of the location of each discharge on the waterway indicating whether such discharge/activity is new or existing;
 - (e) A statement of the tentative determination to issue or deny a permit for the discharge described in the application;
 - (f) A brief description of the procedures for the formulation of final determinations, including the 30-day comment period required by this rule and any other means by which interested persons may influence or comment upon those determinations;

(Rule 0400-40-05-.06, continued)

- (g) Address and phone number of the premises at which interested persons may obtain further information, request a copy of the draft permit, request a copy of the rationale and inspect and copy forms and related documents; and
 - (h) Any other information that the Commissioner deems necessary.
- (11) Interested persons may submit written comments on the tentative determinations within either 30 days of public notice or such greater period as the Commissioner allows. All written comments submitted shall be retained and considered in the final determination. The Commissioner shall give any state or interstate agencies whose waters will be affected a written explanation of the decision not to incorporate any written recommendation made by that state or agency.
- (12) Interested persons may request in writing that the Commissioner hold a public hearing on any application. The request shall be filed within the period allowed for public comment and shall indicate the interest of the party filing it and the reasons why a hearing is warranted. If there is a significant public interest in having a hearing, the Commissioner shall hold one in the geographical area of the proposed discharge. Instances of doubt should be resolved in favor of holding the hearing.
- (13) Special provisions regarding public notices for public hearings
- (a) In addition to the public notice procedures of paragraph (9) of this rule, notice of public hearing shall be sent to all persons who received a copy of the notice or rationale for the application, any person who submitted comments on the draft permit action, all persons who requested the public hearing and any person who specifically requests a copy of the notice of hearing.
 - (b) Each notice of a public hearing shall include at least the following contents:
 - 1. Name, address, and phone number of the Division;
 - 2. Name and address of each applicant whose application will be considered at the hearing;
 - 3. Name of waterway to which each discharge is made or to which each activity is adjacent and a short description of the location of each discharge on the waterway indicating whether such discharge/activity is new or existing;
 - 4. A brief reference to the public notice issued for each application, including identification number and date of issuance;
 - 5. Information regarding the time and location for the hearing;
 - 6. The purpose of the hearing;
 - 7. A concise statement of the issues raised by the persons requesting the hearing;
 - 8. Address and phone number of premises at which interested persons may obtain further information, request a copy of each draft permit, request a copy of each fact sheet, and inspect and copy forms and related documents;
 - 9. A brief description of the nature of the hearing, including the rules and procedures to be followed; and
 - 10. Any other information deemed necessary by the Commissioner.

(Rule 0400-40-05-.06, continued)

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.07 TERMS AND CONDITIONS OF PERMITS.

- (1) When a permit is granted it shall be subject to the provisions of T.C.A. §§ 69-3-101 et seq., these regulations, and any special terms or conditions the Commissioner determines are necessary to fulfill the purposes or enforce the provisions of that section.
 - (a) The terms and conditions of each permit shall insure compliance with applicable effluent limitations, including schedules of compliance, promulgated by the Board. If more stringent effluent limitations are necessary to implement applicable water quality standards, to avoid conflict with an approved area-wide waste treatment management plan, or to comply with other state or federal laws or regulations, then they should be imposed in the permit.
 - (b) If the permit is for the discharge of pollutants from a vessel or other floating craft, the permit shall insure compliance with any applicable regulations promulgated by the Secretary of the department in which the Coast Guard is operating, establishing specifications for safe transportation, handling, carriage, storage, and stowage of pollutants.
 - (c) In the application of effluent standards and limitations, water quality standards, and other legally applicable requirements, the Commissioner may, for each issued permit, specify average and maximum daily quantitative limitations for the level of pollutants in the authorized discharge in terms of weight (except pH, temperature, radiation, and any other pollutants not appropriately expressed by weight). The Commissioner may, in addition to the specifications of daily quantitative limitations by weight, specify daily average and daily maximum concentration limits for those pollutants subject to limitation. In addition, limitations expressed in other terminology may be required when necessary to protect water quality or to describe adequate operation of a treatment facility.
- (2) The following standard conditions, where appropriate, apply to NPDES permits as well as state permits issued for the treatment, collection or disposal of wastewater:
 - (a) Duty to comply.

The permittee shall comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Water Quality Control Act and is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or denial of a permit renewal application.
 - (b) Duty to reapply.

If the permittee wishes to continue an activity regulated by this permit after the expiration date of this permit, the permittee shall apply for and obtain a new permit.
 - (c) Proper operation and maintenance.

The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of backup or auxiliary

(Rule 0400-40-05-.07, continued)

facilities or similar systems, which are installed by a permittee only when the operation is necessary to achieve compliance with the conditions of the permit.

(d) Permit actions.

This permit may be modified, revoked and reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance does not stay any permit condition. Causes for such permit action include but are not limited to the following:

1. Violation of any terms or conditions of the permit;
2. Obtaining a permit by misrepresentation or failure to disclose fully all relevant facts; and
3. A change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge.

(e) Property rights.

This permit does not convey property rights of any sort, or any exclusive privilege.

(f) Duty to provide information.

The permittee shall furnish to the Commissioner, within a reasonable time, any information which the Commissioner may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit or to determine compliance with this permit. The permittee shall also furnish to the Commissioner upon request, copies of records required to be kept by this permit.

(g) Inspection and entry.

The permittee shall allow the Commissioner, or an authorized representative, upon presentation of credentials and other documents as may be required by law, to:

1. Enter upon the permittee's premises where a regulated facility or activity is located or conducted, or where records shall be kept under the conditions of this permit;
2. Have access to and copy, at reasonable times, any records that shall be kept under the conditions of this permit;
3. Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and
4. Sample or monitor at reasonable times, for the purposes of assuring permit compliance or as otherwise authorized by the Commissioner.

(h) Monitoring, records and reporting.

Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity. The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all

(Rule 0400-40-05-.07, continued)

reports required by this permit, and records of all data used to complete the application for this permit, for a period of at least 3 years from the date of the sample, measurement, report or application. This period may be extended by request of the Director at any time.

1. Records of monitoring information shall include:
 - (i) The date, exact place, and time of sampling or measurements;
 - (ii) The individual(s) who performed the sampling or measurements;
 - (iii) The date analyses were performed;
 - (iv) The individual(s) who performed the analyses;
 - (v) The laboratory where the analyses were performed;
 - (vi) The analytical techniques or methods used; and
 - (vii) The results of such analyses.
2. Monitoring results shall be conducted according to test procedures approved under 40 CFR part 136.
3. Regular reporting (at a frequency of not less than once per year) to assure that compliance is being achieved will normally be required of the discharger in any permit as indicated below:
 - (i) Monitoring results shall be reported on a Discharge Monitoring Report (DMR) or forms provided or specified by the Commissioner. Monitoring may also be reported via electronic reporting methods established by the Commissioner.
 - (ii) If the permittee monitors any pollutant more frequently than required by the permit using test procedures approved under 40 CFR Part 136, or as specified in the permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the DMR or other reporting form specified by the Commissioner.
 - (iii) Calculations for all limitations, which require averaging of measurements, shall utilize an arithmetic mean unless otherwise specified in the permit.

- (i) Signatory requirement.

All applications, reports, or information submitted to the Commissioner shall be signed and certified by the persons identified in subparagraphs (6)(a) through (c) of Rule 0400-40-05-.05.

- (j) Planned changes.

The permittee shall give notice to the Director as soon as possible of any planned physical alterations or additions to the permitted facility. Notice is required only when:

1. The alteration or addition to a permitted facility is considered a new source as defined in Rule 0400-40-05-.02;

(Rule 0400-40-05-.07, continued)

2. The alteration or addition could significantly change the nature or increase the quantity of pollutants discharged; or
3. The alteration or addition results in a significant change in the permittee's sludge use or disposal practices.

(k) Transfers.

Individual permits are not transferable to any person except after notice to the Commissioner, as specified below. The Commissioner may require modification or revocation and reissuance of the permit to change the name of the permittee.

1. The permittee notifies the Commissioner of the proposed transfer at least 30 days in advance of the proposed transfer date.
2. The notice includes a written agreement between the existing and new permittees containing a specified date for transfer of permit responsibility, coverage, and liability between them.
3. The permittee shall provide the following information to the Commissioner in their formal notice of intent to transfer ownership:
 - (i) The permit number of the subject permit;
 - (ii) The effective date of the proposed transfer;
 - (iii) The name and address of the transferor;
 - (iv) The name and address of the transferee;
 - (v) The names of the responsible parties for both the transferor and transferee;
 - (vi) A statement that the transferee assumes responsibility for the subject permit;
 - (vii) A statement that the transferor relinquishes responsibility for the subject permit;
 - (viii) The signatures of the responsible parties for both the transferor and transferee pursuant to the signatory requirements of subparagraph (i) of this paragraph; and
 - (ix) A statement regarding any proposed modifications to the facility, its operations, or any other changes, which might affect the permit, limits and conditions contained in the permit.

(l) Bypass, as defined in Rule 0400-40-05-.02, is prohibited unless:

1. Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;
2. There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate backup equipment should have been installed in the exercise of reasonable

(Rule 0400-40-05-.07, continued)

- engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and
3. For anticipated bypass, the permittee submits prior notice, if possible at least ten days before the date of the bypass; or
 4. For unanticipated bypass, the permittee submits notice of an unanticipated bypass within 24 hours from the time that the permittee becomes aware of the bypass.
- (m) A bypass that does not cause effluent limitations to be exceeded may be allowed only if the bypass is necessary for essential maintenance to assure efficient operation.
- (n) Sanitary sewer overflows, including dry-weather overflows and wet weather overflows as defined in Rule 0400-40-05-.02 are prohibited.
- (o) In the case of any noncompliance which could cause a threat to human health or the environment, the permittee shall report the noncompliance to the commissioner within 24 hours from the time the permittee becomes aware of the circumstances. A written submission shall be provided within 5 days of the time the permittee becomes aware of the noncompliance. The permittee shall provide the following information:
1. A description of, and the cause of the noncompliance;
 2. The period of noncompliance, including exact dates and times or, if not corrected, the anticipated time the noncompliance is expected to continue; and
 3. The steps being taken to reduce, eliminate, and prevent recurrence of the noncompliance.
- (p) An upset shall constitute an affirmative defense to an action brought for noncompliance with such technology-based permit effluent limitations if the permittee demonstrates, through properly signed, contemporaneous operating logs, or other relevant evidence that:
1. An upset occurred and that the permittee can identify the cause(s) of the upset;
 2. The permitted facility was at the time being operated in a prudent and workman-like manner and in compliance with proper operation and maintenance procedures;
 3. The permittee submitted information required under "Reporting of Noncompliance" within 24 hours of becoming aware of the upset (if this information is provided orally, a written submission shall be provided within 5 days); and
 4. The permittee complied with any remedial measures required under "Adverse Impact."
- (q) The permittee shall take all reasonable steps to minimize any adverse impact to the waters of Tennessee resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the non-complying discharge. It shall not be a defense for the permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

(Rule 0400-40-05-.07, continued)

- (r) The following notification requirements apply to industrial/mining dischargers and publicly owned treatment works.
1. Industrial/mining dischargers shall notify the Commissioner as soon as they know or have reason to believe:
 - (i) That any activity has occurred or will occur which would result in the discharge on a routine or frequent basis, of any toxic substance(s) (listed at 40 CFR Part 122, Appendix D, Table II and III) which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels":
 - (I) 100 micrograms per liter (100 µg/l);
 - (II) 200 micrograms per liter (200 µg/l) for acrolein and acrylonitrile; 500 micrograms per liter (500 µg/l) for 2,4-dinitrophenol and for 2-methyl-4,6-dinitrophenol; and 1 milligram per liter (1 mg/L) for antimony;
 - (III) 5 times the maximum concentration value reported for that pollutant(s) in the permit application; or
 - (IV) The level established by the Commissioner.
 - (ii) That any activity has occurred or will occur which would result in any discharge, on a non-routine or infrequent basis, of a toxic pollutant which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels":
 - (I) 500 micrograms per liter (500 µg/l);
 - (II) 1 milligram per liter (1 mg/L) for antimony;
 - (III) 10 times the maximum concentration value reported for that pollutant in the permit application; or
 - (IV) The level established by the Commissioner.
- (s) If the permit is for a discharge from a publicly owned treatment works, the permittee shall provide notice to the Commissioner of the following:
1. Any new introduction of pollutants into such treatment works from a source which would be a new source subject to new source performance standards if such source were discharging pollutants;
 2. Except as to such categories and classes of sources or discharges specified by the Commissioner, any new introduction of pollutants into such treatment works from a source which would be required to obtain a permit if such source were discharging pollutants; and,
 3. Any substantial change in volume or character of pollutants being introduced into such treatment works by a source introducing pollutants into such works at the time of issuance of the permit; and
 4. Such notice shall include information on (i) the quality and quantity of effluent to be introduced into such treatment works and (ii) any anticipated impact of such

(Rule 0400-40-05-.07, continued)

change in the quantity or quality of effluent to be discharged from such publicly owned treatment works.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.08 EFFLUENT LIMITATIONS AND STANDARDS.

- (1) Effluent standards and limitations shall be formulated in accordance with the following guidelines:
 - (a) For existing sources, other than publicly owned treatment works, effluent limitations shall be designed to require application of the best practicable control technology currently available and application of the best available technology economically achievable in accordance with requirements of Section 301(b)(2)(A), Federal Water Pollution Control Act, PL 92-500.
 - (b) For new sources technology-based effluent limitations shall require the greatest degree of effluent reduction achievable through application of the best available demonstrated control technology, which shall be new source performance standards, if available.
 - (c) Reserved.
 - (d) Toxic effluent limitations shall be based on consideration of the toxicity of the pollutant, its persistence, its degradability, the usual or potential presence of the affected organisms in any waters, the importance of the affected organisms and the nature and extent of the effect of the toxic pollutant on such organisms.
 - (e) Pretreatment standards shall be designed to prevent the introduction into publicly owned treatment works of those pollutants that may interfere with, pass through, or otherwise be incompatible with such works.
 - (f) All effluent limitations or standards shall meet or exceed any minimum standards promulgated by the administrator and currently effective under the Federal Water Pollution Control Act, P.L. 92-500 as amended or any subsequent applicable acts.
 - (g) All pollutants shall receive treatment or corrective action to insure compliance with effluent limitations established by the U.S. Environmental Protection Agency pursuant to Sections 301 and 302 and standards of performance for new sources pursuant to Section 306, effluent limitations and prohibitions and pretreatment standards pursuant to Section 307 of the Federal Water Pollution Control Act as amended, PL 92-500; also to insure compliance with any approved water quality standard, or avoid conflict with an approved area-wide waste treatment management plan prepared according to Section 208 of the federal law.
 - (h) Any schedules of compliance under this rule shall require compliance as soon as possible, but not later than the applicable statutory deadline under the federal law.
 - (i) Best management practices to control or abate the discharge of pollutants when numeric effluent limitations are infeasible and the practices are reasonably necessary to achieve effluent limitations and standards or to carry out the purposes and intent of TWQCA.
 - (j) 1. When a permit is renewed or reissued, effluent limitations, standards or conditions shall be at least as stringent as the effluent limitations, standards, or conditions in the previous permit unless:

(Rule 0400-40-05-.08, continued)

- (i) The circumstances on which the previous permit was based have materially and substantially changed since the time the permit was issued and would constitute cause for permit modification or revocation and reissuance;
 - (ii) Material and substantial alterations or additions to the permitted facility occurred after permit issuance which justify the application of a less stringent effluent limitation;
 - (iii) Information is available which was not available at the time of permit issuance (other than revised regulations, guidance, or test methods) and which would have justified the application of a less stringent effluent limitation at the time of permit issuance;
 - (iv) Technical mistakes or mistaken interpretations of law were made in issuing the permit;
 - (v) A less stringent effluent limitation is necessary because of events over which the permittee has no control and for which there is no reasonably available remedy; or
 - (vi) The permittee has installed the treatment facilities required to meet the effluent limitations in the previous permit and has properly operated and maintained the facilities but has nevertheless been unable to achieve the previous effluent limitations, in which case the limitations in the reviewed, reissued, or modified permit may reflect the level of pollutant control actually achieved.
- 2. In no event may a permit with respect to which this rule applies be renewed, reissued, or modified to contain an effluent limitation which is less stringent than required by effluent guidelines in effect at the time the permit is renewed, reissued, or modified.
 - 3. In no event may such a permit to discharge into waters be renewed, issued, or modified to contain a less stringent effluent limitation if the implementation of such limitation would result in a violation of a water quality standard.
- (k) All permit effluent limitations, standards, and prohibitions shall be established for each outfall or discharge point of the permitted facility, except as otherwise provided for BMPs where limitations on effluent or internal waste streams are infeasible.
 - (l) In the case of POTWs or domestic wastewater treatment plants, permit effluent limitations, standards, or prohibitions shall be calculated based on design flow.
 - (m) For continuous discharges, all permit effluent limitations, standards, and prohibitions shall be expressed as maximum daily, weekly average (for POTWs only) and monthly average, unless impracticable.
 - (n) Non-continuous discharges shall be limited in terms of frequency, total mass, maximum rate of discharge, and mass or concentrations of specified pollutants, as appropriate.
 - (o) Any permit limitations, standards, or prohibitions based on production shall be based upon a reasonable measure of actual production.

(Rule 0400-40-05-.08, continued)

1. For new sources or dischargers, actual production shall be estimated from projected production.
 2. The time period of the measure of production shall correspond to the time period of the resulting permit limits. For example, monthly production levels shall be used to calculate monthly average permit limits.
- (p) All permit effluent limitations, standard, or prohibitions for a metal shall be expressed as "total recoverable metal" unless a promulgated effluent guideline specifies otherwise.
- (q) When permit effluent limitations or standards imposed at the point of discharge are impractical or infeasible, effluent limitations or standards for discharges of pollutants may be imposed on internal waste streams before mixing with other waste streams or cooling water streams. In those instances, the monitoring required shall also be applied to the internal waste streams. Limits on internal waste streams will be imposed only when the rationale sets forth the exceptional circumstances which make such limitations necessary, such as when the final discharge point is inaccessible (for example, under water), the wastes at the point of discharge are so diluted as to make monitoring impracticable, or the interferences among pollutants at the point of discharge would make detection or analysis impracticable.
- (r) Instantaneous maximum concentration or similar limitations may be imposed in permits when:
1. Toxic or harmful parameters are present in such significant amounts or concentrations as to represent a threat to the possibility of maintaining receiving waters in accordance with established classifications; and
 2. The discharge is characterized as irregular, such as high peak, short duration flow.
- (s) Any discharge or activity authorized by a permit which is not a minor discharge or activity, or the regional administrator requests, in writing, be monitored, or contains a toxic pollutant for which an effluent standard has been established shall be monitored by the permittee for the following:
1. Flow (in million gallons per day); and
 2. Any of the following pollutants:
 - (i) Pollutants (either directly or indirectly through the use of accepted correlation coefficients or equivalent measurements determined to be applicable to the discharge to which they are applied) which are subject to reduction or elimination under the terms and conditions of the permit;
 - (ii) Pollutants which the commissioner finds, on the basis of information available, could have a significant impact on the quality of waters;
 - (iii) Pollutants specified by the administrator, in regulations issued pursuant to the Federal Water Pollution Control Act, as subject to monitoring; and
 - (iv) Any pollutants, in addition to those identified in subparts (i) through (iii) of this part, which the regional administrator or the Commissioner request be monitored.

(Rule 0400-40-05-.08, continued)

- (t) If a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established for a toxic pollutant which is present in the permittee's discharge and such standard or prohibition is more stringent than any limitation upon such pollutant in the permit, the Commissioner shall revise or modify the permit in accordance with established procedure to include the toxic effluent standard or prohibition and so notify the permittee.
- (2) All discharges authorized by the permit shall be consistent with the terms and conditions of the permit; facility expansions, production increases, or process modifications which result in new or increased discharges of pollutants shall be reported by submission of a new application or, if such discharge does not violate effluent limitations specified in the permit, by submission to the Commissioner of notice of such new or increased discharges of pollutants; the discharge of any pollutant more frequently than or at a level in excess of that identified and authorized by the permit shall constitute a violation of the terms and conditions of the permit.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014. Amendments filed May 24, 2018; effective August 22, 2018.

0400-40-05-.09 TECHNOLOGY-BASED EFFLUENT LIMITATIONS.

- (1) The U.S. Environmental Protection Agency has adopted effluent limitations and guidelines for existing sources and standards of performance for new sources pursuant to Section 301, 304, and 306 of the Federal Water Pollution Control Act as amended, PL 92-500. Permits for discharges will contain limitations and standards in accordance with these guidelines, when such are in effect unless more stringent limits are necessary to maintain designated uses. The Commissioner has authority pursuant to T.C.A. § 69-3-108 and Chapter 0400-40-03, to require wastewater treatment, independent of federal guidelines. The Commissioner may require a set of effluent limitations in each permit, which will indicate adequate operation or performance of treatment units used and which will appropriately limit those harmful parameters present in the wastewater. In the absence of federal guidelines, treatment units will be required to achieve the following as maximum effluent limitations when such parameters are present as a result of processes causing the contamination or discharges:
 - (a) Municipal and domestic wastewater treatment plants shall be limited by application of monthly average concentrations, weekly average concentrations, daily maximum amounts, and daily maximum concentrations of the 5 day, 20°C biochemical or carbonaceous biochemical oxygen demand (BOD₅ or CBOD₅) and suspended solids. In some cases, the daily maximum amount may be replaced by a minimum daily percent removal requirement. Limitations on chlorine residual may be required to prevent harmful amounts of chlorine discharge to the receiving waters. In addition, where harmful materials are acquired in a collection system, effluent limitations applicable to the treatment system will be required for such parameters.

1. Conventional Secondary Treatment Plants

| Parameter | Monthly Average (mg/l) | Weekly Average (mg/l) | Daily Maximum (mg/l) | Monthly Average % Removal |
|---------------------------------------|------------------------|-----------------------|----------------------|---------------------------|
| BOD ₅ or CBOD ₅ | 30/25 | 40/35 | 45/40 | 85 |
| TSS | 30 | 40 | 45 | 85 |

The concentration of settleable solids shall not exceed 1.0 ml/l as measured by the standard one-hour Imhoff cone test.

(Rule 0400-40-05-.09, continued)

2. Domestic waste stabilization lagoons

| Parameter | Monthly Average (mg/l) | Weekly Average (mg/l) | Daily Maximum (mg/l) | Monthly Average % Removal |
|-------------------------------------|------------------------|-----------------------|----------------------|---------------------------|
| BOD ₅ /CBOD ₅ | 45/40 | 50/45 | 65/60 | 65 |
| TSS | 100 | 110 | 120 | n/a |

3. Non-discharging systems

Facilities that treat municipal and/or domestic wastewater, but do not discharge into waters of the state, shall be limited in terms of BOD₅ and other pollutants such as NH₃-N, NO₃-N, and fecal coliform as necessary. Limits shall be set in such a way to assure efficient operation and protection of groundwater.

(b) Industrial discharges

1. For industrial discharges with applicable federal effluent guidelines, technology-based effluent limitations and standards in accordance with those guidelines shall be applied.
2. For industrial discharges without applicable federal effluent guidelines, best professional judgment should be employed to determine appropriate effluent limitations and standards.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.10 WATER QUALITY-BASED PERMITTING.

- (1) Effluent limitations on toxic substances will be required in accordance with the General Water Quality Criteria, Chapter 0400-40-03, using the LC₅₀ and/or IC₂₅ criteria and appropriate application factor for each toxic parameter.
- (2) Appropriate limitations on organic related and other oxygen demanding parameters will be required in any permit to insure adequate dissolved oxygen in the state's waters in accordance with the General Water Quality Criteria, Chapter 0400-40-03.
- (3) When a treatment process greater than BAT or conventional unit treatment processes is required by application of these rules, a set of effluent limitations will be required in any permit which will completely describe expected results of such treatment process.
- (4) Effluent limitations may be required in any permits to insure compliance with the Antidegradation Statement, Rule 0400-40-03-.06.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.11 DURATION AND REISSUANCE OF PERMITS.

- (1) Each issued permit shall have a fixed term not to exceed 5 years, which shall be stated in the permit.
- (2) Any permittee who wishes to continue to discharge or operate after the expiration date of the permit shall apply for reissuance in accordance with the provisions of Rule 0400-40-05-.05. Timely receipt of a completed application for an NPDES or state operating permit is

(Rule 0400-40-05-.11, continued)

necessary for permit continuance. However, the Commissioner, at his or her discretion, may accept alternative submittal materials.

- (3) The Commissioner shall review the permit and other available information to insure:
 - (a) That the permittee is in compliance with or has substantially complied with all terms, conditions, requirements, and schedules of compliance of the expiring or expired permit;
 - (b) That the Commissioner has up-to-date information on the permittee's production levels, permittee's waste treatment practices, nature, contents, and frequency of permittee's discharge, pursuant to monitoring records and reports submitted to the Commissioner by the permittee; and
 - (c) That the discharge is consistent with applicable effluent standards and limitations, water quality standards, and other legally applicable requirements including any additions to, or revisions or modifications of such effluent standards and limitations, water quality standards, or other legally applicable requirements during the term of the permit.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.12 APPEALS.

- (1) Permittees, applicants for permits, and aggrieved persons meeting the criteria of paragraph (3) of this rule who disagree with the denial, terms, or conditions of a permit are entitled to review of the Commissioner's decision by the Board of Water Quality, Oil and Gas (the Board) pursuant to T.C.A. § 69-3-105(i) and § 69-3-110.
- (2) Permittees and applicants for permits shall specify what terms or conditions they are appealing in their petition. Only those terms or conditions specified in the petition will be considered subject to appeal. For permit modifications only those terms that were the subject of the modification may be appealed.
- (3) In order to be entitled to a review of the Commissioner's permit decision, permittees, applicants, and aggrieved persons shall:
 - (a) Have submitted a written comment during the public comment period on the permit;
 - (b) Have engaged in other direct communication with the department regarding the proposed permit action during the comment period;
 - (c) Given testimony at a formal public hearing on the permit; or
 - (d) Attended a public hearing as evidenced by completion of a Department of Environment and Conservation Record of Attendance Card or other method as determined by the Department.
- (4) The basis for the appeal for aggrieved persons may only include issues that:
 - (a) Were provided to the Commissioner in writing during the public comment period;
 - (b) Were provided in testimony at a formal public hearing on the permit; or

(Rule 0400-40-05-.12, continued)

- (c) Arise from any material change to conditions in the final permit from those in the draft, unless the material change has been subject to additional opportunity for public comment.
- (5) All petitions for permit appeals shall be filed within 30 days after the date that public notice of the permit issuance, denial, or modification is given by way of distribution of the notice of determination to persons who meet the criteria of paragraph (3) of this rule.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.13 ADOPTION OF EPA-ISSUED PERMITS.

- (1) The Commissioner may adopt and enforce permits that have been previously issued by the United States Environmental Protection Agency under the National Pollutant Discharge Elimination System established by Public Law 92-500. When such NPDES permit previously issued by the Environmental Protection Agency has been adopted by the State of Tennessee, any permit issued previously for the same discharge by the Commissioner shall become null and void. In any instance where the Commissioner has not adopted an existing NPDES permit and a discharge is not authorized by a Tennessee permit, the Commissioner may require the discharger to apply for a Tennessee permit and otherwise comply with Tennessee law. Permits previously issued pursuant to T.C.A. § 69-3-108 shall remain in full force and effect until replaced by an NPDES Permit transferred to the state or issued by the state.

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

0400-40-05-.14 ANIMAL FEEDING OPERATIONS.

- (1) In addition to the applicable provisions of Rules 0400-40-05-.01 through 0400-40-05-.13, CAFOs are also subject to the provisions of this rule.
- (2) AFOs meeting or exceeding the size thresholds in the second column of TABLE 0400-40-05-.14.1 are considered large (Class I) CAFOs.
- (3) AFOs within the size thresholds given in the third column of TABLE 0400-40-05-.14.1 are considered medium (Class II) CAFOs if any of the following conditions are met:
 - (a) Pollutants are discharged into waters through a man-made ditch, flushing system, or other similar man-made device;
 - (b) Pollutants are discharged directly into waters which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation;
 - (c) The AFO is located adjacent to a waterbody that has been identified by the Department as being impaired for nutrients or pathogens;
 - (d) The AFO began operation on or after May 1, 1999; or
 - (e) The AFO expanded its operation so that it falls within the range given in the third column of TABLE 0400-40-05-.14.1 on or after July 21, 2004.

TABLE 0400-40-05-.14.1

(Rule 0400-40-05-.14, continued)

| Animal Type | Large (Class I) CAFO | Medium (Class II) CAFO |
|---|---|---|
| Mature dairy cows (milked or dry) | 700+ | 200 – 699 |
| Veal calves | 1,000+ | 300 – 999 |
| Cattle ¹ | 1,000+ | 300 – 999 |
| Swine | 2,500+ (≥ 55 lbs) 10,000 (< 55 lbs) | 750 – 2,499 (≥ 55 lbs) 3,000 – 9,999 (< 55 lbs) |
| Chickens (liquid waste management) | 30,000+ (laying hens or broilers) | 9,000 – 29,999 |
| Chickens (dry waste management ²) | 125,000+ (non-layers) 82,000+ (layers) | 37,500 – 124,999 (non-layers) 25,000 – 81,999 (layers) |
| Horses | 500+ | 150 – 499 |
| Sheep/lambs | 10,000+ | 3,000 – 9,999 |
| Turkeys | 55,000+ | 16,500 – 54,999 |
| Ducks (liquid waste management) | 5,000+ | 1,500 – 4,999 |
| Ducks (dry waste management ²) | 30,000+ | 10,000 – 29,999 |

¹ Other than mature dairy cows or veal calves. Cattle includes, but is not limited to, heifers, steers, bulls, and cow/calf pairs.

² Dry waste management refers to systems where continuously overflowing watering systems are not used and birds are raised in an enclosed building with earthen or concrete floors spread with layer of sawdust, wood shavings, rice hulls, or chopped straw.

- (4) Other AFOs may be designated as CAFOs at the discretion of the Director. Factors to be considered in this determination include the AFO's size; the amount of waste reaching waters of the state; the location of the AFO; the means of waste conveyance to waters of the state; and the slope, vegetation, rainfall, and other factors affecting the likelihood or frequency of discharge of animal wastes into waters of the state. The Director shall conduct an on-site inspection prior to determining that an operation should be regulated under the CAFO permit program. AFOs below the threshold for a medium CAFO (shown in the third column in TABLE 0400-40-05-.14.1) may not be designated as a CAFO unless:
- (a) Pollutants are discharged into waters through a man-made ditch, flushing system, or other similar man-made device; or
 - (b) Pollutants are discharged directly into waters which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation.
- (5) All AFOs defined as CAFOs shall seek permit coverage as follows:
- (a) Large, medium, and designated CAFOs that discharge shall obtain an individual NPDES permit and the permit shall be in effect prior to any discharge.
 - (b) All other CAFOs shall obtain coverage under a state permit.
- (6) All CAFOs shall submit application information in accordance with paragraph (2) of Rule 0400-40-05-.05.

(Rule 0400-40-05-.14, continued)

- (a) All CAFOs shall submit application information to the Tennessee Department of Agriculture, which will provide the Department with copies of the initial application and the approved application and nutrient management plan.
- (b) In addition to the application requirements of paragraph (2) of Rule 0400-40-05-.05, CAFOs shall submit, at the time of application:
 - 1. A closure/ rehabilitation plan for the waste system storage/treatment structure(s) that meets or exceeds USDA-NRCS technical standards and guidelines, and, at a minimum, addresses maintenance of the facility until proper closure is completed and includes a proposed schedule for closure not to exceed 360 days; and
 - 2. A nutrient management plan as outlined in paragraph (10) of this rule.
- (7) Reserved
- (8) CAFOs shall comply with the permit reissuance requirements of paragraph (4) of Rule 0400-40-05-.05 and shall maintain permit coverage until such time as the CAFO demonstrates to the satisfaction of the Director that it no longer meets the definitions set forth in paragraphs (2), (3), or (4) of this rule.
- (9) CAFOs shall have a nutrient management plan developed and approved and have all measures, structures, etc., in place to fully implement the plan upon the date of permit coverage.
- (10) CAFO Nutrient Management Plan (NMP) Requirements
 - (a) Any permit issued to a CAFO shall include a requirement to develop, submit for state approval, implement, and keep on site a site-specific nutrient management plan that:
 - 1. Includes best management practices and procedures necessary to implement applicable effluent limitations and standards;
 - 2. Ensures adequate storage of manure, litter, and process wastewater including procedures to ensure proper operation and maintenance of the storage facilities;
 - 3. Ensures proper management of mortalities (i.e., dead animals) so that they are not disposed of in a liquid manure, stormwater, or process wastewater storage or treatment system that is not specifically designed to treat animal mortalities as outlined in USDA-NRCS Conservation Practice Standard 316, October 2002 (or most recent) and/or the USDA-NRCS Animal Waste Handbook, and/or University of Tennessee Extension publications;
 - 4. Ensures that clean water is diverted, as appropriate, from the production area;
 - 5. Prevents direct contact of confined animals with waters of the state;
 - 6. Ensures that chemicals and other contaminants handled on-site are not disposed of in any manure, litter, process wastewater, or stormwater storage or treatment system unless specifically designed to treat such chemicals and other contaminants;
 - 7. Identifies appropriate site specific conservation practices to be implemented, including, as appropriate, buffers or equivalent practices, to control runoff of pollutants to waters of the state (these practices shall meet minimum standards

(Rule 0400-40-05-.14, continued)

set in the USDA-NRCS Field Office Practice Standard and/or the USDA-NRCS Animal Waste Handbook), as follows:

- (i) Manure, litter, and process wastewater shall be applied no closer than 100 feet to any down-gradient surface waters, open tile line intake structures, sinkholes, agricultural well heads, or other conduits to surface waters unless:
 - (I) The CAFO substitutes the 100-foot setback with a 35-foot wide vegetated buffer or by leaving in place a 60-foot natural riparian buffer, where applications of manure, litter, or process wastewater are prohibited; or
 - (II) The CAFO demonstrates that a setback or buffer is not necessary because implementation of alternative conservation practices or field-specific conditions will provide pollutant reductions equivalent to or better than the reductions that would be achieved by the 100-foot setback;
 - (ii) Manure, litter, and process wastewater shall be applied no closer than 100 feet for any potable well, public or private, or as recommended by the University of Tennessee Extension; and
 - (iii) For new CAFOs that are located adjacent to exceptional Tennessee waters and outstanding national resource waters (as identified by the Department), leave in place a minimum 60-foot natural riparian buffer between the stream and the land application area;
8. Provides for annual manure analysis for nitrogen and phosphorus content, following University of Tennessee Extension guidelines, and soil analysis at a minimum of once every 5 years for phosphorus content (the results of these analyses are to be used in determining application rates for manure, litter, and other process wastewater);
9. Establishes protocols to land apply manure, litter, or process wastewater in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of the nutrients in the manure, litter, or process wastewater. Application rates for manure, litter, and other process wastewater applied to land under the ownership or operational control of the CAFO shall minimize phosphorus and nitrogen transport from the field to surface waters in compliance with technical standards for nutrient management that:
- (i) Include a field-specific assessment of the potential for nitrogen and phosphorus transport from the field to surface waters, and address the form, source, amount, timing, and method of application of nutrients on each field to achieve realistic production goals, while minimizing nitrogen and phosphorus movement to surface waters, that employs the Tennessee Phosphorus Index (a tool developed by the University of Tennessee Extension Service and the USDA-NRCS to assess the risk of phosphorus movement from the application area to waters of the state); and
 - (ii) Include appropriate flexibilities for any CAFO to implement nutrient management practices to comply with the technical standards, including consideration of multi-year phosphorus application on fields that do not have a high potential for phosphorus runoff to surface water, phased implementation of phosphorus-based nutrient management, and other

(Rule 0400-40-05-.14, continued)

components, in consideration of recommendations from the University of Tennessee Extension and as determined appropriate by the Director;

10. Provides for periodic inspection of equipment used for land application of manure, litter, and other process wastewater.

(b) Nutrient management plan terms

Any permit issued to a CAFO shall require compliance with the terms of the CAFO's site-specific nutrient management plan such that the plan is enforceable through the permit. The terms of the nutrient management plan are the information, protocols, best management practices, and other conditions in the nutrient management plan determined by the Director to be necessary to implement the nutrient management plan. For NPDES permits, the terms of the nutrient management plan, with respect to protocols that ensure appropriate agricultural utilization of the nutrients in the manure, litter, or process wastewater, shall include the fields available for land application; field-specific rates of application properly developed through either the linear approach or the narrative approach; and any timing limitations identified in the nutrient management plan concerning land application on the fields available for land application.

1. Linear approach

An approach that expresses rates of application as pounds of nitrogen and phosphorus, according to the following specifications:

(i) The terms include:

- (I) Maximum application rates from manure, litter, and process wastewater for each year of permit coverage and for each crop identified in the nutrient management plan, in terms of total nitrogen and phosphorus, in pounds per acre, per year, for each field to be used for land application;
- (II) The outcome of the field-specific assessment of the potential for nitrogen and phosphorus transport from each field as described in subpart (a)9.(i) of this paragraph;
- (III) The crops to be planted in each field or any other uses of a field such as pasture or fallow fields; the realistic yield goal for each crop or use identified for each field;
- (IV) The nitrogen and phosphorus recommendations as recommended by the University of Tennessee Extension for each crop or use identified for each field;
- (V) Credits for all residual nitrogen in the field that will be plant available as recommended by the University of Tennessee Extension;
- (VI) Consideration of multi-year phosphorus application in accordance with subpart (a)9.(ii) of this paragraph;
- (VII) An accounting of all other additions of plant available nitrogen and phosphorus to the field;
- (VIII) The form and source of manure, litter, and process wastewater to be land-applied;

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- (IX) The timing and method of land application; and
 - (X) The methodology by which the nutrient management plan accounts for the amount of nitrogen and phosphorus in the manure, litter, and process wastewater to be applied as described in part (a)8. of this paragraph.
- (ii) Large CAFOs that use this approach shall calculate the maximum amount of manure, litter, and process wastewater to be land applied at least once each year using the results of the most recent representative manure, litter, and process wastewater tests for nitrogen and phosphorus taken within 12 months of the date of land application.
2. Narrative rate approach

An approach that expresses rates of application as a narrative rate of application that results in the amount, in tons or gallons, of manure, litter, and process wastewater to be land applied, according to the following specifications:

- (i) The terms include:
 - (I) Maximum amounts of nitrogen and phosphorus derived from all sources of nutrients, for each crop identified in the nutrient management plan, in terms of total nitrogen and phosphorus, in pounds per acre, for each field, and certain factors necessary to determine such amounts.
 - (II) The outcome of the field-specific assessment of the potential for nitrogen and phosphorus transport from each field as described in subpart (a)9.(i) of this paragraph;
 - (III) The crops to be planted in each field or any other uses such as pasture or fallow fields (including alternative crops identified in subpart (iii) of this part;
 - (IV) The realistic yield goal for each crop or use identified for each field; and
 - (V) The nitrogen and phosphorus recommendations as recommended by the University of Tennessee Extension for each crop or use identified for each field for each crop or use identified for each field.
- (ii) The terms include the methodology by which the nutrient management plan accounts for the following factors when calculating the amounts of manure, litter, and process wastewater to be land applied:
 - (I) Results of soil tests conducted in accordance with protocols identified in part (a)8. of this paragraph;
 - (II) Credits for all residual nitrogen in the field that will be plant available as recommended by the University of Tennessee;
 - (III) The amount of nitrogen and phosphorus in the manure, litter, and process wastewater to be applied;

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- (IV) Consideration of multi-year phosphorus application in accordance with subpart (a)9.(ii) of this paragraph;
 - (V) Accounting for all other additions of plant available nitrogen and phosphorus to the field;
 - (VI) The form and source of manure, litter, and process wastewater;
 - (VII) The timing, except as described in subpart (iv) of this part and method of land application; and
 - (VIII) Volatilization of nitrogen and mineralization of organic nitrogen.
- (iii) The terms of the nutrient management plan include alternative crops identified in the CAFO's nutrient management plan that are not in the planned crop rotation. Where a CAFO includes alternative crops in its nutrient management plan, the crops shall be listed by field, in addition to the crops identified in the planned crop rotation for that field, and the nutrient management plan shall include realistic crop yield goals and the nitrogen and phosphorus recommendations as recommended by the University of Tennessee for each crop. Maximum amounts of nitrogen and phosphorus from all sources of nutrients and the amounts of manure, litter, and process wastewater to be applied shall be determined in accordance with the methodology described in items (ii)(I) through (VIII) of this part.
- (iv) For CAFOs using this approach, the following projections shall be included in the nutrient management plan submitted to the director, but are not terms of the nutrient management plan: The CAFO's planned crop rotations for each field for the period of permit coverage; the projected amount of manure, litter, or process wastewater to be applied; projected credits for all nitrogen in the field that will be plant available; consideration of multi-year phosphorus application; accounting for all other additions of plant available nitrogen and phosphorus to the field; and the predicted form, source, and method of application of manure, litter, and process wastewater for each crop. Timing of application for each field, insofar as it concerns the calculation of rates of application, is not a term of the nutrient management plan.
- (v) CAFOs that use this approach shall calculate maximum amounts of manure, litter, and process wastewater to be land applied at least once each year using the methodology required in subpart (ii) of this part before land applying manure, litter and process wastewater and shall rely on the following data:
- (I) A field-specific determination of soil levels of nitrogen and phosphorus, including, for nitrogen, a concurrent determination of nitrogen that will be plant available consistent with the methodology required by subpart (ii) of this part, and for phosphorus, the results of the most recent soil test conducted in accordance with soil testing requirements approved by the Commissioner; and
 - (II) The results of most recent representative manure, litter, and process wastewater tests for nitrogen and phosphorus taken within 12 months of the date of land application, in order to determine the amount of nitrogen and phosphorus in the manure, litter, and process wastewater to be applied.

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(c) Changes to a nutrient management plan

1. Any NPDES permit issued to a CAFO shall require the following procedures when a CAFO owner or operator makes changes to the CAFO's nutrient management plan previously submitted to the Director:
 - (i) The CAFO owner or operator shall provide the Director with the most current version of the CAFO's nutrient management plan and identify changes from the previous version, except that the results of calculations made in accordance with the requirements of subparts (b)1.(ii) and (b)2.(v) of this paragraph are not considered to be changes to the nutrient management plan subject to the requirements of this paragraph.
 - (ii) The Director shall review the revised nutrient management plan to ensure that it meets the requirements of this paragraph and applicable effluent limitations and standards and shall determine whether the changes to the nutrient management plan include revision to the terms of the nutrient management plan as set forth in subparagraph (b) of this paragraph. If the terms of the nutrient management plan are not revised, the Director shall notify the CAFO owner or operator and upon such notification the CAFO may implement the revised nutrient management plan. If the terms of the nutrient management plan are revised, the Director shall determine whether such changes are substantial changes as described in part 2. of this subparagraph.
 - (iii) If the Director determines that the changes to the terms of the nutrient management plan are not substantial, the Director shall make the revised nutrient management plan publicly available and include it in the permit record and inform the public of any changes to the terms of the nutrient management plan.
 - (iv) If the Director determines that the changes to the terms of the nutrient management plan are substantial, the Director shall notify the public and make the proposed changes and the information submitted by the CAFO owner or operator available for public review and comment. The process for public notice and participation shall follow the procedures applicable to draft permits set forth in Rule 0400-40-05-.06. The Director shall consider all significant comments received during the comment period and require the CAFO owner or operator to further revise the nutrient management plan if necessary. Once the Director approves the revised terms of the nutrient management plan, the Director shall issue a notice of determination that addresses all comments received and notifies the owner or operator and the public of the final decision concerning revisions to the nutrient management plan.
2. Substantial changes to the terms of a nutrient management plan incorporated as terms and conditions of a permit include, but are not limited to:
 - (i) Addition of new land application areas not previously included in the CAFO's nutrient management plan or in the terms of a nutrient management plan incorporated into an existing NPDES permit. If the CAFO owner or operator applies manure, litter, or process wastewater on the newly added land application area in accordance with existing field-specific permit terms applicable to the newly added land application area, such addition of new land would be a change to the new CAFO owner or

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- operator's nutrient management plan but not a substantial change for purposes of this paragraph;
- (ii) Any changes to the field-specific maximum annual rates for land application set in accordance with the linear approach or to the maximum amounts of nitrogen and phosphorus derived from all sources for each crop set in accordance with the narrative approach;
 - (iii) Addition of any crop or other uses not included in the terms of the CAFO's nutrient management plan and corresponding field-specific rates of application; and
 - (iv) Changes to site-specific components of the CAFO's nutrient management plan, where such changes are likely to increase the risk of nitrogen and phosphorus transport to waters of the state.
3. CAFOs covered by state permits are subject to the following procedures when the CAFO owner or operator makes changes to the CAFO's nutrient management plan previously submitted to the Director:
- (i) The CAFO owner or operator shall provide the Director with the most current version of the CAFO's nutrient management plan and identify changes from the previous version.
 - (ii) The Director shall review the revised nutrient management plan to ensure that it meets the requirements of this paragraph and applicable effluent limitations and standards and shall determine whether the changes to the nutrient management plan include revisions to the terms of the nutrient management plan as set forth in subparagraph (b) of this paragraph. The Director shall advise the CAFO owner or operator whether or not the changes meet the requirements of this paragraph and applicable effluent limitations and standards and upon such notification the CAFO shall either make further revisions to the nutrient management plan or implement the revised nutrient management plan.

(11) CAFO Recordkeeping and Reporting Requirements

Any permit issued to a CAFO shall include:

- (a) A requirement that the permittee shall create, maintain for 5 years, and make available to the Director, upon request, the following records:
 - 1. Records documenting the implementation and management of the minimum elements described in subparagraph (10)(a) of this rule and all applicable records identified in parts 2. through 18. of this subparagraph;
 - 2. A copy of the CAFO's site-specific nutrient management plan;
 - 3. Records documenting the following visual inspections:
 - (i) Weekly inspections of all storm water diversion devices, runoff diversion structures, and devices channeling contaminated storm water to the wastewater and manure storage and containment structure;
 - (ii) Daily inspections of water lines, including drinking or cooling water lines; and

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- (iii) Weekly inspections of the manure, litter, and process wastewater impoundments noting the liquid level in the impoundments;
 - 4. Weekly records of the depth of the manure and process wastewater in any open surface liquid impoundment as indicated by the required depth marker which indicates the minimum capacity necessary to contain the runoff and direct precipitation of the 25-year, 24-hour rainfall event. In the case of swine or poultry CAFOs that are new sources, the depth marker shall indicate minimum capacity necessary to contain the runoff and direct precipitation associated with the design storm used for sizing the impoundment;
 - 5. Records documenting any corrective actions taken (if deficiencies are not corrected within 30 days of notice of deficiency, the records shall include an explanation of the factors preventing immediate correction);
 - 6. Records of mortalities management and practices used to comply with the nutrient management plan;
 - 7. Records documenting the current design of any manure or litter storage structures, including volume for solids accumulation, design treatment volume, total design volume, and approximate number of days of storage capacity;
 - 8. Records of the date, time, and estimated volume of any overflow;
 - 9. Expected and actual crop yields;
 - 10. The date(s) manure, litter, or process wastewater is applied to each field;
 - 11. Weather conditions at time of application and for 24 hours prior to and following application;
 - 12. Test methods used to sample and analyze manure, litter, process wastewater, and soil;
 - 13. Results from manure, litter, process wastewater, and soil sampling;
 - 14. Explanation of the basis for determining manure application rates, as provided in the technical standards established by the University of Tennessee Extension or as otherwise approved by the Director or the Tennessee Department of Agriculture and consistent with applicable state and federal rules;
 - 15. Calculations showing the total nitrogen and phosphorus to be applied to each field, including sources other than manure, litter, or process wastewater;
 - 16. Total amount of nitrogen and phosphorus actually applied to each field, including documentation of calculations for the total amount applied;
 - 17. The method used to apply the manure, litter, or process wastewater; and
 - 18. Date(s) of manure application equipment inspection and calibration;
- (b) Recordkeeping for third-party waste transfers

A requirement that prior to transferring manure, litter, or process wastewater to a 3rd party, all CAFOs shall provide the recipient of the manure, litter, or process wastewater

(Rule 0400-40-05-.14, continued)

with the most current nutrient analysis (consistent with 40 CFR Part 412 and approved by the University of Tennessee Extension). Large CAFOs shall ensure that the 3rd party signs an agreement for the removal of manure, litter, or process wastewater for all transfers of manure, litter, or process wastewater. All other CAFOs shall ensure that the 3rd party signs an agreement for the removal of manure, litter, or process wastewater only if the CAFO transfers more than 100 tons of manure, litter, or process wastewater. The agreement for the removal of manure, litter, or process wastewater shall be retained for 5 years and shall include the following information, at a minimum:

1. The name and location of the facility that is exporting manure, litter, or process wastewater;
2. The type and amount of material that is removed from the CAFO;
3. The date the material was removed from the CAFO;
4. The following best management practice recommendations:
 - (i) The manure, litter, or process wastewater shall be managed to ensure there is no discharge of manure, litter, or process wastewater to surface or groundwater.
 - (ii) When removed from the facility, manure, litter, or process wastewater should be applied directly to the field or stockpiled and covered with plastic or stored in a building.
 - (iii) Manure, litter, or process wastewater shall not be stockpiled near streams, sinkholes, wetlands, or wells.
 - (iv) Fields receiving manure, litter, or process wastewater should be soil tested at least every 5 years.
 - (v) A manure, litter, or process wastewater nutrient analysis should be used to determine application rates for various crops.
 - (vi) Calibrate spreading equipment and apply manure, litter or process wastewater uniformly.
 - (vii) Apply no more nitrogen or phosphorus than can be used by the crop.
 - (viii) A buffer zone is recommended between the application sites and adjacent streams, lakes, ponds, sinkholes, and wells. The following non-application buffer widths, based on the USDA-NRCS Conservation Practice Standard 590 (January 2013 version, or most recent version), should be used when applicable:
 - (I) 150 ft. from wells located upslope of the application site;
 - (II) 300 ft. from wells located downslope of the application site, if conditions warrant application;
 - (III) 30-100 ft. from waterbodies, depending on the amount and quality of vegetation and slope;
 - (IV) 300 ft. from all public use areas; and

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- (V) 300 ft. from all residences other than the producer's.
 - (ix) Do not apply manure, litter, or process wastewater when the ground is frozen, flooded, saturated, or on steep slopes subject to flooding, erosion, or rapid runoff.
 - (x) Cover vehicles hauling manure, litter, or process wastewater on public roads.
 - (xi) Keep records of locations where manure, litter, or process wastewater will be land applied or used as a fertilizer.
5. A signed certification statement from the recipient of the material from the CAFO, including the recipient's name, address, and phone number.
- (c) A requirement that CAFOs submit to TDEC, an annual report between January 1 and February 15 that includes:
1. The number and type of animals on site whether in open confinement or housed under roof;
 2. Estimated amount of total manure, litter, and process wastewater generated by the CAFO in the previous calendar year (tons or gallons);
 3. Estimated amount of total manure, litter, and process wastewater transferred to a 3rd party by the CAFO in the previous calendar year (tons or gallons);
 4. Total number of acres for land application covered by the nutrient management plan;
 5. Total number of acres under control of the CAFO that were used for land application of manure, litter, and process wastewater in the previous calendar year;
 6. A summary of all manure, litter, and process wastewater discharges to waters of the state from the production area that have occurred in the previous calendar year, including date, time, and approximate volume;
 7. A statement indicating whether the current version of the CAFO's nutrient management plan was developed or approved by a certified nutrient management planner;
 8. The actual crop(s) planted and actual yield(s) for each field;
 9. The actual nitrogen and phosphorus content of the manure, litter and process wastewater;
 10. The results of calculations to determine the maximum amount of manure, litter, and process wastewater to be land applied and the data used in the calculations;
 11. The actual amount of manure, litter, and process wastewater applied during the previous 12 months;
 12. The results of any soil tests for nitrogen and phosphorus conducted in the previous 12 months; and

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13. The amount of any supplemental fertilizer applied during the previous 12 months.
- (12) For CAFOs with applicable federal effluent guidelines, technology-based effluent limitations and standards in accordance with those guidelines shall be applied.
- (13) For CAFOs that are not subject to applicable federal effluent guidelines, the following standards shall be applied:
 - (a) For CAFOs that either discharge or are designed, constructed, operated, or maintained such that a discharge could occur, the production area shall be designed, constructed, operated, and maintained to contain all manure, litter, and process wastewater including the runoff and the direct precipitation from a 25-year, 24-hour rainfall event.
 - (b) For all other CAFOs not subject to applicable federal effluent guidelines, the production area shall be designed, constructed, operated, and maintained so that no discharge will occur.
- (14) No CAFO liquid waste management system shall be constructed, modified, repaired, or placed into operation after April 13, 2006, unless it is designed, constructed, operated, and maintained in accordance with final design plans and specifications which meet or exceed standards in the USDA-NRCS Field Office Technical Guide and other guidelines as accepted by the Departments of Environment and Conservation or Agriculture. Specifically, plans shall contain the following:
 - (a) Any new or additional confinement buildings, waste/wastewater handling system, waste/wastewater transport structures, waste/wastewater treatment structures, settling basins, lagoons, holding ponds, sumps, or pits, and other agricultural waste containment/treatment structures constructed after April 13, 2006, shall be located in accordance with USDA-NRCS Conservation Practice Standard 313.
 - (b) Information to be used in the design of the open manure storage structure including, but not limited to, minimum storage for rainy seasons, minimum capacity for chronic rainfall events, the prohibition of land application to frozen, saturated, or snow-covered ground, the dewatering schedules set in the CAFO's Nutrient Management Plan, additional storage capacity for any manure intended to be transferred to another recipient at a later time, and any other factors that would affect the sizing of the open manure storage structure.
 - (c) The design of the open manure storage structure as determined by the most recent version of the USDA-NRCS's Animal Waste Management (AWM) software. CAFOs may use equivalent design software or procedures as approved by the Director.
 - (d) All inputs used in the open manure storage structure design including actual climate data for the previous 30 years consisting of historical average monthly precipitation and evaporation values, the number and types of animals, anticipated animal sizes or weights, any added water and bedding, any other process wastewater, and the size and condition of outside areas exposed to rainfall and contributing runoff to the open manure storage structure.
 - (e) The planning minimum period of storage in months including, but not limited to, the factors for designing an open manure storage structure listed in subparagraph (b) of this paragraph. Alternatively the CAFO may determine the minimum period of storage by specifying times the storage pond will be emptied consistent with the CAFO's Nutrient Management Plan.

(Rule 0400-40-05-.14, continued)

- (f) A subsurface investigation for earthen holding pond, pit, sump, treatment lagoon, or other earthen storage/containment structure suitability and liner requirements shall be a component of the system design. The subsurface investigation will include a detailed soils investigation with special attention to the water table depth and seepage potential. The investigation shall evaluate soils to a depth of 2 feet below the planned bottom grade of the storage structure. Deeper investigations may be required in karst regions. A soils/geologic investigation shall be performed by a soil scientist (as described in Rule 0400-48-01-.18) and qualified geologist. A qualified geologist is defined as an individual who is a Registered Professional Geologist licensed by the State of Tennessee or an individual who meets the requirements for the title of Certified Professional Geologist as defined by the American Institute of Professional Geologists. Unless relevant information is available to the contrary, compliance with this provision during design and construction of the facility will normally demonstrate that the hydrologic connection does not exceed a maximum allowable specific discharge of 0.0028 ft/day (1×10^{-6} cm/sec).

Authority: T.C.A. §§ 4-5-201, et seq. and 69-3-101, et seq. **Administrative History:** Original rule filed November 20, 2013; effective February 18, 2014.

**RULES
OF
THE TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
BOARD OF WATER AND WASTEWATER OPERATOR CERTIFICATION**

**CHAPTER 0400-49-01
RULES GOVERNING WATER AND WASTEWATER OPERATOR CERTIFICATION**

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0400-49-01-.01 APPLICATION FOR CERTIFICATE.

- (1) Application for certification by examination.
- (a) A separate application for each certification shall be made on an original form approved by the Board for that purpose and available upon request from the Secretary of the Board.
- (b) An application for certification must be submitted to the Secretary of the Board and include the following items:
1. A sworn application signed by the applicant.
 2. Payment of a non-refundable \$100 fee for each application for examination.
 3. A copy of any verifying document in support of an application must be submitted with the application unless the applicant has previously provided such documentation to the Secretary of the Board. This includes, but is not limited to, proof of high school education or equivalent of the applicant. College transcripts, if needed to document experience credit, must be submitted directly from the college and/or university to the Secretary to the Board. Credit for enrollment in special training courses and programs will only be granted to an applicant upon verification that he/she satisfactorily completed all course or program requirements. If training credit is requested, a copy of a course attendance card, a class roster, or a certificate of completion must be submitted to the Secretary. Verification of work experience must be provided in a written document signed by a certified operator of a similar or higher classification, familiar with the applicant's work experience. However, if no such person is available, it may be documented by a person in authority with the system. The Board may exempt applicants from the verification of work experience requirement where there are unusual circumstances.
- (c) A complete application must be received by the Secretary sixty (60) days or more in advance of the scheduled examination date for consideration. Applications received less than sixty (60) days prior to an examination date will be reviewed for the next examination. Upon written request by an applicant, the Board may choose to review,

(Rule 0400-49-01-.01, continued)

at the next Board meeting, a late exam application where extenuating circumstances contribute to the delay.

- (d) Applications will be reviewed for completeness and for compliance with the requirements of Rules 0400-49-01-.07 and 0400-49-01-.09 for education and experience by staff of the Board under the supervision of the Secretary. The operating experience of an applicant will be determined through the end of the month in which the examination for the operator classification desired is given.
 - 1. Applications which are not complete or which provide inadequate information to allow a reasonable judgment of experience and/or education shall either be returned to the applicant by the Secretary for amendment or the Secretary may request additional information from the applicant. Upon notification of a deficiency in an application by the Secretary, the applicant shall have ten (10) days or up to the Board meeting date, whichever date comes first, to submit the required information. If an amendment to the application is not received by the aforementioned date, the application will be denied, and the applicant must submit a new application and fees for further consideration.
 - 2. The staff of the Board under the supervision of the Secretary shall make a recommendation to approve, disapprove, or refer to the Board each applicant with a complete application.
 - 3. Upon consideration of the recommendation of the Secretary and after any evaluation considered desirable by the Board, the Board shall act to approve or disapprove all applicants with complete applications.
 - 4. If an application for examination is denied, the applicant must submit a new application with fees for consideration for any future examination.
- (2) Application for certification by reciprocity.
 - (a) A separate application for each certification shall be made on an original form approved by the Board for that purpose and available upon request from the Secretary of the Board.
 - (b) An application for certification must be submitted to the Secretary of the Board and include the following items:
 - 1. A sworn application signed by the applicant.
 - 2. Payment of a non-refundable \$100 for each application for reciprocity.
 - 3. A copy of any verifying document in support of an application must be submitted with the application unless the applicant has previously provided such documentation to the Secretary of the Board. This includes, but is not limited to, proof of high school education or equivalent of the applicant. College transcripts, if needed to document experience credit, must be submitted directly from the college and/or university to the Secretary to the Board. Credit for enrollment in special training courses and programs will only be granted to an applicant upon verification that he/she satisfactorily completed all course or program requirements. If training credit is requested, a copy of a course attendance card, a class roster, or a certificate of completion must be submitted to the Secretary.

(Rule 0400-49-01-.01, continued)

- (c) A complete application must be received by the Secretary sixty (60) days or more in advance of the scheduled Board meeting date for consideration. Applications received less than sixty (60) days prior to the Board meeting date will be reviewed at the next Board meeting. Upon written request by an applicant, the Board may choose to review a late reciprocity application where extenuating circumstances occur.
- (d) Applications will be reviewed for completeness and for compliance with the requirements of Rules 0400-49-01-.07 and 0400-49-01-.09 for education and experience by staff of the Board under the supervision of the Secretary.
 - 1. Applications which are not complete or which provide inadequate information to allow a reasonable judgment of experience and/or education shall either be returned to the applicant by the Secretary for amendment or the Secretary may request additional information from the applicant. Upon notification of a deficiency in an application by the Secretary, the applicant shall have ten (10) days or up to the Board meeting date, whichever date comes first, to submit the deficient information. If an amendment to the application is not received by the aforementioned date, the application will be denied, and the applicant must submit a new application with fees for further consideration.
 - 2. Verification of certification from the reciprocating state must be received before staff of the Board can make a recommendation and before the application can be offered to the Board for review.
 - 3. The staff of the Board under the supervision of the Secretary shall make a recommendation to approve, disapprove, or refer to the Board each applicant with a complete application.
 - 4. Upon consideration of the recommendation of the Secretary and after any evaluation considered desirable by the Board, the Board shall act to approve or disapprove all applicants with complete applications.
 - 5. If an application for reciprocity is denied, the applicant must submit a new application with fees for consideration for any future reciprocity requests.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed January 18, 2017; effective April 18, 2017.

0400-49-01-.02 EXAMINATIONS.

- (1) All examinations shall be taken in a manner provided by the Board; however, the Board may approve alternate examination methods if an applicant has a disability which would prevent him/her from taking the provided methods of examination. The Board may provide examinations in written or electronic formats.
- (2) All examinations shall be taken by the applicant without the assistance of course text materials, student notes, computer stored materials, or other materials.
- (3) The examination may contain one or more of the following type questions: matching, multiple choice, true-false, discussion, short answer, and problems.
- (4) An applicant who correctly scores at least seventy percent (70%) on a written examination, and who is otherwise eligible, shall receive a certificate of competency.

(Rule 0400-49-01-.02, continued)

- (5) An applicant shall be notified in writing whether his/her examination score was satisfactory for the issuance of a certificate.
- (6) An applicant who fails to achieve a satisfactory score may reapply for the next examination by submitting an abbreviated application for examination with fees, but he/she shall not be eligible to take another examination for the particular operator classification which he/she failed until five months have elapsed from the date that examination was taken.
- (7) All examinations shall be administered by the Board or its authorized representatives who are empowered to maintain the integrity of all examinations.
- (8) (a) An applicant shall be guilty of cheating upon a written examination who does an act including, but not limited to, the following:
 - 1. violates paragraph (2) of this rule; or
 - 2. without express authorization from examination officials,
 - (i) removes examination materials furnished by the Board or the written examination itself, in whole or in part, from the examination room, or
 - (ii) aids another applicant in answering examination questions during a written examination; or
 - 3. violates the examination rules.
- (b) Upon a determination by the Commissioner that an applicant is guilty of cheating upon a written examination for a particular operator classification, the applicant shall not be issued an initial certificate of competency for that classification.
- (c) An applicant shall be ineligible to again apply for certification in that same operator classification for one year from the date the determination of cheating becomes final.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed January 18, 2017; effective April 18, 2017.

0400-49-01-.03 FEES.

- (1) Fees for Certification
 - (a) Fees for certification shall be required of each applicant and paid in advance as follows:
 - 1. Application fee for each operator examination or reciprocity request applied for\$100
 - 2. Discount annual renewal fee for each operator certificate:
(Payment prior to February 1).....\$50
 - 3. Standard annual renewal fee for each operator certificate:
(Payment from February 1 through June 30.).....\$100
 - (b) No application fee will be returned.

(Rule 0400-49-01-.03, continued)

- (c) Upon payment of an application fee and approval by the Board, an applicant may take any one scheduled examination during the following twelve (12) months. If an applicant chooses not to take or fails to appear for, the first examination offered after receiving approval, the applicant must register on a form approved by the Board to be scheduled for a subsequent exam within the established time. The registration must occur sixty (60) days in advance of the examination he/she wishes to take. If an applicant does not take the examination within twelve (12) months of the Board's approval, he/she must reapply by submitting a new application with fees in order to be considered to take a subsequent examination.

 - (d) Each year a certified operator shall submit to the Board for the following year a completed certificate renewal application and a fee for the renewal of each operator certificate he/she possesses. Applications received prior to February 1 of each year shall be subject to discount renewal fees. Applications received February 1 through June 30 of each year shall be subject to standard renewal fees. Any person failing to meet the June 30 deadline may, within sixty (60) days of the deadline, request that the Board grant a variance. A variance may be granted when the delay was caused by Board or staff error, Board action, or documented postal error. A completed certificate renewal application or appropriate annual renewal fee for an expired certificate not received by the Board by June 30 shall preclude the recertification of the operator in his/her expired classification until he/she shall have fulfilled all the requirements for the issuance of an initial certificate in that classification, including the satisfactory completion of a written examination. When an operator classification is upgraded, the certificate he/she was upgraded from becomes void; and no additional fee payment is necessary until renewal.
- (2) Fees for Cross Connection Control Training Registration
- (a) Fees for Cross Connection Control Training registration shall be required of each person and paid in advance as follows:
 - 1. Registration fee for a Cross Connection Control Basic Class (full time employees of public water systems as defined in T.C.A. § 68-221-703 and Department employees who assist with cross connection control training or testing classes are exempt).....\$275
 - 2. Registration fee for a Cross Connection Control Renewal Class (full time employees of public water systems as defined in T.C.A. § 68-221-703 and Department employees who assist with cross connection control training or testing classes are exempt)..... \$110
 - (b) No registration fee will be returned.
 - (c) The registration fee must be received thirty (30) days in advance of the class he/she wishes to take.
- (3) Fees for Cross Connection Control Testing Application
- (a) Fees for Cross Connection Control Testing Application shall be required of each person and paid in advance as follows:
 - 1. Application for a Cross Connection Control Basic Test (Department employees who assist with cross connection control training or testing are exempt).....\$60

(Rule 0400-49-01-.03, continued)

2. Application fee for Cross Connection Control Renewal Test (Department employees who assist with cross connection control training or testing are exempt).....\$60
- (b) Application fees are not refundable or transferable.
- (c) The application for testing conducted by the Department must be received a minimum of thirty (30) days in advance of the test he/she wishes to take, however, applications from private institutions may be received the day the test materials are submitted to the Fleming Training Center.
- (d) Prior to sitting for a test, an applicant must present proof of completion of training accepted by the Department for the appropriate test. Basic training may be accepted by the Department if it has a minimum class length of 480 minutes (300 minutes minimum in classroom), including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working practice station and test kit for each three students. Renewal training may be accepted by the Department if it has a minimum class length of 300 minutes (180 minutes minimum in classroom) including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working station and test kit for each three students.
- (e) An applicant must take the test within twelve (12) months of receipt of the training certificate.

Authority: T.C.A. §§ 4-5-201 et seq., 68-203-101 et seq., 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed January 18, 2017; effective April 18, 2017.

0400-49-01-.04 GENERAL.

- (1) Certification under T.C.A. §§ 68-221-901 et seq., being the “Water and Wastewater Operator Certification Act,” is available to any operator of a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system who meets the minimum qualifications of a given classification.
- (2) Each person in direct charge at a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system shall hold a certificate in a grade equal to or higher than the grade of the treatment plant, distribution system, or collection system he/she operates. The grade of a facility will be established by the criteria set forth in this chapter of rules.
- (3) All operating personnel making process control/system integrity decisions about water quality or quantity that affect public health must be certified. A designated certified operator must be available for each operating shift.
- (4) Each water supply system and wastewater system required to have a certified operator shall, no later than the first day of August annually, inform the Board, through its designated agent, the Division of Water Resources, in writing of the name of each person who is a certified operator in direct charge of any water treatment plant, wastewater treatment plant, water

(Rule 0400-49-01-.04, continued)

distribution system or wastewater collection system it operates. A system shall notify the Division of Water Resources in writing within thirty (30) days of its loss of the services of a certified operator in direct charge.

- (5) A certified operator shall be responsible for keeping the Board Secretary informed of his/her current address.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-.05 DEFINITIONS.

- (1) "Available" means that a certified operator must be on site or able to be contacted as needed to initiate the appropriate action in a timely manner, based on system size, complexity and the quality of either the source water or the receiving stream.
- (2) "Board" means the board of certification as described in T.C.A. § 68-221-905.
- (3) "Commissioner" and "Department" mean the Commissioner of the Tennessee Department of Environment and Conservation or his/her duly authorized representative.
- (4) "Operating Shift" is that period of time during which operator decisions that affect public health are necessary for proper operation of the system.
- (5) "Process control/system integrity decisions" means decisions regarding the manipulation of equipment, chemicals or processes that determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.
- (6) "Person in direct charge" as used in these rules means the person or persons expressly designated to be in direct charge and so named in writing to the Board's authorized representative by each water supply system and wastewater system, whose decisions and directions to system personnel control the manipulation of equipment and thereby determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-.06 CLASSIFICATION OF WATER TREATMENT PLANTS AND WATER DISTRIBUTION SYSTEMS.

- (1) Water treatment plants shall be classified by the Board or its authorized representative into one of five groups, designated either as Small Water, Grade I, II, III, or IV. These classifications shall be made according to the number of population served, the type of treatment plant, and the complexity of treatment required for a particular water.
- (2) The classification of a water treatment plant or a water distribution system may be changed by the Board or its authorized representative because of changes in the conditions or the circumstances upon which the original classification was based. Notice of such a classification change shall be given to the management officers of the plant or system.
- (3) Types of Water Systems:

(Rule 0400-49-01-.06, continued)

- (a) Water Treatment. A water treatment plant using filtration, iron removal, and/or lime-soda softening processes or requiring chemical or bacteriological control of operation will be classified in accordance with the following point totals:

| | |
|-----------|-------------------|
| Grade IV | 61 or more points |
| Grade III | 35 to 60 points |
| Grade II | 16 to 34 points |
| Grade I | 15 or less points |

Point totals for plant classification shall be computed in accordance with the following rating value criteria:

Rating Value
 Points

Design Flow - For every one million gallons per day design capacity, or fraction thereof, a plant will be awarded a rating value of:1 pt.

Water Supply Source - Based upon the type and quality of the raw water source, a plant will be awarded rating values of:

| | |
|---|------------|
| Groundwater..... | 3 pts. |
| Ground water under the direct influence of surface water..... | 5 pts. |
| Surface water..... | 5 pts. |
| Average raw water quality..... | 0-10 pts.* |

Treatment Process - A plant employing any of the following treatment processes will be awarded rating values of:

| | |
|-----------------------------|---------|
| Aeration | 4 pts. |
| Presetting | 2 pts. |
| Flash mix | 2 pts. |
| Coagulation..... | 6 pts. |
| Flocculation | 5 pts. |
| Settling | 5 pts. |
| Upflow Solids Contact | 8 pts. |
| Lime softening | 5 pts. |
| Gravity Filtration | |
| slow sand | 2 pts. |
| rapid | 6 pts. |
| Pressure Filtration | 3 pts. |
| Recarbonation | 3 pts. |
| Membrane Filtration | 20 pts. |
| Activated alumina | 10 pts. |
| Ion Exchange | 5 pts. |

Chemical Treatment - A plant utilizing any of the following chemicals or chemical treatment processes will be awarded rating values of:

| | |
|-----------------------------------|--------|
| Fluoridation | 3 pts. |
| Disinfection | |
| Gaseous chlorine | 5 pts. |
| Liquid or powdered chlorine | 3 pts. |
| Chlorine dioxide | 7 pts. |

(Rule 0400-49-01-.06, continued)

| | |
|--|---------|
| Ozonization (on-site generation) | 10 pts. |
| On-site generation of Chlorine | 5 pts. |
| Mixed Oxidants | 7 pts. |
| UV Light | 3 pts. |

Taste and Odor Control

| | |
|---------------------------------|--------|
| Peroxide | 3 pts. |
| Potassium Permanganate | 2 pts. |
| Powdered activated carbon | 4 pts. |
| Activated carbon columns | 6 pts. |
| Activated carbon slurry | 8 pts. |

Chemical Stabilization

| | |
|---------------------------------------|--------|
| (polyphosphate, Soda Ash, etc.) | 4 pts. |
|---------------------------------------|--------|

Laboratory Control by Plant Personnel - Based upon the type and the difficulty of the laboratory work performed at a plant, a plant will be awarded rating values of:

| | |
|-----------------------|------------|
| Bacteriological | 0-10 pts.* |
| Chemical | 0-10 pts.* |

Total Points **

* See Table 1

** If a rating value points total would not accurately reflect special conditions at a plant and a material distortion in its rating would occur, the Board will establish the classification of the plant after a review of its special conditions.

Table 1

*Average Raw Water Quality - Points are assigned to a plant as follows:

| | |
|---|---------|
| Raw water quality varies enough to require treatment process changes less than thirty-six (36) days each calendar year | 2 pts. |
| Raw water quality varies enough to require treatment process changes thirty-six (36) days or more each calendar year | 5 pts. |
| Raw water quality varies enough to require treatment process changes due to existing industrial waste pollution sources | 10 pts. |

*Laboratory Control by Plant Personnel (Bacteriological) - Points are assigned in accordance with the type of laboratory control performed at the plant:

| | |
|---|---------|
| Lab work done outside of plant | 0 pts. |
| Enzyme Substrate Method | 4 pts. |
| Membrane filter procedure | 5 pts. |
| Fermentation tubes or any dilution method | 7 pts. |
| Biological identification | 10 pts. |

*Laboratory Control by Plant Personnel (Chemical) - Points are assigned in accordance with the type of laboratory control performed at the plant:

| | |
|--|--------|
| Lab work done outside the plant | 0 pts. |
| Colorimetric methods for simple tests such as chlorine, pH | 3 pts. |
| Procedures such as titration, jar tests | 5 pts. |

(Rule 0400-49-01-.06, continued)

More advanced determinations including inorganics 7 pts.
Highly sophisticated instrumentation such as atomic absorption and
gas chromatography 10 pts.

- (b) Grade I Distribution. This classification is for a water distribution system that serves at least fifty (50) service connections but no more than five thousand (5,000) service connections. This classification serves as a certificate to operate a small water system.
- (c) Grade II Distribution. This classification is for a water distribution system that serves more than five thousand (5,000) service connections. This classification serves as a certificate to operate a small water system.
- (d) Small Water Systems. This classification includes:
 - 1. All community and non-transient non-community water systems which have a ground water source not under the direct influence of surface water and serve less than fifty (50) service connections, provided the system does not use any treatment other than disinfection, and those systems which purchase water for resale and serve less than fifty (50) service connections; and
 - 2. Transient non-community water systems which have a ground water source not under the direct influence of surface water and serve less than one-hundred (100) service connections, provided the system does not use any treatment other than disinfection and/or cartridge filtration.

This classification serves as a distribution system certification for those systems meeting the definition of a small water system.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-.07 CLASSIFICATIONS AND QUALIFICATIONS OF WATER TREATMENT PLANT OPERATORS AND WATER DISTRIBUTION SYSTEM OPERATORS.

- (1) (a) Grade IV Water Treatment Plant Operator - Certification as an operator in this classification will be made only upon the satisfactory completion by the applicant of the requirements of either part 1 or 2 of this subparagraph.
 - 1. An applicant must have a bachelor degree in engineering, chemistry or a related science from an accredited college or university, must have twelve (12) months of operating experience at a Grade III or a Grade IV Water Treatment plant, and must satisfactorily complete a written examination.
 - 2. An applicant must have a high school education or equivalent, must have sixty (60) months of operating experience at a Grade III or a Grade IV Water Treatment plant, and must satisfactorily complete a written examination. Within the discretion of the Board, college course work in related science or engineering courses satisfactorily completed or Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of water treatment satisfactorily completed through schools for operators, correspondence courses, or other special training may be credited toward the required operating experience to a maximum equivalency of thirty-six (36) months.
 - 3. To receive full time operating experience credit, a minimum of 100% of the activities must be work experience duties. The Board reserves the right to adjust

(Rule 0400-49-01-.07, continued)

calendar months of experience to a reduced number of months of experience where it is obvious that an applicant's experience routinely includes other duties. The Board encourages documented apprenticeship training programs and classroom training provided by the employer to better prepare an operator to make decisions in plant operation to assure public health protection.

(b) Grade III Water Treatment Plant Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience at a Grade III water treatment plant or twelve (12) months at a Grade II and six months at a Grade III, and must satisfactorily complete a written examination. Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of water treatment satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.
2. To receive full time operating experience credit, a minimum of 50% of the activities must be work experience duties.

(c) Grade II Water Treatment Plant Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience at a Grade I or a Grade II Water Treatment plant, and must satisfactorily complete a written examination. Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of water treatment satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.
2. To receive full time operating experience credit, a minimum of 33% of the activities must be work experience duties.

(d) Grade I Water Treatment Plant Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience at a Grade I water treatment plant or a small water system, and must satisfactorily complete a written examination. Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of water treatment satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.
2. To receive full time operating experience credit, a minimum of 33% of the activities must be work experience duties.

(e) Small Water System Operator - An applicant must have a high school education or equivalent, and must have three (3) months of experience in a water system classified as a "small water system" and must satisfactorily complete a written examination.

(f) Grades I & II Water Distribution System Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience at a water distribution system, and must

(Rule 0400-49-01-.07, continued)

satisfactorily complete a written examination. Board sanctioned comprehensive training including installation, operation, maintenance and repair of distribution systems, satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.

2. To receive full time operating experience credit, a minimum of 50% of the activities must be work experience duties.

(2) Reclassifications Resulting from Amendments of this Chapter

- (a) The reclassification of a water treatment plant or a water distribution system that immediately occurs as a result of amendments to this chapter shall not reduce the operator classification of a certified operator then employed at that plant or system to a lower operator classification.
- (b) The reclassification of a water treatment plant or a water distribution system that immediately occurs as a result of amendments to this chapter shall raise the operator classification of a certified operator then employed at that plant or system to a higher operator classification equivalent with the new classification of the plant or system. This subparagraph shall apply only to a certified operator whose operator classification, immediately prior to reclassification of the plant or system pursuant to amendments to this chapter, is at least equivalent with the classification of the plant or system at which he/she is employed.
- (c) An applicant for examination who is employed at a water treatment plant or a water distribution system that has been reclassified by the Department and certified at the appropriate level may have his/her experience at the facility applied at a rate equal to the level of the reclassified facility.
- (d) An operator classification authorized under prior rules that is eliminated upon amendments to this chapter becoming effective shall be reclassified to the highest comparable operator classification authorized under these rules.
- (e) An operator's classification may be changed by the Board if the operator is employed at a water plant or distribution system that has been incorrectly classified by the Department for one year or more. The operator must hold a valid certificate equal to the incorrect plant or system classification and must have applied for and achieved the certificate based on the incorrect classification.

(3) Operating Experience Credit for Approved Study

- (a) For part (1)(a)2 of this rule, the Board may approve for each one (1) semester hour, or one and one half (1½) quarter hours, of academic study satisfactorily completed at an accredited college or university in related science or engineering courses as equal to one month of the operating experience required as a qualification of a certified water treatment plant operator.
- (b) For parts (1)(a)2, (1)(b)1, (1)(c)1, (1)(d)1, and (1)(f)1 of this rule, each day of Board sanctioned comprehensive training, satisfactorily completed, through schools for operators, correspondence courses, or other special training programs may be equal to one month of the operating experience required as a qualification of a certified water treatment plant operator.

(4) Work Experience

(Rule 0400-49-01-.07, continued)

- (a) The Board may approve the water treatment operating experience required in parts (1)(a)1, (1)(a)2, (1)(b)1, (1)(c)1, and (1)(d)1 of this rule in two or more of the following work experience duties:

Operation and/or maintenance of:

- Pretreatment systems
- Coagulant feed systems
- Filtration systems
- Fluoride feed systems
- Stabilization feed systems
- Hypochlorination systems
- Gas chlorination systems
- Pumps and/or motors
- Laboratory Control Tests
- Interpretation and plant adjustments

- (b) An operator applying for a Grade IV water treatment system certification may be granted partial credit by the Board for up to sixty percent (60%) of any approved operating experience obtained in a wastewater system.

- (c) The Board may approve the distribution system operating experience required in part (1)(f)1 of this rule in two or more of the following work experience duties:

Operation and/or maintenance of:

- Pumps
- Booster stations
- Fire hydrants
- Valves
- Storage tanks
- Distribution system flushing
- Pipeline installation
- Tap installation
- Leak detection
- Leak repairs
- Cross connection control

(5) Summary of Water Treatment Plant and Distribution System Operator Education and Experience Requirements

Water Treatment Plant Operators

| Classification | Experience | | | Maximum Training or College Classwork Substitution | Maximum Related Work Substitution |
|---|---|--------------|-----------|--|-----------------------------------|
| | Experience needed with: | HS Education | BS Degree | | |
| Grade IV | Gained at a Grade III or IV Water Plant | *60 months | 12 Months | 36 Months | 36 Months |
| *Regardless of the substitution allowances, a minimum of 1 year of actual work experience is required | | | | | |
| Grade III | Gained at a Grade III Water Plant | 12 Months | | 3 Months | |
| | Gained at a Grade II and | 12 Months | | 3 Months | |
| | Gained at a Grade III | 6 Months | | | |

(Rule 0400-49-01-.07, continued)

| | | | | | |
|-----------|--|-----------|--|----------|--|
| Grade II | Gained at a Grade I or II Water Plant | 12 Months | | 3 Months | |
| Grade I | Gained at a Grade I Water Plant or SWS | 12 Months | | 3 Months | |
| Grade SWS | Gained at a Small Water System (SWS) | 3 Months | | | |

Distribution System Operators

| Classification | Experience | | Maximum Training or College Classwork Substitution | Maximum Related Work Substitution |
|----------------|---|--------------|--|-----------------------------------|
| | Experience needed with: | HS Education | | |
| Grade II | Gained at a Distribution I or II System | 12 Months | 3 Months | |
| Grade I | Gained at a Distribution I or II System | 12 Months | 3 Months | |

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-.08 CLASSIFICATION OF WASTEWATER TREATMENT PLANTS AND WASTEWATER COLLECTION SYSTEMS.

- (1) Wastewater treatment plants shall be classified by the Board or its authorized representative into one of five groups, designated either as Biological/Natural, Grade I, II, III, or IV. These classifications shall be made in accordance with the point total scheme below which takes into account the design flow of the plant, its type of unit processes, its character, and the volume of wastewater it treats.
- (2) The term “collection system” means a system for the collection and transmission of wastewater to a treatment plant.
- (3) The classification of a wastewater treatment plant or a wastewater collection system may be changed by the Board or its authorized representative because of changes in the conditions or the circumstances upon which the original classification was based. Notice of such a classification change shall be given to the management officers of the plant or system.
- (4) Types of Wastewater Systems:
 - (a) A wastewater treatment plant, except Biological/Natural, will be classified either as Grade I, II, III or IV in accordance with the following point totals:

| | |
|-----------------|--|
| Grade IV | 76 or more points |
| Grade III | 56 to 75 points |
| Grade II | 55 points or less |
| Grade I..... | This classification is for a wastewater treatment plant with a capacity of seventy-five thousand (75,000) gallons per day or less. This classification serves as a Collection System certification for Grade I Collection Systems with less than fifteen (15) service connections. |

Biological/Natural This classification is for wastewater systems using natural biological treatment as the predominant means for treatment. This includes stabilization ponds, intermittent sand filters, recirculating sand filters, spray-irrigation, constructed wetlands, aerated lagoons, and overland flow

(Rule 0400-49-01-.08, continued)

systems. This classification serves as a Collection System certification for Grade I Collection Systems with less than fifteen (15) service connections.

Point totals for plant classification shall be computed in accordance with the following rating value criteria:

| | Rating Value Points |
|---|------------------------|
| Design Flow - For every one million (1,000,000) gallons per day design capacity, fraction thereof, a plant will be awarded rating value of: | 2 pts. |
| (30 points maximum) | |

Effluent Discharge - Based upon the following factors, a plant will be awarded rating values of:

| | |
|--------------------------------------|-----------|
| Receiving stream (sensitivity) | 0-7 pts.* |
| Land disposal – evaporation | 2 pts. |
| Subsurface disposal | 4 pts. |

Variation in Raw Wastes - Based upon the variation in the quality of the raw wastes, plant will be awarded a rating value of: 0-6 pts.*

Preliminary Treatment Units - A plant employing any of the following preliminary treatment processes will be awarded rating values of:

| | |
|---|--------|
| Manually cleaned screens | 2 pts. |
| Mechanically cleaned screens | 3 pts. |
| Preaeration | 2 pts. |
| Comminutor, barminutor, grinders, etc | 3 pts. |
| Grit removal | 3 pts. |
| Raw sewage pumping | 3 pts. |
| Flow equalization basins (Aerated) | 5 pts. |
| Flow equalization basins (Unaerated) | 2 pts. |
| Fine screens | 3 pts. |

Primary Treatment Units - A plant employing any of the following primary treatment processes will be awarded rating values of:

| | |
|---|--------|
| Pre-chlorination | 3 pts. |
| Primary Clarifiers | 5 pts. |
| Primary Clarifiers with chemical settling aid | 7 pts. |
| Swirl system | 3 pts. |

Secondary Treatment Units - A plant employing any of the following secondary treatment processes will be awarded rating values of:

| | |
|---|---------|
| Secondary Clarifiers | 5 pts. |
| Flocculation with or without chemical aid | 7 pts. |
| Trickling Filter without recirculation | 6 pts. |
| Trickling Filter with recirculation | 8 pts. |
| Activated Sludge+ | |
| Oxidation ditch | 8 pts. |
| Mechanical aeration | 9 pts. |
| Diffused or dispersed aeration | 10 pts. |
| Batch Treatment (ICEAS, etc) | 10 pts. |

(Rule 0400-49-01-.08, continued)

Pure oxygen 15 pts.

+ Add ten (10) additional points for a two-stage activated sludge facility

Tertiary Treatment Units/Advanced Treatment - A plant employing any of the following tertiary, or advanced, treatment processes will be awarded rating values of:

Polishing pond or Effluent flow equalization 2 pts.
 Land application of treated effluent 5 pts.
 Chemical treatment removal 6 pts.
 Denitrification 10 pts.
 Sand or mixed media filters 8 pts.
 Activated Carbon Beds 10 pts.
 Nitrification required by permit
 By Activated Sludge 6 pts.
 Nitrification by other process 5 pts.

Disinfection - Based upon the type of disinfection process employed, a plant will be awarded rating values of:

Chlorination 5 pts.
 Dechlorination 5 pts.
 Ozonization 10 pts.
 Ultraviolet 5 pts.

Sludge Treatment and Handling - A plant employing any of the following sludge treatment and handling facilities will be awarded rating values of:

Anaerobic digestion
 Unheated 5 pts.
 Heated 10 pts.
 Aerobic digestion 7 pts.
 Drying beds 3 pts.
 Sand bed with polymer added 5 pts.
 Gravity thickener 5 pts.
 Dissolved air floatation thickener 8 pts.
 Vacuum filter 8 pts.
 Centrifuge 8 pts.
 Belt Press, Plate & Frame 8 pts.
 Solids reduction (Incinerator, wet oxidation, etc.) 15 pts.
 Land application 5 pts.
 Chemical stabilization with lime 8 pts.
 All other dewatering units including wedgewire and vacuum beds,
 both with polymers 5 pts.
 Composting: In vessel 10 pts.
 Composting: Static Pile 5 pts.
 Sludge Lagoon 3 pts.

Laboratory Control by Plant Personnel - Based upon the type and difficulty of laboratory work performed at a plant, a plant will be awarded rating values of:

Bacteriological (Complexity) 0-10 pts.*
 Chemical/Physical (Complexity) 0-10 pts.*

Total Points **

(Rule 0400-49-01-.08, continued)

- * See Table 2
- ** If a rating value points total would not accurately reflect special conditions at a plant and a material distortion in its rating would occur, the Board will establish the classification of the plant after a review of its special conditions.

Table 2

Effluent Discharge - Points are assigned to a plant based upon the following receiving stream sensitivity criteria 0-7 pts.*

The key concept is the degree of dilution provided under low flow conditions. Assigned point values are:

- Secondary, or equivalent to secondary, wastewater treatment only is required 1 pt.
- Advanced secondary treatment 3 pts.
- Tertiary treatment 5 pts.
- Effluent used in a direct reuse system 7 pts.

Variation in Raw Wastes - Points are assigned to a plant based upon the variation from slight to extreme of the following factors: 0-6 pts.*

The key concept is frequency and/or intensity of deviation or excessive variation from normal or typical fluctuations; such deviation can be in terms of strength, toxicity, shock.

- Recurring deviations or excessive variations in strength and/or flow less than 100 percent 0 pts.
- Recurring deviations or excessive variations in strength and/or flow from 100 to 200 percent 2 pts.
- Recurring deviations or excessive variations in strength and/or flow of more than 200 percent 4 pts.
- Raw wastes subject to toxic waste discharges 6 pts.

Laboratory Control by Plant Personnel - Points are assigned in accordance with the type of laboratory control performed at the plant:

Bacteriological/biological (complexity) 0-10 pts.*

The key concept is to credit bacteriological/biological lab work done on-site by plant personnel. Assigned point values are:

- Lab work done outside the plant 0 pts.
- Membrane filter procedures 3 pts.
- Use of fermentation tubes or any dilution method 5 pts.
- Biological identification 7 pts.

Chemical/physical (complexity) 0-10 pts.*

The key concept is to credit chemical/ physical lab work done on-site by plant personnel.

- Lab work done outside the plant 0 pts.

(Rule 0400-49-01-.08, continued)

| | |
|--|---------|
| Push-button or visual methods for simple tests such as pH, settleable solids | 3 pts. |
| Additional procedures such as DO, COD, BOD, gas analysis, titrations, solids, volatile content | 5 pts. |
| More advanced determinations such as specific nutrients, total oils, phenols, etc | 7 pts. |
| Highly sophisticated instrumentation such as atomic absorption and gas chromatography | 10 pts. |

These terms describe the minimum level of effluent quality attainable for treated wastewater under standard design conditions in terms of the arithmetic mean of the values for effluent samples collected in a period of thirty (30) consecutive days for the following parameters: five-day biochemical oxygen demand (BOD₅); total suspended solids (TSS); and acidity/alkalinity (pH).

1. "Equivalent to secondary wastewater treatment" means the 30-day average for BOD₅ does not exceed 45 mg/l and there is no ammonia limit.
 2. "Secondary wastewater treatment" means the 30-day average for BOD₅ does not exceed 30 mg/l and there is no ammonia limit.
 3. "Advanced secondary wastewater treatment" means that the biochemical oxygen demand is expressed as the carbonaceous form (CBOD₅) that is equal to or greater than 10 mg/l and is equal to or less than 25 mg/l; and there is an ammonia limit.
 4. "Tertiary wastewater treatment" means that the CBOD₅ is less than 10 mg/l and there is an ammonia limit.
- (b) Grade I Collection System. This classification is for a wastewater collection system that uses collector and/or transmission lines to transport wastewater to a treatment plant and which serves no more than five thousand (5,000) service connections.
- (c) Grade II Collection System. This classification is for a wastewater collection system that uses collector and/or transmission lines to transport wastewater to a treatment plant and which serves more than five thousand (5,000) service connections.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-.09 CLASSIFICATIONS AND QUALIFICATIONS OF WASTEWATER TREATMENT PLANT OPERATORS AND WASTEWATER COLLECTION SYSTEM OPERATORS.

- (1) (a) Grade IV Wastewater Treatment Plant Operator

Certification as an operator in this classification will be made only upon the satisfactory completion by the applicant of the requirements of either parts 1 or 2 of this subparagraph.

1. An applicant must have a bachelor degree in engineering, chemistry or a related science from an accredited college or university, must have twelve (12) months of operating experience at a Grade III or a Grade IV Wastewater Treatment plant, and must satisfactorily complete a written examination.

(Rule 0400-49-01-.09, continued)

2. An applicant must have a high school education or equivalent, must have sixty (60) months of operating experience at a Grade III or a Grade IV Wastewater Treatment plant, and must satisfactorily complete a written examination. Within the discretion of the Board, college course work in related science or engineering courses satisfactorily completed, or Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of wastewater treatment satisfactorily completed through schools for operators, correspondence courses, or other special training, may be credited toward the required operating experience to a maximum equivalency of thirty-six (36) months.
3. To receive full time operating experience credit, a minimum of 100% of the activities must be work experience duties. The Board reserves the right to adjust calendar months of experience to a reduced number of months of experience where it is obvious that an applicant's experience routinely includes other duties. The Board encourages documented apprenticeship training programs and classroom training provided by the employer to better prepare an operator to make decisions in plant operation to assure public health protection.

(b) Grade III Wastewater Treatment Plant Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience at a Grade II wastewater treatment plant or a Grade III wastewater treatment plant, and must satisfactorily complete a written examination. Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of wastewater treatment satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.
2. To receive full time operating experience credit, a minimum of 50% of the activities must be work experience duties.

(c) Grade II Wastewater Treatment Plant Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience at a Grade I wastewater treatment plant or a Grade II wastewater treatment plant, and must satisfactorily complete a written examination. Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of wastewater treatment satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.
2. To receive full time operating experience credit, a minimum of 33% of the activities must be work experience duties.

(d) Grade I Wastewater Treatment Plant Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience in a Grade I wastewater treatment plant or twelve (12) months operating experience at a biological/natural system and six (6) months at a Grade I wastewater treatment plant, and must satisfactorily complete a written examination. Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of wastewater treatment satisfactorily completed through schools for operators, correspondence courses,

(Rule 0400-49-01-.09, continued)

or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.

2. To receive full time operating experience credit, a minimum of 33% of the activities must be work experience duties.

(e) Biological/Natural System Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience in a wastewater system classified as a biological/natural system, and must satisfactorily complete a written examination. Board sanctioned comprehensive training in chemistry, bacteriology, and the fundamentals of wastewater treatment satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.
2. To receive full time operating experience credit, a minimum of 33% of the activities must be work experience duties.

(f) Grades I & II Wastewater Collection System Operator

1. An applicant must have a high school education or equivalent, must have twelve (12) months of operating experience at a wastewater collection system, and must satisfactorily complete a written examination. Board sanctioned comprehensive training including installation, operation, maintenance and repair of collection systems, satisfactorily completed through schools for operators, correspondence courses, or other special training programs may be credited toward the required operating experience to a maximum equivalency of three (3) months.
2. To receive full time operating experience credit, a minimum of 50% of the activities must be work experience duties.

(2) Reclassifications Resulting from Amendments to this Chapter

- (a) The reclassification of a wastewater treatment plant or a wastewater collection system that immediately occurs as a result of amendments to this chapter shall not reduce the operator classification of a certified operator then employed at that plant or system to a lower operator classification.
- (b) The reclassification of a wastewater treatment plant or a wastewater collection system that immediately occurs as a result of amendments to this chapter shall raise the operator classification of a certified operator then employed at that plant or system to a higher operator classification equivalent with the new classification of the plant or system. This subparagraph shall apply only to a certified operator whose operator classification, immediately prior to reclassification of the plant or system pursuant to amendments to this chapter, is at least equivalent with the classification of the plant or system at which he/she is employed.
- (c) An applicant for examination who is employed at a wastewater treatment plant or a wastewater collection system that has been reclassified by the Department, and certified at the appropriate level, may have his/her experience at the facility applied at a rate equal to the level of the reclassified facility.

(Rule 0400-49-01-.09, continued)

- (d) An operator classification authorized under prior rules that is eliminated upon amendments to this chapter becoming effective shall be reclassified to the highest comparable operator classification authorized under these rules. (Industrial Biological Waste Treatment certificates become Grade IV Wastewater certificates).
 - (e) An operator's classification may be changed by the Board if the operator is employed at a wastewater plant or collection system that has been incorrectly classified by the Department for one (1) year or more. The operator must hold a valid certificate equal to the incorrect plant or system classification and the operator must have applied for and achieved the certificate based on the incorrect classification.
- (3) Operating Experience Credit for Approved Study
- (a) For part (1)(a)2 of this rule, the Board may approve each one (1) semester hour, or one and one half (1½) quarter hour, of academic study satisfactorily completed at an accredited college or university in related science or engineering courses as equal to one month of the operating experience required as a qualification of a certified wastewater treatment plant operator.
 - (b) For parts (1)(a)2, (1)(b)1, (1)(c)1, (1)(d)1, (1)(e)1, and (1)(f)1 of this rule, each day of Board sanctioned comprehensive training, satisfactorily completed, through schools for operators, correspondence courses, or other special training programs may be equal to one month of the operating experience required as a qualification of a certified wastewater treatment plant operator.
- (4) Work Experience
- (a) The Board may approve the wastewater treatment operating experience required in parts (1)(a)1, (1)(a)2, (1)(a)3, (1)(b)1, (1)(c)1, (1)(d)1, and (1)(e)1 of this rule in two (2) or more of the following work experience duties:
 - Control of:
 - Solids pumping from clarifiers
 - Scum removal in clarifiers
 - Return and waste sludge rates
 - Aeration rates
 - Recirculation rates to trickling filter or rotating biological contactor (RBC)
 - Operation of:
 - Disinfection system feed rates
 - Digesters and/or solids conditioning processes
 - Performance of:
 - Calculations and plant control
 - Interpretation of laboratory test results
 - Interpretation of process control data
 - Cleaning and maintenance of preliminary treatment
 - Adjustment of wastewater levels or flow through a lagoon system
 - (b) An operator applying for a Grade IV wastewater system certification may be granted partial credit by the Board for up to forty percent (40%) of any approved operating experience obtained in a water supply system.
 - (c) The Board may approve the collection system operating experience required in part (1)(f)1 of this rule in two or more of the following work experience duties:

Operation and/or maintenance of:

(Rule 0400-49-01-.09, continued)

- Pumps
- Lift stations
- Valves
- Lines and equipment
- Pipeline installation
- Service connection installation
- Leak detection
- TV crew activities
- Line repairs
- Line cleaning
- Manhole maintenance
- Pretreatment

(5) Summary of Wastewater Treatment Plant and Collection System Operator Education and Experience

Wastewater Treatment Plant Operators

| Classification | Experience | | | Maximum Training or College Classwork Substitution | Maximum Related Work Substitution |
|---|---|-----------------------|-----------|--|-----------------------------------|
| | Experience needed with: | HS Education | BS Degree | | |
| Grade IV | Gained at a Grade III or IV Wastewater Plant | *60 months | 12 Months | 36 Months | 24 Months |
| *Regardless of the substitution allowances, a minimum of 1 year of actual work experience is required | | | | | |
| Grade III | Gained at a Grade II or III Wastewater Plant | 12 Months | | 3 Months | |
| Grade II | Gained at a Grade I or II Wastewater Plant | 12 Months | | 3 Months | |
| Grade I | Gained at a Grade I Wastewater Plant | 12 Months | | 3 Months | |
| | Gained at Biological/Natural and Grade I Wastewater Plant | 12 Months 6 Months | | | |
| Grade BNS | Gained at a BNS Wastewater Plant | 12 Months | | 3 Months | |

COLLECTION SYSTEM OPERATORS

| Classification | Experience | | Maximum Training or College Classwork Substitution | Maximum Related Work Substitution |
|----------------|---------------------------------------|--------------|--|-----------------------------------|
| | Experience needed with: | HS Education | | |
| Grade II | Gained at a Collection I or II System | 12 Months | 3 Months | |
| Grade I | Gained at a Collection I or II System | 12 Months | 3 Months | |

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-10 CONTINUING EDUCATION.

At least once during every continuing education period each certified operator shall satisfactorily complete the required number of continuing education hours approved by the Board for the particular type of certificate he/she holds. The continuing education period for a certified operator shall begin either with the date the certified operator obtained his/her certificate or the date the certified operator last satisfactorily completed the required number of continuing education hours and shall end at the conclusion of the annual continuing education term three (3) calendar years thereafter. An annual continuing education

(Rule 0400-49-01-.10, continued)

term shall begin each year on October 1 and shall end on September 30 of the following year. The failure of an operator to satisfactorily complete the required number of continuing education hours approved by the Board Secretary during his/her continuing education period shall be grounds for the denial of his/her application for the renewal of his/her certificate. An operator shall notify the Board Secretary upon his/her satisfactory completion of the continuing education requirement by furnishing appropriate documentation of course completion. Notification by the operator is not necessary in those cases where an agency notifies the Board Secretary of such activity. An operator that fails to satisfactorily complete the required number of continuing education hours during his/her continuing education period due to an unusual event such as an incapacitating illness or similar unavoidable circumstances may make a written request to the Board for an extension of time to do so. All requests by an operator for an extension of time to meet the continuing education requirement must be made in writing to the Board either within two (2) months of the elapsed continuing education period or by the date of return of the operator to active employment, whichever is later. All such requests must be accompanied by complete supporting documentation of the circumstances causing the failure to meet the continuing education requirement.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-.11 SUMMARY SUSPENSION AND REVOCATION OF CERTIFICATE.

- (1) An operator's certificate may be revoked when:
 - (a) In accordance with paragraph (2) of this rule, an operator has not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties as a certified operator, or
 - (b) In accordance with paragraph (3) of this rule, an operator is incompetent to perform those duties properly; or
 - (c) In accordance with paragraph (4) of this rule, an operator has practiced fraud or deception.
- (2) An operator shall be deemed to have not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties if he/she does not comply with the laws, rules, permit requirements, or orders of any governmental agency or court which govern the water supply system or the wastewater system he/she operates. Such acts of noncompliance include but are not limited to the following:
 - (a) The intentional or the negligent failure by the operator or persons under his/her supervision to act that results in a water supply system facility or a wastewater system facility not operating in the manner in which it is capable of being operated for the performance of its designed function.
 - (b) The intentional or the negligent failure by the operator or persons under his/her supervision to comply with the monitoring, sampling, analysis, or reporting requirements for a water supply system facility or a wastewater system facility.
 - (c) The intentional or the negligent unlawful discharge of wastes from a water supply system facility or a wastewater system facility.
 - (d) The intentional or the negligent failure by the operator or persons under his/her supervision to notify the Department of conditions: which may affect the quantity or quality of water being supplied to the customers of a water supply system; which cause the pollution of the waters of the State of Tennessee; or, which are violative of a standard of water quality promulgated by any governmental agency.

(Rule 0400-49-01-.11, continued)

- (3) An operator shall be deemed to be incompetent to perform his/her duties properly when he/she does not possess the basic skills and knowledge necessary to operate a water supply system facility or a wastewater system facility including laboratory functions or if he/she fails to have a system of verification and oversight of employees under his/her charge. Incompetency shall be determined by examining the technical skills of the operator in operating the type of facility of which he/she is in direct charge.
- (4) An operator shall be deemed to have practiced fraud or deception as follows:
 - (a) Obtained his/her certificate through fraud, deceit, or the submission of inaccurate data regarding his/her qualifications upon his/her application for a certificate.;
 - (b) Has practiced fraud or deception during the performance of his/her duties as a certified operator; or
 - (c) Has prepared and/or signed reports of laboratory analysis results for the system that:
 1. Contain inaccurate data and are known or should be known by the operator to be false; or,
 2. Contain inaccurate data because the operator has not used reasonable care, judgment, or the application of his/her knowledge either in the performance of the laboratory analysis or in the preparation of the laboratory analytical reports.
- (5) Revocation
 - (a) The Commissioner may initiate the process to revoke a certificate when he/she believes an operator has engaged in any of the activities set forth in paragraph (1) of this rule.
 - (b) The Commissioner shall give notice by mail to the affected operator of facts or conduct that warrants revocation of the certificate and give the affected operator an opportunity to show compliance with these rules by conducting an informal hearing as provided in T.C.A. § 4-5-320(c).
 - (c) After the T.C.A. § 4-5-320(c) informal hearing, if the Commissioner determines that the affected operator has failed to demonstrate compliance, the Commissioner shall issue a notice of hearing for revocation and include a recommendation to the Board to revoke and reinstate or not to reinstate the certificate. Any recommendation of reinstatement of the certificate shall include terms for such reinstatement.
 - (d) The notice of hearing for revocation shall contain the information required by part 1 of this subparagraph and be served in accordance with part 2 of this subparagraph.
 1. The notice shall include:
 - (i) A statement of the time, place, nature of the hearing, and the right to be represented by counsel;
 - (ii) A statement of the legal authority and jurisdiction under which the hearing is to be held, including a reference to the particular sections of the statute and rules involved; and

(Rule 0400-49-01-.11, continued)

(iii) A short and plain statement of the facts or conduct that warrant a revocation. (If the Commissioner is unable to state the matters in detail at the time the notice is served, the initial notice may be limited to a statement of the issues involved. Thereafter, upon timely, written application a more definite and detailed statement shall be furnished ten (10) days prior to the time set the hearing.)

2. A copy of the notice of hearing shall be:

- (i) Served upon the operator no later than thirty (30) days prior to the hearing date; and
- (ii) Served by personal service, return receipt mail or equivalent carrier with a return receipt,

A person making personal service on the operator affected shall return a statement indicating the time and place of service, and a return receipt must be signed by the operator affected. However, if the affected operator evades or attempts to evade service, service may be made by leaving the notice or a copy of the notice at the affected operator's dwelling house or usual place of abode with some person of suitable age and discretion residing therein, whose name shall appear on the proof of service or return receipt card. Service may also be made by delivering the notice or copy to an agent authorized by appointment or by law to receive service on behalf of the affected operator, or by any other method allowed by law in judicial proceedings.

(6) Summary Suspension and Revocation

- (a) The Commissioner may initiate the process of summary suspension and revocation of the certificate when the Commissioner believes that an emergency action is needed to protect the public health, safety or welfare.
- (b) The Commissioner shall give a notice to the affected operator by any reasonable means and shall inform the affected operator of the intended action, the acts or conduct that warrants summary suspension and revocation of the certificate and hold an informal hearing, as provided in T.C.A. § 4-5-320(d), to give the operator an opportunity to address the issue of whether there is an emergency.
- (c) The Commissioner shall appoint a hearing officer to conduct this T.C.A. § 4-5-320(d) hearing and the hearing shall be recorded and transcribed.
- (d) After the informal hearing as provided in T.C.A. § 4-5-320(d), if the Commissioner determines that an emergency action is warranted, the Commissioner shall issue an Order of Summary Suspension and a notice of hearing for revocation and include a recommendation to the Board to reinstate or not to reinstate the certificate. Any recommendation of reinstatement of the certificate shall include terms for such reinstatement.
- (e) The Order of Summary Suspension and the notice for revocation shall contain the information required by part (5)(d)1 of this rule and be served in accordance with part (5)(d)2 of this rule.
- (f) When the Commissioner has issued an Order of Summary Suspension and Notice of Revocation, the Board shall conduct its revocation hearing and render a decision within ninety (90) days of the operator's summary suspension. In the event the Board does

(Rule 0400-49-01-.11, continued)

not render its decision within ninety (90) days of the operator's summary suspension, the Order of Summary Suspension shall expire and no longer be in force or effect. However, the Commissioner may reissue an Order of Summary Suspension in accordance with this paragraph, for a period not to exceed ninety (90) days.

- (7) The revocation hearing before the Board shall be held in accordance with T.C.A. §§ 4-5-301 et seq. and Rule Chapter 1360-04-01 Uniform Rules of Procedure for Hearing Contested Cases Before State Administrative Agencies.
- (8) The Board may revoke the certificate of an operator when it is found that the operator has practiced fraud or deception; that reasonable care, judgment or the application of such operator's knowledge was not used in performance of such operator's duties; or that the operator is incompetent to properly perform such operator's duties. If the certificate is revoked and is to be reinstated, the Board shall determine the timing, terms and conditions for reinstatement.
- (9) An operator who receives an order of the Board for the revocation of his/her certificate may appeal the order to the Chancery Court of Davidson County within sixty (60) days.
- (10) An operator whose certificate is revoked for failure to use reasonable care, judgment or the application of operator knowledge in performing the operator's duties or for incompetency shall be ineligible to again apply for certification as an operator for a minimum of one (1) year. An operator whose certificate is revoked for practicing fraud or deception, willfully violating regulations or permit conditions, or falsifying records and reports shall be ineligible to again apply for certification as an operator for a minimum of five years. When an operator whose certificate has been revoked has applied for a certificate after the minimum time has passed, the Board shall determine whether the operator has taken appropriate action to address the circumstances that were the cause of the revocation. The Board may request records and review his/her experience, education, training and past performance. The Board may request the former operator's presence at a meeting of the Board and interview him/her to assess the potential of future violations. After the reviews, the Board shall decide to accept or refuse the application.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

0400-49-01-.12 CIVIL PENALTIES.

- (1) The Commissioner may assess the civil penalty authorized by law against a municipality, utility district, corporation, or any person operating a water supply system or a wastewater system if the competency of the person in direct charge of a system facility has not first been certified in accordance with these rules.
- (2) A certified operator may be assessed the civil penalty authorized by law for the same acts and omissions that would constitute grounds for the revocation of his/her certificate by the Board.
- (3) Prior to issuing an order that assess a civil penalty, in accordance with paragraphs (1) and (2) of this rule the Commissioner may hold a show cause meeting with the person or entity to whom the order is proposed to be issued.

Authority: T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.

Tenn. Code Ann. § 68-221-901

Current through the 2018 Regular Session.

- [Tennessee Code Annotated](#)
- [Title 68 Health, Safety and Environmental Protection](#)
- [Environmental Protection](#)
- [Chapter 221 Water and Sewerage](#)
- [Part 9 Water And Wastewater Operator Certification Act](#)

68-221-901. Short title.

This part shall be known and may be cited as the "Water and Wastewater Operator Certification Act."

68-221-902. Legislative purpose.

Recognizing that correct operation of water and wastewater systems is necessary for the protection of the public health and the quality of the environment, it is declared to be the purpose of this part to prevent inadequate operation of all such systems through a system of certification of operators and penalties for noncompliance.

68-221-903. Part definitions.

As used in this part, unless the context otherwise requires:

- (1) "Board" means the board of certification created in § 68-221-905;
- (2) "Certificate" means a certificate of competency issued by the commissioner stating that the operator has met the requirements for the specified operator classification of the certification program;
- (3) "Commissioner" means the commissioner of environment and conservation or the commissioner's duly authorized representative;
- (4) "Operator" means a person who is in direct charge, or that by education, training and experience is qualified to be in direct charge, of a water treatment plant, wastewater treatment plant, water distribution system or wastewater collection system;
- (5) "Wastewater collection system" means the entire system of pipes, valves, pumping stations and appurtenances through which wastewater is collected and conveyed to the wastewater treatment plant;
- (6) "Wastewater treatment plant" means the facility or group of units provided for the treatment of wastewater, either or both domestic and industrial wastes. Industrial wastes which do not enter a public wastewater system are excluded;
- (7) "Water distribution system" means that portion of the water supply system in which water is conveyed from the water treatment plant or other supply point to the premises of the consumer;
- (8) "Water supply system" means the system of pipes, structures and facilities through which water is obtained, treated, and sold, distributed or otherwise offered

to the public for household use or any use by humans, if such system has at least fifteen (15) service connections or regularly serves an average of at least twenty-five (25) individuals at least one hundred twenty (120) days or at least sixty (60) consecutive days out of the year. An industrial water system not delivering water for human consumption is excluded from this definition; and

(9) "Water treatment plant" means the portion of the water supply system which in some way alters the physical, chemical or bacteriological quality of the water.

68-221-904. Certified operators only -- Violations of part -- Penalties.

(a) It is unlawful for any person, firm or corporation, both municipal and private, operating a water supply system or wastewater system, to operate the water treatment plant, wastewater treatment plant, water distribution system, or wastewater collection system unless the competency of the operators in direct charge of such system are duly certified by the commissioner under this part in effect on and after May 25, 1984, or under former chapter 13, part 3 of this title in effect prior to May 25, 1984.

(b) Any municipality, utility district, corporation, or persons violating any provisions of this part or the rules and regulations adopted thereunder commits a Class C misdemeanor, and each day in violation constitutes a separate offense.

(c)

(1) Additionally, any municipality, utility district, corporation or persons violating any provisions of this part, or the rules and regulations adopted thereunder, shall be subject to civil penalties up to ten thousand dollars (\$10,000) per day, for each day during which the violation occurs.

(2) The commissioner has the duty and authority to levy civil penalties authorized in subdivision (c)(1), the duty and authority to issue orders requiring compliance with this part, and to hold show cause meetings with the persons or entities to whom the orders are proposed to be issued.

68-221-905. Board of certification.

(a)

(1) A board of certification is established for the administration of the certification program.

(2) The board is charged with the responsibility of conducting all work necessary to promote the program and maintain records, and shall also promulgate rules and regulations required in performing its obligations.

(b) (1) Such board shall be composed of the following members, appointed by the governor:

(A) One (1) member shall be a certified operator of a water or wastewater system who holds a certificate of the highest class issued by the board, who may be appointed from lists of qualified persons submitted by interested water and wastewater groups including, but not limited to, the Tennessee Water and Wastewater Association;

(B) One (1) member shall be a certified operator of a water or wastewater utility district, who may be appointed from lists of qualified persons submitted by interested utility district groups including, but not limited to, the Tennessee Association of Utility Districts;

(C) One (1) member shall be a person knowledgeable about water or wastewater systems with experience working for such systems, who may be appointed from lists of qualified persons submitted by interested municipal groups including, but not limited to, the Tennessee Municipal League;

(D) One member shall be a faculty member of a college, university or state technical institute whose major field is related to water or wastewater systems, who may be appointed from lists of qualified persons submitted by interested engineering groups including, but not limited to, the Tennessee Society of Professional Engineers; and

(E) The commissioner or such qualified member of the commissioner's staff as the commissioner may designate.

(2) The governor shall consult with interested groups, including, but not limited to, the organizations listed in subdivision (b)(1) to determine qualified persons to fill positions on the board.

(c)

(1) Board members shall serve for three-year terms except as designated herein, and all appointments shall expire on June 30 of the appropriate year. A board member shall continue to serve, however, until a successor has been appointed, or until the board member has been reappointed.

(2) Appointments to succeed a board member who is unable to serve such board member's full term shall be for the remainder of that term.

(3) Board members may be reappointed, but they do not succeed themselves automatically.

(4) Appointments to the board for the remainder of an unexpired term, and reappointments shall be made in the same manner as under subsection (b).

(5) Any board member who moves from Tennessee is automatically terminated from the board.

(d) At the first meeting each year after July 1, the board shall elect from its membership a chair and vice chair.

(e) The director of the division of water resources or the director's designated representative shall serve as secretary of the board and be responsible for maintaining records.

68-221-906. Powers and duties of board.

(a) Duties and authority of the board include:

(1) Adopt, modify, repeal, promulgate in accordance with the Uniform Administrative Procedures Act, compiled in title 4, chapter 5, and, after due notice, enforce rules and regulations which the board deems necessary for proper administration of this part;

(2) Hold at least one (1) examination annually at a designated time and place for the purpose of examining candidates for certification;

(3) Advertise and promote the program;

(4) Encourage other operators to become certified besides those required by law;

(5) Distribute applications and notices;

(6) Receive and evaluate applications;

(7) Prepare, conduct and grade examinations;

(8) Set up a system of fees and late penalties for applicants to support the expenses of the program;

- (9)** Maintain all records of the program, and maintain a register of certified operators;
- (10)** Promote and schedule regular training schools and programs;
- (11)** Hear appeals from any order or ruling issued by the commissioner, and affirm, modify or revoke such order or ruling; issue notices of such appeals and subpoenas requiring attendance of such witnesses and production of such evidence; administer oaths; and take such testimony as the board deems necessary. Any such appeals must be filed with the board within thirty (30) days of issuance of such order or ruling; and
- (12)** Recommend to the commissioner the staff required to effectively administer the requirements of this part.
- (b)** The board has the authority to hear appeals from orders and civil penalties made or assessed by the commissioner under this part.
- (f)** Each member of the board, other than the ex officio member, shall be entitled to be paid fifty dollars (\$50.00) for attendance at each meeting of the board at which a quorum is present and for actual and necessary expenses incurred. All reimbursement for travel expenses shall be in accordance with the comprehensive travel regulations as promulgated by the department of finance and administration and approved by the attorney general and reporter.
- (g)** A quorum of the board shall be at least three (3) members.

68-221-907. Classification of facilities and systems.

The board shall classify all water treatment plants, wastewater treatment plants, water distribution systems, and wastewater collection systems with due regard to the size, type, physical conditions affecting such treatment plants, collection systems and distributions systems, and according to the skill, knowledge and experience that the operator must have to supervise successfully the operation of the plant or system, so as to protect the public health.

68-221-908. Certification by commissioner.

The commissioner, in accordance with the rules and regulations of the board, shall certify persons as to their qualifications to supervise successfully the operation of such water treatment plants, wastewater treatment plants, water distribution systems, and wastewater collection systems, after considering the recommendations of the board appointed by the governor.

68-221-909. Certification of operators -- Responsibilities -- Multiple functions.

- (a)** All operators of water and wastewater systems are encouraged to become certified, although this part requires only that a person in direct charge of a water treatment plant, wastewater treatment plant, water distribution system or wastewater collection system be certified.
- (b)** There is nothing in the part to prohibit a single person becoming a certified operator for more than one (1) of the functions listed in subsection (a).

(c) It is permissible for one (1) certified operator to have the responsibility for more than one (1) water and/or wastewater system where two (2) or more systems are involved in reasonable proximity to one another, and where the duties of operation are such that the work time of one (1) person may properly be divided among two (2) or more systems, or where a certified operator may adequately supervise the work of others in more than one (1) system.

68-221-910. Issuance, duration and renewal of certificates -- Reciprocity.

(a)

(1) Upon satisfactory fulfillment of the requirements and based upon recommendation of the board, the commissioner shall issue a suitable certificate to the applicant designating the applicant's competency.

(2) The certificate will indicate that portion of the plant or system for which the operator is qualified.

(3) Certificates shall be permanent except as noted subsequently in this part.

(b) Certificates shall be renewed annually upon payment of the renewal fee and the fulfillment of continuing education and/or experience requirements established by the board, unless revoked or replaced by one of a higher grade.

(c) Operators who desire to become certified in a higher grade must satisfactorily complete the requirements before the certificate is issued.

(d)

(1) Certificates shall be valid only so long as the holder uses reasonable care, judgment and application of such holder's knowledge in the performance of such holder's duties.

(2) No certificate will be valid if obtained through fraud, deceit or the submission of inaccurate data on qualifications.

(e) Certificates may be issued, without examination, in a comparable classification to any person who holds a certificate in another state; provided, that the requirements of that state are comparable or higher; and provided further, that such requirements do not conflict with this part. Such issuance of a certificate may be contingent upon reciprocal privileges being granted by that state to an operator from Tennessee.

68-221-911. Revocation of certificates -- Appeals.

(a) The board may revoke the certificate of an operator when it is found that the operator has practiced fraud or deception; that reasonable care, judgment or the application of such operator's knowledge was not used in performance of such operator's duties; or that the operator is incompetent to properly perform such operator's duties.

(b) When the commissioner believes an operator has engaged in any of the activities set forth in subsection (a), the commissioner may issue an order suspending the operator's certificate until the board conducts a hearing on the revocation of the operator's certificate for such activities. When the commissioner has issued a suspension order, the board shall conduct its revocation hearing and render its decision within ninety (90) days of the operator's suspension. In the event the board does not render its decision within ninety (90) days of the operator's suspension, the suspension order shall expire and no longer be in force.

or effect. However, the commissioner may reissue an order of suspension for a period not to exceed ninety (90) days.

(c) When the board determines an operator's certificate should be revoked under subsection (a), the board shall establish the timing, terms and conditions for any reinstatement of the operator's certificate.

68-221-912. Replacement of certified operator.

(a) The board may allow a period of up to six (6) months for the replacement of a certified operator whose services have been lost by death, illness or other unusual events.

(b) Further extensions of thirty (30) days, up to a total of one hundred eighty (180) additional days, may be granted if deemed necessary by the board.

(c) A system shall notify the board in writing within thirty (30) days of the loss of certified operator(s).

68-221-913. Collection of fees -- Funding.

(a) All fees collected under this part shall be paid into the state treasury.

(b) The department of finance and administration, with the governor's approval, is authorized to allot to the department of environment and conservation such funds as are necessary for the administration of this part, and the department is designated as the administrative agency for the board created by this part.

68-221-914. Appeals of board's rulings.

(a) Any party to a hearing before the board regarding a revocation or an appeal of an order or assessment of a civil penalty by the commissioner may appeal the final order of the board to the chancery court of Davidson County.

(b) Such appeal must be filed within sixty (60) days.

68-221-915. Complaints -- Procedures -- Determinations -- Appeals.

(a) Any person may file with the commissioner a signed complaint against any person allegedly violating any provisions of this part.

(b) Unless the commissioner determines that such a complaint is duplicitous or frivolous, the commissioner shall immediately serve a copy of it upon the person or persons named therein, promptly investigate the allegations contained therein, and shall notify the alleged violator of what action, if any, the commissioner will take.

(c) In all cases, the commissioner shall notify the complainant of the commissioner's action or determination within ninety (90) days from the date of the commissioner's receipt of the written complaint.

(d)

(1) If either the complainant or the alleged violator believes that the commissioner's action or determination is or will be inadequate or too severe, such person may appeal to the board for a hearing which will be conducted pursuant to this part.

(2) Such appeal must be made within thirty (30) days after receipt of the notification sent by the commissioner.

(e) If the commissioner fails to take the action stated in the commissioner's notification, the complainant may make an appeal to the board within thirty (30) days from the time at which the complainant knows or has reason to know of such failure.

(f) The department shall not be obligated to assist a complainant in gathering information or making investigations or to provide counsel for the purpose of drawing such complainant's complaint.