Introduction to Water Treatment

For All Grades

Course # 301

Week 1

Updated 11-2022

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Section 1

Overview

Overview of Water Treatment

Purpose of water treatment – to provide safe drinking water that does not contain objectionable taste, odor or color; to provide adequate quantities of water for domestic, commercial, industrial and fire protection needs.

All water produced by public water systems must be drinking water quality, even though only about 1% of water produced is used for drinking and cooking.

Schematic of conventional water treatment:

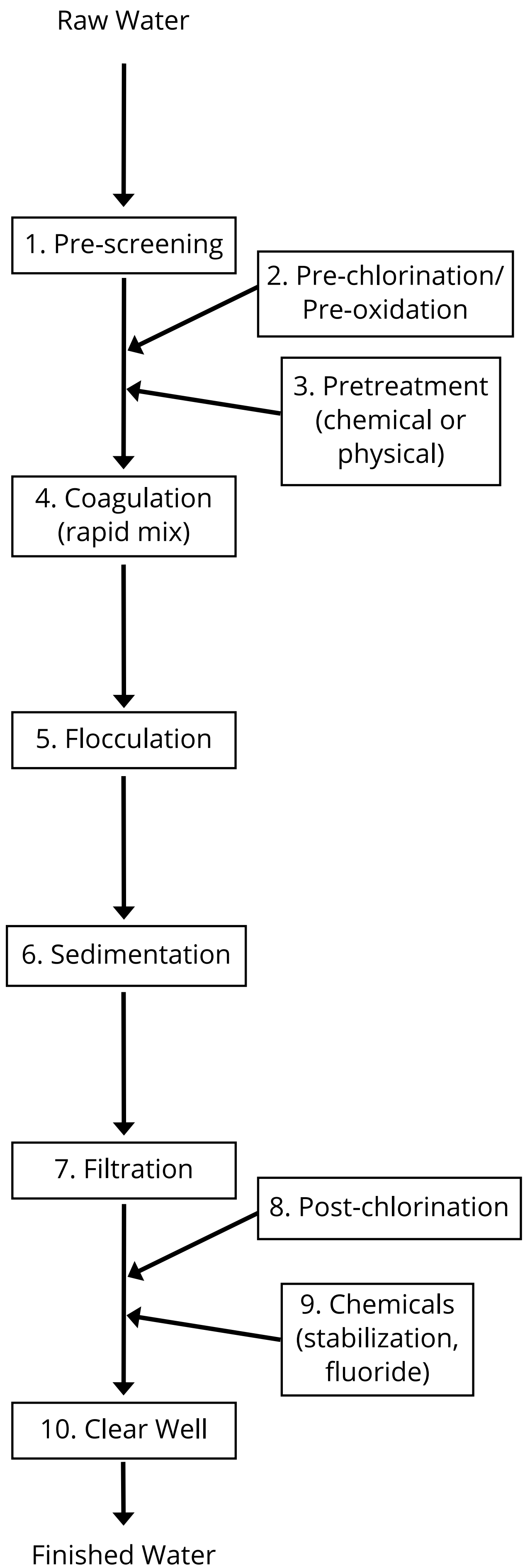
- Water is withdrawn from a lake, reservoir or river at the intake
- It is screened to remove debris
- Water then enters the flash mixing tank where coagulants and other chemicals are added
- Then it is divided into the flocculation basin
- After flocculation, the water enters the settling basins where solids are removed
- Filtration then removes particles that are too small to settle by gravity
- The water is disinfected using some form of chlorine
- Other chemicals such as fluoride, phosphate corrosion inhibitors or pH adjustment chemicals may be added
- After a minimum detention time, the water may be pumped to the distribution systems

Other processes may occur, such as pre-oxidation or activated carbon treatment.

Groundwater treatment is much less involved than surface water treatment. Groundwater has fewer impurities. Aeration may be required to remove dissolved gases and aid in the removal of dissolved minerals. Fluoride is sometimes added, but often the only step is disinfection. Addition of chemicals to reduce corrosion may also be needed.

Various regulations exist to control contaminants in drinking water in order to ensure public safety. Part of an operator's job is to collect samples, test them and report the results to the state, which enforces these regulations. Operators must be able to recognize problems in the treatment process that could result in violations. They should also be familiar with the limits of certain substances in water so they can recognize when lab tests indicate violations.

Treatment Process



Process Purpose

1. Removes large debris such as: leaves, sticks, fish and other large debris.
2. Kills most disease-causing organisms / Helps control taste and odor causing substances.
3. Pretreatment chemicals such as carbon, permanganate, or peroxide are used to remove organics prior to the treatment process.
4. Coagulants cause very fine particles to clump together into larger particles.
5. Promotes collisions between coagulated particles (floc) and non-settleable solids in the water.
    a. Gathers together fine, light particles to form larger particles (floc) to aid the sedimentation and filtration process.
6. Settles out larger suspended particles.
7. Filters out remaining suspended particles.
8. Kills/inactivates disease causing organisms. Provides chlorine residual for distribution system.
9. Phosphates for control corrosion. Fluoride helps prevent dental decay.
10. Provides chlorine contact time for disinfection. Stores water for high demand.

Common Abbreviations

ASTM – America Society for Testing & Materials
ANSI – American National Standards Institute
AWWA – America Water Works Association
CCR – Consumer Confidence Report
CWS – Community Water System
CFU – Colony Forming Units
DCVA – Double Check Valve Assembly
DBP – Disinfection By-Product
DO – Dissolved Oxygen
DWR – Division of Water Resources
EBCT – Empty Bed Contact Time
EPA – Environmental Protection Agency
GAC – Granular Activated Carbon
HAA_5 – Haloacetic Acids
HPC – Heterotrophic Plate Count
HTH – High Test Hypochlorite; calcium hypochlorite
LCR – Lead and Copper Rule
LSI – Langelier Saturation Index
MCL – Maximum Contaminant Level
MCLG – Maximum Contaminant Level Goal
MGD – Millions of Gallons per Day
MPN – Most Probable Number
MRDL – Maximum Residual Disinfectant Level
MTF – Multiple Tube Fermentation
NCWS – Non-Community Water System
NOM – Natural Organic Matter
NPDES – National Pollutant Discharge Elimination System
NPDWR – National Primary Drinking Water Regulation
NSF – National Sanitation Foundation
NTNCWS – Non-Transient Non-Community Water System
NTU – Nephelometric Turbidity Units
OSHA – Occupational Safety & Health Administration
P-A – Presence-Absence
PAC – Polyaluminum Chloride
PAC – Powdered Activated Carbon
PN – Public Notification
PPE – Personal Protective Equipment
PPM – Parts Per Million (≈ mg/L)
PSI – Pounds per Square Inch
PWS – Public Water System
RPBP – Reduced Pressure Backflow Prevention
RTCR – Revised Total Coliform Rule
SCBA – Self-Contained Breathing
SCD – Streaming Current Detector
SDS – Safety Data Sheet (MSDS)
SDWA – Safe Drinking Water Act
sMCL – Secondary Maximum Contaminant Level
SOC – Synthetic Organic Compounds
SOP – Standard Operating Procedure
TDEC – Tennessee Department of Environment & Conservation
TDS – Total Dissolved Solids
THM – Trihalomethanes
TTHM – Total Trihalomethanes
TOC – Total Organic Carbon
TNCWS – Transient Non-Community Water System
UV – UltraViolet
VOC – Volatile Organic Compounds

Chemical Formula	Common Name(s)
$Al(OH)_3$	aluminum hydroxide; jellylike floc particles
$Al_2(SO_4)_3 \bullet 7H_2O$	alum; aluminum sulfate
AsO_3	arsenite
AsO_4	arsenate
Br_2	bromine
$CaCl_2$	calcium chloride
$CaCO_3$	calcium carbonate
$Ca(HCO_3)_2$	calcium bicarbonate
CaO	calcium oxide; unslaked lime; quicklime
$Ca(OCl)_2$	calcium hypochlorite; HTH
$Ca(OH)_2$	calcium hydroxide; lime; hydrated lime; slaked lime
$CaSO_4$	calcium sulfate
CH_4	methane
Cl_2	chlorine gas; liquid chlorine
ClO_2	chlorine dioxide
CO_2	carbon dioxide
$CuSO_4 \bullet 5H_2O$	copper sulfate; bluestone; copper sulfate pentahydrate
Fe	iron
$FeCl_3$	ferric chloride
$Fe(OH)_3$	ferric hydroxide
Fe_2S_2	iron sulfide
$Fe_2(SO_4)_3$	ferric sulfate
$Fe_2(SO_4)_3 \bullet 7H_2O$	ferrous sulfate
HCl	hydrochloric acid; muriatic acid
H_2O	water
HOCl	hypochlorous acid
H_2S	hydrogen sulfide
H_2SiF_6	fluorosilicic acid; hydrofluorosilicic acid; silly acid
H_2SO_4	sulfuric acid
I_2	iodine
$KMnO_4$	potassium permanganate

Chemical Formula	Common Name(s)
Mg	magnesium
$MgCl_2$	magnesium chloride
$MgCO_3$	magnesium carbonate
$Mg(HCO_3)_2$	magnesium bicarbonate
$Mg(OH)_2$	magnesium hydroxide
$MgSO_4$	magnesium sulfate
Mn	manganese
$Mn(OH)_2$	manganese hydroxide
$Na_2Al_2O_4$	sodium aluminate
Na_2CO_3	sodium carbonate; soda ash
NaF	sodium fluoride
$NaHCO_3$	sodium bicarbonate; baking powder
$NaMnO_4$	sodium permanganate
$Na_2O \bullet (SiO_2)_3$	sodium silicate
$NaOCl$	sodium hypochlorite; bleach
$NaOH$	sodium hydroxide; caustic soda
$Na_4P_2O_7$	tetrasodium pyrophosphate
$(NaPO)_{14}Na_2O$	sodium hexametaphosphate; sodium polyphosphate
Na_2SiF_6	sodium fluorosilicate; sodium silicofluoride
NCl_3	trichloramine
NH_2Cl	monochloramine
$NHCl_2$	dichloramine
NO_3^-	nitrate ion
NO_2^-	nitrite ion
O_3	ozone
OCl^-	hypochlorite ion
SO_4^{2-}	sulfate ion
$Zn_3(PO_4)_2$	zinc orthophosphate

Section 2

Source Water

Water Sources & Characteristics

Developing the Water Supply
AWWA WSO: Water Sources

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Learning Objectives

- Hydrologic Cycle
- Characteristics of Groundwater and Surface Water
- Sources of Groundwater and Surface Water
- Water Rights
- Source Development and Protection
- Wells Operation and Maintenance
- Regulatory Publications and Rules

2

Water Supply Hydrology and the Hydrologic Cycle

- Hydrologic Water Cycle
  - movement of water from the surface of the earth to the atmosphere and back
- Process of evaporation and transpiration
- Condensation forms water vapor droplets
- Precipitation returns water to earth
- Water penetrates ground via infiltration, percolation, and runoff
  - Surface runoff occurs when ground is saturated

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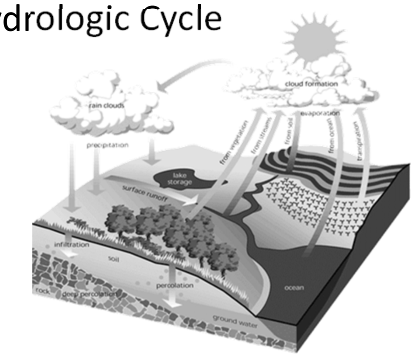
Hydrologic Cycle



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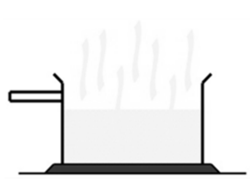
Hydrologic Cycle

- Evaporation and Transpiration
  - Evaporation
    - the changing of liquid to gas (water to water vapor)
  - Water is constantly evaporating from the earth
  - Transpiration
    - the process in which water from the earth is absorbed by plants and transferred to the air through the leaves



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Hydrologic Cycle

- Condensation and Precipitation
  - Condensation
    - occurs when water vapor condenses as it cools and forms tiny droplets of water or clouds
  - Precipitation
    - occurs when the droplets become too heavy to stay airborne
    - these droplets fall back to earth as rain, snow, sleet or hail

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Hydrologic Cycle

- Infiltration and Percolation
  - As precipitation falls, it soaks into the ground
  - Infiltration
    - the movement of water through the soil
  - Some of the water goes back to the surface due to *capillary action*
    - the movement of water above a water surface
  - The rest percolates (continues downward) to the water table

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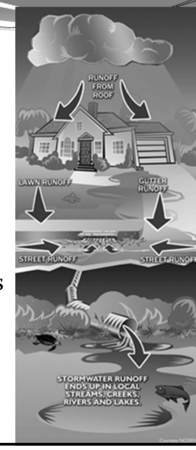
Hydrologic Cycle

- Surface Runoff
  - When the soil can hold no more water, it flows downward over the ground surface
  - It flows into streams or lakes or, eventually, the ocean



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Groundwater

- Water below the surface
- Hidden resource
- Provides 20% of water used in the US
- Has few contaminants
- Resultant of infiltration and percolation
- Relatively free from micro contamination
- Characterized by:
  - high TDS
    - Fe & Mn
  - high dissolved gases
    - radon, CH_4, H_2S
  - low dissolved oxygen
  - low color
  - high hardness
- Can be influenced by natural and human activities

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Groundwater

- Sources
  - Aquifers
    - confined and unconfined
  - Springs
- Half of the world's groundwater resource is located within one mile of the ground surface
- Other half is found in deep aquifers

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Aquifers

Unconfined Aquifers

- Upper surface is free to rise and fall
- Water table wells
  - wells constructed to reach an unconfined aquifer
- Amount of water produced varies widely as water table rises and falls in relation to rainfall
- Indicates water table level of surrounding aquifer

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Aquifers

Confined Aquifers

- Also known as Artesian Aquifer
- Permeable layer confined by an upper level and lower level of low permeability material
- Water recharge area usually higher than main part of aquifer
- Water is usually under pressure
- Flowing artesian well
  - pressure causes water to rise above ground surface
- Non-flowing artesian well
  - water doesn't rise to the surface
- Piezometric surface
  - height that water rises

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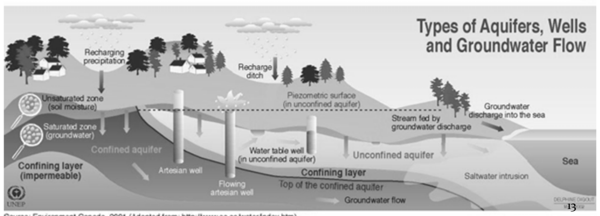
Aquifers

- Characteristics
  - Underground layer of gravel, sand, sandstone, shattered rock, or limestone
  - Impermeable layer of rock, clay or granite keeps water from sinking downward
  - Water table is upper surface of an aquifer
  - Classified as water table or artesian and confined or unconfined



Source: Environment Canada, 2001 (Adapted from: http://www.ec.ca/water/index.htm)

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Aquifers Terms & Materials

- Porosity
  - amount of water the material will hold
- Hydraulic conductivity
  - how easily the water will flow thought the aquifer material
- Both determine how much the aquifer will yield
- Pumping rates are higher in coarser material and cost less
  - less pumping head loss
- Consolidated aquifer formations consist of limestone and fractured rock and produce large quantities of water

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Groundwater Movement Characteristics

- Movement of water is naturally downhill
- Rainfall percolates down to the water table
- Water moves slowly through soil which removes suspended particles
- Soil acts as a natural filtration process
  - Dissolved pollutants cannot be removed
  - Contaminants can be picked up
- Water table is never completely level

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Springs

- Occur if water table intersects the ground surface
- Difficult to determine source of springs
- They should be considered contaminated until sanitary survey is conducted
- Flows vary considerably and are influenced by artesian pressures
- Enclose intake in a concrete spring box

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Surface Water Characteristics

- Higher turbidity
- Suspended solids
- More color
- Microbial contamination
- Impurities in snow and rain
- Impurities from runoff
  - soluble formations such as limestone, gypsum, & rock salt affect characteristics
- Precipitation dissolves gases in atmosphere
- Dust and solids from industrial processes
- Usually soft, low in solids and alkalinity, and pH slightly below 7
- Usually corrosive
- Seasonal changes

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Surface Water Supply and Operating Problems

- Contamination
- Loss of water source by evaporation & seepage
- Weather (rain and snowfall)
- Exposure to environmental changes
- Icing
- Rainfall intensity and droughts
- Soil composition
- Human influences
- More and varied treatment processes

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Wells

You surface water people stay awake!
This is a GROUNDWATER people session.

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Wells

- Advantages
  - Provide 20% of water used in US
  - Facilities cost less to operate
  - Water is less turbid
  - Contains fewer bacteriological and viral contaminants
    - require less treatment
  - Maintain uniform temperature

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Parts of a Well

- **Sanitary seal**
  - prevents contamination
  - seal has openings for discharge pipe, pump controls, and air vent
- **Well casing**
  - liner to prevent walls from caving in
  - protects water quality
- **Well casing vent**
  - prevents pump vacuum and contamination from entering

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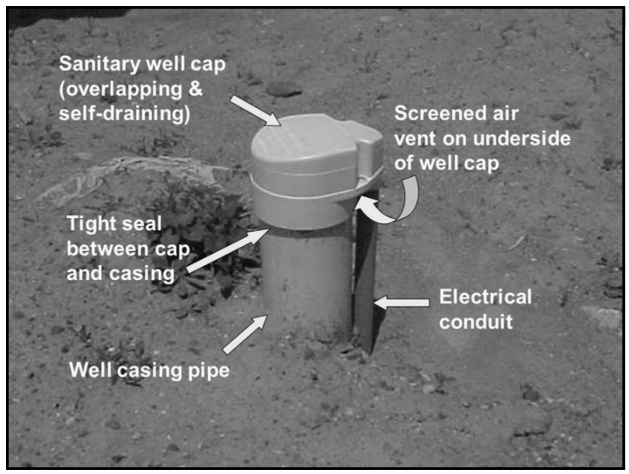
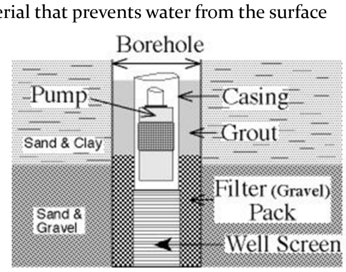


Parts of a Well

- **Grout**
  - cement or other material that prevents water from the surface from entering well
- **Intake screen**
  - prevents sand or other material from entering the well and allows water to flow freely



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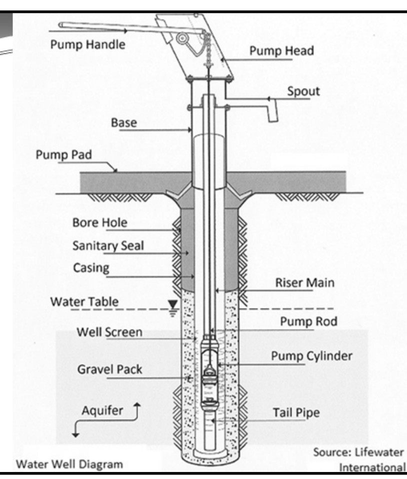

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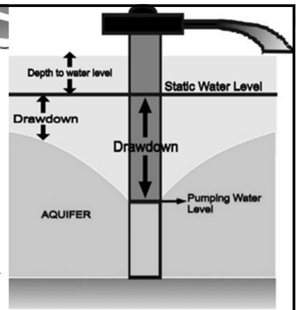
Well Terms



- **Static water level**
  - water surface level when no water is being drawn
- **Pumping water level**
  - level at which water drops and stabilizes as it is pumped
- **Drawdown**
  - drop between static and pumping level

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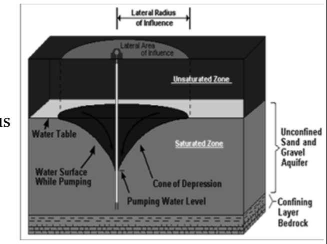
Well Terms

- **Cone of depression**
  - depression in the water level around a well during pumping
- **Zone of influence**
  - length and depth of Radius of Influence
  - determined by Cone of Depression



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Well Terms

- **Residual drawdown**
  - difference between the original water level and water level after pumping has stopped
- **Well yield**
  - rate of water withdrawal that a well can supply over a long period of time
- **Safe yield**
  - maximum amount of water that can be withdrawn continuously during the driest periods
- **Specific capacity**
  - yield per unit of drawdown (can indicate problems)

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Well Location & Sanitary Considerations

- Located to produce max yield while being protected
- Deep as possible to prevent contamination from the surface
- If shallow groundwater source, ensure casing and hole grouted
- Prefer a 2-foot-deep layer of clay within a 50-foot radius around the well

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Well Operation and Maintenance

- Record Keeping
  - Static water level after pump has been idle for a period of time
  - Pumping water level
  - Drawdown
  - Well production
  - Well yield
  - Time required for recovery after pumping
  - Specific capacity

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Well Operation and Maintenance

- Regular Maintenance
  - Plugging of screen most common problem
    - encrustation of biological growth
    - precipitates of Fe, Mn, and hardness
  - Can be cleaned using hydrochloric acid (muriatic acid)
    - refer to AWWA manual M21
  - Well can fail if screen collapses or corrodes
  - Bacteriological samples should be periodically
  - Disinfection may be needed sometimes

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Procedures for Well Abandonment

- Eliminate any physical hazards
- Take measures to prevent groundwater contamination and protect other nearby wells
- Conservation of the aquifer
- Return to geological conditions present before well was constructed
- Private wells must be properly abandoned and plugged
  - can be a cross connection if home is connected to both a well and public water supply
  - it should be permanently disconnected
- **Must be done properly**

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Water Source Protection

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Surface Water Source Development

- Includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake

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Surface Water Source Development

- Factors
  - Quantity
  - Quality
  - Structures
  - Impoundments and reservoirs
    - Site preparation
    - Construction
- Tennessee Public Water System Design Criteria part 3

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Groundwater Source Development

- Includes all water obtained from drilled wells or springs
- General Well Construction Requirements
- Tennessee Public Water System Design Criteria part 3.3

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Safe Drinking Water Act (SDWA)

- Establishes primary drinking water standards
- Secondary standards
- Public notification procedures and requirements
- Federal Enforcement
- Established a cooperative program among local, state, and federal agencies
- EPA executive agency
- Established MCL's (Maximum Contaminate Level)
- Established sampling and testing requirements

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Tennessee Water Program

- Governing agency
  - Department of Environment and Conservation Bureau of Environment Division of Water Resources
  - Rules/Regulations
    - Chapter 0400-45-1 Public Water Systems
  - Sanitary surveys
  - Wellhead Protection Plan
  - Technical assistance
  - Laboratory services
  - Enforcement
  - Environmental Field Offices(EFOs)
  - Design criteria

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Physical Characteristics of Water

- Relates to sensory qualities of water
- Temperature
  - most familiar characteristic
  - effects lake turnovers, dissolving of chemicals and palatability
  - most desirable drinking water is considered cool
- Turbidity
  - cloudiness of water
  - indicator of health significance
  - operational considerations
  - aesthetics
- Color
  - indicates contamination, dissolved organics, and humic substances that could form THMs
- Taste & odor
  - degradation aesthetic quality

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Chemical Characteristics of Water

- Inorganic
  - pH
    - indicator of acidity or alkalinity
  - Hardness
  - Dissolved oxygen
    - measured in mg/L
  - Dissolved solids
    - toxic minerals include
      - chromium
      - lead
      - mercury
      - silver
      - arsenic
      - barium
      - fluoride
      - nitrate
- Organic
  - Includes
    - pesticides
    - herbicides
    - domestic wastes
    - industrial wastes
    - watershed runoff
  - Can cause taste, odor, and toxicity problems

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Biological Characteristics of Water

- Aquatic life (algae)
- Bacteria
- Coliform bacterial (TC, FC, EC)
- Viruses
- Protozoa
- Spores
- Cysts
- Many originate with fecal discharges
- Not easily identified and isolated

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Radiological Factors in Water

- Development of atomic energy and mining of radioactive materials made it necessary to examine safe limits
- Divided into two categories:
  - Natural and Man-made
- Sources are
  - Natural deposits and Man-made deposits

If someone is glowing, Be Suspicious! ☺

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Fundamental Principles

- The quality of source water is influenced by natural and human activities
- It is the responsibility of the operators to minimize harm from both of these
- Surface waters are more influenced by human activities
- Groundwater can also be influenced

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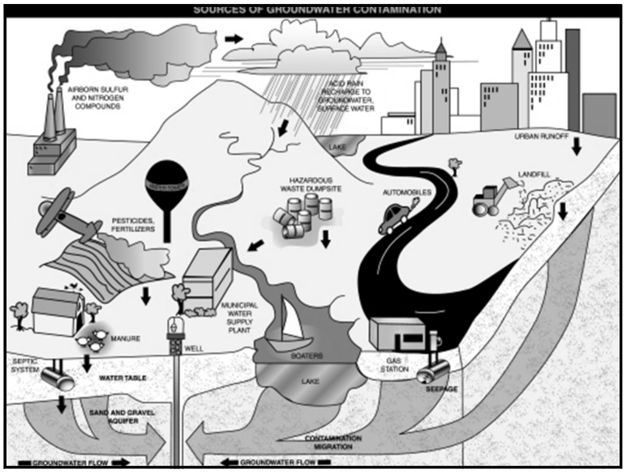

Benefits of Source Water Protection Program

- Source control is the first barrier in a multiple-barrier treatment plan
- Water treatment methods are not 100% effective in removing contaminants
  - The risks of residual contaminants can be too high
- As the quality of source water deteriorates, the cost of treatment goes up and can become prohibitive

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Benefits of Source Water Protection Program

- Increase in public confidence
- Decrease in public health risks
- Due to difficulty to analyze, remove, and/or disinfect pathogens with conventional methods, keeping pathogens out of the source water may be the only way of providing protection

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Developing a Source Water Protection Program

- Inventory and characterize the water source
- Identify pollutant sources and relative impact
- Assess vulnerability of intake to contaminants
- Establish source water protection goals

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Developing a Source Water Protection Program

- Develop source water protection strategies
- Implement the program
- Monitor and evaluate program effectiveness

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Developing a Source Water Protection Program

- Identify area that needs protection and who has an interest in protecting it
  - For wellhead protection
    - aquifer delineation
  - For surface water sources
    - watershed mapping

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Developing a Groundwater Source Protection Program

- Aquifer Delineation (**Wellhead Protection Area**)
  - Define the land area over the portion of the aquifer that influences the quality of the water
  - Should be identified and inventoried for potential of contamination
  - For microbiological contaminants, a small area is suitable

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Developing a Groundwater Source Protection Program

- Aquifer Delineation (Wellhead Protection Area)
  - Chemical contaminants can travel from several thousand feet for relatively deep wells
  - USGS maps are a good place to start
  - 1986 SDWA amendments require each state to develop a Wellhead Protection Program
  - Limit activities in area to protect well and aquifer from contamination

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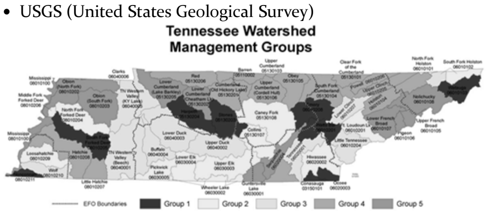
Developing a Surface Water Source Protection Program

- Watershed Mapping
  - Surface water sources
  - Watershed is area sloped toward water source that drains to it
  - Watershed should be identified and inventoried for potential sources of contamination
  - USGS (United States Geological Survey)



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Developing a Source Water Protection Program

- Regulations
  - Tennessee Regulations for Wellhead Protection
    - Section 0400-45-1-.34

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Developing a Surface Water Source Protection Program

- Watershed Mapping
  - If utility can purchase lands in the watershed, it can limit activities that could affect water quality
  - If land cannot be bought, buffer zones for logging and agriculture operations should be implemented
  - Promote community activities that emphasize protection of watershed

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Developing a Source Water Protection Program

- Identify Pollutant Sources and Relative Impact
  - Sewage disposal
  - Urban, industrial, agricultural and mine runoff
  - Animal population
  - Forestry/soil disturbance runoff
  - Recreation

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Developing a Source Water Protection Program

- Assess Vulnerability of Intake to Contaminants
  - Purpose
    - identify contaminant
    - identify amount of contaminant
    - correlate land use to contaminant level
  - Assessment methods
    - water quality monitoring
    - modeling
    - onsite assessment

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Developing a Source Water Protection Program

- Strategies
  - Land use controls
    - buffer zones
    - land acquisition
    - comprehensive planning
    - watershed/recharge area inspections

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Developing a Source Water Protection Program

- Vandalism and Terrorism
  - Before 9/11/01, no serious threat
  - Protect intakes
  - Safeguard area around source, if possible
  - Monitoring and surveillance may be required if threat is serious
  - Be alert of suspicious events

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Developing a Source Water Protection Program

- Title IV Drinking Water Security and Safety
  - Must have assessment of system
  - Dateline is dependent on size of system
  - ERPs (Emergency Response Plans) are due 6 months after assessment
  - Plans include actions, procedures, and identification of equipment which can prevent or lessen the impact of a terrorist act

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Developing a Source Water Protection Program

- Source of Contamination
  - After WHPA or watershed boundary for a water source has been determined, inventory of potential contaminant sources is to be performed
  - Community volunteer effort along with utility personnel is encouraged
    - volunteer fire dept., citizen group, etc.

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Water Sources and Characteristics Review Questions

1. Draw the basic hydrologic cycle.

2. What is the water table?

3. Define the term aquifer.

4. What two things determine the amount of water an aquifer will yield?
   - ➢
   - ➢

5. Describe the differences in water characteristics of groundwater and surface water.

6. Define the term watershed.

7. List six factors that influence the amount of surface runoff.
   - ➢
   - ➢
   - ➢
   - ➢
   - ➢
   - ➢

8. What is the purpose of an impoundment?

Water Sources & Treatment Vocabulary

A. Acid rain
B. Appropriative
C. Aquifer
D. Artesian
E. Capillary fringe
F. Contamination
G. Cross connection
H. Detention Time
I. Direct runoff
J. Drawdown
K. Evaporation
L. Evapotranspiration
M. Hydrologic cycle
N. Impermeable
O. Infiltration
P. Microorganisms
Q. Nonpotable
R. Pathogenic organisms
S. Percolation
T. Potable water
U. Precipitation
V. Raw water
W. Safe Drinking Water Act
X. Safe yield
Y. Stratification
Z. Transpiration
AA. Trihalomethanes
BB. Turbidity
CC. Water table

______ 1. Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

______ 2. The introduction into water of microorganisms, chemicals, toxic substances, wastes or wastewater in concentration that makes the water unfit for its next intended use.

______ 3. Precipitation which has been rendered acidic by airborne pollutants.

______ 4. The process of evaporation of water into the air and its return to earth by precipitation, including transpiration, groundwater movement, and runoff into rivers, streams and the ocean.

______ 5. The upper surface of the zone of saturation of groundwater in an unconfined aquifer.

______ 6. An act passed by the US Congress in 1974 that establishes a cooperative program among local, state and federal agencies to ensure safe drinking water for consumers.

______ 7. Living organisms that can be seen individually only with the aid of a microscope.

______ 8. Water rights to or ownership of a water supply which is acquired for the beneficial use of water by following a specific legal procedure.

______ 9. The drop in the water table or level of water in the ground when water is being pumped from a well.

______ 10. The process by which water vapor passes into the atmosphere from living plants.

______ 11. Derivatives of methane in which three halogen atoms are substituted for three of the hydrogen atoms. Often formed by chlorination of organic matter.

______ 12. Organisms capable of causing diseases in a host.

______ 13. Water that may contain objectionable pollution, contamination, minerals or infective

______ 14. A connection between a drinking water system and an unapproved water supply.

______ 15. The annual quantity of water that can be taken from a source of supply over a period of years without depleting the source permanently.

______ 16. The slow passage of water through a filter medium or the gradual penetration of soil & rocks by water.

______ 17. Water flows over the ground surface or through the ground directly into streams, rivers, or lakes.

______ 18. The process by which water vapor is released to the atmosphere by living plants.

______ 19. The cloudy appearance of water caused by the presence of suspended and colloidal matter.

______ 20. The process by which atmospheric moisture falls onto a land or water surface as rain, snow, hail, or other forms of moisture.

______ 21. The formation of separate layers in lake or reservoir.

______ 22. The process by which water or other liquid becomes a gas.

______ 23. The porous material just above the water table which may hold water by capillarity in the smaller void spaces.

______ 24. The seepage of groundwater into a sewer system, including service connections.

______ 25. The theoretical time required for a small amount of water to pass through a tank at a given rate of flow.

______ 26. Water in its natural state, prior to any treatment.

______ 27. A natural underground layer of porous, water bearing materials usually capable of yielding a large amount or supply of water.

______ 28. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water

______ 29. Pertaining to groundwater, a well or underground basin where the water is under a pressure greater than atmospheric and will rise above the level of its upper confining surface if given an opportunity to do so.

Answers

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

Parts of a Well – Matching

Draw a line from the term to its definition:

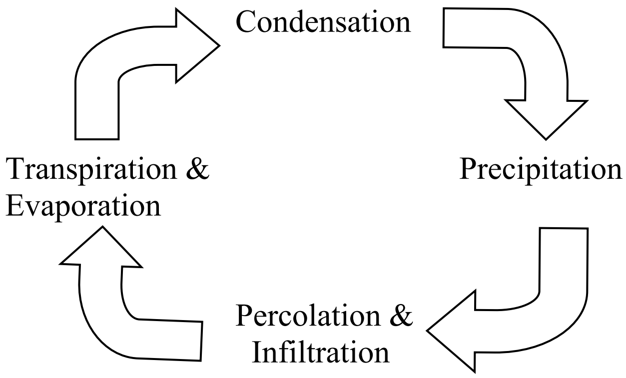
Sanitary Seal	Allows water to flow freely from an aquifer to a well; keeps sand out of a well.
Well Casing	Concrete area placed around the casing to support pumping equipment.
Intake Screen	A liner placed in the bore hole of a well to prevent the walls from caving in.
Grout	Prevents contamination from entering the well at the surface.
Well Slab	Seals the space between the casing and the bore hole.

Well Terms – Matching

Draw a line from the term to its definition:

Static Water Level	Inverted cone-shaped depression in water level while pump is operating.
Pumping Water Level	Water level when no water is being pumped from the aquifer.
Drawdown	Difference between original water level and the level after pumping has stopped.
Cone of Depression	Well yield ÷ drawdown.
Zone of Influence	Level to which water drops and stabilizes as it is pumped.
Residual Drawdown	Length and depth of radius of influence as determined by the cone of depression.
Well Yield	The drop between the static water level and the pumping water level.
Specific Capacity	The rate of water withdrawal that can be supplied over a period of time.

Answers to Water Sources and Characteristics Review Questions

1. 

2. The water table is the upper surface of an aquifer.

3. An aquifer is a porous, water-bearing geological formation.

4. The porosity and hydraulic conductivity determine the amount of water an aquifer will yield.

5. Groundwater:
   - High dissolved solids
   - Dissolved gasses
   - Low color
   - High hardness
   - Free from microbes

   Surface water:
   - Suspended solids
   - Higher turbidity
   - Higher color
   - Lower hardness
   - Microbial contamination

6. A watershed is the land area that is sloped toward a water source and drains into it.

7. Six factors influencing the amount of surface runoff are:
   rainfall intensity, rainfall duration, soil composition, soil moisture, ground slope, vegetation cover

8. An impoundment stores water for use during water deficiencies.

Parts of a Well – Matching

Draw a line from the term to its definition:

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Section 3

Pretreatment

RESERVOIRS AND INTAKES

CSUS – Water Treatment Plant Operation Vol. I

OBJECTIVES

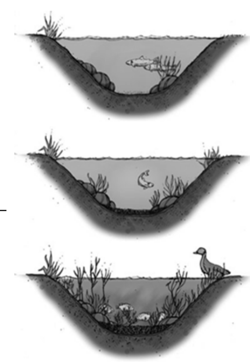
- Water Quality
  - Factors affecting
  - Causes of water quality problems
- Reservoir Management
  - Watershed management
  - Algae control
  - Reaeration/destratification
- Intake Structures

FACTORS AFFECTING WATER QUALITY

- Climate
  - Temperature, intensity and direction of wind movements, type, pattern, intensity, and duration of precipitation
- Watershed and Drainage Areas
  - Geology, topography, type and extent of vegetation, and use by native animals
- Wildfires
  - Caused by lightning
- Reservoir Area
  - Geology, land form including depth, area, and bottom topography, and surface vegetation at the time the reservoir is filled

CAUSES OF WATER QUALITY PROBLEMS

- Nutrients
  - Act as a fertilizer
    - Phosphate
    - Nitrate
    - Organic nitrogen compounds
  - Lake will become eutrophic – rich in nutrients and plant life



CAUSES OF WATER QUALITY PROBLEMS

- Algal Blooms
  - Eutrophic lakes support large populations of phytoplankton (very small plants) and zooplankton (very small animals)
  - A sudden large increase in phytoplankton is called an algal bloom
    - Can last from a few days to several weeks or months
  - Problems:
    - Taste and odor problems
    - Shortened filter runs of traditional treatment plants
    - Organic Loading
    - Increased pH**
      - Reduction in chlorine efficiency
    - Dissolved oxygen depletion after die-off**

CAUSES OF WATER QUALITY PROBLEMS

- Tastes and Odors
  - Often related to occurrence of algal blooms
  - Common taste and odors caused
    - Fishy
    - Aromatic
    - Grassy
    - Septic
    - Musty
    - Earthy
  - Odors most noticeable when hot water is in use
  - Geosmin and MIB (methyl-isoborneol) can be detected at just a few parts per trillion (ppt)

CAUSES OF WATER QUALITY PROBLEMS

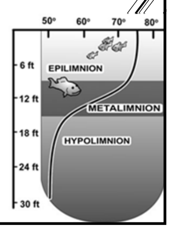
- Shortened Filter Runs
  - Clogged filters caused by diatoms and plankton in large numbers
- Increased pH
  - pH will increase during daylight
    - Photosynthesis decreases carbon dioxide in water, increasing the pH
  - pH will decrease during dark
    - Respiration increases carbon dioxide, lowering the pH

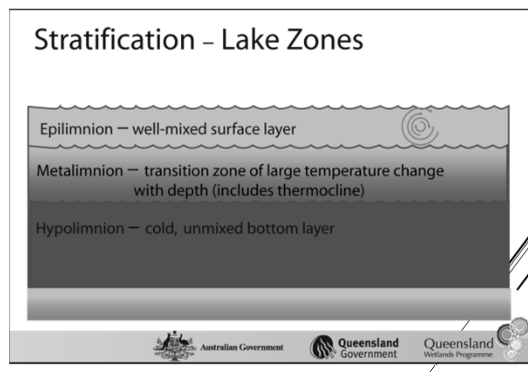
CAUSES OF WATER QUALITY PROBLEMS

- Dissolved Oxygen Depletion
  - Algal blooms increase the amount of DO as a result of photosynthesis
  - When algal cells die, bacteria decomposing the cells consume the dissolved oxygen
    - Can result in a fish kill
- Organic Loading
  - Result in color and chlorine demand increase
  - Increase disinfection by-product (DBP) precursors

CAUSES OF WATER QUALITY PROBLEMS

- Thermal Stratification
  - Layers of different temperature water within a lake or reservoir
  - Different temperatures result in different densities
    - Decrease in density of warmer water on top slows the vertical mixing action and forms a barrier between the upper and lower levels
  - Epilimnion – upper, warmer layer
  - Metalimnion – middle transition layer
    - Aka thermocline
  - Hypolimnion – bottom, colder layer
    - Anaerobic environment
  - As temperatures drop, the lake will destratify or "turnover"





CAUSES OF WATER QUALITY PROBLEMS

- Anaerobic conditions
  - Problems caused by reduction – removal of oxygen or sulfur when oxygen is absent
  - Noted by the presence of a rotten egg odor
  - Iron and manganese in bottom sediments pass into solution
    - Iron is changed from the oxidized ferric state into the soluble ferrous state
    - Manganese is changed from the oxidized maganic state into the soluble manganous state

RESERVOIR MANAGEMENT

Fleming Training Center
TN Department of Environment & Conservation

WATERSHED MANAGEMENT

- Primary purpose should be to control, minimize or eliminate any practices within the watershed area that are harmful to water quality within the domestic water supply reservoir
- Wastewater
  - Nutrient loading of the lake
  - Microbial contamination
  - Major source is septic systems
    - Two dependable solutions:
      - Replace all septic systems with sewer
      - Adopt ordinances that regulate the design and installation of septic systems

WATERSHED MANAGEMENT

- Fertilization
  - Results in large amounts of nitrogen in water
  - Cause eutrophication and algal blooms
  - Best solution is public education
- Soil Grading and Farming Practices
  - Contributes to turbidity of surface water
  - Can be controlled through regulations and ordinances
    - Limit the time of year of soil disturbance
    - Limit amount of time soil is left exposed

WATERSHED MANAGEMENT

- Livestock Grazing
  - Increase erosion, turbidity and eutrophication
- Wildfires
  - Large amounts of debris, nutrients, silt and other pollutants
  - Fire prevention and control programs are a must
- Highway Stormwater Runoff
  - Toxic metals, nutrients, bacteriological constituents, oil and grease, floating materials, trash and litter, pesticides, herbicides, and deicing salts

ALGAE CONTROL BY CHEMICAL METHODS

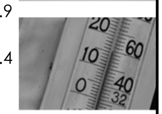
- Purpose of Chemical Methods
  - To prevent or control taste and odor problems resulting from algal blooms
  - To reduce the overall biological productivity
  - To maintain acceptable aesthetic conditions in the lake or reservoir

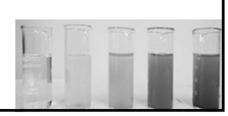
ALGAE CONTROL BY CHEMICAL METHODS

- Chemicals Available
  - Copper sulfate pentahydrate ($CuSO_4 \bullet 5\ H_2O$)
    - Aka bluestone
    - Primary algicide
    - Toxic to many species of algae but does not present health hazard to workers or consumers
    - Can be a hazard to trout
    - Must monitor copper levels in distribution system
  - Chlorine
    - Used as a bactericide or oxidizing agent, may also produce the effects of an algicide
    - High chance of producing DBPs

ALGAE CONTROL BY CHEMICAL METHODS

- Chemical Doses
  - Three major water quality indicators affect the effectiveness of copper sulfate
    - Alkalinity
      - If methyl orange alkalinity < 50, dose 0.9 lb/acre-ft
      - If methyl orange alkalinity > 50, dose 5.4 lb/acre-ft
    - Suspended Matter
      - Can reduce effectiveness by adsorbing copper sulfate
    - Temperature
      - Higher dosage feed rates required below 50°F (10°C)





ALGAE CONTROL BY CHEMICAL METHODS

- Chemical Doses
  - pH
    - The lower the pH, the more effective the copper sulfate
      - More copper ions are present making it more effective
    - The higher the pH, the less effective the copper sulfate
      - Copper more likely to precipitate out leaving none available as an algicide
  - EPA's Lead and Copper Rule limit the concentration allowed for dosing of the water
    - Copper action level = 1.3 mg/L

ALGAE CONTROL BY CHEMICAL METHODS

- Methods of Chemical Application
  - Drag burlap bags containing the copper material through the water using a boat
    - Simplest method
    - Very small lakes and reservoirs
  - Dump dry copper sulfate crystals into hopper mounted on a boat and fed into a broadcaster
  - Mix copper sulfate into solution and spray it onto the reservoir surface
    - Most efficient and safest method
    - Mount pipe with holes behind a boat

ALGAE CONTROL BY CHEMICAL METHODS

- Monitoring
  - Historical data can show when an algal bloom may occur
  - Monitoring should be carried out before, during and after the use of chemicals
- Recordkeeping
  - Important part of algae control program
  - Used to evaluate current and historical treatment programs
    - Designing new or revising existing programs
    - Showing compliance with regulations

ALGAE CONTROL BY CHEMICAL METHODS

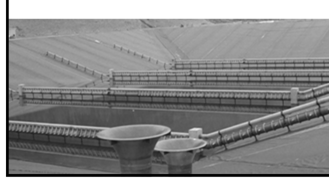
- Safety
  - Follow proper procedures for handling and chemical application
    - Wear special PPE for dust
  - Follow water safety procedures

REAERATION AND DESTRATIFICATION

- Terminology
  - <u>Aeration</u> – The process of adding air to water
  - <u>Reaeration</u> – The introduction of air through forced air diffusers into the lower layers of the reservoirs
  - <u>Destratification</u> – the development of vertical mixing within a lake or reservoir to eliminate separate layers of temperature, plant or animal life
  - <u>Reaeration-destratification</u> – using air to destratify the reservoir

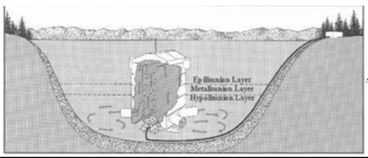
REAERATION AND DESTRATIFICATION

- Purposes of Reaeration-Destratification Programs
  - To eliminate, control, or minimize the negative effects on domestic water quality
  - To increase recreational values of the reservoirs
  - To reduce winter fish kills in water that becomes anaerobic during winter freezes



REAERATION AND DESTRATIFICATION

- Methods of Reaeration
  - Destratification
    - Alters or totally eliminates thermal stratification
  - Hypolimnetic reaeration
    - Adds dissolved oxygen directly to the hypolimnion without significantly altering the pattern of the thermal stratification



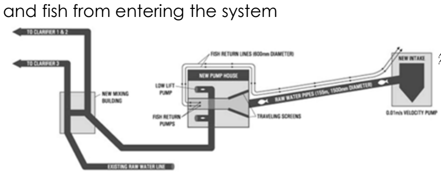
REAERATION AND DESTRATIFICATION

- Destratification
  - Accomplished by inducing vertical mixing within the reservoir
    - Mechanically by pumping hypolimnetic waters to the surface or by pumping surface waters downward
    - Through the use of diffused air
      - Diffusers release air near the bottom of the lake
      - As the bubbles rise, they carry the cold, denser water upward
      - The cold, dense water will eventually settle back to the bottom, creating vertical circulation
      - Disadvantage: deeper waters may become warmer than desired for domestic water and for certain species of fish

SURFACE WATER INTAKE STRUCTURES

INTAKE STRUCTURES

- Purpose of Intake Structures
  - Used to deliver water to water treatment plants
  - Should be constructed on the basis of the specific function that they must serve at a give source
  - Must be capable of supplying the maximum rate or flow required for the water treatment plant
  - Should be constructed to prevent algal scums, trash, logs and fish from entering the system



INTAKE STRUCTURES

- Types of Intake-Outlet Structures
  - Single-level intakes
    - Located in the deepest portion of the stream or reservoir so that water service can still be provided even when the body of water is down to its minimum operating level
    - Most suitable in relatively shallow lakes that do not stratify significantly and have fairly uniform water from top to bottom

INTAKE STRUCTURES

- Types of Intake-Outlet Structures
  - Multilevel intakes
    - Found in vertical towers located in deeper portions of the lake and extending above the water surface
    - Each inlet is equipped with an individually operated gate or valve at the point of inlet
    - Some intakes are inclined rather than vertical
      - Commonly located on inclined face of a dam

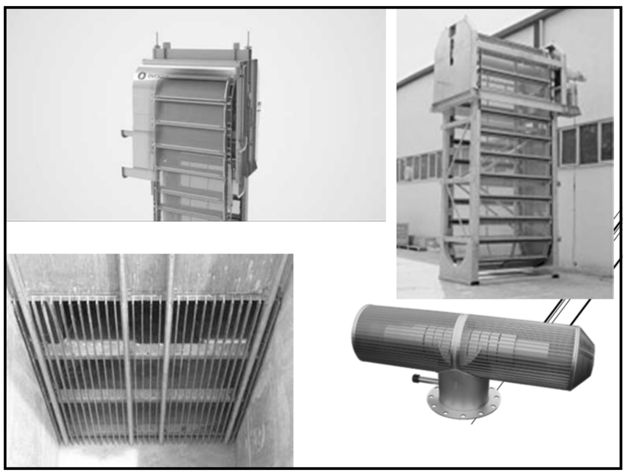
Wet intake tower

INTAKE STRUCTURES

- Types of Intake-Outlet Structures
  - Single-level intakes
    - Advantages
      - Less complicated so less costly to construct on multilevel structures
      - Easier and less costly to operate and maintain
    - Disadvantages
      - Major water quality issues due to be located in the hypolimnion
        - Water may be anaerobic, have high levels of Fe & Mn, or contain hydrogen sulfide
  - Multilevel intakes
    - Advantage: they make it possible to serve water from the depth where the best water quality is located

INTAKE STRUCTURES

- Types of Intake Gates
  - Most common are slide gates, gate valves, and butterfly valves
- Intake Screens and Trash Racks
  - Type depends on several factors
    - Depth(s) at which the inlets are located
    - Location of the intake structure in relation to where debris accumulates in the reservoir or stream
    - Frequency and intensity of algal scum or algal mass accumulations
    - Quantity and type of debris encountered
    - Size, depth, distribution, and number of fish, crayfish, and other forms of aquatic life



INTAKE STRUCTURES

- Operation and Maintenance Procedures
  - Major causes of faulty operation of gates and valves
    - Settlement or shifting of support structure, which could cause binding of gates
    - Worn, corroded, loose, or broken parts
    - Lack of use
    - Lack of lubrication
    - Vibration
    - Improper operating procedures
    - Design errors or deficiencies
    - Failure of power source or circuit failure
    - Vandalism
  - To adjust the tension on a travelling screen, turn the capstan

PRELIMINARY TREATMENT

AWWA WSO: Grade 1

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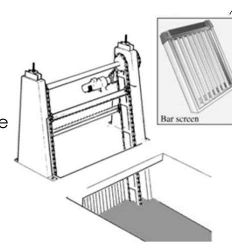
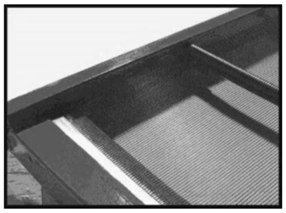
SCREENING

- Coarse screens located on intake structure to prevent clogging of the intake by removing sticks, logs, or other large debris in surface water source
  - aka trash racks or debris racks
- Bar Screens
  - Made of straight steel bars and ranked by distance between bars
    - i.e. fine, medium, coarse
  - Typically installed at 60° - 80° angle to aid in debris removal
    - As debris builds up, passing water lifts and pushes it up the slope



SCREENING

- Wire Mesh Screens
  - Woven from stainless steel or corrosion-resistant material
  - For streams and lakes with a lot of debris
  - Can be lifted out for cleaning or installed with automatic cleaning



PRESEDIMENTATION

- Removal of silt, sand, and gravel from raw water before it enters the flash mix
  - Surface waters with extensive sediment after rainfall
  - Reduces amount of coagulant needed
  - Reduces potential damage to pumps and other moving parts

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PRESEDIMENTATION SYSTEMS

- Impoundments
  - Basin which allows sediment to settle out before the flash mix
  - Benefit - stores water for later use
  - Problems - growth of algae and aquatic plants
  - To clean, drain, dry, and remove accumulated material

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PRESEDIMENTATION SYSTEMS

- Sand traps
  - Depression at the bottom of structure to slow water as it enters and allow the heavy solids to settle
    - e.g. bottom of a wet well
  - Installed with baffle to slow water and drain valve to flush out accumulated solids
  - Best suited for water that contains <100 mg/L sand & grit
  - Cleaned by allowing accumulations to discharge through a drain line installed at bottom
  - Hose down wet-well during draining through access cover

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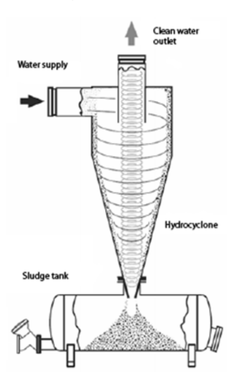
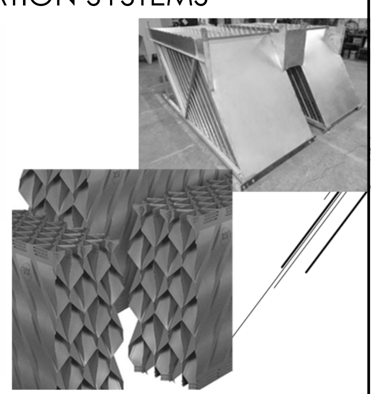
PRESEDIMENTATION SYSTEMS

- Mechanical Sand-and-Grit Removal Devices
  - Used when raw water contains large amounts of suspended solids
  - A centrifugal sand-and-grit removal device is called a *cyclone degritter*
  - Sand-laden water hits unit travelling in spiral path inside cylinder
  - Centrifugal force throws sand toward wall
  - Clean water leaves the unit with almost all sand removed
- Plate and Tube Settlers
  - Provide elevated surfaces on which solids can settle, rather than fall to the basin's bottom

PRESEDIMENTATION SYSTEMS

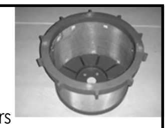




PRESEDIMENTATION

- Operation
  - Requires cleaning to prevent buildup and re-suspension of solids
  - Deposits can become anaerobic, causing taste and odors
- Record Keeping
  - Date of sampling and testing
  - Concentration of suspended solids in raw water (mg/L or mL/L)
  - Amount of suspended solids in presedimentation effluent
  - Cleaning date, time required, and estimated quantity of removed material.

MICROSTRAINING



- Removes small debris which could clog filters
- Stainless steel wire fabric
- Rotating drum – algae adheres to fabric
- High-pressure jet causes mat to break away, falls into removal trough
- Advantages
  - Removes filter-clogging material
  - Decreases chlorine demand
- Disadvantages
  - Does not remove all algae, dissolved solids, bacteria, or viruses
  - Cannot replace any treatment process

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MICROSTRAINING

- Chlorine should not be fed before the microstrainer
  - Dead algae are hard to clean off screen
  - Iron can precipitate on screen
  - Chlorine will cause corrosion
  - Chlorine reaction with algae can cause taste and odor problems

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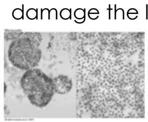
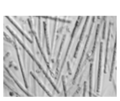
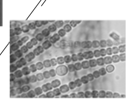
ALGAE

- No true leaves, stems, or roots
- Reproduce by spores, cell division, or fragmentation
- Blue-green, green, diatoms, and flagellates

ALGAE

- Need sunlight and nutrients to grow
- High levels of <u>nitrogen</u> and <u>phosphorus</u> can cause *algal blooms*
- Some species can produce powerful toxins that damage the liver and nervous system



PROBLEMS CAUSED BY ALGAE

- Slime accumulation
- Taste, odor and color
- Interference with treatment processes
- Toxicity
- Filter clogging
- Corrosion
- THM precursors

POTASSIUM PERMANGANATE

- Can be used for control of algae in reservoirs by applying directly to reservoir
- Oxidant used for iron & manganese control, some organic precursor control, and taste & odor control
- Changes color at end point
  - Pink to straw or yellow
- Reactions dependent largely on pH
- Can run demand test in lab to determine dosage

POWDERED ACTIVATED CARBON (PAC)

- Fed directly to reservoir: acts to physically block light, restricting algae growth
  - Only practical for small reservoirs
- Fed to intake help control those organic compounds responsible for tastes and odors
- Acts as weighting agent in coagulation step

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POWDERED ACTIVATED CARBON (PAC)

- Application considerations:
  - Minimum 15 minutes contact time
  - PAC particles will lose adsorption ability if coated with coagulants or other chemicals
  - PAC will adsorb chlorine
    - If fed together, will result in decreased organics removal and increased chlorine demand

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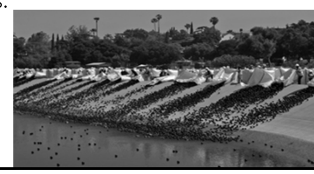
INNOVATIVE ALGAE CONTROL

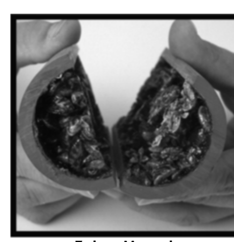
- Department of Water and Power workers are emptying out bales of plastic balls in the Los Angeles reservoir.
  - About 96 million 4-inch black plastic balls were released to form a floating cover over the 175-acre reservoir.
  - The reservoir holds up to 3.3 billion gallons, enough to supply the city with drinking water for up to three weeks.



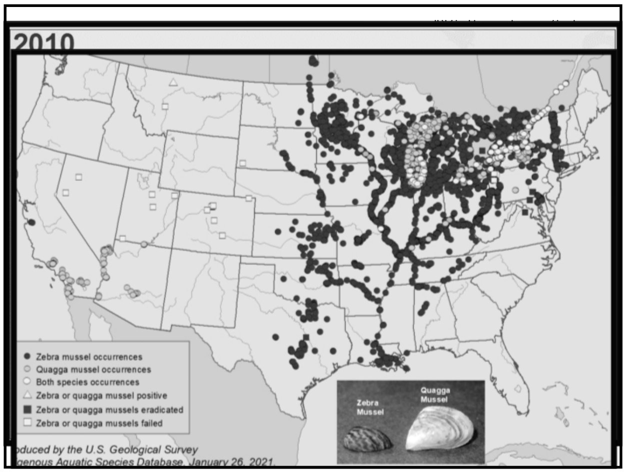
INNOVATIVE ALGAE CONTROL

ASIATIC CLAMS & ZEBRA MUSSELS

- Asiatic Clams
  - Introduced to US from Southeast Asia in 1938
  - Clams can infest raw-water intake pipelines and treatment facilities leading to low flow capacities and clogging of mechanical equipment
- Zebra Mussels
  - Freshwater shellfish that invaded the Great Lakes in the 1980's
  - Native to Black and Caspian Seas and thought to have been brought over in freighter's ballast water
  - Population is spreading to most waters of North America



Zebra Mussels



ZEBRA MUSSELS

- Attach to intakes, clog intake screens, reduce flow capacity
- Rapid die-off causes taste & odor problems
- Shells of dead mussels can clog intakes

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ZEBRA MUSSELS AND CLAMS

- Treatment should begin prior to invasion
- Treatment:
  - Chlorine, potassium permanganate, or copper sulfate applied at intake

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TASTE AND ODOR PROBLEMS

- Customers judge the quality of their water by its aesthetic properties
  - Mainly taste and odor
- To prevent or treat a problem, you must know the source of the problem
- Preventative Measures
  - Watershed protection and control of nutrients entering water source
  - Prevent stagnation
  - Physical and chemical pretreatment are an important step in improving the overall efficiency and effectiveness of the treatment process

Vocabulary

A. Adsorption

B. Aeration

C. Aerobic

D. Anaerobic

E. Coliform

F. Colloids

G. Conductivity

H. Decomposition

I. Destratification

J. Diatoms

K. Electrolyte

L. Epilimnion

M. Eutrophic

N. Eutrophication

O. Evapotranspiration

P. Hypolimnion

Q. Inorganic

R. Metalimnion

S. Organic

T. Overturn

U. Oxidation

V. Potable

W. Precipitate

X. Reduction

Y. Septic

Z. Stratification

AA. Threshold Odor Number

_____ 1. The conversion of chemically unstable materials to more stable forms by chemical or biological action.

_____ 2. The upper layer of water in a thermally stratified lake or reservoir.

_____ 3. The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material.

_____ 4. An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.

_____ 5. Substances that comes from animal or plant sources and always contain carbon.

_____ 6. The addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound.

_____ 7. The increase in the nutrient levels of a lake or other body of water.

_____ 8. A measure of the ability of a solution (water) to carry an electric current.

_____ 9. The middle layer in a thermally stratified lake or reservoir.

_____ 10. The addition of hydrogen, removal of oxygen, or addition of electrons to an element or compound.

_____ 11. The greatest dilution of a sample with odor-free water that still yields a just-detectable odor.

_____ 12. A condition in which atmospheric or dissolved molecular oxygen is present in the aquatic (water) environment.

_____ 13. The development of vertical mixing within a lake or reservoir to eliminate separate layers of temperature, plant, or animal life.

_____ 14. A condition in which atmospheric or dissolved molecular oxygen is NOT present in the aquatic (water) environment.

_____ 15. A substance which dissolves (separates) into two or more ions when it is dissolved in water .

_____ 16. Material such as sand, salt, iron, calcium salts and other minerals materials.

_____ 17. The formation of separate layers (of temperature, plant, or animal life) in a lake or reservoir.

_____ 18. Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

_____ 19. A group of bacteria found in the intestines of warm-blooded animals and also in plants, soil, air and water. Their presence is an indication that the water is polluted and may contain pathogenic (disease causing) organisms.

_____ 20. The process of adding air to water. Air can be added to water by either passing air through water or passing water through air.

_____ 21. The process by which water vapor passes into the atmosphere from living plants.

_____ 22. Very small, finely divided solids that remain dispersed in a liquid for a long time due to their small size and electrical charge.

_____ 23. Reservoirs and lakes which are rich in nutrients and very productive in terms of aquatic animal and plant life.

_____ 24. The most spontaneous mixing of all layers of water in a reservoir or lake when the water temperature becomes similar from top to bottom.

_____ 25. A condition produced by bacteria when all oxygen supplies are depleted.

_____ 26. The lowest layer in a thermally stratified late or reservoir.

_____ 27. Unicellular (single cell), microscopic algae with a rigid internal structure consisting mainly of silica.

1. H
2. L
3. A
4. W
5. S
6. U
7. N
8. G
9. R
10. X
11. AA
12. C
13. I
14. D
15. K
16. Q
17. Z
18. V
19. E
20. B
21. O
22. F
23. M
24. T
25. Y
26. P
27. J

Reservoirs and Intakes

Review Questions

1. Large quantities of what nutrients are undesirable in a water supply reservoir?

2. What is an "algal bloom"?

3. What types of tastes and odors are produced by algae?

4. What problems do algae cause on filters?

5. What is the influence of algal blooms on pH?

6. What is the influence of algal blooms on dissolved oxygen?

7. Increased organic loadings from algal blooms can cause what kind of water quality problems?

8. When a lake warms in the spring or summer, how does the decrease in density of the warmer surface water influence mixing action within the lake?

9. What problems are caused by anaerobic conditions in reservoirs?

10. What should be the primary purpose of a watershed management program?

11. What problems can be caused in reservoirs from raw wastewater contamination?

12. How can the adverse impacts of soil disturbances from farming, logging, and construction be minimized?

13. What problems can be created as a result of a wildfire?

14. Why are chemicals used in domestic water supply reservoirs to prevent or control attached and floating aquatic growths?

15. What chemical other than copper sulfate may be used as an algicide?

16. How does suspended particulate matter in a reservoir reduce the effectiveness of copper as and algicide?

17. What is the major factor limiting the maximum rate of application of copper sulfate in the sources of a domestic water supply?

18. What safety precautions should be taken by a person applying copper sulfate in the dry form?

19. What is the primary purpose of reaeration-destratification programs in domestic water supply reservoirs?

20. What are the most common types of intake gates?

21. List the factors that influence the type of screen needed in a specific reservoir.

Reservoirs and Intakes
Review Questions Answers

1. Phosphate, nitrate, and organic nitrogen compounds
2. Very large increase in plankton (algae) population over a very short period of time
3. fishy, aromatic, grassy, septic, musty, and earthy
4. clog filters reducing filter rates and run times
5. fluctuations in pH from day to night
6. increases DO during the bloom; decreases DO when algae dies
7. decreased oxygen levels, increase color and chlorine demand; increase DBP precursors
8. The decrease in density of the warmer water reduces the mixing action within the lake and a barrier is formed between the upper and lower layers
9. Causes the release of hydrogen sulfide and cause iron and manganese in bottom sediments to go into solution into the water
10. To control, minimize, or eliminate practices within the watershed of a domestic water supply reservoir that would lower water quality
11. Nutrient loading and microbial contamination
12. Ordinances that limit such activities to those times of the year when the danger of erosion from surface runoff is at a minimum

13. During the runoff period, large quantities of debris, nutrients, silt, and other pollutants may enter a water supply reservoir

14. to prevent or control taste and odor problems resulting from algal blooms

15. chlorine

16. reduces the effectiveness of copper as an algicide by providing sites or masses other than algal bodies where the copper is adsorbed

17. regulations limiting the concentration of copper in potable water

18. special clothing, gloves, and breathing apparatus, personal flotation advice

19. to eliminate, control, or minimize the negative effects on domestic water quality that occur during periods of thermal stratification and dissolved oxygen depletion

20. slide gates, gate valves, and butterfly valves

21. depth(s) at which the inlets are located, location of the intake structure in relation to where debris accumulates in the reservoir or stream, frequency and intensity of algal scum or algal mass accumulations, quantity and type of debris encountered, size, depth, distribution, and number of fish, crayfish, and other forms of aquatic life

Section 4

Coagulation/Flocculation

COAGULATION AND FLOCCULATION

California State University: Sacramento
Volume I

Objectives

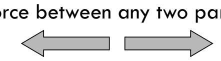
- Nature of Particulate Impurities in Water
- Coagulation
- Flocculation
- Mixing Mechanisms
- Process Performance Considerations
- Process and Support Equipment
- Enhanced Coagulation

Nature of Particulate Impurities in Water

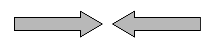
- Surface water contains suspended and dissolved organic and inorganic material
- Settleable solids – Larger sized particles that can be removed from water by slowing down the flow to allow for gravity settling
- Nonsettleable solids – smaller sized particles that do not readily settle
  - Treatment is required to produce larger particles that are settleable
  - AKA Colloidal matter
    - Has a net negative charge

Nature of Particulate Impurities in Water

- Zeta potential
  - repelling force between any two particles of like charge



- Van der Waals force
  - attraction between particles pulling them together



- Particles will stay in suspension if zeta potential is greater than the van der Waals force

Coagulation and Flocculation

- Need for Coagulation and Flocculation
  - To remove particulate impurities, particularly nonsettleable solids and colors
  - Chemicals are added that will cause the particles to clump together in the coagulation process
  - The particles to gather together to form larger particles in the flocculation process

Coagulation and Flocculation

- Coagulation
  - reduces the zeta potential so that van der Waals force can pull particles together to form *microfloc*
- Flocculation
  - brings the microfloc particles together to form larger particles called *macrofloc*

Coagulation

Process Description

- Coagulation describes the effect produced when certain chemicals are added to raw water
- Flash mixing
  - The mixing of the coagulant chemical and raw water
  - Equally distributes the chemical through the water
  - Chemical process (hydrolysis) occurs very quickly
    - approximately 2-5 seconds
  - Forms very small particles (microfloc)
- Detention time
  - The actual or theoretical time that it takes for water to pass through a basin
  - Less than 30 seconds (TN Design Criteria)

Basic Coagulant Chemistry

- Coagulation is a physical and chemical reaction
- Best pH range is 5 to 7 s.u.
- Alkalinity reacts with coagulants to form floc and serves as a buffer to prevent pH from changing
  - If alkalinity in source water is too low, complete precipitation of coagulant may not occur
    - Weak floc is easy shear/break or may dissolve back into solution
  - Alkalinity can be increased by addition of lime or soda ash

Coagulants

- Primary coagulants neutralize (destabilize) the electrical charge of particles, which causes them to begin to clump together
- Synthetic Organic Polymers
- Metallic Salts
  - Enough chemical must be added to exceed the solubility limit of the metal hydroxide, resulting in precipitation (aka floc formation)
  - Common additives:
    - Aluminum, Al^{+3}
      - Aluminum sulfate [$Al_2(SO_4)_3 \bullet 14H_2O$]
    - Iron, Fe^{+3}
      - Ferric sulfate [$Fe_2(SO_4)_3$]
      - Ferrous sulfate [$Fe_2(SO_4)_3 \bullet 7H_2O$]

Coagulants - Metallic Salts

- Metallic salts react with other ions in the water
  - Chemical quantities must be sufficient to exceed the solubility limit of the metal hydroxide
    - This will result in the formation of floc
    - The floc will adsorb onto the turbidity in the water

$$\underbrace{Al_2(SO_4)_3}_{\text{alum}} + \underbrace{3Ca(HCO_3)_2}_{\text{natural bicarbonate alkalinity}} \rightarrow \underbrace{2Al(OH)_3\downarrow}_{\text{aluminum hydroxide floc}} + \underbrace{3CaSO_4\downarrow}_{\text{calcium sulfate}} + \underbrace{6CO_2}_{\text{carbon dioxide}}$$

↓ Indicates precipitation occurring

Coagulants - Aluminum Sulfate

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- $Al_2(SO_4)_3 \bullet 14\ H_2O$
- Most widely used coagulant
- Available in liquid or dry form
- Neutralizes the negatively charged particles of color or turbidity almost instantaneously (1-2 seconds)
- Reacts with alkalinity present in water to form a jelly-like floc – aluminum hydroxide $Al(OH)_3$,
- Works best in pH range of 5.8 to 8.5
  - Liquid alum
    - Strong acid
  - Dry alum
    - Available in powder, lump form

Coagulants - Ferric Chloride

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- $FeCl_3$
  - Highly corrosive
  - liquid is 35-45% strength
  - will crystallize at 30ºF
- Effective over wider pH range than alum, works better in cold water, forms heavier denser floc
- Requires 0.6 mg/L alkalinity for each mg/L ferric chloride
- Reacts with alkalinity in the water to form an insoluble hydroxide $Fe(OH)_3$

Coagulants - Ferric Sulfate

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- $Fe_2(SO_4) \bullet 3\ H_2O$ or
- $Fe(SO_4)_3 \bullet 2\ H_2O$
- Often used with lime softening
- Effective over wider pH range than alum, produces heavier denser flock
- Requires 0.75 mg/L alkalinity for each mg/L ferric sulfate
- Reacts with alkalinity in the water to form an insoluble hydroxide $Fe(OH)_3$

Coagulants - Polymers

- Polymers are commonly used as coagulation chemicals
  - Primary coagulants neutralize the electrical charges of the particles, which causes them to being to clump together
  - Coagulant aids add density to slow settling floc and toughness to minimize the floc breaking up
  - Synthetic organic polymers
    - Cationic polyelectrolytes – polymers that release ions with a positive (+) charge
    - Anionic polyelectrolytes – polymers that release ions with a negative (-) charge
    - Nonionic polyelectrolytes – polymers that release both positively and negatively charged ions

Coagulants

- Considerations when choosing a coagulant:
  - Polymer overdosing will adversely affect coagulation efficiency
  - Not all water supplies can be treated with equal success
  - Some polymers lose their effectiveness when used in the presence of a chlorine residual
  - Some polymers are dosage limited

Process Performance Considerations

- Coagulation Basins
  - Accomplished in a special rectangular tank with mixing devices
  - Can occur in the influent channel or pipeline
  - Shape of basin is part of system design

Coagulant Aids

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- May be added to:
  - Improve coagulation
  - Build stronger, more settleable floc
  - Overcome the effect of temperature drops that slow coagulation
  - Decrease amount of primary coagulant needed
  - Reduces amount of sludge produced
- 3 types of coagulant aids
  1. activated silica
  2. weighting agents
  3. polyelectrolytes (polymers)

Coagulant Aids - Polymers

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Polymers
- Have extremely large molecules, that when dissolved in water, produce highly charged ions
- The basic types
  - Cationic (+)
  - Anionic (-)
  - Nonionic

Coagulant Aids - Polymers

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Cationic Polymer
- Produce **positively** charged ions when dissolved in water
- Advantages
  - Coagulant can be reduced
  - Floc settles better
  - Less sensitivity to pH
  - Flocculation of bacteria and algae are improved

Coagulant Aids - Polymers

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Anionic Polymer
- Produce **negatively** charged ions when dissolved in water
- Advantages
  - Increased floc size
  - Improved settling
  - Strong floc, generally

Coagulant Aids - Polymers

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Nonionic Polymer
- Have a balanced or **neutral** charge
  - They release both positively and negatively charged ions when dissolved
- Less expensive but have higher dosages
  - Cationic and anionic have dosages around 0.1-1.0 mg/L
  - Nonionic dose can range from 1-10 mg/L

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Flocculation

Flocculation

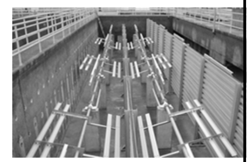
- Process Description
  - Slow stirring process that causes the gathering together of small, coagulated particles into larger, settleable particles
- Floc Formation
  - Controlled by rate at which collisions occur between particles
  - Purpose is to create a floc of good size, density, and toughness
  - Best floc size rages from 0.1 mm to 3 mm

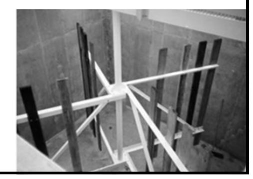
Flocculation

- Process Performance Consideration
  - Insufficient mixing will result in ineffective collisions and poor floc formation.
  - Excessive mixing may tear apart or shear the floc that has been formed
- Detention Time
  - Required for the necessary chemical reactions to take place
  - Minimum 30 minutes with 45 minutes recommended

Types of Flocculators

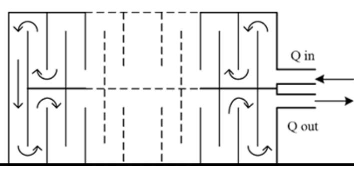
- Mechanical
  - Paddle wheel flocculators
    - Horizontal
      - Submerged mechanics
    - Vertical
      - Requires less maintenance
      - Propeller, paddle, or turbine types





Types of Flocculators

- Hydraulic
  - Turbulence resulting from the roughness in conduits or channels
    - Limited use due to very localized distribution of turbulence, inadequate detention time, and widely variable turbulence



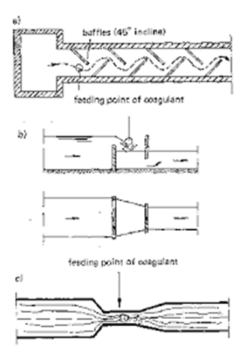
Flocculation Basin

- Rectangular for horizontal flocculators
- Nearly square for vertical flocculators
- Compartmentalized basins achieve best flocculation
  - Separated by baffles
  - Prevents short circuiting by having compartments/basins in series
- Solids-contact basins (upflow clarifiers)
  - Combines coagulation, flocculation and sedimentation process into a single basin

Mixing Mechanisms

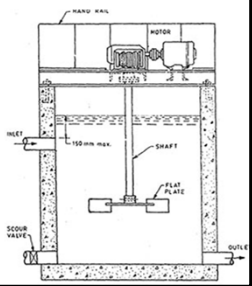
Methods of Mixing

- Hydraulic mixing using flow energy in the systems
  - With baffles or throttling valves if sufficient velocity to cause turbulence
  - Turbulence mixes chemicals with the water



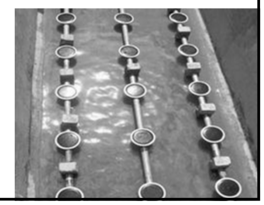
Methods of Mixing

- Mechanical mixing
  - Paddles, turbines, and propellers
  - Versatile and reliable
  - Use greatest amount of energy



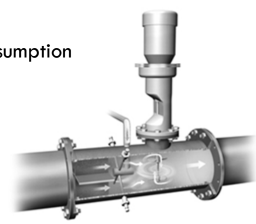
Methods of Mixing

- Diffusers and grid systems
  - Perforated tubes or nozzles
  - Equally distribute flow over entire basin
  - Sensitive to flow changes
  - Require frequent adjustments



Methods of Mixing

- Pumped blenders
  - Coagulant added directly to the water being treated through a diffuser in a pipe
  - Can provide rapid dispersion of chemical
  - No significant head loss
  - Considerably low energy consumption



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Process Performance Considerations

Interaction with Other Treatment Processes

- The effectiveness of the sedimentation and filtration processes depends upon successful coagulation-flocculation
- Disinfection can be affected by poor coagulation-flocculation performance
- Effective coagulation-flocculation promotes the removal of natural organic matter

Water Characteristics Affecting Chemical Selection

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turbidity alkalinity
pH
color temperature

- As water quality changes, coagulant effectiveness changes

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Water Characteristics Affecting Chemical Selection

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Turbidity

- Floc doesn't form well when turbidity is low
- May have to add weighting agent
- Coagulant dose must be raised when turbidity increases
- Don't lower coagulant dose too soon when turbidity starts to drop

Water Characteristics Affecting Chemical Selection

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pH

- There is an optimal range for each chemical
- Lime, soda ash, & caustic soda raise pH
- Sulfuric acid lowers pH

Alkalinity

- at least 10 mg/L left over

Water Temperature

- Reactions occur slower in colder water
- Requires more coagulant in cold water

Water Characteristics Affecting Chemical Selection

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Color

- Caused by organics, such as humic acid
- Highly colored water is often low in turbidity
- Usually has low alkalinity
- Color removal is an increasing concern because there seems to be a link between color-causing substances (organics) and THM formation when chlorine is added

Water Characteristics Affecting Chemical Selection

40

Total Organic Carbons (TOC)

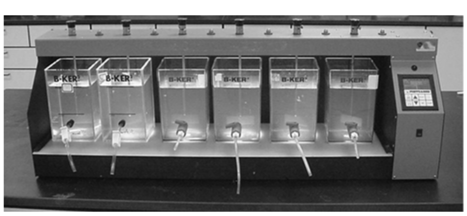
- Measured in raw and finished water
- Disinfection By-Product (DBP) precursor

Specific Ultraviolet Absorbance (SUVA)

- Measures UV light at 254 nm and divides that value by the Dissolved Organic Carbon (DOC)
- The SUVA is an indicator of humic content (a DBP precursor)

Process Control

- Most important consideration is selection of the proper type and amount of coagulant chemical
- Determined by jar testing



Process Actions

- Monitor process performance
- Evaluate water quality conditions (raw and treated)
  - Visual observations and routine laboratory tests
    - Turbidity, alkalinity, pH, color, temperature, chlorine demand
- Check and adjust process controls and equipment
- Visually inspect facilities
  - Observation of turbulence of water in flash mix
  - Observation of size & distribution of floc in floc basins
    - Uneven distribution could mean short-circuiting

Preparation of Chemical Solutions

- Concentration depends on type of polymer and the polymer's molecular weight
  - The higher molecular weight, the more difficult it is to mix the polymer into solution
    - Solution becomes very viscous (thick)
  - Anionic and nonionic dry polymers often prepared as very weak solutions (0.25%-1%)
  - Cationic dry polymers have small molecular weights so they can be prepared at high solutions (5%-10%)

Recordkeeping

- Source of water quality
  - pH, turbidity, temperature, alkalinity, chlorine demand, and color
- Process water quality
  - pH, turbidity, and alkalinity
- Process production inventories
  - Chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage
- Process equipment performance
  - Types of equipment in operation, maintenance procedures performed, equipment calibration and adjustments
- Entries should include date, time, and operator initials

Abnormal Conditions

- Changes in source water turbidity
  - Verify the effectiveness of coagulant and dosage
  - Best accomplished by running a jar test
- Visual observations of flash-mixing intensity as well as the condition of the floc in the floc basins
  - Adjust mixer speed or coagulant dose

Abnormal Conditions

- Alkalinity, pH, and temperature changes impact floc formation
  - Temperature change may require adjustment of mixing intensity
- Sudden increases in filtered water turbidity
  - Due to poor coagulation-flocculation performance
  - Add filter-aid, such as nonionic polymer
  - Run jar tests to see how to best adjust the process

Troubleshooting - Coagulation Process

Coagulation Process Effluent Quality Changes	Operator Actions	Possible Process Changes
• Turbidity • Temperature • Alkalinity • pH • Color	• Perform necessary analyses to determine extent of change • Evaluate overall process performance • Perform jar tests if indicated • Make appropriate process changes • Increase frequency of process monitoring • Verify response to process changes at appropriate time	• Change coagulant(s) • Adjust coagulant dosage • Adjust flash-mixer/flocculator mixing intensity • Adjust coagulant aid or filter aid • Adjust alkalinity or pH

Troubleshooting - Flocculation

Flocculation Basin Floc Quality Changes	Operator Actions	Possible Process Changes

• Turbidity
• Alkalinity
• pH
	• Evaluate source water quality
	• Perform jar tests if indicated
	• Verify process performance:
	  • Coagulant feed rate
	  • Flash-mixer operation
	• Make appropriate process changes
	• Verify response to process changes at appropriate time
		• Change coagulant(s)
		• Adjust coagulant dosage
		• Adjust flash-mixer intensity
		• Adjust alkalinity or pH

Troubleshooting - Source Water Quality

Source Water Quality Changes	Operator Actions	Possible Process Changes
• Floc formation	• Observe floc condition in basin: • Dispersion • Size • Floc strength (breakup) • Evaluate overall process performance • Perform jar tests if indicated: • Evaluate floc size, settling rate, and strength • Evaluate quality of supernatant: clarity (turbidity), pH, and color • Make appropriate process changes • Verify response to process changes at appropriate time	• Change coagulant(s) • Adjust coagulant dosage • Adjust flash-mixer/flocculator mixing intensity • Adjust coagulant aid • Adjust alkalinity or pH

Laboratory Tests

- Process Control Water Quality Indicators
  - Turbidity, alkalinity, chlorine demand, color, pH, temperature, odor, and appearance
- Sampling Procedures
  - Either grab samples or continuous sampling
  - Process samples must be representative
    - Water that is nearly as identical in content and consistency as possible to that in the larger body of water being sampled

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Process and Support Equipment

Types of Equipment

- Liquid (solution) feeders
  - A diluted solution of known concentration is fed directly into water being treated
  - Fed through metering pumps and rotameters
- Dry feeders
  - Deliver a measured quantity of dry chemical during a specified time
  - Volumetric feeders – deliver a specific volume of chemical during a given time
  - Gravimetric feeders – delivers a predetermined weight of chemical in a specific unit of time
    - More accurate

Chemical Feed Equipment

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Flash Mixers

- Provide agitation to evenly mix coagulant through water
- Add chemicals to center of mixing chamber
- Coagulation occurs in less than 1-2 seconds
- This stage determines the success of coagulation
- Detention time should not exceed 30 seconds (Design Criteria)

Chemical Feed Equipment

54

Types of Flash Mixers

- Mechanical mixers
- Static mixers
- Pumps and conduits
- Baffled chambers

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Chemical Feed Equipment

55

Mechanical Mixers

- Placed in a chamber or tank
- Mounted in a pipeline (*in-line mixers*)
- Most reliable and versatile
- Use most energy

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Chemical Feed Equipment

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Static Mixers

- Produce turbulence and mixing through use of fixed sloping vanes
- Effective and economical to install and operate
- High head loss
- Mixing energy directly related to flow with no way to adjust

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Chemical Feed Equipment

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Pumps and Conduits

- Chemicals added to suction side of low-lift pump
- Mixing energy caused by turbulence in pipeline
- Energy determined by speed of pump

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Chemical Feed Equipment

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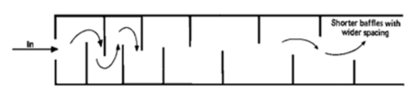
Baffled Chambers

- Mixing occurs as water travels over and under baffles
- Turbulence related to flow, cannot be controlled



Operation and Maintenance

- Equipment Operation
  - Before starting equipment, be sure unit is properly lubricated and its operational status is known
  - After start up, always check for excessive noise and vibration, overheating, and leakage

Operation and Maintenance

- Preventive Maintenance Procedure
  - Keep motors free of dirt and moisture
  - Ensuring good ventilation in equipment work areas
  - Checking pumps for leaks, unusual noise, vibrations, or overheating
  - Maintaining proper lubrication and oil levels
  - Inspecting for alignment of shafts and couplings
  - Checking bearings for wear, overheating, and proper lubrication
  - Exercising infrequently used valves on a regular schedule and checking all valves for proper operation
  - Calibrating flowmeters and chemical feeders

Enhanced Coagulation

Enhanced Coagulation

- Process designed to remove NOM from water by adjusting both the coagulant dose and the pH
  - Adjust pH by adding acid or alkali
  - Differs from "sweep" method where pH range is achieved by overdosing the coagulant
- Natural organic matter comprised of organic acids called humic substances
  - Composed of humic and fulvic acids

Chemical Reactions

- Fulvic and humic substances in water are negatively charged
- Negative charge is neutralized and destabilized by positively charged coagulants
- Destabilized particles come together and form larger floc particles that can be settled out
- Chemistry that deals with this particular coagulation process is known as charge chemistry

Chemical Reactions

- pH range for color removal with aluminum sulfate is 5.5 – 7.0
  - Optimum pH is 5.8
- pH range for color removal with ferric sulfate is 4.0 – 6.2
  - Optimum pH is 4.5
- At the lower (optimum) pH, four effects take place that enhance coagulation
  - Humic and fulvic molecules dissociate
  - Coagulant demand decreases
  - Flocculation is improved at lower pH
  - Sulfuric acid addition preconditions the organic compounds

Process Control

- Color results from presence of minerals, inorganic chemicals, metals, decomposition of organic matter from soils, aquatic organisms, and vegetation
- True color – color of the water from which turbidity has been removed (filtered)
- Apparent color – color of the water that includes the color and the suspended matter
- Measured in color units
- Color is reported in whole numbers from 1 to 500
- Sample pH is always reported with color units
  - Color determinations will increase as the pH of the water increases

Process Control

- pH optimization necessary for coagulation
  - Automated pH is a must
  - pH backfeed process control loop required
  - Must have pH monitoring meter located after flash mix and feed valve controllers for acid and alkalinity chemical addition

Troubleshooting

Treatment Condition Flocculator Effluent	Corrective Action
High coagulation pH with optimum color removal	1. Increase acid feed 2. Decrease alkalinity adjustment in raw water source
High coagulation pH without optimum color removal	1. Increase coagulant 2. Decrease acid feed to maintain optimum pH
Low coagulation pH with optimum color removal	1. Decrease acid feed 2. Increase alkalinity adjustment in raw water source
Low coagulation without optimum pH color removal	1. Decrease acid if below optimal pH zone 2. Increase coagulant and alkalinity
Loss of acid feed	1. Increase coagulant to achieve optimal pH

Troubleshooting

Treatment Condition Flocculator Effluent	Corrective Action
Optimal pH without optimized color removal	1. Increase coagulant, decrease acid, or increase alkalinity
Optimal pH and color removal with floc carryover	1. Decrease coagulant 2. Increase polymer 3. Increase removal of settled floc 4. Decrease flow-through velocities
High turbidities and coagulant residuals in settled water	1. Check for floc carryover 2. Adjust polymer feed to enhance settling 3. Jar test to determine optimum acid and coagulant dosage

Coagulation and Flocculation
Vocabulary

A. Alkalinity
B. Anionic Polymer
C. Apparent Color
D. Cationic Polymer
E. Coagulants
F. Coagulation
G. Colloids
H. Composite Sample
I. Disinfection By-product
J. Floc
K. Flocculation
L. Grab Sample
M. Jar Test
N. Natural Organic Matter (NOM)
O. Nonionic Polymer
P. Particulate
Q. Polymer
R. Precipitate
S. Representative Sample
T. Total Organic Carbon
U. Trihalomethanes
V. True Color
W. Turbidimeter
X. Turbidity

_____ 1. An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.

_____ 2. A single sample of water collected at a particular time and place which represents the composition of the water only at the time and place.

_____ 3. An instrument for measuring and comparing the turbidity of liquids passing light through them and determining how much light is reflected by the particles in the liquid.

_____ 4. A polymer having positively charged groups of ions. Often used as a coagulant aid.

_____ 5. A polymer having negatively charged groups of ions.

_____ 6. A sample portion of material or water that is a nearly identical in content and consistence as possible to that in the larger body of material or water being sampled.

_____ 7. Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

_____ 8. A laboratory procedure that simulates a water treatment plant's coagulation/flocculation units with differing chemical doses and also energy of rapid mix, energy of slow mix, and settling time.

_____ 9. Color of the water that includes not only the color due to substances in the water but suspended matter as well.

_____ 10. Derivatives of methane often formed during chlorination by reactions with natural organic materials in the water.

_____ 11. The clumping together of very fine particles into larger particles (floc) caused by the use of chemicals (coagulants).

_____ 12. A contaminant formed by the reaction of disinfection chemicals with other substances in the water being disinfected.

_____ 13. A polymer that has no net electrical charge.

_____ 14. Clumps of bacteria and particulate impurities that have come together and formed a cluster.

_____ 15. The cloudy appearance of water caused by the presence of suspended and colloidal matter.

_____ 16. A very small solid suspended in water which can vary widely in size, shape, density, and electrical charge.

_____ 17. Chemicals that cause very fine particles to clump (floc) together into larger particles.

_____ 18. Humic substances composed of humic and fulvic acids that come from decayed vegetation.

_____ 19. The gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing

_____ 20. Color of the water from which turbidity has been removed.

_____ 21. A collection of individual samples obtained at regular intervals.

_____ 22. The capacity of water to neutralize acids or resist a change in pH.

_____ 23. A measure of the amount of organic carbon in water.

_____ 24. A long-chain molecule formed by the union of many monomers; used with coagulants to aid in binding small suspended particles to large chemical flocs.

Answers

1. R	4. D	7. G	10. U	13. O	16. P	19. K	22. A
2. L	5. B	8. M	11. F	14. J	17. E	20. V	23. T
3. W	6. S	9. C	12. I	15. X	18. N	21. H	24. Q

Coagulation and Flocculation
Review Questions

1. What is the purpose of coagulation and flocculation?

2. What happens in the coagulation and flocculation processes?

3. What is the primary purpose of flash mixing?

4. Why are both primary coagulants and coagulant aids used in the coagulation process?

5. List four methods of mixing coagulant chemicals into the plant flow.

6. What is a hydraulic mixing device?

7. What is flocculation?

8. How long is the typical mixing time in the coagulation process?

9. What is the recommended minimum detention time for flocculation?

10. What is an advantage of vertical flocculators over horizontal flocculators?

11. Why is coagulation-flocculation important to other treatment processes?

12. How is the effectiveness of the solids removal processes commonly monitored?

13. List the typical functions performed by an operator in the normal operation of the coagulation-flocculation process.

14. Which laboratory tests would you use to monitor the coagulation-flocculation process?

15. What would you look for when visually observing the performance of a coagulation-flocculation process?

16. What information should be recorded for all entries in a record book?

17. What kinds of sudden changes in either raw or filtered water quality are signals that you should immediately review the performance of the coagulation-flocculation process?

18. What is the relationship between pH and color in a water sample?

19. List the process control water quality indicators of importance in the operation of the coagulation-flocculation process.

20. How do chemical liquid feeders work in the coagulation process?

21. Selection of a chemical feeder for a given application depends on what factors?

Answers

1. To remove particulate impurities and color from the water being treated
2. Chemicals are added that will cause the particles to begin to clump together
3. To rapidly mix and uniformly distribute the coagulant chemical throughout the water
4. Primary coagulants are used to neutralize the electrical charge of the particles and cause the particles and cause the particles
5. Hydraulic mixing, mechanical mixing, diffusers and grid systems, pumped blenders

6. Hydraulic mixing devices rely on the turbulence created by flowing water to mix chemicals with the water
7. A slow stirring process that causes the gathering together of small, coagulated particles into larger, settleable floc particles
8. 2-5 seconds with 30 seconds as maximum detention time
9. 30 minutes minimum with 45 minutes recommended
10. Vertical flocculators usually require les maintenance since they eliminate submerged bearings and packings
11. It influences the effectiveness of the sedimentation, filtration, and disinfection processes. It causes bacteria and other disease-causing organisms to be bound up in suspended solids and floc.
12. By measuring the turbidity of filtered water
13. Monitor process performance, evaluate water quality conditions, check and adjust process controls and equipment, visually inspect facilities
14. Turbidity, alkalinity, temperature, color, pH, and chlorine demand
15. Observe the degree of agitation of the water in the flash mix and observe the size and distribution of floc in the flocculation basin
16. Date, time of an event, and initials of the operator making the entry
17. pH, alkalinity, temperature, or chlorine demand
18. Color determinations are always extremely pH dependent and will always increase as the pH of the water increases
19. Turbidity, temperature, alkalinity, chlorine demand, color, pH, odor and appearance
20. They feed a solution of known concentration directly into the water being treated
21. Type of chemical compound, availability of chemical, chemical form (dry or liquid), and the amount to be fed daily

Section 5

Sedimentation

Sedimentation

California State University: Sacramento

1

Objectives

- Process Description
- Sedimentation Basins
- Solids-Contact Clarification
- Sludge Handling and Disposal
- Process Control
- Sedimentation Equipment and Safety

2

Process Definition

- To remove suspended solids that are denser than water and to reduce the load on the filters
- Suspended solids
  - Natural state
    - bacteria, clays or silts
  - Modified/preconditioned
    - to form floc
  - Precipitated impurities
    - hardness, iron precipitates formed by the addition of chemicals

3

Factors Affecting Sedimentation

- Particle size and distribution
  - larger particles will settle out faster
- Shape of particles
  - smoother circular particles will settle faster
- Density of particles
  - Denser particles settle out better
- Temperature of water
  - Decrease in temperature increases settling time required
- Electrical charge on particles
  - Colloidal particles are generally negatively charged

4

Factors Affecting Sedimentation

- Dissolved substances in water
- Flocculation characteristics of the suspended material
- Environmental conditions (e.g. wind effects)
- Sedimentation basin hydraulic and design characteristics (i.e. inlet conditions & basin shape)

5

Factors Affecting Sedimentation

- Sand and silt particles > 10 microns can be removed by sedimentation

Source	Diameter of Particle(microns)
Coarse turbidity	1 - 1,000
Algae	3 - 1,000
Silt	10
Bacteria	0.3 - 10
Fine turbidity	0.1 - 1
Viruses	0.02 - 0.26
Colloids	0.001 - 1

1 micron = 0.001 mm

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Currents

- Types
  - Surface currents
    - caused by winds
  - Density currents
    - caused by differences in suspended solids concentrations and temperature differences
  - Eddy currents
    - produced by the flow of the water coming into and leaving the basin
- Can cause suspended particles to distribute unevenly
- Can be reduced with baffled inlets or basin covers

7

Detention Time

- 2 definitions
  - The actual time required for a small amount of water to pass through a sedimentation basin at a given rate of flow
  - The theoretical time (calculated) required for a small amount of water to pass through a basin at a given rate of flow
  - Minimum DT = 4 hours
  - Minimum DT, if high-rate settlers installed = 1 hour
- Factors affecting detention time
  - Short circuiting
  - Effective exchange volume
    - Portion of basin through which the water flows
  - Other hydraulic conditions
    - Basin inlet and outlet design

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Sedimentation Basins

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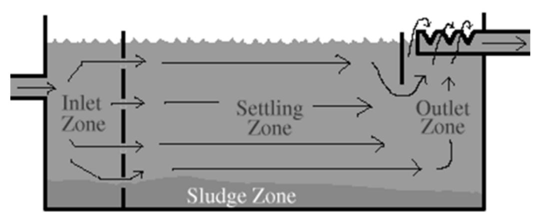
Sedimentation Basins

- 4 zones
  - Inlet zone
  - Settling zone
  - Sludge zone
  - Outlet zone



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Inlet Zone

- Provides a smooth transition from flocculation basin
- Distributes flocculated water uniformly over the entire cross section of the basin
- If properly designed, it will decrease short circuiting
- Over 50% of sludge will settle the first 1/3 of the tank
- Inlet baffle wall will
  - Minimize density currents due to temperature differences
  - Minimize wind currents
  - Minimize tendency of water to flow at the inlet velocity straight through the basin

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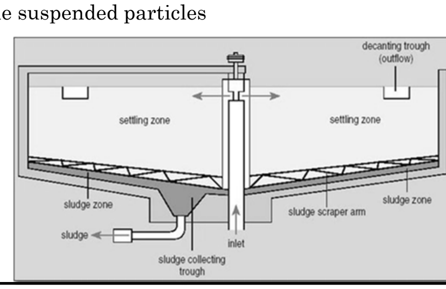
Settling Zone

- Largest portion of basin
- Provides calm, undisturbed storage of the flocculated water to permit effective settling of the suspended particles



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Sludge Zone

- Serves as a temporary storage place for the settled particles
- Located at the bottom of the sedimentation basin
- If sludge becomes too great
  - Decrease effective depth of the basin
  - Cause localized high flow velocities
  - Cause sludge scouring
  - Decrease in process efficiency
- Sludge removed by scraper or vacuum moving along bottom of basin
  - If removal devices do not cover full length of basin, it may have to be drained and flushed to remove the sludge

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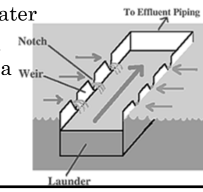
Outlet Zone

- Provides smooth transition from sedimentation basin to settled water conduit or channel
- Can control basin's water level
- Launders are used to uniformly collect settled/clarified water
- V-notch weirs are attached to launders to enable a uniform draw-off of basin water
- If water leaves sedimentation basin unevenly or at too high a velocity, floc can be carried over to the filters



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Basin Types

- Rectangular Basin
- Double-Deck Basin
- Circular and Square Basins
  - Referred to as clarifiers
- High Rate Settlers
  - Placed in basins
- Solids Contact Units

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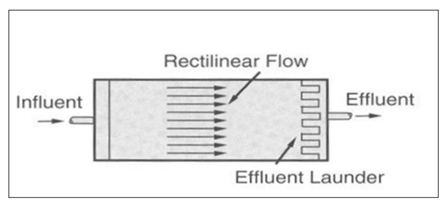
Types of Sedimentation Basins

- Rectangular Basins
  - Flow is in one direction
    - parallel to the basin length
    - called *rectilinear flow*
  - High tolerance to changing water conditions



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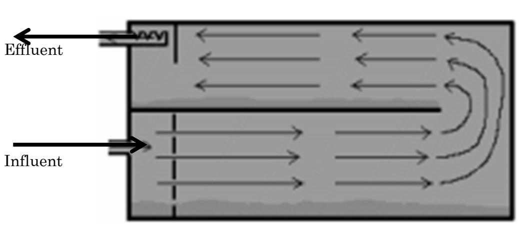
Types of Sedimentation Basins

- Double Deck Basin
  - Stack one rectangular basin on top of another
  - Doubles the effective sedimentation surface area



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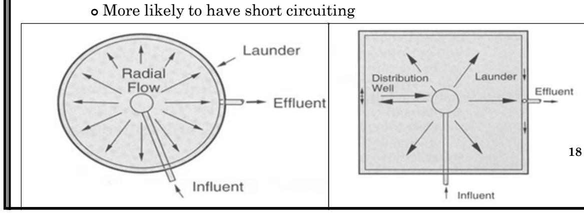
Types of Sedimentation Basins

- Circular and Square Basins (center feed)
  - Often called clarifiers
  - Water flows radially from center to outside
    - Must keep velocity and flow as even as possible
    - Bottom is conical and slopes downward for easier sludge removal
    - More likely to have short circuiting



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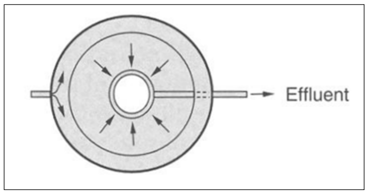
Types of Sedimentation Basins

- Circular Basins (peripheral feed with radial flow)
  - Flow is from the outside edge (periphery) to the center of the basin
  - Design is similar to central feed, radial flow



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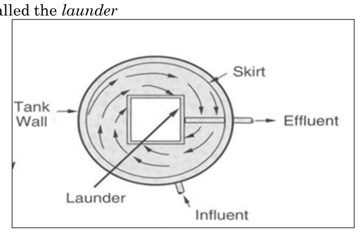
Types of Sedimentation Basins

- Circular Basins (peripheral feed with spiral flow)
  - Water enters at outside edges
  - Flows in a circle around the basin
  - Leaves at the center collector
    - called the *launder*



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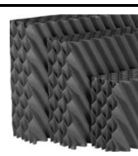
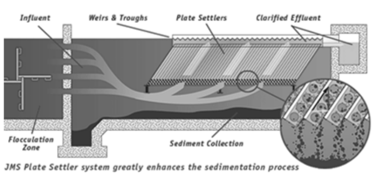
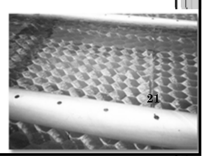
Types of Sedimentation Basins



- High-Rate Settlers aka Tube Settlers
  - Increases settling efficiency of conventional rectangular sedimentation basins
  - Water enters the tubes and flows upward
  - Settled particles collect on surfaces of tubes or settle to bottom of basin
  - Can be tube design or plate design of settlers





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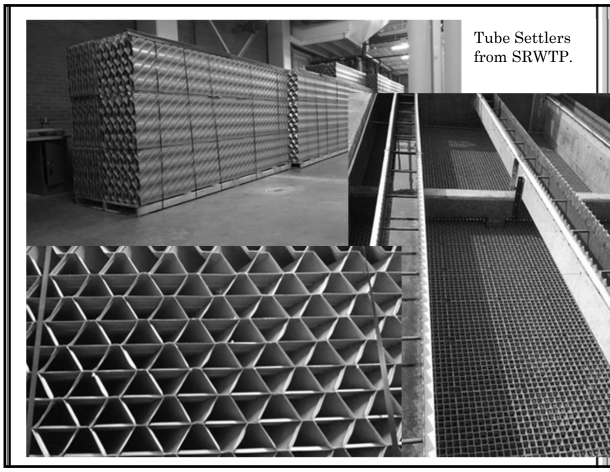

Tube Settlers from SRWTP.

Solids-Contact Clarification

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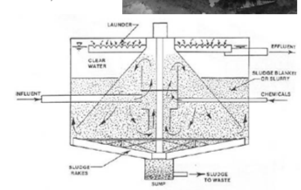
Solids-Contact Units

- Improves overall solids removal process under certain design conditions
- Combine coagulation, flocculation and sedimentation into a single basin
- Water flows upward through a sludge blanket or slurry of flocculated, suspended solids



Solids-Contact Units

- Uniform sludge blanket must be maintained
- Sludge blanket sensitive to changes in water temperature
- Changes in rate of flow should be made infrequently, slowly, and carefully
- Operational factors of importance
  - Temperature
  - Control of chemical dosage
  - Mixing of chemicals
  - Control of sludge blanket
- Perform a drawdown on sludge blanket to check thickness and concentration
  - AWWA: check solids concentration 2 times a day
  - State of TN: check solids concentration every 8 hours (3 times a day)

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Solids-Contact Clarification

- Known as solids-contact clarifiers, upflow clarifiers, reactivators, and precipitators
- Sludge – settled materials from coagulation or settling
- Slurry – the suspended floc clumps in the clarifier
- Internal mechanism consists of 3 distinct processes that function in the same way as conventional treatment
- Sludge produce by the unit is recycled through the process to act as a coagulant aid

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Solids-Contact Clarification

- Advantages
  - Reduced maintenance costs since all 3 processes are in one basin
  - Ability to adjust volume slurry
    - Operator can increase amount of slurry during good periods and remove it during periods when the coag process isn't functioning well
- Disadvantages
  - Requires a high level of operator knowledge and skill
  - Instability during rapid changes in flow, turbidity level, and temperature

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Fundamentals of Operation

- Chemical Dosage
  - Must be sufficient alkalinity
  - Always run jar test before making any changes
- Recirculation Rate
  - Established by speed of impeller, turbine, pumping unit or air injection
  - Entire mass of suspended floc clumps billows and flows within the chamber
    - This recirculating sludge mixes with the raw water and goes through coagulation & flocculation in the reaction zone
- Sludge Control
  - Accumulated sludge on bottom of clarifier (settling zone) is removed via hydraulic means (water pressure)

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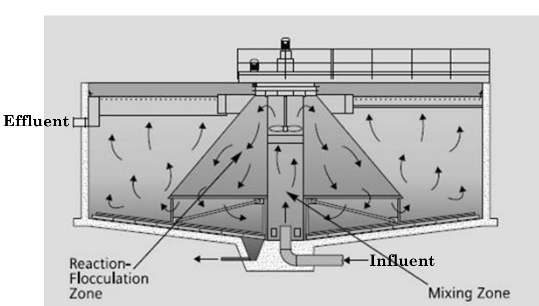
Fundamentals of Operation



Recirculation Zone – where coagulation & flocculation occur

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Sludge Removal

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Sludge Handling

- Sludge must be removed from bottom of basins
  - To prevent interference with the settling process
  - To prevent the sludge from becoming septic or providing an environment for the growth of microorganisms
  - To prevent excessive reduction in the cross-sectional area of the basin (reduction in DT)
- Mechanical sludge removal devices
  - Mechanical rakes
  - Drag-chain and flights
  - Traveling bridges

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Sludge Handling

- Mechanical rakes
  - Used in circular or square basins to push sludge toward a center outlet of sloped basin floor
- Drag-chain & flights
  - Simplest mechanism for rectangular basins
  - Endless chain with scrapers (flights) pushes sludge into a sump
  - Has high operation and maintenance costs
- Traveling bridges
  - Spans width of sedimentation basin and travels along basin walls
  - Sweeps hung from bridge remove sludge from basin floor with suction pumps or by siphon action

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Mechanical Rake

Travelling Bridge

Drag-chain and Flights

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Operation of sludge removal equipment

- Sludge removal frequency depends on
  - Rate of sludge buildup
    - Dependent on amount of suspended material & flock removed
  - Size and capacity of sludge pump
  - Manual removal should be performed twice per year
- Sludge level measured by
  - Sludge blanket sounder
  - Bubbler tube
  - Aspirator
  - Ultrasonic level indicator
- If sludge is too thick and bulks, increase removal frequency
- If sludge is too low in solids (soupy), decrease removal frequency

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Process Control

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Process Control

- Performance of sedimentation basin depends on
  - Settling characteristics of suspended particles
  - Flow rate through basin (surface overflow rate)
- To control settling characteristics of particles
  - Adjust coagulant dose
  - Adjust coagulation-flocculation process
- Flow rate through basin controls process efficiency
  - Higher rate of flow means lower efficiency

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Surface Overflow Rate (SOR)

- Also called Surface Loading Rate (SLR)
  - Measures the amount of water leaving a sedimentation tank per foot of tank surface area
  - gpd/ft^2
- Translates into velocity and is equal to the settling velocity of the smallest particle the basin will remove
  - The faster the water leaves a tank, the more turbulence is created, and the more suspended solids are carried over the weir
    - Only the heavy particles can settle in fast moving water
- The overflow rate is controlled by a change in the flow rate into the tank

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Normal Operating Procedures

- Monitor
  - Turbidity of water entering and leaving the sedimentation basin
    - Entering indicates the load on the sedimentation process
    - Leaving reveals effectiveness of sedimentation
  - Temperature of entering water
    - Colder water means slower settling
- Uneven distribution of floc may indicate raw water quality change or operational problems

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Normal Operating Procedures – Process Actions

- Floc observation
  - Floc should only be visible for a short distance in sedimentation basin
  - If visible for long distance beyond inlet, sedimentation is poor
- Sludge blanket
  - Normal density but close to surface means more sludge should be wasted
  - Light density indicates coag-floc process must be adjusted
  - Floc coming over weir at end of basin indicate density currents, short circuiting, too deep sludge blankets, or high flows
  - Frequent clogging of sludge discharge line indicates too high sludge concentration

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Normal Operating Procedures – Process Actions

- Sludge solids volume analysis - used to determine sludge solids concentration
  - Collect sludge sample and pour known volume into a drying dish
  - Place sample dish in drying oven and evaporate sample to dryness at 103-105°C
  - Weigh remaining solids

$$\text{Sludge solids, \%} = \frac{(\text{Weight of sample, mg})(1\text{ mL})}{(\text{Volume of sample, mL})(1000\text{ mg})} \times 100$$

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Record Keeping

- Influent and effluent turbidity and influent temperature
- Process production inventory
  - Amount of water processed and volume of sludge produced
- Process equipment performance
  - Types of equipment in operation, maintenance procedures performed, and equipment calibration

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Abnormal Operating Conditions – Process Actions

- Measurement of turbidity levels at inlet and outlet of sedimentation basin shows process removal efficiency
- If coagulant dosage increases, sludge removal frequency may also increase
- Decreasing water temperature decreases settling rate and vice versa
- Increased settled water turbidity can lead to premature clogging of filters

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Sedimentation Process Troubleshooting

Source Water Quality Change	Operator Action	Possible Process Changes
Turbidity Temperature Alkalinity pH Color	1. Perform necessary analyses to determine extent of change 2. Evaluate overall process performance 3. Perform jar tests 4. Make process changes 5. Increase frequency of process monitoring 6. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Change frequency of sludge removal 5. Increase alkalinity by adding lime, caustic soda, or soda ash

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Sedimentation Process Troubleshooting

Flocculation Process Effluent Quality Changes	Operator Actions	Possible Process Changes
Turbidity Alkalinity pH	1. Evaluate overall process performance 2. Perform jar tests 3. Verify performance of coag-floc process 4. Make process changes 5. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Adjust improperly working chemical feeder

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Sedimentation Process Troubleshooting

Sedimentation Basin Changes	Operator Actions	Possible Process Changes
Floc settling Rising or floating sludge	1. Observe floc settling characteristics: • Dispersion • Size • Settling rate 2. Evaluate overall process performance 3. Perform jar tests • Assess floc size and settling rate • Assess quality of settled water 4. Make process changes 5. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Change frequency of sludge removal 5. Remove sludge from basin 6. Repair broke sludge rakes

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Sedimentation Process Troubleshooting

Sedimentation Process Effluent Quality Changes	Operator Actions	Possible Process Changes
Turbidity color	1. Evaluate overall process performance 2. Perform jar tests 3. Verify process performance • Coag-floc process • Floc settling characteristics 4. Make process changes 5. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Change frequency of sludge removal

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Types of Equipment

- Sludge removal equipment
- Sludge pumps
- Sump pumps
- Valves
- Flowmeters and gauges
- Water quality monitors
- Control systems

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Sedimentation

Vocabulary

A. Absorption
B. Adsorption
C. Clarifier
D. Complete Treatment
E. Density
F. Detention Time
G. Dewater
H. Direct Filtration
I. Effluent
J. Influent
K. Launders
L. Overflow Rate
M. Plug Flow
N. Precipitate
O. Representative Sample
P. Sedimentation
Q. Septic
R. Shock Load
S. Short-Circuiting
T. Slurry
U. Supernatant
V. Tube Settler
W. Turbidity

_____ 1. A watery mixture or suspension (not dissolved) matter; a thin, watery mud or any substance resembling it.

_____ 2. To remove or separate a portion of the water present in a sludge or slurry.

_____ 3. The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material.

_____ 4. A sample portion of material or water that is as nearly identical in content and consistency as possible to that in the larger body of water being sampled.

_____ 5. A measure of the cloudiness of water.

_____ 6. A type of flow that occurs in tanks, basins or reactors when a slug of water moves through a tank without ever dispersing or mixing with the rest of the water flowing through the tank.

_____ 7. Water or other liquid flowing from a reservoir, basin, treatment process, or treatment plant.

_____ 8. A larger circular or rectangular tank or basin in which water is held for a period of time during which the heavier suspended solids settle to the bottom.

_____ 9. The theoretical (calculated) time required for a small amount of water to pass through a tank at a given rate of flow.

_____ 10. Liquid removed from settled sludge.

_____ 11. Sedimentation basin and filter discharge channels consisting of overflow weir plates and conveying troughs.

_____ 12. A condition that occurs in tanks or basins when some of the flowing water entering a tank flows along a nearly direct pathway from the inlet to the outlet.

_____ 13. A measure of how heavy a substance (solid, liquid, or gas) is for its size.

_____ 14. A condition produced by bacteria when all oxygen supplies are depleted.

_____ 15. A method of treating water consists of the addition of coagulant chemicals, flash mixing, coagulation, minimal flocculation, and filtration.

_____ 16. The taking in or soaking up of one substance into the body of another by molecular or chemical action.

_____ 17. The arrival at a water treatment plant of raw water containing unusual amounts of algae, colloidal matter, color, suspended solids, turbidity or other pollutants.

_____ 18. A device that uses bundles of small-bore tubes installed on an incline as an aid to sedimentation.

_____ 19. A water treatment process in which solid particles settle out of the water being treated in a large clarifier or sedimentation basin.

_____ 20. A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation-flocculation, sedimentation and filtration. Also called conventional treatment.

_____ 21. One of the guidelines for the design of settling tanks and clarifiers in treatment plants;

_____ 22. An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.

_____ 23. Water or other liquid flowing into a reservoir, basin, treatment process, or treatment plant.

Answers

1. T	7. I	13. E	19. P
2. G	8. C	14. Q	20. D
3. B	9. F	15. H	21. L
4. O	10. U	16. A	22. N
5. W	11. K	17. R	23. J
6. M	12. S	18. V	

Review Questions
Sedimentation

1. List as many factors as you can recall that affect particle setting in a sedimentation basin.

2. What types of currents may be found in a typical sedimentation basin?

3. List the four zones into which a typical sedimentation basin can be divided.

4. What is the purpose of the settling zone in a sedimentation basin?

5. What are launders?

6. List three possible shapes for sedimentation basins.

7. Why are rectangular sedimentation basins often preferred over circular basins?

8. During the operation of a solids-contact unit, what items should be of particular concern to the operator?

9. List two advantages of solids-contact units.

10. List the devices that may be used to provide recirculation in a solids-contact unit.

11. Why must accumulated sludge be removed periodically from the bottom sedimentation basins?

12. How can the depth of sludge in a sedimentation basin be measured?

13. The actual performance of sedimentation basins depends on what two major factors?

14. What items should an operator monitor during the normal operation of the sedimentation process?

15. What should be attempted if the sludge line plugs frequently?

16. In the routine operation of the sedimentation process, what types of records should be maintained?

Sedimentation Review Questions
Answers

1. (1) Particle size and distribution, (2) shape of particles, (3) density of particles, (4) temperature of water, (5) electrical charge on particles, (6) dissolved substances in water, (7) flocculation characteristics of the suspended material, (8) environmental conditions, (9) sedimentation basin hydraulic and design characteristics

2. (1) Surface currents induced by winds, (2) density currents caused by differences in suspended solids concentrations and temperature differences, and (3) eddy currents produced by the flow of the water coming into and leaving the basin

3. (1) Inlet zone, (2) settling zone, (3) sludge zone, (4) outlet zone

4. To provide a calm, undisturbed storage place for the flocculated water for a sufficient time period to permit effective settling of the suspended particles in the water being treated

5. Launders are skimming or effluent troughs used to uniformly collect settled water. Adjustable V-notch weirs are generally attached to the launders for controlling the water level in the sedimentation basin

6. Sedimentation basins are available in circular, rectangular, or square shapes

7. Rectangular sedimentation basins are often preferred over circular basins because circular basins are generally more sensitive to short-circuiting and achieve poorer solids removal.

8. Care must be exercised to ensure that a uniform sludge blanket is formed and is subsequently maintained throughout the solids removal process. Other important factors include control of chemical dosages, mixing of chemicals, and control of the sludge blanket.

9. (1) Only one reaction unit to contend with, (2) ability to accumulate slurry during periods of severe taste and odor problems, (3) use slurry accumulation to carry plant when coagulation fails because of increased algal activities

10. Recirculation in a solids-contact unit may be provided by impellers, turbines, pumping units, or by air injection.

11. (1) Prevent interference with the settling process, (2) prevent the sludge from becoming septic or providing an environment for the growth of microorganisms that can create taste and odor problems, (3) prevent excessive reduction in the cross-sectional area of the basin

12. The depth of sludge in a sedimentation basin can be measured with a sludge blanket sounder, a bubbler tube, an aspirator, or an ultrasonic level indicator.

13. (1) the settling characteristics of the suspended particles, (2) the flow rate through the sedimentation basins

14. The operator should monitor the turbidity of the water entering and leaving the basin and the temperature of the water entering the basin.

15. Frequent clogging of the sludge discharge line is an indication that the sludge concentration is too high. If this occurs, try increasing the frequency of operation of the sludge removal equipment.

16. (1) influent and effluent turbidity and influent temperature, (2) process production inventory, and (3) process equipment performance

Section 6

Filtration

FILTRATION

CALIFORNIA STATE UNIVERSITY: SACRAMENTO

WATER TREATMENT PLANT OPERATION VOL. I

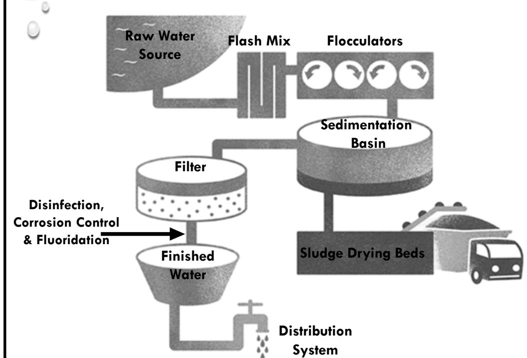
OBJECTIVES

- Filtration Process and Mechanisms
- Types of Filters
- Operational Criteria
- Filter Operation
- Process Performance Considerations

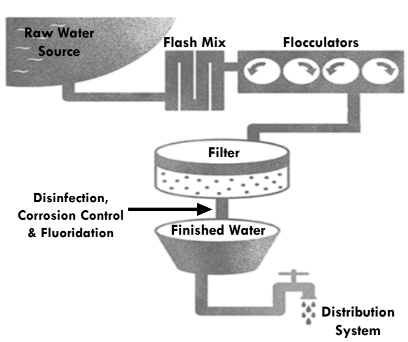
PROCESS DESCRIPTION

- Process of passing water through a material to remove floc and particulate matter (colloids)
  - Filter through a bed of sand, coal, or other granular substances
- Conventional Filtration
  - Coagulation, flocculation, sedimentation and filtration
- Direct Filtration
  - Sedimentation step is omitted

CONVENTIONAL FILTRATION



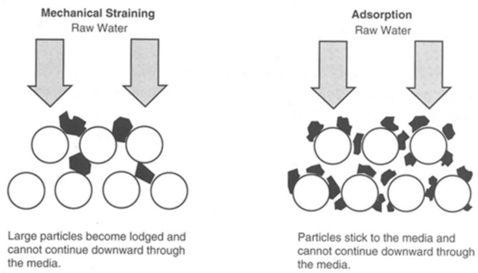
DIRECT FILTRATION



FILTRATION MECHANISMS

- Physical and chemical process
- Removal mechanisms
  - Sedimentation on media
  - Adsorption
  - Biological action
  - Absorption
  - Straining
- Removal mechanisms based on
  - Chemical characteristics of the water being treated
  - Nature of suspension
  - Types and degree of pretreatment
  - Filter type and operation

FILTRATION MECHANISMS



TYPES OF FILTERS

TYPES OF FILTERS

- Gravity filtration
  - Sand, dual media, and mixed media
- Pressure filtration
  - Mixed media
- Diatomaceous earth
  - Precoat filtration
- Slow sand filtration

GRAVITY FILTRATION

- Particulate impurities are removed in/on the media
- Water level or pressure (head) above the media forces water through the filter
- Types of gravity filters (TN Design Criteria)
  - Single media
    - Depth of at least 30 inches
  - Dual media
    - Sand (10 inches) and crushed anthracite (20 inches)
  - Multimedia
    - To be approved by department
- Filtration Rates (average)
  - 2 gpm/ft^2 for turbidity removal
  - 3 gpm/ft^2 for iron removal plants

GRAVITY FILTRATION

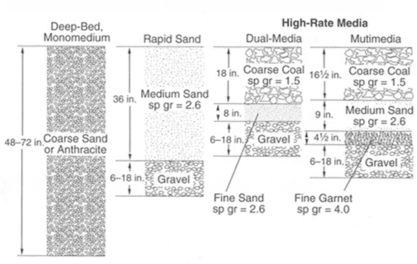
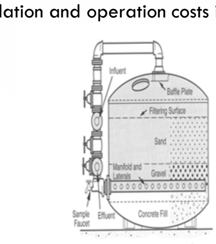


FIGURE 6-8 Comparison of deep-bed, rapid sand, and high-rate filter media

PRESSURE FILTRATION

- Similar to gravity filter except completely enclosed in a pressure vessel
- Lower installation and operation costs ins small filtration plants

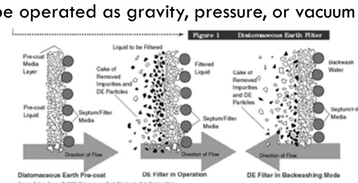


Courtesy of Celite Corporation

FIGURE 6-37 Vertical sand pressure filter tank

DIATOMACEOUS EARTH (DE) FILTRATION

- Aka precoat filtration
- Filter media is added to the water as a slurry, then collected on a septum or screening device
- After the initial precoat application, water is filtered by passing it through the coated stream
- Primarily a straining process
- Can be operated as gravity, pressure, or vacuum filter



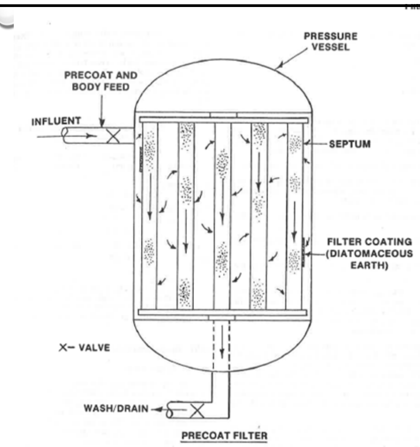
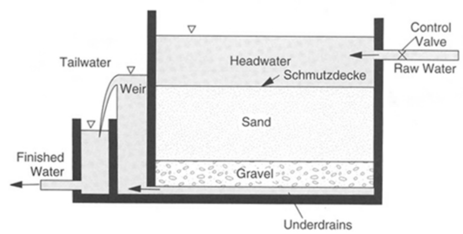


Fig. 6.5 Diatomaceous earth filter

SLOW SAND FILTRATION

- Water drawn through the filter media by gravity
- Filtration rates are very low
- Most particulate matter removed in top several inches of sand
- Entire layer must be physically removed when filter becomes clogged
  - No backwashing
  - No chemical pretreatment
  - Schmutzdecke – fine sand and a sticky mat of suspended matter that forms on the sand surface

SLOW SAND FILTRATION



Source: Barrett et al. (1991).

FIGURE 6–7 Schematic cross section of a slow sand filter

OPERATIONAL CRITERIA

FILTER MEDIA CLASSIFICATION

- Effective size (ES) – size of a sieve opening that permits 10% of the particles to pass through
  - If limiting head loss is a problem, but turbidity breakthrough is not, consider larger media size
  - If turbidity breakthrough is a problem but not limiting head loss, smaller media may be considered
  - If both head loss and turbidity breakthrough are a constant problem, use a deeper filter bed with larger media
- Uniformity coefficient (UC) – the ratio of particle diameters comprising 60% and 10% media weight
  - Media with lower uniformity coefficients are composed of more uniform particles
- Specific gravity
- Hardness

FILTER PRODUCTION & FILTRATION RATE

- Measures of the amount of water that can be processed through an individual filter in a given period of time
- Filter Production
  - Measured in MGD (millions of gallons per day)
- Filtration Rate (aka hydraulic loading)
  - Used to measure flow of water through a filter
  - Measured in gallons per minute per square foot (gpm/ft^2)
  - Average filtration rates
    - 2 gpm/ft^2 for turbidity removal
    - 3 gpm/ft^2 for iron removal plants

FILTRATION EFFICIENCY

- Measured by overall plant reduction in turbidity
- Removal efficiency depends on
  - The quality of the water being treated
  - The effectiveness of the pretreatment (coag/floc) processes
  - Filter operation
  - Filter design
  - Media type and thickness
    - Sand filters have fine, light grains on top that stop all particulates at the surface
    - Dual media filters have lighter larger diameter grains at the top that stop the larger particles; smaller particles are usually stopped farter down in the filter

FILTER OPERATION

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FILTRATION MODE

- Water containing suspended solids is applied to the surface of the filter media
- Clogging – buildup of head loss (pressure drop) across the filter media
  - Total design head loss ranges from 6 to 10 feet
  - Terminal head loss is considered to be at 10 ft, but this will be different from plant to plant
- Clogging leads to breakthrough – a condition in which solids are no longer removed
  - Solids pass into the filter effluent where they appear as increased turbidity

BACKWASHING

- Process of reversing the flow of water through the filter media to remove entrapped solids after
  - Maximum head loss reached
  - Breakthrough occurs
  - Specified time period has passed
- Filter media must be fluidized (expanded) by reversing flow
- Backwash rates of 10-25 gpm/ft^2 required
- Insufficient backwashing may not adequately clean filter
- Too high backwash rate may cause excessive loss of media
- Higher backwash rates are required at higher temperatures due to less viscous water
- 50% bed expansion (TN Design Criteria)

BACKWASHING

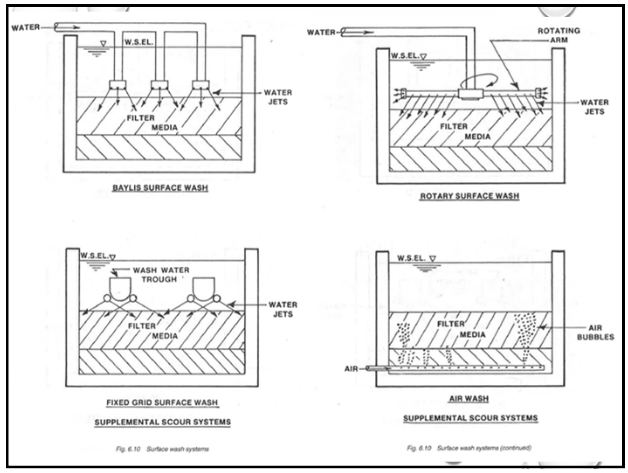
Filter Backwash Video

https://youtu.be/UmzR3TRTz2U

- Water use for backwashing may be recycled directly to the headworks (ahead of the flash mix)
- Filter Backwash Rule requires that recycled filter backwash water, sedimentation basin sludge thickener supernatant, and liquids from sludge dewatering processes be returned upstream of all conventional treatment systems
  - Systems may apply to the State for approval
  - Purpose is to improve performance at filtration pants by reducing opportunity for microbes such as *Cryptosporidium* to pass through the treatment process

SURFACE WASH

- Provides additional scrubbing action to remove attached floc and other entrapped solids from the filter media
- 4 types:
  - Baylis
  - Fixed grid
  - Rotary
  - Air scour



FILTER CONTROL SYSTEMS

- Regulate flow rates through the filter
- Control system types
  - Rate-of-flow
    - Each filter effluent control valve is connected to a flow meter
    - As the media begins to clog, the control valve opens to maintain a constant flow
    - All filters operate at same flow rate
  - Split-flow
    - Equal flow to each filter influent is split or divided by a weir
    - Effluent valve position controlled by water level in the filter

FILTER CONTROL SYSTEMS

- Regulate flow rates through the filter
- Control system types
  - Declining-rate
    - Flow rate varies with head loss
    - Each filter operates the same but has variable, water surface levels
  - Self-backwashing (or Streicher design)
    - Influent flow to each filter is divide by a weir
    - Water surface level varies according to head loss while flow rate remains constant
    - Reduces amount of equipment needed

PROCESS PERFORMANCE CONSIDERATIONS

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PROCESS PERFORMANCE

- Activated Carbon Contactors
  - High adsorptive capacity of activated carbon enables it to remove taste and odor causing compounds and other organics
- Importance of Pretreatment
  - Floc particles carried over into the filter must be small enough to penetrate the upper filter media
  - Floc that is too large will clog the top portion of the filter bed rapidly
  - Floc removal is accomplished by contact with the media grains
    - Ripening period - time after initial coating of media surfaces with floc; subsequent applications of floc will build up on the material previously deposited
      - High effluent turbidities may occur during the ripening period

IN-LINE FILTRATION

- The addition of coagulant chemicals immediately before the water enters the filtration system
- Filter aids are added directly to the filter inlet pipe and mixed by the flowing water
  - Separate flocculation and sedimentation facilities are eliminated
- Not as efficient as conventional or direct filtration
- Important process control guidelines
  - Filter influent water quality – turbidity
  - Filter performance - head loss buildup rate and filter run time
  - Filter effluent water quality - turbidity

NORMAL OPERATING CONDITIONS

- Filter effluent turbidities will give a good indication of overall process performance
- Operator should monitor filter influent turbidity as well as filter effluent turbidity levels
- Monitor head loss buildup and filter effluent color
- Guidelines would help evaluate normal process conditions and in recognizing abnormal conditions

PROCESS ACTIONS

- Measurement of head loss buildup can indicate performance of solids removal process
  - Total designed head loss in a gravity filter is usually about 10 feet
  - Loss-in-head – actual head loss from a point above the filter media to a reference point in the effluent
  - Sudden increase in head loss may indicate surface sealing of the filter media (lack of depth penetration)

PROCESS ACTIONS

- Filter Run Time or Length
  - Should be calculated based on head loss, effluent turbidity and/or elapsed run time
  - A predetermined value set for each parameter as a cutoff point for filter operation
    - When any one of these levels is reached, the filter is backwashed
  - Filter run length not a satisfactory basis for comparing filter runs without considering filtration rate as well

PROCESS ACTIONS

- Unit Filter Run Volume (UFRV)
  - Volume of water produced by the surface area of the filter during the course of the filter run divided by the surface area of the filter
  - Expressed in gallons per square foot (gal/ft^2)
  - UFRV > 5,000 gal/ft^2 is good
  - UFRV > 10,000 gal/ft^2 is better
- Examine and evaluate filter media annually
  - Measure media thickness
    - Can be lost during backwash
  - Measure mudball accumulation
    - Indicates insufficient backwashing

PROCESS ACTIONS

- Observe backwash process to assess process performance
  - Watch for media boils, media carryover, waste wash water clarity
- Never "bump" filter to avoid backwashing
  - Bumping is the act of opening the backwash valve during the course of a filter run to dislodge the trapped solids and increase the filter run
- Observe the condition of the media surface and check for filter sidewall or media surface cracks
  - After completion of backwash cycle

INDICATORS OF ABNORMAL CONDITIONS

- Rapid changes in head loss buildup or turbidity breakthrough may be indicators of abnormal operation conditions:
  - Mudballs in filter media
  - Media cracking or shrinkage
  - Media boils during backwash
  - Excessive media loss or visible disturbance
  - Short filter runs
  - Filters that will not come clean during backwash
  - Algae on walls and media

PROCESS ACTIONS

- If filter turbidity removal efficiency is decreasing, evaluate coag/floc process and coagulant dosage
- Increases in source water turbidity may require a decrease in filtration rates or backwash filters more frequently
- Adding filter aids chemicals can help when pretreatment processes don't readily respond to source water quality changes
  - Overdosing can cause sealing of the filter media
- Decrease in alkalinity and pH can affect filtration since the coag/floc process performance can decrease

PROCESS ACTIONS

- Increases in filter effluent turbidity may also result from floc carryover from the sedimentation process
- Short filter runs can be caused by increased solids loading, filter aid overdosing, excessively high filtration rates, excessive mudball formation, or clogging of the filter underdrain system
- Backwash problems can be resolved by adjusting backwash flow rates, surface wash flow rates or duration, or adjusting the time sequence or duration of the backwash cycle
- Improper backwashing can result in mudball formation or filter cracks and shrinkage

AIR BINDING

- Caused by the release of dissolved air in saturated cold water due to a decrease in pressure
- Air is released from the water when passing through a filter bed by differences in pressure produced by friction through the bed
- The released air is entrapped in the filter bed
- Whenever a filter is operated to a head loss that exceeds the head of water over the media, air will be released
  - Occurs more frequently when large head losses are allowed to develop in filter
- Causes shortened filter runs due to water flow being restricted due to bound air

EXCESSIVE HEAD LOSS

- Filter underdrain system and head loss measurement equipment should be checked if excessive head losses remain after backwashing
- Can be caused by reduction in size and number of underdrain openings
  - Due to media clogging, corrosion, or chemical deposits

START UP PROCEDURES - BACKWASH

- Filters should be washed before placing them in service
  - Check length of cycle times set for backwash and surface wash cycles are correct
  - Surface wash should be activated before the backwash cycle starts and stopped before completion of the backwash cycle
  - Filter wash should begin slowly and provide uniform expansion of the filter bed
  - When backwash water coming up through filter becomes clear, media is clean (3-8 minutes)
  - Reduce backwash rate if media carryover or flooding of water troughs occurs
  - Waste backwash water is either recycled or sent to settling basin
    - Supernatant is then recycled through the plant

PARTICLE COUNTERS

- A device which counts and measures the size of individual particles in water
  - Particles are divided into size ranges and the number of particles is counted in each of these ranges
- One of the best monitoring tools available to optimize plant performance for the removal of particles
  - i.e. *Giardia* and *Cryptosporidium*
  - Monitors the removal efficiency of particles in the same size range as *Giardia* and *Crypto*
- Cannot replace other analytical tests for *Giardia* and *Crypto*
  - Cannot tell difference between clay particle and microorganism

RECORDKEEPING

- Accurate records should be maintained
  - Process water quality
    - Turbidity and color
  - Process operation
    - Filters in service, filtration rates, loss of head, length of filter runs, frequency of backwash, backwash rates, UFRV
  - Process water production
    - Water processed, amount of backwash water used, and chemicals used
  - Percent of water production used to backwash filters
  - Process equipment performance
    - Types of equipment in operation, equipment adjustments, maintenance procedures performed, and equipment calibration

SURFACE WATER TREATMENT RULE (SWTR)

- Set of treatment technique requirements that apply to all water systems using surface water and those using groundwater that is under the influence of surface water (subpart H systems)
- Defines surface water as "all water open to the atmosphere and subject to surface runoff"
- Requires that all systems properly filter the water
- Requires that all systems using surface water to disinfect the water (no exceptions)
- At least 99.99% (4-log) removal and/or inactivation of enteric (intestinal) viruses
- At least 99.9% (3-log) removal and/or inactivation of *Giardia* cysts
- At least 99% (2-log) removal of cryptosporidium

TURBIDITY REQUIREMENTS

Type of Filtration	Monitoring Frequency	Turbidity Level
Conventional	Every 4 hours	< 0.3 NTU
Direct	Every 4 hours	< 0.3 NTU
Diatomaceous Earth	Every 4 hours	< 1.0 NTU
Slow Sand	Once per day*	< 1.0 NTU

- All filtration systems must meet these standards in 95% of the measurements taken for each month (0400-45-01-.31)

*For any system using slow sand filtration or filtration treatment other than conventional treatment, direct filtration, or diatomaceous earth filtration, the Department may reduce the sampling frequency to once per day if it determines that less frequent monitoring is sufficient to indicate effective filtration performance.

Filtration
Vocabulary

A. Absorption

B. Activated Carbon

C. Adsorption

D. Air Binding

E. Backwashing

F. Breakthrough

G. Colloids

H. Conventional Filtration

I. Diatomaceous Earth

J. Diatoms

K. Direct Filtration

L. Fluidized

M. Head Loss

N. Uniformity Coefficient

_____ 1. Adsorptive particles or granules of carbon usually obtained by heating carbon.

_____ 2. A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation, minimal flocculation, and filtration.

_____ 3. The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, or restriction caused by fittings.

_____ 4. The ration of the diameter of a grain of a size that is barely too large to pass through a sieve that allows 60% material (by weight) to pass through

_____ 5. The process of reversing the flow of water back through the filter media to remove the entrapped solids.

_____ 6. Very small, finely divided solids that remain dispersed in a liquid for a long time due to their small size and electrical charge.

_____ 7. A fine, siliceous (made of silica) "earth" composed mainly of the skeletal remains of diatoms.

_____ 8. The clogging of a filter due to the presence of air released from water.

_____ 9. The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material.

_____ 10. A method of treating water that consists of the addition of coagulant chemicals, flash mixing, coagulation-flocculation, sedimentation and filtration.

_____ 11. Unicellular (single cell), microscopic algae with a rigid internal structure consisting mainly of silica.

_____ 12. A mass of solid particles that is made to flow like a liquid by injection of water or gas

_____ 13. A crack or break in a filter bed allowing the passage of floc or particulate matter through a filter.

_____ 14. The taking in or soaking up of one substance into the body of another by molecular or chemical action.

Answers

1. B
2. K
3. M
4. N
5. E
6. G
7. I
8. D
9. C
10. H
11. J
12. L
13. F
14. A

Filtration
Review Questions

1. What is the major difference between conventional filtration and direct filtration?

2. List the particle removal mechanisms involved in the filtration process.

3. List the four specific classes of filters.

4. What material is used for precoat and body-feed operations?

5. Filtration rate is commonly expressed in what units?

6. What is the major operation difference between sand and dual-media filters?

7. What two main factors influence the time period before a filter becomes clogged?

8. Under what conditions is the filtration process stopped and the filter taken out of service for cleaning or backwashing?

9. List four types of surface wash systems for filters.

10. What is the primary purpose of using activated carbon (granular form) as filter media?

11. What is in-line filtration?

12. When and where are filter aid chemicals used?

13. What factors must an operator measure to control the performance of the filtration process on a day to day basis?

14. What is the most important water quality indicator used to monitor the filtration process?

15. List some of the typical functions performed by operators in the normal operation of the filtration process.

16. What could cause a sudden increase in head loss through a filter?

17. What types of records should be kept when operating a filtration process?

18. How would you identify an upset or failure in the filtration process or pretreatment processes?

19. List the indicators of abnormal filtration process conditions.

20. How could you make a quick determination of filtration removal efficiency?

21. What problems may be encountered during backwash?

22. How does a filter become air bound?

23. What is the SWTR definition of surface water?

24. Particle counters can be used as a substitute for indicating the potential removal of what two microorganisms that are a threat to public health when found in drinking water?

Filtration
Review Question Answers

1. Filtration, preceded by coagulation, flocculation, and sedimentation, is commonly referred to as conventional filtration process, the sedimentation step is omitted. Flocculation facilities are reduced in size or may be omitted.

2. Sedimentation on media, adsorption, biological action, absorption, straining

3. Gravity filtration, pressure filtration, diatomaceous earth filtration, slow sand filtration

4. Diatomaceous earth

5. Gallons per minute per square foot

6. Sand filters require more frequent backwashing because of their smaller media grain size. Dual media filters permit a higher filtration rate without a high head loss.

7. The amount of suspended solids in the water being treated and the filtration rate

8. A filter is operated until just before clogging or breakthrough occurs, a specified time period has passed or a specific head loss is reached.

9. Baylis, fixed grid, rotary, air scour

10. To remove taste and odor causing compounds, as well as other trace organics from the water

11. Inline filtration refers to the addition of filter aid chemicals immediately prior filtration. Chemicals are added directly to the filter inlet pipe and are mixed by the flowing water

12. Filter aid chemicals are usually added just prior to filtration in the solids removal process during normal operation and during periods of pretreatment process upset, or when operating at high filtration rates.

13. Filter influent water quality (turbidity), filter performance, filter effluent water quality

14. Filter influent and effluent turbidity

15. Monitor process performance, evaluate water quality conditions and make appropriate changes, Check and adjust process equipment, backwash filters, evaluate filter media conditions, visually inspect facilities

16. Surface sealing of the filter media

17. Process water quality, process operation, process water production, percent of water production used to backwash filters, process equipment performance

18. Rapid changes in head loss buildup in the filter or turbidity breakthrough

19. Mudballs in filter media, media cracking or shrinkage, media boils during backwash, excessive media loss or visible disturbance, short filter runs, rapid head loss buildup, turbidity breakthrough, filters that will not come clean during backwash, algae on walls and media

20. Comparing filter influent and effluent turbidity levels with those of recent record

21. Media boils, media loss, and failure of the filter to come clean during the backwash process

22. By the release of dissolved air in saturated cold water due to the decrease in pressure

23. All water open to the atmosphere and subject to surface runoff

24. *Giardia* and *Cryptosporidium*

Section 7

Solids Handling & Disposal

Handling and Disposal of Process Wastes

California State University - Sacramento

Need for Handling and Disposal of Process Wastes

- Water Pollution Control Act Amendments of 1972 restricts discharge of process wastes
- National Pollutant Discharge Elimination System (NPDES) requires a permit to discharge to a body of water
- Three categories of water treatment plants
  - *Category 1* – Plants that use coagulation, oxidative Fe and Mn removal, OR direct filtration
  - *Category 2* – Plants that use only chemical softening process
  - *Category 3* – Plants that are a combination of 1 & 2

Process Sludge Volumes

- Sludge accumulation based on
  - Type & amount of suspended matter in source water
  - Level & type of coagulant used
- Organic polymers produce less sludge than alum
- Polymers are denser and easier to dewater
- Sedimentation tanks should be drained and cleaned at least twice a year
  - More often if sludge buildup interferes with treatment process

Methods of Handling and Disposal

- Remove sludge regularly during day
  - Send to drying bed
  - Regular removal of water on top of bed will speed drying
- Drain tank and remove sludge semi-annually
- Backwash recovery ponds or lagoons separate water from solids
  - Also used to concentrate or thicken sludges
- Thickening, conditioning, and dewatering
- Discharge to wastewater collection system
- Spreading on land or dumping in landfill

Methods of Handling and Disposal

- Thickening – treatment to remove water from the sludge mass to reduce the volume that must be handled
- Conditioning – pretreatment of sludge to facilitate removal of water in subsequent treatment processes
  - Polymers can be added to condition sludge
- Dewater – to dry sludge so it can be handled and disposed of
  - Belt filter presses, centrifuges, filter presses, vacuum filters, solar lagoons, and sand drying beds

Draining and Cleaning of Tanks

- Should be done twice a year
  - Before and after peak demand months
- Determine water table level before draining underground storage tank
  - If table is high, tank can float
- Hose down all surfaces as tank is draining
  - Dried sludge is very difficult to remove
- Drain should be located in the headworks area
  - Sludge is denser near the entrance to tank

Sludge Dewatering

Solar Drying Lagoons

- Shallow, small-volume storage ponds
- Sludge settles to bottom and supernatant is skimmed off top
- Sludge is dried to concentration of 30-50% solids by evaporation and solar drying
- Sludge then disposed of on site or at landfill
- Due to process taking a long time, several lagoons should be provided

Sludge Dewatering

Sand Drying Beds

- Consists of layer of sand, support gravel layer, underdrain, system, sludge removal method
- Drying can vary from days to weeks
  - Precondition sludge with coagulant to improve dewatering process
- Sludge will not expand once even partially dried
  - Layer of layer of wet sludge can be added over a period of time
  - Sludge must be at least 2-3% solids

Sludge Dewatering

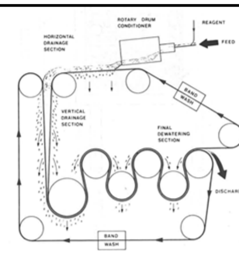
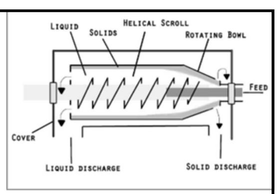


Fig. 17.9 Flow diagram of Winklepress (a continuous-belt filter press)
(Permission of Ashbrook-Simon-Hartley)

Belt Filter Presses

- Two primary mechanisms:
  - Gravity drainage
  - Pressure dewatering
- Dries to 35-40% solids
- Sludge is conveyed and dewatered between two endless belts
- Three distinct zones
  - Horizontal zone for gravity drainage
  - Vertical sandwich draining zone
  - Final dewatering zone containing arrangement of staggered rollers to squeeze out remaining free water

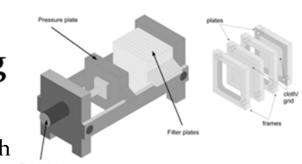
Sludge Dewatering



Centrifuges

- Two types
  - Scroll centrifuge
    - Solids introduced horizontally into center of unit
    - Spinning action forces solids against outer wall
    - Solids transported to discharge end by rotating screw
  - Basket centrifuge
    - Sludge introduced vertically bottom of bowl and supernatant is discharged over weir at top
    - When solids in supernatant gets too high, operation is stopped and the dense solids cake is removed by a knife unloader

Sludge Dewatering



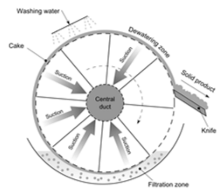
Filter Presses

- Best suited for sludges with high specific resistance
  - the internal resistance of a sludge cake to the passage of water
- Consists of a series of vertical plates covered with cloth
  - Sludge fed into press
  - Plates pressed together at pressures as high as 225 psi
  - Water passes through cloth; solids retained on cloth
  - Cake is formed that is removed when press is depressurized

Sludge Dewatering

Vacuum Filters

- Cylindrical drum rotates in a tank of sludge
- Vacuum applied under belt to form cake on surface
- Belt separates from drum as goes over top
- Belt is then washed before it re-enters the vat
- Precoat of diatomaceous earth required to dewater alum sludge



Disposal of Sludge

- Lime sludge is excellent for agricultural purposes
- Alum sludge must not be applied to agricultural land
  - Causes soils to harden and does not provide any beneficial value
  - Can be sent to landfill or land applied and plowed into soil
- Slow sand filter for iron treatment has top layer removed instead of backwashing
  - Must be disposed of in sanitary landfill
- Ion exchange softener regeneration wastewater may be very slowly and carefully discharged into sewer
- Filter backwash water must be recycled through water treatment plant or placed in storage pond

Section 8

Safety

SAFETY

ACCIDENT

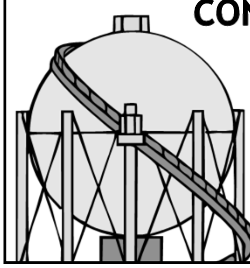
- An accident is caused by either an unsafe act or an unsafe environment

GENERAL DUTY CLAUSE

Federal – 29 CFR 1903.1

- EMPLOYERS MUST:
  - Furnish a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm to employees
  - Comply with occupational safety and health standards promulgated under the Williams-Steiger Occupational Safety and Health Act of 1970.

CONFINED SPACES



CONFINED SPACE CONDITIONS

- Large enough and so configured that an employee can bodily enter and perform assigned work
- Limited or restricted means of entry or exit
- Not designed for continuous employee occupancy

CONFINED SPACE EXAMPLES

- Vaults
- Silos
- Inside filters
- Basins
- Storage tanks
- Pits
- Hoppers

EQUIPMENT NEEDED

- Safety harness with lifeline, tripod, and winch
- Electrochemical sensors
- Ventilation blower with hose

EQUIPMENT NEEDED cont'd

- PPE
- Ladder
- Rope
- Breathing apparatus

PERMIT REQUIRED CONFINED SPACE

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf an entrant
- Entrant could be trapped or asphyxiated
- Positions required for entrance into a permit required confined space
  - Supervisor
  - Attendant – at least one person much be outside a permit required space
  - Entrant

ATMOSPHERIC HAZARDS

- Need to have atmosphere monitored!!!
- In order
  - Depletion or elimination of breathable oxygen
  - Explosive or flammable air
  - Toxic air

HYDROGEN SULFIDE - H_2S

- Detected by the smell of rotten eggs
- Loss of ability to detect short exposures
- Not noticeable at high concentrations
- Exposures to 0.07% to 0.1% will cause acute poisoning and paralyze the respiratory center of the body
- At the above levels, death and/or rapid loss of consciousness occur

METHANE GAS - CH_4

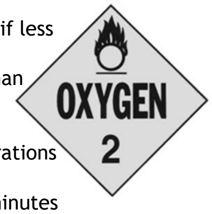
- Product of waste decomposition
- Leaks in natural gas pipelines can saturate the soil
- Explosive at a concentration of 5%
- Spaces may contain concentrations above the Lower Explosive Limits (LEL) and still have oxygen above the 19.5% allowable
- Gasoline storage tanks, gas stations, petroleum product pipelines, accidental spills by traffic accidents

CARBON MONOXIDE - CO

- Decreases amount of oxygen present
- ALWAYS VENTILATE
- 0.15% (1500 ppm) = DEATH
- Will cause headaches at 0.02% in a two hour period
- Maximum amount of 0.04% in 60 minute period
- Colorless, odorless, tasteless, flammable and poisonous

OXYGEN - O_2

- ALWAYS ventilate – normal air contains ~ 21%
- Oxygen deficient atmosphere if less than 19.5%
- Oxygen enriched at greater than 23.5%
  - Speeds combustion
- Leave area if oxygen concentrations approach 22%
- At 8%, you will be dead in 6 minutes
- At 6%, coma in 40 seconds and then you die



OXYGEN – O_2

- When O_2 levels drop below 16%, a person experiences
  - Rapid fatigue
  - Inability to think clearly
  - Poor coordination
  - Difficulty breathing
  - Ringing in the ears
  - Also, a false sense of well-being may develop

OXYGEN – O_2

- In a confined space, the amount of oxygen in the atmosphere may be reduced by several factors
  - Oxygen consumption
    - During combustion of flammable substances
    - Welding, heating, cutting or even rust formation
  - Oxygen displacement
    - Carbon dioxide can displace oxygen
  - Bacterial action

ATMOSPHERIC ALARM UNITS

- Should continuously sample the atmosphere of the area
- Test atmospheres before entering
- Test for oxygen first
- Combustible gases second

ATMOSPHERIC ALARM UNITS

- Alarms set to read flammable gasses exceeding 10% of the lower explosive limit
  - H_2S exceeds 10 ppm and/or O_2 percentage drops below 19.5%
- Calibrate unit before using
- Most desirable units simultaneously sample, analyze, and alarm all 3 atmospheric conditions

SPACES THAT REQUIRE PERMITS

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf and entrant
- Entrant could be trapped or asphyxiated

WRITTEN ENTRY SYSTEM

- Employer shall document entry permits
- Entry supervisor signs permits
- Permit posted
- Shall not exceed time required
- Retain permits for at least 1 year

INFORMATION ON PERMIT FORMS

- Space to be entered
- Purpose
- Date and authorized duration
- Attendant ID by name
- Authorized entrants ID by name
- Entry supervisor name and signature
- Hazards of permit space
- Measures to eliminate, isolate, or control the hazards
- Results of tests
- Rescue and emergency services
- Communications

INFORMATION ON EQUIPMENT

- PPE (personal protective equipment)
- Testing equipment

DUTIES OF ENTRANTS

- Know signs, symptoms, and consequence of exposure
- Properly use equipment
- Alert attendant of warning signs, symptoms and other possible hazards
- Exit when ordered to evacuate by supervisor or attendant

DUTIES OF CONFINED SPACE ATTENDANT

- Know signs, symptoms, and consequences of exposure
- Possible behavioral effects of hazards
- Maintain accurate count of entrants
- Remain outside permit space
- Communicate with entrants
- Summon rescue and emergency units

DUTIES OF CONFINED SPACE ATTENDANT

- Warn unauthorized persons to stay away
- Perform non-entry rescue
- Do not perform any duties that interfere with primary duty of monitoring and protecting entrants

DUTIES OF SUPERVISORS AND MANAGERS

- Knowledge of signs, symptoms, and consequences of exposure
- Verify appropriate entries, procedures, tests and equipment
- Terminate entries and cancel permits if warranted
- Verify means for summoning rescue
- Ensure that acceptable conditions are maintained and operations remain consistent with entry permit

REQUIRED TRAINING

- Employer shall train all employees on hazards, procedures, and skills to perform their jobs safely
- Employees trained before first assigned duty
- Employer shall certify training of employees
- Maintain individual training records of employees

RECORD KEEPING

- Identification and evaluation of all hazardous areas in workplace
- Entrance permits filed
- Training certification
- Written confined space program

GENERAL REQUIREMENTS

- Identify, evaluate, and monitor hazards in permit-required confined spaces
- Post signs "Permit Required"
- Prevent unauthorized entries
- Re-evaluate areas
- Inform contractors
- Have a written program available for employees
- Have proper PPE
- Annual training (OSHA requirement)

CONFINED SPACE REQUIREMENTS

- All electrodes removed and machines disconnected from power sources
- Gas supply shut off
- Gas cylinders outside of work area
- All employees entering must undergo confined space training
- Ventilation used to keep toxic fumes, gasses, and dusts below max levels

LOCKOUT / TAGOUT

LOCKOUT/TAGOUT

General Requirements

- Written program
- Utilize tagout system if energy isolating device not capable of being locked out
- Lockout/tagout hardware provided
- Devices used only for intended purposes
- Tagout shall warn:
  - **DO NOT START. DO NOT ENERGIZE. DO NOT OPERATE.**
- Only trained employees shall perform lockout/tagout

LOCKOUT/TAGOUT

Requirements When Lockout of Equipment

- Notify employees
- Employees notified after completion of work and equipment are re-energized

LOCKOUT/TAGOUT

Recommended Steps for Lockout/Tagout

- Notify employees that device is locked and tagged out
- Turn off machinery normally
- De-activate energy
- Use appropriate lockout/tagout equipment
- Release any stored energy
- Try to start machine by normal means

LOCKOUT/TAGOUT

Steps for Restoring Equipment

- Check area for equipment or tools
- Notify all employees in the area
- Verify controls are in neutral
- Remove lockout/tagout devices and re-energize device
- Notify employees maintenance and/or repairs are complete and equipment is operational

LOCKOUT/TAGOUT

Training Requirements

- Employer shall train all employees
- All new employees trained
- Recognition of applicable hazardous energy
- Purpose of program
- Procedures
- Consequences
- ANNUAL REQUIREMENT

LOCKOUT/TAGOUT

Inspections

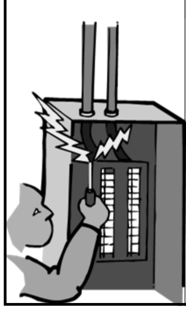
- Conduct periodic inspection, at least annually
- Shall include review between the inspector and each authorized employee
- Recommendation
  - Frequent walk-throughs of work areas and observation of Maintenance and Operation area

LOCKOUT/TAGOUT

Required Record Keeping

- Written lockout/tagout program
- Training
  - Annually and new employees
- Inspections
  - Annual including new equipment, inspection of devices, and procedures

TOP 10 MOST FREQUENTLY CITED STANDARDS



ELECTRICAL SAFETY

ELECTRICAL SAFETY

OSHA says:

- Any electrical installations shall be done by a professionally trained electrician
- Any employee who is in a work area where there is a danger of electric shock shall be trained
- Employees working on electrical machinery shall be trained in lockout/tagout procedures

TRANSFORMER

- Allows energy to be transferred in an AC system for one circuit to another
- Used to convert high voltage to low voltage
  - High voltage is 440 volts or higher
- Standby engines should be run weekly to ensure that it is working properly
- Relays are used to protect electric motors

FIRE PROTECTION

FIRE PROTECTION

Equipment

- Fire extinguishers shall be located where they are readily accessible
- Shall be fully charged and operable at all times
- All fire fighting equipment is to be inspected at least annually

FIRE PROTECTION

Fire Protection Equipment

- Portable fire extinguishers inspected at least monthly and records kept
- Hydrostatic testing on each extinguisher every five years
- Fire detection systems tested monthly if battery operated

TYPES OF FIRE EXTINGUISHERS

- **Class A**

  - Used on combustible materials such as wood, paper or trash
  - Can be water based
- **Class B**

  - Used in areas where there is a presence of a flammable or combustible liquid
  - Shall not be water based
  - Example is dry chemical extinguisher
  - An existing system can be used but not refilled

TYPES OF FIRE EXTINGUISHERS

- **Class C**

  - Use for areas electrical
  - Best is carbon dioxide extinguisher
  - Using water to extinguish a class C fire risks electrical shock
- **Class D**
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire

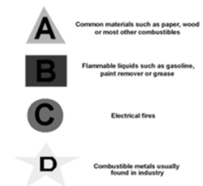
FIRE EXTINGUISHERS

Types of Fire Extinguishers

Class	Material	Method
A	Wood, paper	Water
B	Flammable liquids (oil, grease, paint)	Carbon dioxide, foam, dry chemical, Halon
C	Live electricity	Carbon dioxide, dry chemical, Halon
D	Metals	Carbon dioxide

TYPES OF FIRE EXTINGUISHERS

- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area



FIRE EXTINGUISHERS

- To operate a fire extinguisher, remember the word **PASS**
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you.
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

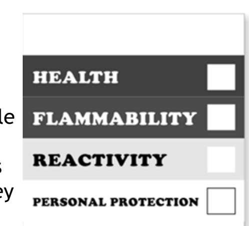
CHEMICAL SAFETY

PERSONAL PROTECTIVE EQUIPMENT (PPE)

- Gloves
- Coveralls/overalls
- Face shield/goggles
- Respirator/SCBA
- Boots
- Ear plugs/muffs

RTK LABELS

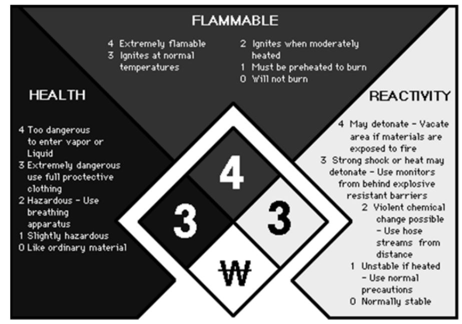
- "Right to Know"
  - In 1983, OSHA instituted Hazard Communication Standard 1910-1200, a rule that gives employees the right to know the hazards of chemicals to which they may be exposed in the workplace.



NFPA

- National Fire Protection Association
- Chemical hazard label
  - Color coded
  - Numerical system
    - Health
    - Flammability
    - Reactivity
  - Special precautions
- Labels are required on all chemicals in the lab

CHEMICAL HAZARD LABEL



CHEMICAL HAZARD LABEL

Degrees of Hazard

- Each of the colored areas has a number in it regarding the degree of hazard
  - 4 → extreme
  - 3 → serious
  - 2 → moderate
  - 1 → slight
  - 0 → minimal

CHEMICAL HAZARD LABEL

Special

- W → water reactive
- Ox → oxidizing agent

SAFETY DATA SHEET

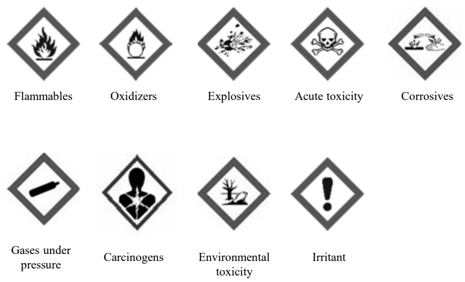
- OSHA moving from HCS (Hazard Communication Standard) to GHS (Globally Harmonized System)
- Revised criteria for chemical hazard classification, labeling & new format for Safety Data Sheets (SDS)
- Final rule effective May 25, 2012 but compliance dates are phased in:
  - Complete training on new label formats: 12/1/13
  - Comply with label and SDS requirements: 6/1/15
  - Update Hazcom programs: 6/1/16

MINIMUM INFO FOR SDS

- Product identification
- Hazard Identification
- Composition/info on ingredients
- First-aid measures
- Fire-fighting measures
- Accidental release measures
- Handling and storage
- Exposure controls
- Physical/chemical properties
- Stability & reactivity
- Toxicological information
- Ecological information*
- Disposal considerations*
- Transport information*
- Regulatory information*
- Other information (including date of SDS or last revision)

* Non mandatory

OSHA PICTOGRAMS



WORKPLACE LABELING

- Can HMIS or NFPA system be used?
- While, the hazard category does not appear on the label, consider

GHS Category	Hazard		HMIS/NFPA Category	Hazard
1	highest		1	slight
2	high		2	moderate
3	medium	→	3	serious
4	low		4	severe

NFPA categories were intended for emergency response, not workplace hazards; only considers acute effects, does not consider chronic effects

TERMS

- Lower Explosive Level (LEL)
  - minimum concentration of flammable gas or vapor in air that supports combustion
- Upper Explosive Level (UEL)
  - maximum concentration of flammable gas or vapor in air that will support combustion
- Teratogen
  - causes structural abnormality following fetal exposure during pregnancy
- Mutagen
  - capable of altering a cell's genetic makeup

LIQUID CHLORINE & HYPOCHLORITE SAFETY

CHLORINE GAS – Cl_2

- 2.5 times as dense as air
- Liquid expands easily into gas at room temperature 460 times
- Pungent, noxious odor
- Greenish-yellow color
- Nonflammable and nonexplosive but will support combustion
- Toxic by inhalation, ingestion and through skin contact
- May irritate or burn skin

CHLORINE GAS – Cl_2

- Inhalation can cause serious lung damage and may be fatal
  - 1000 ppm (0.1%) is likely to be fatal after a few deep breaths
    - half that concentration, fatal after a few minutes
- It takes as little as 0.3 ppm to be detected as a distinct odor

CHLORINE SAFETY

Safety Precautions for Chlorine Gas

- Compressed air
  - 30-minute capacity
- Annually inspected
- Trained/fit tested
- PPE
  - Rubber gloves
  - Apron
  - Goggles
  - Safety shower, eyewash

CHLORINE SAFETY

Where Chlorine Gas Is Used:

- Separate room for chlorine, with window to view inside
- Ventilation provided for one complete air change per minute
- Air outlet located near the floor
- Air inlet near the ceiling
- Temperature controlled room, 60°F
- Switches for lights and fans located outside of room, crash-bar on door inside of chlorine room
- Vents from feeders and storage shall discharge to the outside atmosphere, above grade

CHLORINE SAFETY

Where Chlorine Gas Is Used (cont'd):

- Must have a chlorine gas detection device connected to an alarm that can be heard throughout the treatment plant
- All gaseous feed chlorine installations shall be equipped with appropriate leak repair kits
- A fusible plug, designed to melt at 158º to 165ºF (70-74ºC), is located in the valve on a 150-lb cylinder and on the head of a ton container
  - It is designed to relieve pressure in the cylinder or container when exposed to high heat
- Leak detection – an ammonia solution produces white "smoke" in the presence of chlorine
  - A sensor type leak detector is the best means of detecting small leaks, less than 1ppm

CHLORINE GAS CONTAINERS

- 3 types of Containers
  - 150 lb cylinder – Emergency repair kit A
  - Ton cylinder – Emergency repair kit B
  - Railroad cars – Emergency repair kit C

HYPOCHLORITE SAFETY

Calcium Hypochlorite (HTH)

- Dry, white or yellow granular material
- Strong oxidizer
- Reacts with organics and can start fires
- Gives off lots of heat when mixed with water
- Will give off chlorine gas when it reacts
- Always add HTH to water when mixing
  - **NEVER add water to HTH!!**

HYPOCHLORITE SAFETY

Calcium Hypochlorite (HTH)

- Granular HTH is safer to work with than tablet or liquid form
- HTH should be stored in a cool dry place away from acids, reducing agents, paints, oils, and grease
- Use a carbon dioxide extinguisher to put out fires started by HTH

HYPOCHLORITE SAFETY

Calcium Hypochlorite (HTH)

- If a small amount of calcium hypochlorite is spilled, the chemical should be disposed of by dissolving it in a large amount of water

HYPOCHLORITE SAFETY

Calcium Hypochlorite (HTH) – PPE

- Eye protection, protective clothing
- Rubber gloves
  - It will react with leather
- Rubber boots
  - It will react with leather
- SCBA

Safety Quiz

Lockout / Tagout

True or False

1. The term "lockout" means to block the flow of energy to equipment and keep it blocked by placing a lock to prevent accidental start-up.
True False

2. The term "tagout" means to place a tag on the power source to identify yourself and the purpose of the lockout, and to warn others not to turn the power back on.
True False

3. If someone else has already applied a lock and tag to a piece of machinery you need to work on, you should not add another one.
True False

4. After locking and tagging out the equipment, you should test the equipment to make sure it won't start.
True False

5. You don't need to use the lockout / tagout procedure if a machine has a built-in safety shut-off.
True False

Confined Spaces

Fill in the blank:

6. A ____________________ is a form designed to make sure workers can safely enter a confined space by establishing procedures that must be followed.

7. The acceptable range for oxygen level in a confined space is _________ %.

8. List some activities that can reduce the level of oxygen in a confined space:
____

9. Entry-level permits should be kept on file for at least _________ year(s).

Multiple Choice

10. Which of these are examples of confined spaces? (Circle all that apply)
    a) Storage tanks
    b) Automobiles
    c) Meter pits
    d) Manholes
    e) Meeting rooms

11. When must the atmosphere of a confined space be tested?
    a) Only before a worker enters
    b) Never, if adequate ventilation exists
    c) Continuously
    d) Only if welding or painting is being performed

12. Some gases in a confined space can be:
    a) Colorless
    b) Odorless
    c) Deadly
    d) All of the above

True or False

13. If dangerous conditions exist, you do not have to wait for trained rescue personnel to perform a rescue.

True False

14. Carbon monoxide and hydrogen sulfide are two common dangerous gases found in confined spaces.

True False

Calcium Hypochlorite

Multiple Choice

15. Calcium hypochlorite:
    a) Is an oxidizer
    b) May cause a fire if contaminated
    c) Can release hazardous chlorine gas if stored improperly
    d) All of the above

16. Which form of calcium hypochlorite is the safest?
    a) Granular
    b) Tablet
    c) Liquid

17. Calcium hypochlorite should be stored away from:
    a) Acids
    b) Paint
    c) Reducing agents
    d) Oils and greases
    e) All of the above

18. What should be used to extinguish a fire involving calcium hypochlorite?
    a) Water
    b) Carbon dioxide
    c) Chemical smothering agents
    d) All of the above

19. When cleaning up a small spill, you should dispose of the calcium hypochlorite by:
    a) Burying it
    b) Placing it in the trash can
    c) Putting it back in the container
    d) Neutralizing it with acid or ammonia
    e) Dissolving it in a large amount of water

Fill in the blank

20. What personal protective equipment should you wear when handling calcium hypochlorite?

    ____

21. Why should smoking be prohibited in calcium hypochlorite storage areas?

    ____

22. Why must you never dispose of calcium hypochlorite in the trashcan?

    ____

Answers:
1. True
2. True
3. False
4. True
5. False
6. Confined space permit
7. 19.5% - 23.5%
8. Poor ventilation, welding, absorption, chemical consumption
9. One
10. A and D
11. C
12. D
13. False
14. True
15. D
16. A
17. E
18. B
19. E
20. Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes (rubber gloves and rubber boots)
21. Fire hazard
22. Can react with organic material and cause a flash fire

TOSHA Standards Requiring Annual Training

Class	Regulation	Who should attend?
Medical & Exposure Records	1910.20(g)(1)	All employees (inform-existence, person responsible, location, right of access
Emergency Action	1910.38(a)(5) 1910.38(b)(4)	All employees – based upon other standards and requirements
Noise	1910.95(k)	All employees exposed to an 8 hour TWA or greater of 85dBA
Emergency Response	1910.120(q)	Employees who respond to spills of hazardous chemicals
Personal Protective Equipment	1910.132(f)	Employees who wear PPE
Permit-Required Confined Space	1910.146(g)	Employees who enter, attend or supervise P.R. confined spaces
Lock-Out/Tag-Out	1910.147(c)(7)	Employees who work on machinery
First Aid	1910.151(b)	At least one employee on each shift, annual as required by other standards
Fire Brigade	1910.156(c)	All fire brigade members (quarterly and annually)
Portable Fire Extinguishers	1910.157(g)	All employees expected to use fire extinguishers
Fork Lift Trucks	1910.178(1)	Fork lift truck operators
Mechanical Power Presses	1910.217(f)(2)	Operators
Asbestos	1910.1001(j)(1)	All employees exposures at or above PEL or excursion limit
Lead	1910.1025(1)	Anyone with a potential for exposure at any level – copy of appendix A&B. If exposed at or above action level, must be trained
Bloodborne Pathogens	1910.1030(g)(2)	Employees who render first aid
Hazard Communication	1910.1200(h) TDL 800-1-9-.07	Employees exposed or potentially exposed to any type of chemicals
Hazardous Chemicals in Laboratories	1910.1450(f)(2)	Employees exposed to chemicals

Section 9

Disinfection

DISINFECTION

California State University: Sacramento

Water Treatment Plant Operation Vol. 1

Fleming Training Center | TN Department of Environment & Conservation

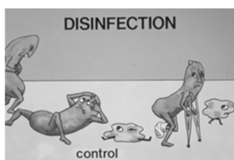
OBJECTIVES

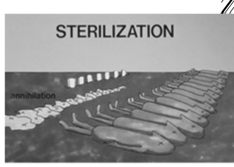
- Safe Drinking Water Laws
- Factors Influencing Disinfection
- Agents of Disinfection
- Chlorine Residuals
- Chlorination Equipment
- Maintenance
- Measurement of Chlorine Residual
- Chlorine Safety Program
- Ultraviolet (UV) Systems
- Ozonation Systems

DISINFECTION VS. STERILIZATION

- Disinfection – the destruction of **pathogenic organisms**
  - To prevent waterborne disease outbreaks
  - Destroys only disease-causing organisms
- Sterilization – the destruction of **all organisms** in the water

  Not all microorganisms are bad!





SAFE DRINKING WATER LAWS

- **US Environmental Protection Agency (USEPA)**
  - An agency of the United States federal government whose mission is to protect human and environmental health
- **Safe Drinking Water Act (SDWA)**
  - Established to protect the quality of drinking water in the U.S.
  - Authorizes EPA to establish minimum standards to protect tap water
    - Sets MCLs (maximum contaminant levels)for substances known to be hazardous to human health

SAFE DRINKING WATER LAWS

- **Surface Water Treatment Rule (SWTR)**
  - Purpose is to reduce illnesses caused by pathogens in drinking water including *Legionella*, *Giardia lamblia, and Cryptosporidium*
  - Applies to all public water systems (PWSs) using surface water sources or ground water sources under the direct influence of surface water (GWUDI)
    - Subpart H systems
  - Establishes maximum contaminant level goals (MCLGs) for viruses, bacteria and Giardia lamblia
  - Includes treatment technique (TT) requirements for filtered and unfiltered systems to protect against adverse health effects of exposure to pathogens

SAFE DRINKING WATER LAWS

- **Interim Enhanced Surface Water Treatment Rule (IESWTR)**
  - Applies to all public water systems using surface water, or GWUDI, that serve 10,000 or more persons
  - Sets a (MCLG) of zero for *Cryptosporidium*
  - Sets a 2-log (99%) *Cryptosporidium* removal requirements for systems that provide filtration
  - Requires that watershed protection programs address *Cryptosporidium* for systems that are not required to provide filtration
  - Requires sanitary surveys, conducted by states, for all surface water systems regardless of size
  - Requires systems to calculate levels of microbial inactivation to address risk trade-offs with disinfection byproducts

SAFE DRINKING WATER LAWS

- **Filter Backwash Recycling Rule (FBRR)**
  - Requires recycled filter backwash water to go through all processes of a system's conventional or direct filtration treatment
- **Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)**
  - Targets additional Cryptosporidium treatment requirements to higher risk systems
  - Provides provisions to ensure that systems maintain microbial protection as they take steps to reduce the formation of disinfection byproducts

SAFE DRINKING WATER LAWS

- **Disinfectants and Disinfection Byproducts Rules (DBPR)**
  - Reduces drinking water exposure to disinfection byproducts
  - Applies to community water systems and non-transient non-community systems that add a disinfectant to the drinking water during any part of the treatment process
  - Stage 2 DBPR strengthens public health protection by tightening compliance monitoring requirements for Trihalomethanes (TTHM) and Haloacetic acids (HAA5).

AGENTS OF DISINFECTION

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PURPOSE OF PROCESS

- To destroy harmful organisms
- Physical disinfection
  - Removes the organisms from the water, or
  - Introduces motion that will disrupt the cells' biological activity and kill or inactivate them
- Chemical disinfection
  - Alter the cell chemistry causing microorganism to die
  - Most widely used is chlorine because it is easily obtained and leaves a measurable residual chlorine

PHYSICAL MEANS OF DISINFECTION

- Ultraviolet Rays (UV)
  - Rays must come in contact with each microorganism
  - Lack of measureable residual
- Heat
  - Rolling boil for 5 minutes
- Ultrasonic Waves
  - Sonic waves destroy microorganisms by vibration

CHEMICAL DISINFECTANTS

- Iodine
  - Limited to emergency use due to high cost and negative health effects
- Bromine
  - Very limited due to handling difficulties
- Bases (sodium hydroxide and lime)
  - High pH leaves a bitter taste in water
- Ozone
  - High costs, lack of chlorine residual, difficult to store, high maintenance requirements

CHEMICAL DISINFECTANTS

- Chlorine gas
  - Cl_2
  - 100% pure
  - gas
  - Liquid chlorine
- Calcium hypochlorite
  - $Ca(OCl)_2$
  - 65% pure
  - solid
  - HTH – high test hypochlorite
- Sodium hypochlorite
  - NaOCl
  - 5-15% pure
  - Liquid
  - Bleach

CHLORINE GAS (Cl_2)

- Properties of Chlorine
  - Greenish-yellow gas
  - 2.5 times heavier than air
  - Volume of gas will increase by almost 90% when temperatures rise
  - Liquid expands to 460 times the volume as a gas
  - Non-flammable but can support combustion

CHLORINE (Cl_2)

- Reaction with Water

$$Cl_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{hydrochloric acid}}{HCl}$$

Lowers pH (HCl)

  - Free chlorine combines with water to form hypochlorous acid
    - Most effective disinfectant
    - Dissociates at higher pH (greater than 7)

$$\underset{\text{hypochlorous acid}}{HOCl} \rightarrow H^+ + \underset{\text{hypochlorite ion}}{OCl^-}$$

  - Hypochlorous acid has a much higher disinfection potential than hypochlorite ion
  - At pH = 7.5, of the chlorine present 50% will be HOCl and 50% will be OCl^-
  - At pH > 8.5 all chlorine present will be OCl^-

CHLORINE (Cl_2)

- Hydrogen sulfide and ammonia are inorganic reducing agents
  - Hydrogen sulfide reacts with chlorine to form sulfuric acid and elemental sulfur
    - Causes odor problems (rotten egg)
  - Ammonia reacts with chlorine to form chloramines
    - As ammonia concentration increases, the disinfectant power of chlorine decreases
  - Organics react with chlorine to form trihalomethanes (carcinogens)

HYPOCHLORITE DISINFECTANTS

- Hypochlorite as a disinfectant achieves the same result as chlorine gas
- May be applied in two forms:
  - Sodium hypochlorite (NaOCl)
  - Calcium hypochlorite (CaOCl)
- Only difference between disinfecting with chlorine gas vs hypochlorite is the side reactions of the end products
  - Chlorine gas tends to lower the pH (HCl)
  - Hypochlorite tends to raise the pH (NaOH or $Ca(OH)_2$)

HYPOCHLORITE (OCl^-)

- Reactions with Water
  - May be applied in the form of calcium hypochlorite ($Ca(OCl)_2$) or sodium hypochlorite (NaOCl)

$$Ca(OCl)_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{calcium hydroxide}}{Ca(OH)_2}$$

$$NaOCl + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{sodium hydroxide}}{NaOH}$$

  - Raises pH due to OH^- ion
  - If is $Ca(OCl)_2$ injected at the same point as sodium fluoride, a severe crust can form at injection point

CHLORINE DIOXIDE (ClO_2)

- May be used as a primary disinfectant
  - Not affected by ammonia
  - Very effective disinfectant at higher pH levels
  - Reacts with sulfide compounds to help remove and eliminate their characteristic odors
  - Can control phenolic tastes and odors where chlorine would intensify them
  - Generated on-site by the reaction of chlorine and sodium chlorite

CHLORINE DIOXIDE (ClO_2)

- Reaction in Water

$$2ClO_2 + H_2O \rightarrow ClO_3^- + ClO_2^- + 2H^+$$

(chlorine dioxide; chlorate ion; chlorite ion; hydrogen ion)

- Reactions with Impurities in Water
  - Inorganic compounds
    - Highly effective in oxidizing iron & manganese
  - Organic compounds
    - Does not react with organics in water leaving little danger of THM formation

CHLORINE RESIDUALS

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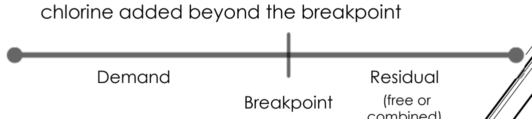
CHLORINATION

- Disinfection Action
  - Chlorine demand - the point where the reaction with organic and inorganic materials (aka reducing agents) stops
  - Chlorine residual – the total of all the compounds with disinfecting properties plus any remaining free chlorine
  - Chlorine dose – the amount of chlorine needed to satisfy the chlorine demand and the amount of chlorine residual needed for disinfection

Dose = Demand + Residual

BREAKPOINT CHLORINATION

- The process of adding chlorine to water until the chlorine demand has been satisfied
  - Further additions of chlorine will result in a chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint



- Dose = Residual + Demand

  OR

- Demand = Dose - Residual

TOTAL RESIDUAL CHLORINE (TRC)

Total Residual Chlorine = Combined Residual + Free Residual

Combined Residual = Total Residual Chlorine – Free Residual

BREAKPOINT CHLORINATION

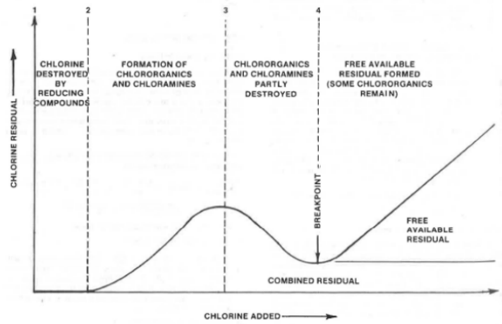


Fig. 7.2 Breakpoint chlorination curve

CHLORAMINATION

- Chloramines have been used as an alternative disinfectant for over 80 years
- An operator's decision to use chloramines depends on several factors
- However, chloramination alone is <u>not an approved method</u> of disinfection in the state of Tennessee
  - TN requires a Free Chlorine Residual
  - Chloramination produces a combined chlorine residual

CHLORINE RESIDUAL

- Chlorine is effective in controlling biological agents and eliminating coliform bacteria
- To ensure adequate control of coliform aftergrowth, a minimum free chlorine residual of 0.2 mg/L in the distribution system is required
  - A lack of this residual could indicate the presence of a heavy contamination

CRITICAL FACTORS AFFECTING CHLORINATION

- Effectiveness of upstream treatment processes
- Injection point and method of mixing
- Temperature
  - The higher temp, the more rapid the disinfection
- Dosage and type of chemical
  - The higher the dose, the faster the disinfection
- pH
  - The lower the pH, the better the disinfection
- Contact time
  - Longer contact time has better disinfection
- Concentration
  - Chlorine residual

MOST IMPORTANT

CT VALUES

"kill" is proportional to C x T

- Destruction of organisms depends on the concentration of chlorine added (C) and the amount of time the chlorine is in contact with the organisms (T)
- Inversely proportional
  - If one is decreased, the other must be increased to ensure that "kill" remains the same

POINTS OF CHLORINE APPLICATION

- Prechlorination
  - Application of chlorine ahead of any other treatment processes
  - Benefits
    - Control of algal and slime growths
    - Control of mudball formation
    - Improved coagulation
    - Reduction of tastes and odors
    - Increased chlorine contact time
    - Increased safety factor in disinfection of heavily contaminated waters
  - Disadvantages
    - High chance of creating disinfection by-products

POINTS OF CHLORINE APPLICATION

- Postchlorination
  - Application of chlorine after the water has been treated but before it enters the distribution system
  - Primary point of disinfection
- Rechlorination (booster chlorination)
  - Practice of adding chlorine in the distribution system
  - Common when distribution system is long or complex
- Wells
  - Good practice whenever wells are used for public water supplies

POINTS OF CHLORINE APPLICATION

- Distribution Mains
  - After initial installation and any repairs
- Tanks and Reservoirs
  - To resolve specific problems
  - After initial installation, repairs, maintenance, repainting, and cleaning
- Water Supply Systems
  - i.e. Small water systems

FACTORS INFLUENCING DISINFECTION

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FACTORS INFLUENCING DISINFECTION

- pH
  - Chlorine disinfects faster at pH of 7 than at pH > 8
  - Hypochlorous acid disassociates at a higher pH
- Temperature
  - Higher temperature means more efficient disinfection
  - Longer contact time required at lower temperatures
  - Chlorine will dissipate faster in warmer waters
- Microorganisms
  - Number and type greatly influence disinfection effectiveness
  - Cysts and viruses can be very resistant to disinfection

FACTORS INFLUENCING DISINFECTION

- Turbidity
  - Excessive turbidity greatly reduces disinfection efficiency
- Reducing Agents
  - Any substance that will readily donate or give up electrons
    - *Reduces the chlorine concentration*
  - 3 primary reducing agents
    - Inorganic Matter
    - Organic Matter
    - Bacteriological

FACTORS INFLUENCING DISINFECTION

- Reducing Agents
  - Inorganic matter
    - Ammonia can combine with disinfectant chemical to form side compounds
  - Inorganic reducing agents
    - Hydrogen sulfide gas (H_2S)
    - Ferrous ion (Fe^{2+})
    - Manganous ion (Mn^{2+})
    - Ammonia (NH_3)
    - Nitrite ion (NO_2^-)

FACTORS INFLUENCING DISINFECTION

- Reducing Agents
  - Organic Matter
    - Organics can consume great amounts of disinfectants while forming unwanted compounds such as disinfection by-products
    - Reactions with organics and other reducing agents will significantly reduce the amount chemical available for disinfection

CHLORINATION EQUIPMENT

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CHLORINE GAS STEEL (150 LB) CYLINDER

- Move cylinders with a properly balanced hand truck
- Can be rolled in a vertical position
- Always replace the protective cap when moving a cylinder
- Keep cylinders away from direct heat and direct sun
- Transport and store cylinders in an upright position
- Store empty cylinders separate from full cylinders
  - Never store near turpentine, ether, anhydrous ammonia, finely divided metals, hydrocarbons, or other materials that are flammable
- Remove outlet cap from cylinder and inspect outlet threads
- Test chlorine cylinders at 800 psi every 5 years

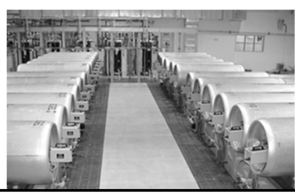
CHLORINE GAS STEEL (150 LB) CYLINDER

- Contains 100 to 150 pounds
- Fusible plug is placed in the valve below the valve seat
  - Safety device to prevent buildup of excessive pressures
  - Melts at 158°-165°F (70°-74°C)



CHLORINE GAS TON TANKS

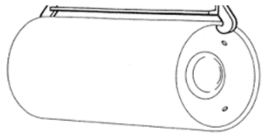
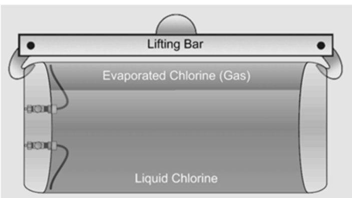
- Loaded weight of about 3,700 pounds
- Openings for fusible plugs and valves
  - 2 operating valves
  - 6 fusible plugs (3 on each end)

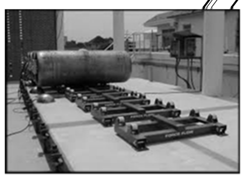




CHLORINE GAS TON TANKS

- Ship ton tanks by rail in multiunit cars, truck or semitrailer
- Handle ton tanks with a suitable lift clamp or in conjunction with a hoist or crane
- Lay ton tanks on their sides
- Do not stack
- Separate tanks by 30 inches for access in case of leaks
- Place ton tanks on trunnions that are equipped with rollers
  - In case of a leak, tank can be rolled so that the leaking chlorine escapes as a gas not a liquid
- Use locking devices to prevent ton tanks from rolling while connected

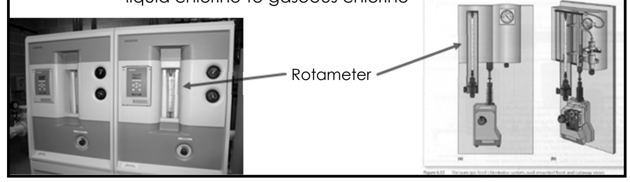
CHLORINE GAS TON TANKS

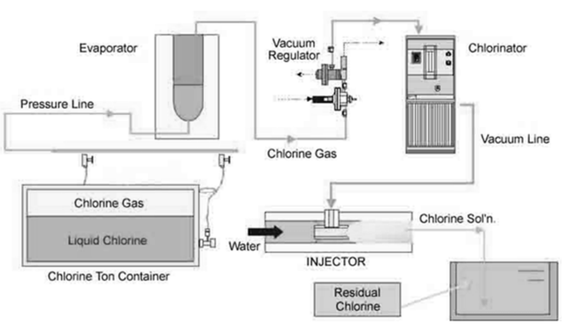


REMOVING CHLORINE FROM TON TANKS

- Must be placed on their sides with valves in vertical positions to allow either chlorine gas or liquid to be removed
  - Top valve to remove chlorine gas
  - Bottom valve to remove liquid chlorine
    - Must use an evaporator – water bath that converts liquid chlorine to gaseous chlorine



REMOVING CHLORINE FROM TON TANKS



CHLORINE GAS RAILROAD CAR

CHLORINATORS (CHLORINE GAS)

- Chlorine gas may be removed from chlorine containers by a valve and piping arrangement
- Chlorine gas is controlled, metered, and introduced into a stream of injector water, and then is conducted as a solution to the point of application
- Safety
  - Protective clothing: gloves and rubber suit
  - Self-contained pressure-demand air supply system (SCBA)
  - Chlorine leak detector and exhaust fan set at floor level
    - Warning device located outside chlorine room

CHLORINATOR FLOW PATH

- Within the chlorinator, gas passes through spring a loaded regulator valve that maintains the operating pressure
- Rotameter indicates the rate of gas flow
  - Rate controlled by orifice
- Gas then moves to the injector where it is dissolved in water
- Mixture leaves the chlorinator as a chlorine solution (HOCl) ready for application

CHLORINATOR FLOW PATH

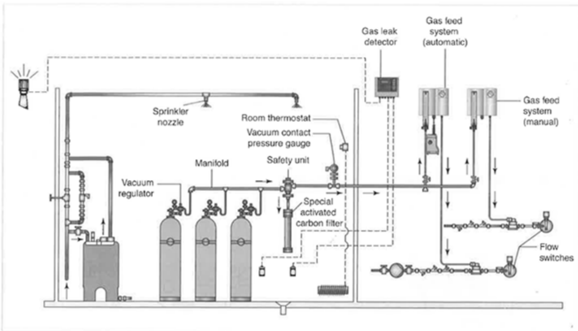
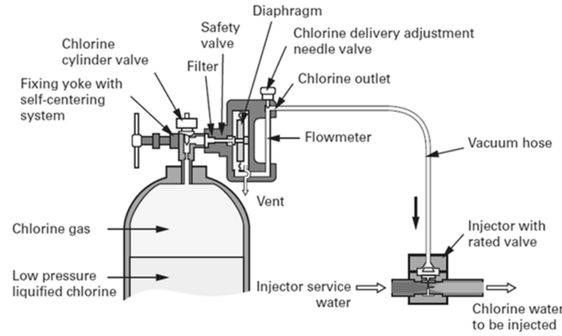


Figure 6.11 Typical vaccum-fed gas chlorinator installation.

CHLORINATORS PARTS



CHLORINATORS PARTS

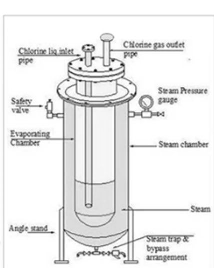
- Injector – portion of chlorination system that feeds chlorine solution into pipe under pressure
  - Creates vacuum to operate chlorinator
- Check valve assembly – prevents water from back-feeding as the water moves through ejector
- Rate valve – controls the flow rate at which chlorine gas enters the chlorinator
- Diaphragm assembly – regulates chlorinator vacuum which can be used to adjust feed rate

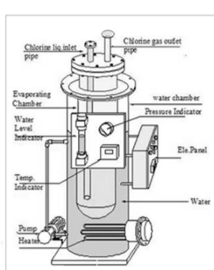
CHLORINATOR PARTS

- Rotameter – device used to measure the flow rate of gases and liquids
  - Gas or liquid flows up a tapered, calibrated tube with a ball/float that rises or falls with the flow rate

CHLORINATOR PARTS

- Evaporator – converts liquid chlorine to gaseous chlorine for use by chlorinators





REMOVING CHLORINE FROM CYLINDERS

- Whenever performing any work or maintenance on chlorine cylinders, a self-contained breathing apparatus (SCBA) should be worn or at least readily available
- Greater than maximum feed rate will result in freezing and a decreased rate of delivery
  - 50 lb cylinder = 40 lb/day
  - Ton cylinder = 400 lb/day
    - With evaporator = 9,600 lb/day
- Frosting may cause gas to condense to liquid which could plug the chlorine supply lines

HYPOCHLORITE CONTAINERS

- Plastic containers commonly used for storage of bleach or HTH solution
- Should be large enough to hold 2-3 days' supply
  - Fresh solution should be prepared every 2-4 days
  - Sodium hypochlorite will lose 2-4% concentration per month at room temperature
  - Recommended shelf life of 60-90 days

HYPOCHLORINATORS

- A piece of equipment used to feed chlorine solutions (bleach)
- Consists of chemical solution tank, diaphragm-type pump, power supply, water pump, pressure switch, water storage tank

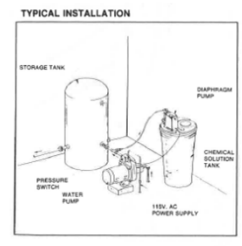


Fig. 7.7 Typical hypochlorinator installation

HYPOCHLORINATORS

- 2 methods of feeding
  - Directly pumped into water
  - Pump through an ejector (injector)
    - Draws in additional water for dilution of solution

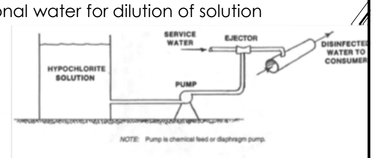


Fig. 7.11 Hypochlorinator injector feed system

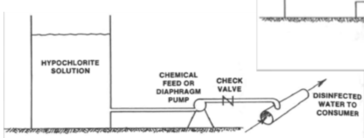
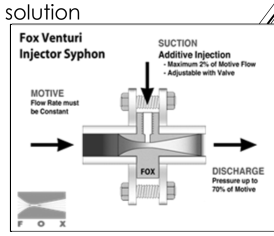


Fig. 7.10 Hypochlorinator direct pumping system

HYPOCHLORINATOR PARTS

- Mix tank – to mix water and bleach into solution
- Day tank – tank designed to hold enough chemical solution for one day or one shift
- Eductor – device that draws in additional water for dilution of the hypochlorite solution
  - aka ejector or injector



HYPOCHLORINATOR SYSTEM

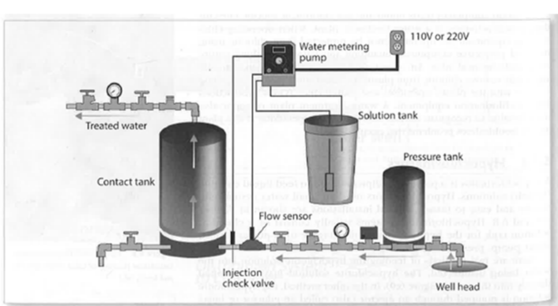


Figure 6.8 Proportional-feed flow meter hypochlorinator system (Adapted from Clean Water Systems and Stores, Inc.)

MEASUREMENT OF CHLORINE RESIDUAL

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METHODS OF MEASURING CHLORINE RESIDUAL

- Amperometric titration
- Colorimetric tests (DPD)

- All subpart H systems (surface water systems and groundwater systems under the influence of surface water) must provide disinfection
- All subpart H systems must collect residual chlorine sample at the same frequency and location as total coliform samples

AMPEROMETRIC TITRATION

- A means of measuring concentrations of certain substances in water based on the electric current that flows during a chemical reaction

AMPEROMETRIC TITRATION

1. Place a 200 mL sample of water in titrator
2. Start the agitator
3. Add 1 mL of pH 7 buffer
4. Titrate with phenylarsene oxide solution (PAO)
5. End point is reached when one drop will cause a deflection on the microammeter and the deflection will remain
6. # mL of PAO used in titration is equal to mg/L of free chlorine residual

COLORIMETRIC TEST (DPD)

- A method of measuring the chlorine residual in water
- N,N-diethyl-p-phenylene-diamine
- "False positive" can occur when sample contains a combined chlorine residual

COLORIMETRIC TEST (DPD)

- The residual may be determined by either titrating
  or comparing a developed color with color standards

1. Collect a sample
   - Typically 10 mL or 25 mL
2. Zero instrument with sample blank
3. Add color reagent
4. Read colored sample in spectrophotomer or colorimeter

MAINTENANCE

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CHLORINE LEAKS

- Chlorine leak can be smelled at concentrations as low as 0.3 ppm
  - Detectors can detect 1ppm or less
- Always work in pairs when looking for and repairing leaks
- If leak is large, all persons in adjacent areas should be warned and evacuated

CHLORINE LEAKS

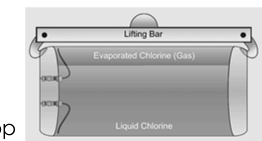
- Any new or repaired system should be cleaned, dried, and tested for leaks
- Ammonia solution on a piece of cloth held near a chlorine leak will produce a white vapor
  - Use concentrated ammonia solution of 28-30% ammonia
  - A squeeze bottle filled with ammonia water to dispense vapor may also be used
- If leak is in the equipment, close the valves at once

CHLORINE LEAKS

- If leak is in cylinder, use emergency repair kit
  - For 150 lb cylinder, Emergency Repair kit A
  - For ton cylinder, Emergency Repair kit B
  - For railroad car, Emergency Repair kit C



CHLORINE LEAKS



- If chlorine leaking as a liquid, rotate cylinder so leak is on top
  - Chlorine is escaping only as a gas
- If prolonged or unstoppable leak, emergency disposal should be provided
  - Chlorine may be absorbed into solutions of caustic soda, soda ash, or agitated hydrated lime
- Never put water on a chlorine leak
  - By-product (hydrochloric acid) will make the leak larger
- Leak around valve stem can be stopped by closing the valve or tightening the packing gland nut

CHLORINE LEAKS

- Leaks at valve discharge outlet can often be stopped by replacing the gasket or adapter connection
- Leaks at fusible plugs and cylinder valves usually require special handling and emergency equipment
- Pinhole leaks in the walls of cylinders can be stopped by using a clamping pressure saddle with a turnbuckle available in repair kits
  - Temporary fix
- A leaking container must not be shipped
- Do not accept delivery of containers showing evidence of leaking, stripped threads, etc.

CHLORINE SAFETY PROGRAM

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CHLORINE HAZARDS

- Chlorine gas is 2.5 times heavier than air
  - Extremely toxic
  - Corrosive in moist atmospheres
  - Very irritating to mucous membranes of the nose, throat, and lungs

Effect	Cl_2 concentration (ppm)
Slight symptoms after several hours' exposure	1
Detectable odor	0.3-3.5
Noxiousness (harmful)	5
Throat irritation	15
Coughing	30
Dangerous from ½ to 1 hour	40
Death after a few deep breaths	1,000

CHLORINE PPE

- Every person should be trained in the use of self-containing breathing apparatus (SCBA), methods of detecting hazards, and should know what to do in case of emergencies
- Clothing exposed to chlorine can be saturated with chlorine, which will irritate the skin if exposed to moisture or sweat
- Self-contained air supply and positive pressure breathing equipment must fit and be used properly
- Wear protective clothing to enter an area containing a chlorine leak
  - Chemical suit will prevent chlorine from contacting the sweat on the body and forming hydrochloric acid

MILD CHLORINE EXPOSURE

- Leave contaminated area
- Move slowly, breathe lightly without exertion, remain calm, keep warm, and resist coughing
- If clothing has been contaminated, remove as soon as possible
- If slight irritation, immediate relief can come from drinking milk

EXTREME CHLORINE EXPOSURE

- Follow established emergency procedures
- Always use proper safety equipment; do not enter area without self-contained breathing apparatus
- Remove patient from affected area immediately
- First-aid
  - Remove contaminated clothes
  - Keep patient warm and cover with blankets
  - Place patient in comfortable position on back
  - Administer oxygen if breathing is difficult
  - Perform mouth-to-mouth resuscitation if breathing seems to have stopped
  - If chlorine has got in eyes, flush with large amounts of water immediately (at least 15 minutes)

HYPOCHLORITE SAFETY

- Wash spills with large volumes of water
- Hypochlorite can damage eyes and skin upon contact
  - Immediately wash affected are thoroughly with water
- Nonflammable, however can cause a fire when comes in contact with organics

ULTRAVIOLET (UV) SYSTEMS

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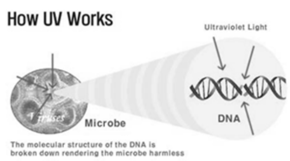
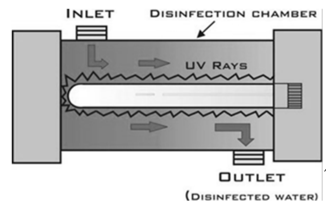
USES OF UV SYSTEMS

- Ultraviolet light – band of electromagnetic radiation just beyond the visible light spectrum
  - UV light absorbed by cells of microorganisms damages the genetic material to cease growth or reproduction



TYPES OF UV LAMPS

- Based on internal operating design
  - Low-pressure, low-intensity
  - Low-pressure, high-intensity
  - Medium-pressure, high-intensity



LOW PRESSURE UV LAMPS

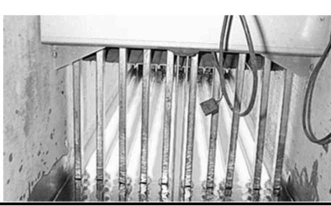
- Source of UV energy in majority of systems
- Last between 8,000 and 10,000 hours
- Operate between 40° and 60°F
- Generate light by transforming electrical energy into UV radiations
- Emits light at wavelength 253.7 nm
- Each lamp protected by quartz sleeve with watertight electrical connections

LOW PRESSURE UV LAMPS

- Lamp assemblies mounted in a rack(s) that are immersed in flowing water
- Can be enclosed in a vessel or in an open channel
  - Enclosed in vessels in pressure systems
- Placed either horizontal and parallel to flow or vertical and perpendicular to flow
- Number of lamps determines water depth in channel

SAFETY

- UV lamp can burn eyes
- Never look into uncovered parts of the UV chamber without protective glasses
- Lamps contain mercury vapor that will be released of lamp breaks



OPERATION

- Water level over lamps must be maintained to ensure all microorganisms are exposed and to prevent short circuiting
- Water level control device must be regulated by the operator to:
  - Minimize variation of the channel's water level
  - Maintain the channel's water level at a defined level
  - Keep the UV lamps submerged at all times
  - Prevent excessive water layer thickness above the top lamp row

OPERATION

- Light must be intense enough to penetrate pathogens' cell walls
  - Intensity affected by the condition of the UV lamps and the quality of the water
  - An old or dirty lamp has a reduced UV light intensity
  - High turbidity inhibits light transmission, reducing the disinfecting power in proportion to its distance from the light source
  - High TSS inhibits light transmission and shields bacteria protecting them from disinfection
- Low UV light intensity will produce a low level of disinfection

OPERATION

- UV Dose Calculation
  - Intensity of UV radiation and contact time determine the UV dose and, therefore, the effectiveness
  - Expressed as mJ/sq cm (milli-joules per square centimeter)
  - Use worse case intensity for calculation (farthest point from UV)
- Channel Volume Calculation
  - Refers to the irradiated volume of the UV reactor
    - Volume of bacteria exposed to UV radiation
  - Fixed calculation

OPERATION

- Routine Operations Tasks
  - Check UV monitors for UV transmission
  - Routinely clean the UV lamps
- Wiping Systems
  - Should be observed to ensure proper operation of the wiping action of a bank and the proper wiping cycle
- Monitoring Lamp Output Intensity
  - Lamp output declines with use
  - Lamps should be replaced with output no longer meets standards or burn out

OPERATION

- Monitoring Influent and Effluent Characteristics
  - Must maintain velocities and low turbidity levels
    - Suspended particles shield microorganisms from UV light
    - Flows should be somewhat turbulent to ensure exposure to all microorganisms, but controlled so that water is exposed for long enough for disinfection to occur
  - Bacteriological tests must be performed frequently since there is no residual left by UV
- Emergency Alarms
  - UV systems require extensive alarm systems to ensure complete disinfection

MAINTENANCE

- Routine Maintenance
  - Check UV monitor for reduction in lamp output
  - Monitor process for major changes
  - Check for fouling of the quartz sleeves
  - Check that all UV lamps are energized
  - Monitor reports to determine UV lamp replacement interval
  - Check quartz sleeves for discoloration
  - Dewater and hose down UV channel if algae and other attached biological growths form on walls and floor

MAINTENANCE

- Quartz Sleeve Fouling
  - Occurs when cations attach to protein and colloidal matter that crystallizes on the quartz sleeves
  - This will decrease the intensity of the UV light
- Sleeve Cleaning
  - Frequency depends on the quality of water being treated and treatment chemicals used
  - Best done by dipping bulbs an inorganic acid solution for 5 minutes
    - i.e. Nitric acid (50%) or phosphoric acid (5-10%)

MAINTENANCE

- UV lamps
  - Service life ranges from 7,500 – 20,000 hours
  - Depends on
    - Level of suspended solids
    - Frequency of on/off cycles
    - Operating temperature of lamp electrodes
  - Lamp output drops 30-40% in first 7,500 hours
  - Lamp electrode failure is most common cause of lamp failure
  - Do not throw used lamps in garbage can
    - Must be disposed properly due to mercury content

OZONATION SYSTEMS

Introduction to Water Treatment

Fleming Training Center TN Department of Environment & Conservation

OZONE (O_3)

- Bluish toxic gas with pungent odor
- Alternative disinfectant
- Very strong oxidant and virucide (kills viruses)
- Must be generated on site
- Generated by passing an electrical current through pure oxygen

$$O_2 + \text{Energy} \rightarrow O + O$$
$$O + O_2 \rightarrow O_3$$

OZONE (O_3)

- Effectiveness of disinfection depends on
  - Susceptibility of the target organisms
  - Contact time
  - Concentration of the ozone
- Because ozone is consumed quickly, it must be exposed to the water uniformly
- Residual ozone measured by the iodometric method
- Dissolved ozone measured by Indigo test

EQUIPMENT

- Consists of 4 major parts
  - Air preparation unit
  - Electrical power unit
  - Ozone generator
  - Contactor

EQUIPMENT

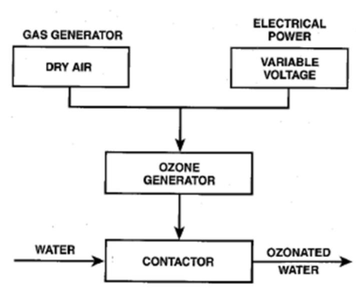


Fig. 7.47 Ozonation equipment

EQUIPMENT

Air preparation

- When air is used as the feed gas for an ozone generator, it must be extremely dry
- The preparation unit usually consists of a commercial air dryer with a dew point monitoring system
  - This is the most critical part of the system
- Air should be clean and dry with a dew point below -51°C (-60°F)

EQUIPMENT

Electrical Power Units

- Usually a very special electrical control system
- Most common unit provides low frequency, variable voltage
- For large installations, medium frequency, variable voltage is used
  - Reduces power costs
  - Allows for higher ozone output

EQUIPMENT

Ozone Generator

- Consists of a pair of electrodes separated by a gas space and a layer of glass insulation
- Air passes through the empty space
- Electrical discharge occurs across the gas space and ozone is formed

Oxygen from air + Electrical voltage → Ionized oxygen + Heat

O_2 + electricity → 2(O)

Ionized oxygen + Non-ionized oxygen → Ozone

$2(O) + 2(O_2) \rightarrow 2\ (O_3)$

EQUIPMENT

Ozone Contactor

- Mixing chamber for the ozone rich material and the water
- Ozone has a very short life
- Must be evenly and efficiently introduced to the water to be treated
  - Critical to the success of the system

EQUIPMENT

Types of Ozone Contactors

- Turbine mixers
- Injectors
- Packed columns
- Spray chambers
- Fine-bubble diffusion
  - Most common
  - Small bubbles rise through the tank transferring the ozone to the water

OZONE ADVANTAGES

- More effective than chlorine in destroying viruses
- No harmful residuals after ozonation
- No regrowth of microorganisms
- Removes color, tastes, and odors
- Oxidizes iron, manganese, sulfides and organics

OZONE LIMITATIONS

- Low dosage may not effectively inactivate some viruses, spores, and cysts
- Complex technology requiring complicated equipment
- Ozone is very reactive and corrosive require corrosion resistant materials
- Ozone is very irritating and possibly toxic
- The cost of treatment can be relatively high in capital and power costs
- Cannot be used as sole means of disinfectant in Tennessee due to Cl_2 residual requirements
- Can combine with bromide to form bromate
  - A carcinogen

APPLICATIONS OF OZONE

- Ozone may be used for more than just disinfection or viral inactivation
  - When used prior to coagulation
    - Treats Fe and Mn, helps flocculation, and removes algae
  - If applied before filtration
    - Oxidizes organics, removes color, and treats tastes and odors

MAINTENANCE

- Inspect electrical equipment and pressure vessels monthly
- Conduct a yearly preventive maintenance program
  - Should be done by a factory representative or an operator trained by the manufacturer
- Lubricate moving parts according to manufacturer's recommendations

SAFETY

- Ozone is a toxic gas and is a hazard to plants and animals
- When ozone breaks down in the atmosphere, the resulting pollutants can be very harmful
- Ozone contactors must have a system to collect ozone off-gas.
  - Ozone generating installations must include a thermal or catalytic ozone destroyer

Common Waterborne Diseases

Waterborne Disease	Causative Organism	Source of Organism in Water	Symptom
Gastroenteritis	*Salmonella* (bacteria)	Animal of human feces	Acute diarrhea and vomitting
Typhoid	*Salmonella typhosa* (bacteria)	Human feces	Inflamed intestine, enlarged spleen, high temperature - **FATAL**
Dysentery	*Shigella* (bacteria)	Human feces	Diarrhea - rarely fatal
Cholera	*Vibrio comma* (bacteria)	Human feces	Vomitting, severe diarrhea, rapid dehydration, mineral loss – high mortality
Infectious Hepatitis	Virus	Human feces, shellfish grown in polluted waters	Yellow skin, enlarged liver, abdominal pain – low mortality, lasts up to 4 months
Amoebic Dysentery	*Entamoeba* histolytica (protozoan)	Human feces	Mild diarrhea, chronic dysentery
Giardiasis	*Giardia lamblia* (protozoan)	Animal or human feces	Diarrhea, cramps, nausea and general weakness – not fatal, lasts 1-30 weeks
Cryptosporidiosis	*Cryptosporidium* (protozoan)	Human and animal feces	Acute diarrhea, abdominal pain, vomiting and low-grade fever
Legionellosis	*Legionella pneomophila* and related bacteria		Acute respiratory illness

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Pipe Disinfection Formulas for <u>50 mg/L</u> of HTH

If a pipe is of size not listed below, the following formula will give the calculations needed to find the amount of HTH needed, if the length of line is given:

Calculation Formula = $0.000026007(X)^2(L)$

L= the length of the line in feet,
X = the diameter in inches

Or, Use the following Chart, if Pipe Diameter is listed

DIAMETER (INCHES)	LBS OF HTH
6	0.000935(L)
8	0.00166(L)
10	0.0026(L)
12	0.00374(L)
14	0.00509(L)
16	0.00665(L)
20	0.01038(L)
C24	0.01495(L)

Contact Amanda Carter At Fleming Training Center

(615) 898-6507

Disinfection Vocabulary

A. Amperometric Titration
B. Bacteria
C. Breakpoint Chlorination
D. Carcinogen
E. Chlorination
F. Chlorine Demand
G. Chlorine Requirement
H. Chlorine Residual
I. Chlororganic
J. Colorimetric Measurement
K. Combined Available Chlorine
L. Combined Available Chlorine Residual
M. Combined Chlorine
N. Combined Residual Chlorination
O. DPD
P. Dew Point
Q. Disinfection
R. Eductor
S. Enteric
T. Free Available Residual Chlorine
U. HTH
V. Hydrolysis
W. Hypochlorination
X. Hypochlorite
Y. IDLH
Z. MPN
AA. Oxidation
BB. Oxidizing Agent
CC. Pathogenic Organisms
DD. Postchlorination
EE. Potable Water
FF. Prechlorination
GG. Precursor, THM
HH. Reagent
II. Reducing Agent
JJ. Reliquefaction
KK. Sterilization
LL. Titrate
MM. Total Chlorine
NN. Total Chlorine Residual
OO. Trihalomethanes
PP. Turbidity
QQ. Ultraviolet

_____ 1. The Most Probable Number of coliform group organisms per unit volume of sample water

_____ 2. Any substance which tends to produce cancer in an organism

_____ 3. A chemical reaction in which a compound is converted into another compound by taking up water.

_____ 4. Any substance that will readily donate electrons

_____ 5. The application of chlorine to water to produce combined available chlorine residual

_____ 6. A hydraulic devise used to create a negative pressure by forcing a liquid through a restriction, such as a Venturi.

______ 7. Organic compounds combined with chlorine

______ 8. Organisms capable of causing diseases in a host

______ 9. The total concentration of chlorine in water, including the combined chlorine and the free available chlorine

______ 10. Pertaining to a band of electromagnetic radiation just beyond the visible light spectrum; used to disinfect water

______ 11. Addition of chlorine to water until the chlorine demand has been satisfied; additional chlorine beyond this point will result in a free chlorine residual

______ 12. Immediately Dangerous to Life or Health; the atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses and immediate threat to life or would cause irreversible or delayed adverse health effects

______ 13. The amount of chlorine that is needed for a particular purpose

______ 14. The addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound

______ 15. The removal or destruction of all microorganisms

______ 16. The cloudy appearance of water caused by the presence of suspended and colloidal matter

______ 17. A pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances

______ 18. The application of hypochlorite compounds to water for the purpose of disinfection.

______ 19. The sum of the chlorine species composed of free chlorine and ammonia

______ 20. The total chlorine, present as chloramine or other derivatives, that is present in a water and is still available for disinfection and for oxidation of organic matter

______ 21. The application of chlorine to water generally for the purpose of disinfection

______ 22. The addition of chlorine at the headworks of the plant prior to other treatment processes mainly for disinfection and control of tastes, odors, and aquatic growths

______ 23. That portion of the total available residual chlorine composed of dissolved chlorine gas, hypochlorous acid, and or hypochlorite ion remaining in water after chlorination.

______ 24. A method of measuring the chlorine residual in water

______ 25. An substance, such as oxygen or chlorine, that will readily add electrons

______ 26. The return of a gas to the liquid state e.g. a condensation of chlorine gas to return it to its liquid form by cooling

______ 27. The concentration of residual chlorine that is combined with ammonia, organic nitrogen, or both in water as a chloramine and is still available to oxidize organic matter and kill bacteria

_____ 28. The difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time

_____ 29. Living organisms, microscopic in size, which usually consist of a single cell

_____ 30. The addition of chlorine to the plant effluent, following plant treatment, for disinfection purposes

_____ 31. The total amount of chlorine residual present in a water sample after a given contact time

_____ 32. Of intestinal origin, especially applied to wastes or bacterias

_____ 33. Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking

_____ 34. The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air

_____ 35. A means of measuring unknown chemical concentrations in water by measuring a sample's color intensity

_____ 36. A means of measuring concentrations of certain substances in water based on the electric current that flows during a chemical reaction

_____ 37. A chemical solution of known strength is added drop by drop until a certain color change, precipitate, or pH change in the sample is observed (end point)

_____ 38. Natural organic compounds found in all surface and groundwaters that may react with halogens such as chlorine

_____ 39. Calcium hypochlorite. $Ca(OCl)_2$

_____ 40. The process designed to kill or inactivate most microorganisms in water, including essentially all pathogenic bacteria

_____ 41. The concentration of chlorine present in water after chlorine demand has been satisfied

_____ 42. Derivatives of methane in which three halogen atoms are substituted for three of the hydrogen atoms

_____ 43. Chemical compounds containing available chlorine

Answers

1. Z	12. Y	23. T	34. P
2. D	13. G	24. O	35. J
3. V	14. AA	25. BB	36. A
4. II	15. KK	26. JJ	37. LL
5. N	16. PP	27. L	38. GG
6. R	17. HH	28. F	39. U
7. I	18. W	29. B	40. Q
8. CC	19. M	30. DD	41. H
9. MM	20. K	31. NN	42. OO
10. QQ	21. E	32. S	43. X
11. C	22. FF	33. EE	

Disinfection
Review Questions

1. What are pathogenic organisms?

2. What is disinfection?

3. Drinking water standards are established by what agency of the United States government?

4. MCL stands for what words?

5. How does pH influence the effectiveness of disinfection?

6. How does the temperature of the water influence disinfection?

7. What two factors influence the effectiveness of disinfection on microorganisms?

8. List the physical agents that have been used for disinfection (chlorine is not a physical agent).

9. List the chemical agents other than chlorine that have been used for disinfection.

10. What is a major limitation to the use of ozone?

11. How is the chlorine dosage determined?

12. List two organic reducing chemicals with which chlorine reacts rapidly.

13. What does chlorine produce when it reacts with organic matter?

14. How do chlorine gas and hypochlorite influence pH?

15. How does pH influence the relationship between HOCl and OCl^-?

16. What is breakpoint chlorination?

17. List the two most common points of chlorination in a water treatment plant.

18. Under what conditions should waters not be prechlorinated?

19. What are the benefits of prechlorination?

20. List the major parts of a typical hypochlorinator system.

21. What are the two common methods of feeding hypochlorite to the water being disinfected?

22. What type of container is commonly used to store hypochlorite?

23. How large a supply of hypochlorite should be available?

24. What is the purpose of the fusible plug?

25. What is removed by the upper and lower valves of ton chlorine tanks?

26. Why are one-ton tanks placed on their sides with the valves in a vertical position?

27. If chlorine is escaping from a cylinder, what would you do?

28. How can chlorine leaks around valve stems be stopped?

29. How can chlorine leaks at the valve discharge outlet be stopped?

30. What properties make chlorine gas so hazardous?

31. What type of breathing apparatus is recommended when repairing chlorine leaks?

32. What first-aid measures should be taken if a person comes in contact with chlorine gas?

33. The UV light intensity that reaches the pathogens in the water is affected by what factors?

34. Routine maintenance of UV disinfection systems includes which tasks?

35. How often should quartz sleeves be cleaned?

36. The service life of UV lamps depends on which factors?

37. How can operators determine the proper way to dispose of used UV lamps?

38. Why is ozone generated on site?

39. The effectiveness of ozone disinfection depends on which factors?

Disinfection
Review Questions

1. Pathogenic organisms are disease-producing organisms
2. Disinfection is the selective destruction or inactivation of pathogenic organisms.
3. The US Environmental Protection Agency establishes drinking water standards.
4. MCL stands for Maximum Contaminant Level.
5. Most disinfectants are more effective in water with a pH around 7.0 than at a pH over 8.0.
6. Relatively cold water requires longer disinfection time or greater quantities of disinfectants.
7. The number and type of organisms present in water influence the effectiveness of disinfection on microorganisms.
8. (1) Ultraviolet rays (2) heat, and (3) ultrasonic waves
9. (1) Iodine (2) bromine (3) bases (sodium hydroxide and lime) (4) ozone
10. The inability of ozone to provide a residual in the distribution system
11. Dose = demand + residual
12. Hydrogen sulfide and ammonia
13. Suspected carcinogenic compounds (trihalomethanes)
14. Chlorine gas lowers the pH; hypochlorite increases the pH
15. The higher the pH the greater the percent of OCl^-
16. The addition of chlorine to water until the chlorine demand has been satisfied and further additions of chlorine result in a free available residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.
17. Prechlorination ahead of any other treatment processes and postchlorination after the water has been treated and before it enters the distribution system
18. When the raw waters contain organic compounds
19. (1) Control of algal and slime growths (2) control of mudball formation (3) improved coagulation (4) reduction of tastes and odors (5) increased chlorine

contact time (6) increased safety factor in disinfection of heavily contaminated water

20. Chemical solution tank for the hypochlorite, diaphragm-type pump, power supply, water pump, pressure switch, and water storage tank
21. (1) Pumping directly into the water (2) pumping through an ejector which draws in additional water for dilution of the hypochlorite solution
22. Plastic containers
23. A week's supply of hypochlorite should be available
24. The fusible is a safety device. The fusible metal softens or melts at 158-165^{o}F to prevent buildup of excessive pressures and the possibility of rupture due to fire or high surrounding temperatures.
25. The upper valve discharges chlorine gas, and the lower valve discharges liquid chlorine from ton chlorine tanks.
26. In this position, either chlorine gas or liquid chlorine may be removed.
27. Turn the cylinder so that the leak is on top and the chlorine will escape as a gas.
28. By closing the valve or tightening the packing gland nut. Tighten the nut or stem by turning it clockwise.
29. By replacing the gasket or adapter connection.
30. Chlorine gas is extremely toxic and corrosive in moist atmospheres.
31. A properly fitting self-contained air or oxygen supply type of breathing apparatus, positive/demand breathing equipment, or rebreather kits are used when repairing a chlorine leak
32. First aid measures depend on the severity of the contact. Move the victim away from the gas area, remove the contaminated clothes and keep the victim warm and quiet. Call a doctor and fire department immediately. Keep the patient breathing.
33. The UV light intensity that reaches the pathogens in the water is affected by the condition of the UV lamps and the quality of the water.
34. (1) Checking the UV monitor for significant reduction in lamp output (2) monitoring the process changes in normal flow conditions (3) checking for fouling of the quartz sleeves and the UV intensity monitor probes (4) checking the indicator light display to ensure that all of the UV lamps are energized (5)

monitoring the elapsed time meter, microbiological results, and lamp log sheet (6) checking the quartz sleeves for discoloration

35. Depends on the quality of the water being treated and the treatment chemicals used prior to disinfection
36. Depends on (1) the level of suspended solids in the water to be disinfected and the fecal coliform level to be achieved (2) the frequency of the on/off cycles (3) the operating temperature of the lamp electrodes
37. Contact the appropriate regulatory agency. Do not throw UV bulbs in trash because they contain mercury.
38. It is unstable and decomposes to elemental oxygen in a short time after generation.

Section 10

Laboratory

1

Laboratory Practices

2

Objectives

- Water Quality
- Sampling
- Bacteriological Testing
- Water Quality Analysis
- Lab Safety
- QA/QC

3

Terminology

- Reaction time
- Holding time
- Autoclave
- Incubator
- Aseptic technique
- Disinfection
- Coliform density

4

Water Quality Analysis

5

Water Quality

- Process control monitoring
  - All public water systems that provide some type of treatment must monitor water quality
- Monitored to ensure safety and integrity
- Monitored to meet state and federal requirements
- Monitor raw, finished, and where you expect a physical/chemical change in your plant
- Monitor in distribution system also
  - Quality can degrade due to contamination or growth of organisms

6

Water Quality Degradation

- Treated water is disinfected, not sterilized
- Disinfection kills or inactivates harmful organisms (pathogens)
- Organisms can grow in distribution system if conditions are right
- To prevent growth of organisms
  - Keep chlorine residuals up
  - Keep excess nutrients out
  - Prevent stagnation
  - Prevent cross-connections

Water Quality Analysis

- The first step in water quality analysis is collecting samples which accurately represent the water
  - Representative sample
    - sample which contains basically the same constituents as the body of water from which it was taken
  - Improper sampling is one of the most common causes of error in water quality
- All biological analysis must be kept for <u>5 years</u>
- All chemical analysis must be kept for <u>10 years</u>

Types of Samples

- Grab sample
  - Single volume of water
  - Representative of water quality at exact time and place of sampling
  - Coliform bacteria, residual chlorine, temperature, pH, dissolved gases
- Composite samples
  - Representative of average water quality of location over a period of time
  - Series of grab samples mixed together
  - Determines average concentration
  - Not suitable for all tests

Sampling

Fleming Training Center TN Department of Environment & Conservation

Sample Volume and Storage

- Volume depends on test requirements
- Use proper sampling container
- Follow recommended holding times and preservation methods
  - If bottle already has preservative or dechlorinator in it, don't over fill or rinse out
- ❖ If you have questions regarding volume, container or holding times, check *Standard Methods* or contact the lab if you have an outside lab do you analysis

Sample Labeling

- Specific location (address)
- Date and time sampled
- Chlorine residual
- pH and temperature
- Sample type
- Name or initials of person taking sample

Sample Labeling

Sample Type

- Routine
- Repeat
  - same
  - upstream
  - downstream
- Special sample

Selecting Sampling Points

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- Raw-water supply
  - Install valve or sample cock on raw-water transmission lines or well discharge pipe
- Treatment plant
  - Sampling from various points helps determine efficiency of processes
  - Sample at every point where a change in water quality is expected
  - Finished water sample point usually at point of discharge from clearwell
- Distribution system
  - Distribution sampling is the best indicator of system water quality
  - Water quality changes in the distribution system

Distribution Samples

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- Allows operator to determine water quality at customers' taps
- Most common tests are chlorine residual and coliform bacteria
- Number of samples depends on population served and water source

17

Bacteriological Testing

Fleming Training Center

TN Department of Environment & Conservation

Collection of Samples

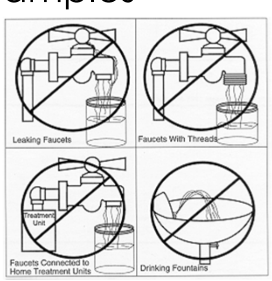
18

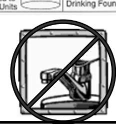
- Only approved containers should be used
  - 125 mL volume
  - Pre-sterilized bottles recommended
  - Other bottles sterilized at **121°C @ 15 psi**
    - 15 minutes
  - Should contain **sodium thiosulfate ($Na_2S_2O_3$)**

Bacteriological Samples

19

- Samples should never be taken from a hydrant or hose
- Only collect samples from approved faucets
- Don't collect samples from mixing faucets
- Only use cold water tap
- Front yard faucets on homes with short service lines are best





Bacteriological Samples

20

- Do not flame faucet with torch
  - Use alcohol or bleach solution to clean
- Turn on faucet to steady flow and flush service line (**2-5 min**) – getting water from the main line
- Fill bottle to proper level
- Label bottle with pertinent information
- **Refrigerate to proper temperature, 4°C**
- Test as soon as possible
  - Hold time **< 30 hours**

Collection of Bacteriological Samples

21

1. Remove aerator or screen
2. Collect sample from cold water tap
3. Sample from homes with short service lines
   - Same side of street as water main, preferably
4. Disinfect faucet with sodium hypochlorite
5. Flush service line
6. Adjust flow so that no splashing will occur
   - Do not touch inside of lid of sample bottle
   - Do not set lid down or put it in your pocket
   - Do not rinse bottle or allow it to overflow

Microbiological Indicator Organism

22

TOTAL COLIFORM

- Always present in contaminated water
- Always absent when no contamination
- Survives longer in water than most other pathogens
- Easily identified

EPA Approved Methods

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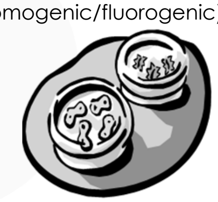
- Multiple-Tube Fermentation
- Presence-Absence Test
- MMO-MUG
- Membrane Filter Method
- Enzyme (chromogenic/fluorogenic) Substrate Tests



State Regulations

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- 0400-45-1-.06(4) Microbiological
  - (a)1. If you collect 40 samples/month, no more than 5% can be positive to be in compliance
  - (a)2. If you collect less than 40 samples/month, no more than 1 sample can be positive to be in compliance
  - (c) If any routine or repeat sample test (+) for total coliform, it must be analyzed for fecal or *E. coli*

State Regulations

25

- 0400-45-1-.07(2) Repeat Monitoring
  - (a) **If a routine sample is total coliform positive, the system must collect a set of repeat samples within 24 hours of being notified of the positive result**
  - (b) **The system must collect one at original site, at least one repeat within five service connections upstream and at least one repeat within five service connections downstream**

Bacteriological Samples

26

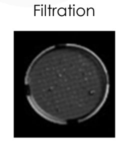
- The "MCL" for coliform bacteria is based on presence or absence
- Finished and distributed water should be Zero (absent)
- Incubate 24 hours @ 35 +/-0.5°C
- Keep records for 5 years

Colilert

Colisure

Colilert Quanti-Tray

Membrane Filtration



Enzyme Substrate Testing

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- Colilert (P/A)
- Colilert Quanti-Tray
- Colilert-18 (P/A)
- Colilert-18 Quanti-Tray
- E*Colite
- Colisure
- Readycult® Coliforms 100 (P/A) and Fluorocult LMX Broth
- Colitag

Colilert/Colilert 18 for P/A

28

- Equipment needed:
  - Incubator
  - UV lamp
  - Comparator
  - pH meter to check tryptic soy broth
- Sample bottle is used in the testing procedure
- Tests for total coliforms and *E. coli* in one step
  - Sample turns yellow if positive for total coliforms
  - Sample turns fluoresces if positive for *E. coli*

Colilert/Colilert 18 for P/A

29

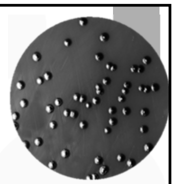
- Detects a single viable coliform per sample
- For Colilert 18, samples need to be pre-warmed to 35°C before incubation period starts
- Colilert 18 can lift boil water notices 6 hours earlier than other methods
- Shelf life is 12 months for media packet

Colisure

30

- Step 1
  - Add reagent (shelf life is 12 months) to sample
  - Incubate for 24 hours
    - if samples are not room temperature, they need to be pre-warmed before incubating
- Step 2
  - Read results
    - yellow = negative
    - magenta = total coliform positive
    - magenta/fluorescent = *E. coli* positive

Membrane Filter Technique



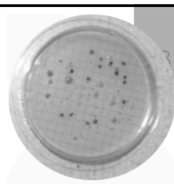
- 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing **M-Endo** broth (food source for bacteria) for **Total Coliforms**
- Petri-dish labeled, turned upside down, placed in incubator at **35° +/- 0.5°C for 24 hours**
- A coliform bacteria colony will grow at each point on filter where a viable bacterium was left during filtering
- **The colonies will appear red with a green-gold metallic sheen**

Membrane Filter Technique

37

- 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing **M-coli blue** broth (food source for bacteria) for **e. Coli**
- Petri-dish labeled, turned upside down, placed in incubator at **35° +/- 0.5°C for 24 hours**
- A coliform bacteria colony will grow at each point on filter where a viable bacterium was left during filtering
- **The colonies will appear blue**

Fecal Coliform Determination



- Membrane filtration test
- More reliably indicates the potential presence of pathogenic organisms
- Same procedure as Total Coliform, 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing **mFC broth**
- Incubation at **44.5° +/- 0.2°C for 24 hrs**
- **Bacterial colonies appear blue**
- Looks for heat tolerant bacteria

Membrane Filtration Pictorial

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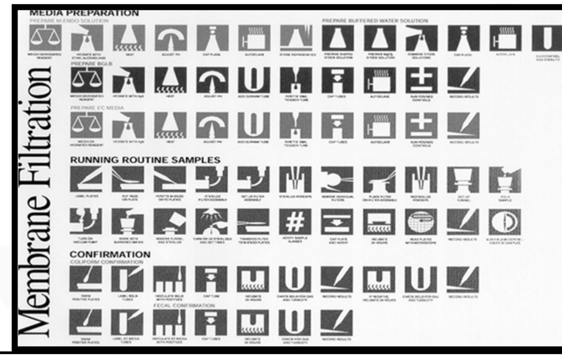

Colilert Method Pictorial

40

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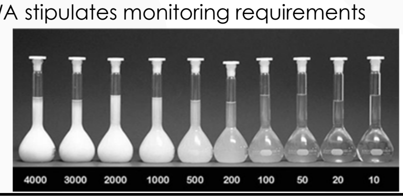
Water Quality Analyses

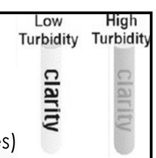
Turbidity

42

- Physical cloudiness of water
  - Due to suspended silt, finely divided organic and inorganic matter, and algae
- Nephelometric method measures scattered light
  - unit - NTU
- SDWA stipulates monitoring requirements

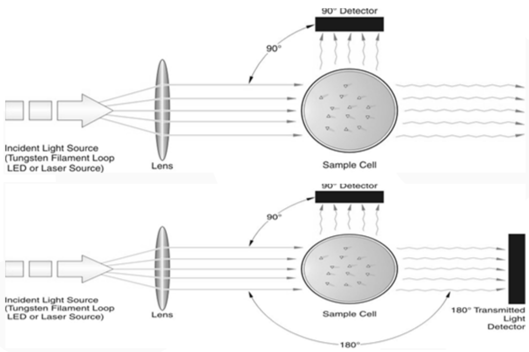


Turbidity



- Measure samples ASAP (within 15 minutes)
  - Turbidity can dissolve and skew the reading
- Keep sample tubes clean and scratch free
- Gently mix samples prior to reading
- Calibrate meter every 90 days → Primary standard
- Verify meter daily → Secondary (gel) standard
- Light source is most important part of turbidimeter
- Records must be retained minimum 5 years

Turbidimeter



Turbidimeters

Hach TU5200 Laboratory Laser Turbidimeter

Hach 2100 N

Free Chlorine Residual

- Free chlorine residual must be tested and recorded when bacteriological samples are collected
- Two most common tests:
  - Amperometric titration
    - Titrate sample with PAO (phenylarsine oxide)
    - less interferences as color and/or turbidity
  - Colorimetric
    - DPD (N,N-diethyl-*p*-phenylenediamine)
- Analysis should be performed ASAP
  - Holding time < 15 minutes
- Exposure to sunlight or agitation of the sample will cause a reduction in the chlorine residual

Free Chlorine Residual

- Colorimetric (DPD) method is most commonly used
  - Match color sample to a standard
  - ***Swirl sample for 20 seconds*** to mix
  - Reaction time: Within ***one minute*** of adding reagent, place sample into colorimeter
    - Different than Total Residual Chlorine
- Must maintain a free residual of 0.2 mg/L throughout entire distribution system
  - "Chlorine residual must not be less than 0.2 mg/L in more that 5% of samples each month for any two consecutive months"

Total Residual Chlorine

- Has a separate method than free chlorine
- Has minimum reaction time of 3 minutes
  - vs free chlorine that has a maximum reaction time
  - Holding the free chlorine sample for three minutes DOES NOT make it a total chlorine reading
  - The tests are independent of each other and looking for different constituents
    - Free Chlorine
      - HOCl & OCl^-
    - Total Chlorine
      - monochloramine, dichloramine, nitrogen trichloride and other chloro- derivatives

pH

- Power of hydrogen
  - Measurement of the hydrogen concentration
  - Each decrease in pH unit equals 10x increase in acid
- Indicates the intensity of its acidity or basicity
- Scale runs from 0 to 14, with 7 being neutral
- pH probe measures millivolts, then converts into pH units
  - Temperature affects millivolts generated, therefore you need a temperature probe as well for corrections
- sMCL = 6.5 - 8.5

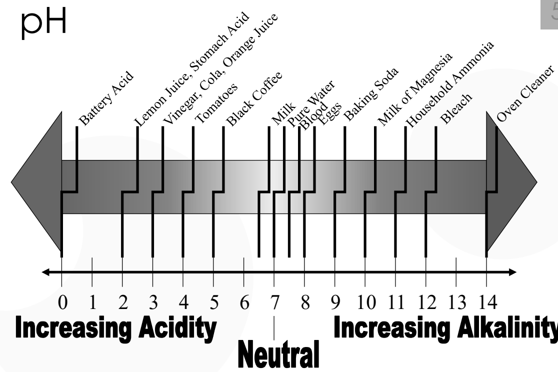
pH

51

- Calibrate daily with **fresh buffers**
  - Use at least two buffers
- Gel filled probes are not recommended for water industry
  - Water is too clean for probe to make an accurate measurement
- Store probe in slightly acidic solution
- Replace probes yearly

pH

52



Fluoride

53

- Added to drinking water for the reduction of dental caries (cavities)
- Interferences
- Primary MCL = 4.0 mg/L
- Secondary MCL = 2.0 mg/L
- State of Tennessee recommends 0.7 mg/L
  - Fluoridation of drinking water in the state of Tennessee is not required

Fluoride Analysis

54

- Colorimetric (SPADNS)
  - interferences are more common with this test
  - aluminum and polyphosphate complexes can interfere
- Ion Selective Electrode (ISE)
  - TISAB removes most of the aluminum interferences
    - Total Ionic Strength Adjustment Buffer
    - Contains CDTA – used to tie up interferences
  - store probe in a standard, the higher the better
  - probes can last 3-5 years
  - can clean with toothpaste

Alkalinity

55

- A measure of the ability of the water body to neutralize acids and bases and thus maintain a fairly stable pH level
  - The buffering capacity of a water body
- Due to presence of
  - Hydroxides (OH^-), Carbonates (CO_3^-), and Bicarbonates (HCO_3^-)
- Many water treatment chemicals (alum, chlorine, lime) alter water quality, including pH and alkalinity

Alkalinity

56

- Measured by titrating sample with 0.02 N H_2SO_4 (sulfuric acid) to a pH endpoint
  - Expressed in mg/L as $CaCO_3$
- Analysis - titration using sulfuric acid (H_2SO_4)to pH endpoint
- Endpoints
  - Phenolphthalein alkalinity pH = 8.3
  - Total alkalinity pH ≈ 4.5
- Can use color change indicator to show pH endpoint

Alkalinity

57

- Phenolphthalein Alkalinity (pH = 8.3)
  - Reagent: Phenolphthalein color indicator
    - Color change: Pink → clear
- Total Alkalinity (pH = 4.5)
  - Reagent: Methyl orange
    - Color change: Orange → peach
  - Reagent: Bromcresol green-methyl red
    - Color change: Blue/green → light pink
  - If testing a chlorinated sample using bromcresol green-methyl red, sodium thiosulfate must be added to remove chlorine that will interferes with the color change

Alkalinity Color Changes

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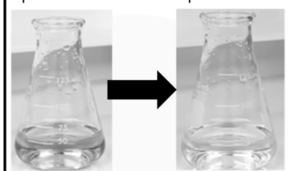
Phenolphthalein Alkalinity

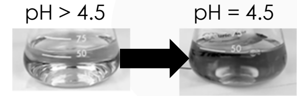
pH > 8.3 pH = 8.3



Total Alkalinity

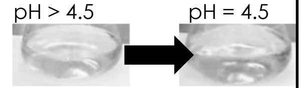
Bromcresol green-methyl red

pH > 4.5 pH = 4.5



Methyl Orange

pH > 4.5 pH = 4.5



Hardness

59

- Characteristic of water caused by the salts of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in solution
  - Bicarbonate, carbonate, sulfate, chloride, and nitrate
- Measured in mg/L as $CaCO_3$
- Total hardness analysis may involve titration of sample to an endpoint
  - Titrant: 0.02 N EDTA
  - Color change endpoint: red → pure blue
  - Metal ions may interfere, so an inhibitor may be needed

Hardness

60

Iron and Manganese

61

- Can precipitate out in distribution system due to oxidation
- Elevated levels in water can cause staining of plumbing fixtures and laundry
- sMCL for iron is 0.3 mg/L
- sMCL for manganese is 0.05 mg/L

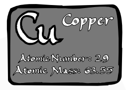
Lead and Copper Rule

62

- Established by EPA in 1991
- All community and non-community water systems must monitor for lead and copper at customers' taps
- If aggressive water is dissolving these metals, system must take action to reduce corrosivity
- Samples must be taken at high-risk locations
  - Homes with lead service lines
- Water must sit in lines for at least 6 hours
  - First draw sample
- One liter of sample collected from cold water tap in kitchen or bathroom
- Test results must be maintained for 12 years

Lead and Copper Rule

63



- Action levels
  - Lead - 0.015 mg/L
  - Copper - 1.3 mg/L
- If action level is exceeded in more than 10% of samples, steps must be taken to control corrosion
  - Corrosion control program
  - Source water treatment
  - Public Education
  - and/or Lead service line replacement

Phosphates

64

- Orthophosphates work well for lead and copper protection
- Polyphosphates work as *sequestering agents* – tie up iron and manganese to prevent color and taste complaints
  - Tie up calcium carbonate as a catalyst
  - Calcium (from alkalinity) is required as a catalyst
  - If low alkalinity, need a blend of polyphosphate and orthophosphate
- **Orthophosphate coats pipe; polyphosphate sequesters**

Phosphates Analysis

65

- Total phosphates
  - Colorimetric test
  - Sample needs to be digested before they can be analyzed
- Ortho-phosphates
  - Also called reactive phosphates
  - Colorimetric test
  - Easily done with Hach test kit

Total Organic Carbon (TOC)

66

- High temperature combustion at 950°C
- Sample is injected into a heated reaction chamber packed with oxidative catalyst such as cobalt oxide
- Water is vaporized and the organic carbon is oxidized to CO_2 and H_2O
- CO_2 is transported in the carrier-gas streams and is measured by means of a nondispersive infrared analyzer (NDIR)
- Samples are preserved with sulfuric or phosphoric acid and cooled to 4°C

Disinfection By-Products (DBPs)

68

Trihalomethane (THM or TTHM)

- Chloroform
- Dibromochloromethane
- Bromodichloromethane
- Tribromomethane

- MCL = 0.080 mg/L

Haloacetic acids (HAA5)

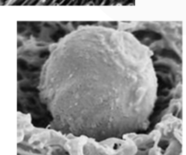
- Monochloracetic acid
- Dichloroaecitic acid
- Trichloroacetic acid
- Monobromoacetic acid
- Dibromoacetic acid

- MCL = 0.060 mg/L

Cryptosporidium (Crypto)

71

- Protozoan parasite
- Common in surface water
- Resistant to traditional disinfectants
- Can pass through filters
- Causes cryptosporidiosis
- Filtration and alternative disinfectants can remove and/or inactivate



Cryptosporidium Oocyst

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Lab Safety

Lab Safety

- Read SDS for all chemicals used in lab
- Store chemicals properly
- Know where safety equipment is stored
- Never pour water into acid
- CPR and First Aid Training (TOSHA requirement)
- Clean chemical spills immediately
- Follow published lab procedures (*Standard Methods*)
- Read and become familiar with Safety SOP

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Safety Data Sheets (SDS)

- Keep on file for all chemicals purchased
  - According to the Americans with Disabilities Act of 1990, SDS's should be kept for a minimum of 30 years
- Includes all information shown on chemical label and more

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Safety Data Sheets (SDS)

- Must be readily available for employee review at all times you are in the work place
  - The can't be locked in an office or filing cabinet to which you don't have access to
  - If they are on a computer, everyone must know how to access them
- If you request to see an SDS for a product you use at work and your employer can't show it to you, after one working day you have the right refuse to work with that product until you are shown the correct SDS

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Safety Data Sheets (SDS)

- Information provided:
  - Identification
  - Hazards identification
  - Composition
  - First aid measures
  - Fire-fighting measures
  - Accidental release measures
  - Exposure controls/personal protection
  - Physical & chemical properties
  - Stability and reactivity
  - Toxicological information
  - Other information, including date of SDS preparation or last revision

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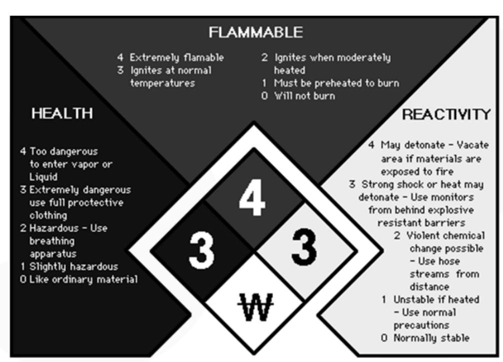
NFPA Chemical Label



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Quality Assurance/Quality Control

81

QA/QC Program

Three Phases

- Record Keeping
- Quality Assurance Plan
  - Addresses the entire **laboratory process**, from the time a sample arrives in your facility, to the moment results are recorded and reported
  - Will ensure that test results obtained are as correct as possible
- Quality Control Program
  - Those **laboratory practices** that are undertaken specifically to achieve accurate and reliable analytical results
  - Tests to demonstrate precision and accuracy

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Quality Assurance/Quality Control

- A QA/QC program consists of the procedures that ensure the precision and accuracy of tests performed on a daily basis
- Precision - repeatability
  - Shooting at a target and hitting the same spot repeatedly
- Accuracy – closeness of test results to the correct (known) value
  - Shooting at a target and hitting the bull's eye

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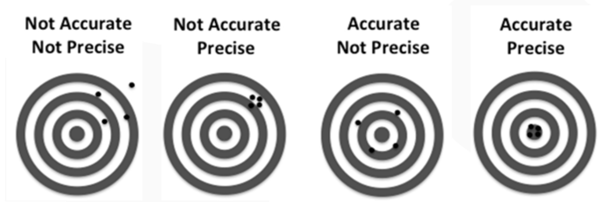
Accuracy vs Precision



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Quality Assurance Program

Record Keeping

- Maintain a complete and accurate list of exact locations of all sampling sites
- Maintain a complete and accurate list of all test procedures used
  - Record method numbers on bench sheets
- Write in pen
- Initial your entries
- Use a notebook

85

Quality Control Tests

- Duplicates
- Blanks
- Lab standards
- Unknown lab standards
- Spikes

Duplicates
86

- Simplest form of QC test
- Run two tests on one sample
  - This shows how precise the analyst's procedure is
  - Sample results should yield very close results
    - goal is to have no difference
- General recommendation is to run a duplicate every 10 samples

Duplicates
87

Common Sources of Error
- Sample size - should be same size
- Insufficient mixing
- Dirty glassware
- Calculation errors
- Reagents
- Titration - misreading burette
- Weighing
- Calibration
- Reagent water

QC Blanks
88

- Can show test interference
- Should be treated as a sample
  - Take through all procedures
  - Add all reagents or incubate along with other samples
- Target value for a blank is zero
- Positive blanks show a problem
  - Bad reagents
  - Bad technique
  - Unclean glassware
  - Bad distilled water

Membrane Filtration Blanks
89

- A blank should never be positive
- Blanks should be run before you filter samples and when you are done filtering samples
  - If the pre-sample blank has colony growth, the equipment was not properly sterilized
  - If the post-sample blank has colony growth, the equipment was not cleaned well enough between samples

Laboratory Standards
90

- Determines accuracy
- If the test value agrees with the true value, the test has been performed accurately
- Mix onsite or purchased from supplier
  - Purchased standards should be the preference because this can reduce the possibility of having mixing errors
  - They also come with a certificate of analysis
- Perform along with duplicates
  - One every 10 samples

Unknown Laboratory Samples
91

- EPA quality control unknowns
- Commercially available
- Gives confidence to analyst
- Can show deficiencies in the testing procedure

Spikes

92

- Determine accuracy
- A known amount of standard is added to a sample
- The results should equal the sample value plus the added known amount
- Goal is to have 100% recovery of spike and sample
- If you use Hach methods, most have directions on how to spike a sample
- If your sample result was 100 mg/L and you added 50 mg/L into the sample
  - you should yield 150 mg/L

Split Samples

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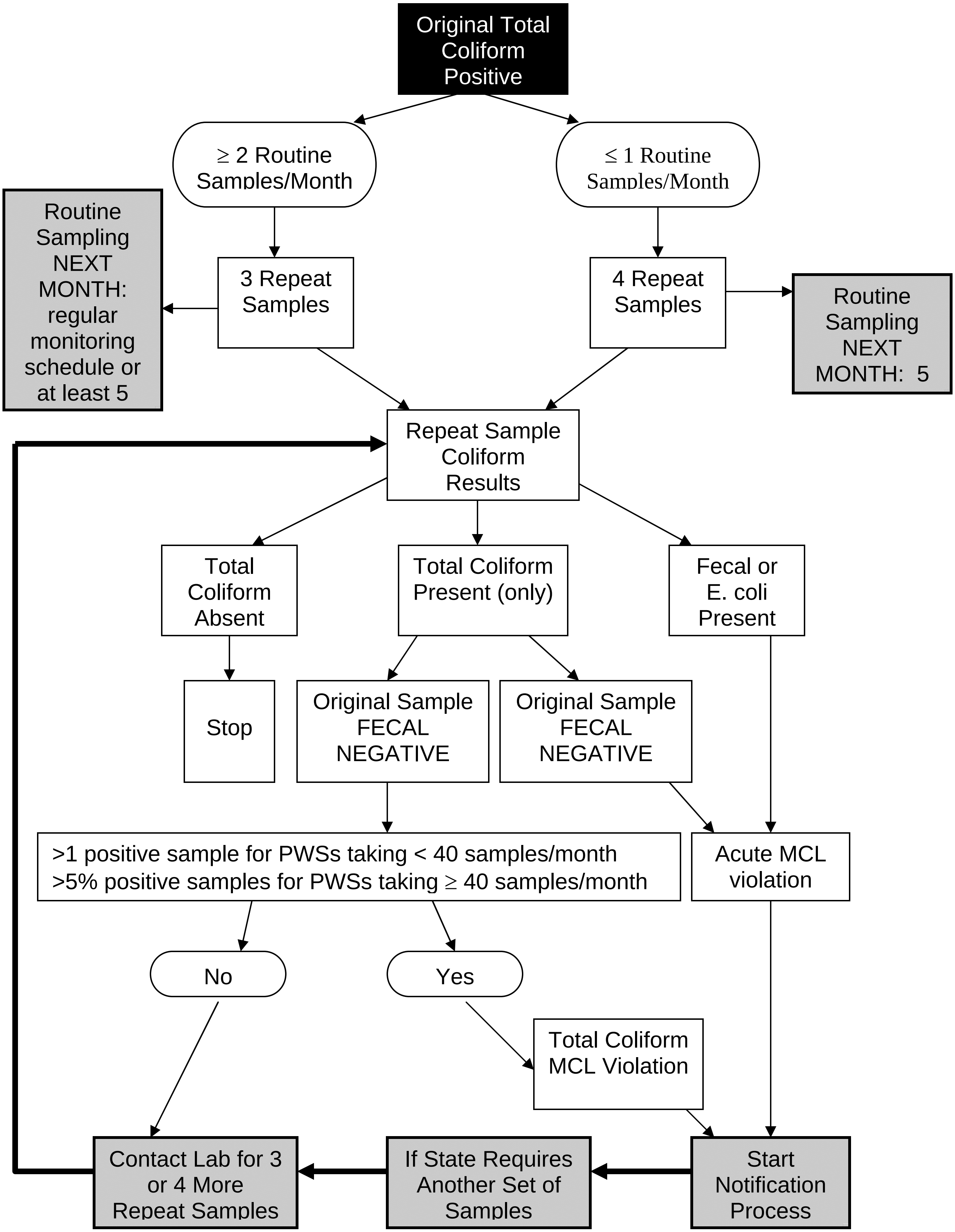
- Some labs split samples with other labs to check the accuracy of the testing procedure
- If you are concerned that your contract lab is getting wrong values, send in a known standard as a sample
  - This does double your cost, but you can see how close they are to the known value
  - Don't tell the contracted lab that the second sample is a known

Total Coliform Monitoring Frequency for Community Water Systems

Population Served	Minimum Number of Samples Per Month
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
3,960,001 or more	480

Total Coliform Action Flow Chart



Water Treatment and Distribution
Laboratory Practice Quiz

1. The MCL for total coliform bacteria is based on their ______________ .
   a. Concentration in mg/L
   b. Concentration in colonies per 100 mL
   c. Presence or absence
   d. All of the above
   e. None of the above

2. The sample volume to be used when running a membrane filter test for coliform bacteria is _______________ .
   a. 20 mL
   b. 40 mL
   c. 60 mL
   d. 80 mL
   e. 100 mL

3. Records of bacteriological analyses must be kept at least ________________ .
   a. Until the next sanitary survey
   b. Three years or until the next sanitary survey
   c. Five years
   d. Ten years
   e. Twelve years

4. Analysis of samples for determining bacteriological quality of the water must be started within _____________ hours of collection.
   a. 24
   b. 30
   c. 36
   d. 42
   e. 48

5. A bacteriological bottle contains a white powder which is placed in the bottle in order to _________________ .
   a. Keep the bottle clean
   b. Kill any bacteria present
   c. Remove any chlorine residual
   d. All of the above
   e. None of the above

6. When the membrane filter method for coliform analysis is used, a typical coliform colony will be pink to dark red with a distinctive ___________________ .
   a. Greenish metallic sheen
   b. Dull bluish coating
   c. Shape
   d. All of the above
   e. None of the above

7. Any sample that contains coliform bacteria is a ___________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

8. Any sample that does not contain coliform bacteria is a __________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

9. For bacteriological sample to be useful, it must contain essentially the same constituents as the body of water from which it was taken. This type of sample is called a _________________ sample.
   a. Grab
   b. Flow-proportional time composite
   c. Representative
   d. Time composite

10. To remove any stagnant water from the customer’s service line, and to make certain that water from the distribution main is being sampled, flush the faucet for ________ minutes.
    a. 1 – 3
    b. 2 – 5
    c. 5 – 7
    d. 7 – 9
    e. 10 – 15

11. Bottles for collecting samples for bacteriological analyses should ______________ .
    a. Not be rinsed before use
    b. Be rinsed before use
    c. Be completely filled
    d. All of the above
    e. None of the above

12. Bottles for collecting samples for bacteriological analyses contain ______________, which destroys any chorine residual in the sample.
    a. Sodium arsenite
    b. Sodium chloride
    c. Sodium fluoride
    d. Sodium hydroxide
    e. Sodium thiosulfate

13. Samples for bacteriological analysis should not be taken from _________________.
    a. Swivel faucets
    b. Leaking faucets
    c. Faucets with aerators, strainers or hose attachments
    d. All of the above
    e. None of the above

14. A sample which consists of a number of grab samples taken from the same sampling point at different times and mixed together before analysis is called a __________________ sample.
    a. Composite
    b. Grab
    c. Flow-proportional time composite
    d. Representative
    e. Time composite

15. High fluoride readings can result from all of the following causes except _________.
    a. Polyphosphates can interfere with the SPADNS method, resulting in high fluoride readings
    b. Not accounting for natural fluoride in the water
    c. Dilution of water which has been fluoridated with unfluoridated water in storage tanks
    d. All of the above
    e. None of the above

16. What is the secondary maximum contaminant level for fluoride?
    a. 0.2 mg/L
    b. 0.4 mg/L
    c. 2.0 mg/L
    d. 4.0 mg/L

17. The maximum permissible level of a contaminant in water as specified in the regulations of the Safe Drinking Water Act is the __________________________ .
    e. Maximum contaminant level
    f. Saturation point
    g. Zeta potential
    h. All of the above
    i. None of the above

18.__________________ is an indicator used when measuring the total alkalinity concentration on a water sample.
j. EDTA
k. Eriochrome black-T
l. Bromcresol Green Methyl Red
m. Phenolphthalein
n. Sodium thiosulfate

19. A(n) ___________________ is a device that sterilizes laboratory equipment by using pressurized steam.
a. Autoclave
b. Beaker
c. Buret
d. Nephelometer
e. Pipet

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

Section 11

Storage Tanks

Fleming Training Center | TN Department of Environment & Conservation

Storage Tanks

CSUS: Water Distribution Systems
AWWA: Water Transmission and Distribution

1

Objectives

- Purpose and Types Water Storage
- Water Storage Facilities
- Inspections and Maintenance
- Disinfection

Purpose of Water Storage

- Equalizing supply and demand
- Increasing operating convenience
- Leveling out pumping requirements
- Decreasing power costs

3

Purpose of Water Storage

- Providing water during power or pump failure
- Providing adequate water for fire fighting
- Providing surge relief
- Increasing detention times
- Blending water sources
- Decrease pumping costs

4

Capacity Requirements

- Based on maximum water demands in different parts of the system
- Too much storage can cause stagnant water and taste & odor problems
  - 20% turnover rate to prevent it from becoming septic within 24 hours
    - less sediment

5

Type of Service

- Operating Storage
  - Tank directly connected to distribution piping
  - Fills and empties based on system pressure
- Emergency Storage
  - Used for emergency, e.g. fire protection
  - Not suitable for potable use
  - Subject to freezing due to lack of circulation

6

WATER STORAGE FACILITIES

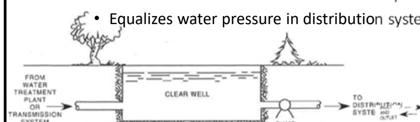
Configuration of Storage Tanks

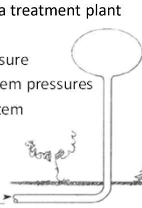
- Elevated Tanks
- Ground-Level Reservoirs
- Standpipes
- Hydropneumatic Tanks
- Surge Tanks

8

Storage Facilities

- Provide a sufficient amount of water to average or equalize the daily demands
- Fire protection, industrial uses, reserve storage
- Types
  - Clear wells
    - Used for the storage of filtered water from a treatment plant
  - Elevated tanks
    - Maintains adequate and fairly uniform pressure
    - Minimizes variations in the distribution system pressures
    - Equalizes water pressure in distribution system





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Storage Facilities

- Types
  - Standpipes
    - Stand on ground and have a height greater than diameter
  - Ground-level reservoirs
    - May be buried or on the ground surface

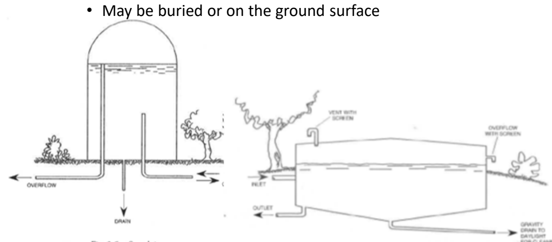

Fig. 2.5 Standpipe

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Ground-Level Reservoirs

This is an old open-topped reservoir that has been converted with a liner-cover

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Storage Facilities

- Types
  - Hydropneumatic or pressure tanks
    - A system in which a water pump is controlled by the air pressure in a tank partially filled with water
    - Must contain proper air to water ratio: 2/3 water to 1/3 air
    - **Insufficient air will cause pump to "short cycle"**
  - Surge tanks
    - Used to control water hammer or regulate flow of water
    - Should be located close to activity that may cause water hammer

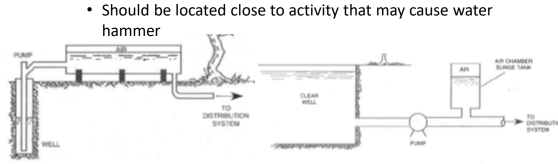

Fig. 2.7 Hydropneumatic or pressure tank

Fig. 2.8 Surge tank

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Storage Facilities – Elevated Tanks

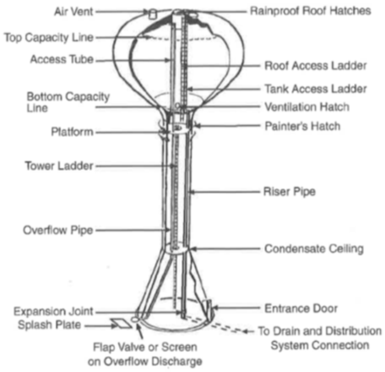

FIGURE 3-9 Principal accessories for an elevated storage tank
Courtesy of CB&I

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Storage Facilities – Elevated Tanks

- Same pipe used for inlet and outlet called a riser
- Overflow pipe required in case water-level controls fail
  - Should be covered by weighted flap valve and **24 mesh non-corrodible screen**
- Must be furnished with drain connection to empty tank for maintenance and inspection
- Water level in tank monitored by either pressure sensor at base or level sensor inside tank
  - Telemetry equipment, altitude valves, overflow and low-level alarms
- Must be furnished with valve a connection to distribution system
- Altitude valve required if tank is not tall enough to accept full system pressure without overflowing
  - Automatically shuts off flow to tank when water level reaches overflow point

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Storage Facilities – Elevated Tanks

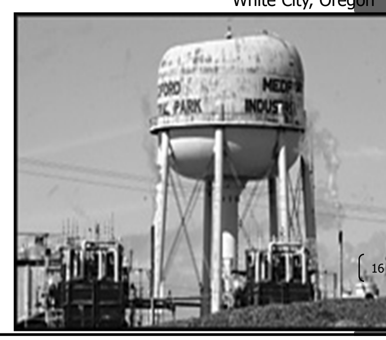
- Multicolumn tanks generally have three ladders
  - One up a leg of tank to a balcony, one from balcony to roof, one installed on the roof
- Vents must be installed to allow air to enter and leave the tank as the water level changes
  - **4 mesh non-corrodible screen required**
- Access hatches must allow for entry and ventilation during maintenance and inspections
  - Hatches on roof must have rims under cover to prevent surface runoff entering the tank
  - Hatches at bottom must be able to withstand pressure of water column

15

Storage Tank Collapse

- Caused by massive leak in 42 inch water main (50,000 gallon per minute) which quickly drained the tank
- Vacuum formed sucking in the roof

White City, Oregon



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Storage Facilities – Elevated Tanks

- Interior and exterior coatings must be able to withstand harsh conditions
  - Exterior coatings must maintain a good appearance over a reasonable period of time
  - All paints must be acceptable to FDA and EPA for contact with potable water
- Cathodic protection reverses flow of current that dissolves iron and causes rust and corrosion
  - Should be used in conjunction with tank coatings
- FAA may require installation of obstruction lighting or strobe lights

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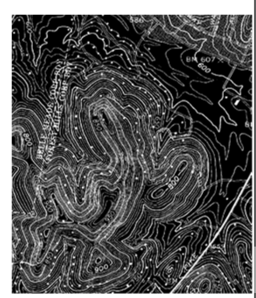
Selection and Location of Storage

- Determined by hydraulics, water demand, elevation of terrain, purpose of tank, etc.
- Type of storage depends on purpose of tank



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Storage Facility Operations

- Supply water during high demand
  - Low demand times are used to fill the tank
- May use variation of pumps to maintain pressure in distribution system
  - Can be controlled automatically by instrumentation
  - Automated systems must be inspected regularly
- Abnormal operating conditions
  - Excessive water demands
  - Broke or out of service pumps, mains, or tanks
  - Stale water leading to taste and odor problems

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Storage Levels

- Water levels drop during peak demands and rise during low demands
- Water demands vary within the day, from day to day, and from season to season
  - Knowing these patterns, the operator can anticipate high-demand periods
- Automatic water level regulation can be achieved using altitude-control valves
  - A valve that automatically shuts off the flow into an elevated tank when the water level in the tank reaches a predetermined level
  - Prevent overflows
  - Maintains a constant water level based on system pressure

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Storage Level Controls

- Electrodes mounted at various levels in tank sense the change in water level and can start/stop the pump as needed
  - Can be difficult to reach for maintenance and replacement
  - Susceptible to corrosion or contamination
- Ultrasonic transmitters send a continuous sound wave to a receiver; when covered with water, the signal is broken
- Pressure switches respond to changes in water pressure
  - Must be properly calibrated
- Solid-state electronic sensors measure the actual water surface level
- Differential-pressure altitude valves can regulate water surface levels based on pressure

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Fleming Training Center
TN Department of Environment & Conservation

INSPECTIONS AND MAINTENANCE

Facility Inspection

- Routine inspections part of normal, daily routine
  - Include check of security items
- Periodic inspections include climbing and looking inside
  - Check security items, site drainage, penetrations into the system, and overflows
- Comprehensive inspection must be performed by professional every 5 years
  - Retain record for minimum of 5 years

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Tank Inspections

- Must be professionally inspected every 5 years in accordance with State requirements (Rule 33)
  - Inspected by draining or by using a diver
  - Inspected by a third party

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Facility Inspection

- Wet inspections conducted by divers or robots allow tank to remain filled
  - Higher chlorine residual required during inspection as well as a cleaning process to protect against bacterial contamination
  - Divers and equipment should be disinfected with 200 mg/L chlorine solution before entering tank
  - Divers equipped with surface supplied air, drysuit, and surface supplied equipment
  - Refer to AWWA C652 Sec 4.4 for more information

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Pumps

- Centrifugal pumps must be primed
- Primed – filling a pump casing with water to remove the air
  - Primer pump will pump water into the pump casing to submerge the impeller
  - Priming water tank or auxiliary water supply can be used to add water to the pump casing bleeding off the air in the casing
  - Electric or hand-operated cause water to flow into the suction pipe and pump casing
- Foot valve – check valve located at bottom end of the suction pipe on a pump
  - Holds pumps prime

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Troubleshooting

- Water Quality Problems
  - Microbiological
    - Loss of chlorine residual
    - Bacterial growth
  - Chemical
    - Leaching of chemicals from linings and coatings
  - Physical
    - Settling and collection of sediment, rust & chemical precipitate

27

Maintenance

- Three types:
  - **Preventive** – repair or adjustment of equipment and facilities that is done before deterioration takes place
  - **Predictive** – attempts to predict when a failure might occur
  - **Corrective** (repair) – maintenance that is necessary when a problem already exists
- Painting
  - Paints and coatings accepted by the Environmental Protection Agency (EPA) and/or the National Sanitation Foundation (NSF) for potable water contact are generally acceptable to the Department

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Corrosion Control

- Factors affecting corrosion
  - Warmer water = increased corrosion
  - Water velocity
    - High velocities in corrosive water will lead to rapid pipe deterioration
    - Low velocities lead to longer contact times and metal pickup (red or dirty water complaints)
  - Dissolved oxygen increases = increased corrosion
  - **Carbon dioxide increases = increased corrosion**
    - CO_2 lowers pH
  - Dissolved minerals increase = increased corrosion
  - Sulfate reducing bacteria = increased corrosion

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Corrosion Control

- A coat of paint is the least expensive type of corrosion control
- Metallic coatings such as zinc
- Nonmetallic coatings
- Chemicals added during treatment of water to deposit a protective coating or film on the tanks metal
  - Calcium hydroxide (lime), sodium carbonate (soda ash), zinc paints
- Cathodic protection - electrical system for prevention of rust, corrosion, and pitting of metal surfaces that in contact with water or soil
  - Direct current applied to electrodes will cause them to corrode or be “sacrificed”

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DISINFECTION

Disinfection

- Disinfection is the inactivation/destruction of disease-causing organisms
- New storage facilities and those that have been repaired, cleaned, or had cathodic protection installed must be disinfected
- Follow AWWA Standard C-652, Disinfection of Water-Storage Facilities
- Always wear protective clothing
- Anyone entering tank must have on a safety harness
- Never enter a tank without two people standing by for rescue purposes

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Disinfection

- Liquid chlorine – Cl_2
  - 100% pure
- Sodium hypochlorite – NaOCl
  - Bleach
  - 5-15% pure
- Calcium hypochlorite – $Ca(OCl)_2$
  - HTH (high test hypochlorite)
  - 65% pure

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Disinfection – AWWA C652

Method 1

- Fill tank to overflow level with potable water
  - Must have 10 mg/L at end of contact period
  - Liquid chlorine/sodium hypochlorite
    - Add to the water during filling operation to give a uniform chlorine concentration
  - Calcium hypochlorite
    - Crushed to not larger than ¼ inch and poured into tank before filling
- Retention period
  - Liquid chlorine – 6 hours
  - Hypochlorite – 24 hours

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Disinfection – AWWA C652

Method 2

- 200 mg/L chlorine applied directly to surface of all parts of tank that may come in contact with potable water
  - Sprayed or brushed on
  - Let sit for 30 minutes then fill tank to overflow

35

Disinfection – AWWA C652

Method 3

- Fill 5% of tank with 50 mg/L chlorine solution
  - Hold for 6 hours
- Fill tank to overflow
  - Hold for 24 hours
  - Must have 2 mg/L at end of contact time

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Disinfection

- After disinfection, highly chlorinated water must be disposed of properly
  - Any water with concentration greater than 2 mg/L should be diluted or dechlorinated before disposal
  - Do not discharge to sanitary sewer without first communicating with the wastewater treatment plant
  - Chlorinated water should not be discharged to any surface waters with permission from the State
- After flushing, bacteriological testing must be performed and have negative results before putting tank in service

37

Storage Facilities

- Inspections must be performed by third party every 5 years
  - Maintain record for 5 years
  - System operators should visually inspect tanks periodically
- Cleaning
  - Out-of-service cleaning consists of draining, washing, and disinfecting tank
  - In-service uses divers or remotely controlled equipment
- Booster pump is used to increase the pressure in the mains
  - Will not produce a negative pressure anywhere in the system
  - Pressure in suction line shall be maintained at or above 20 psi by the use of a pressure sustaining valve or low pressure cutoff device

38

Ground Storage Tank Inspection Report

Job No.: ______________ Date: ________________ Inspector: __________________

Tank owner: ____________________________ Owner's order #: _________________

Owner's representative: _______________________ Title: ______________________

Mailing address: ____

Physical address: ____

City, State: ____ Zip: _________________

County tank is located: __________________ Seismic zone of county: ___________

Telephone: _____________________________ Fax: ____________________________

Location of tank: ____

Original Contractor #: _______________________________ Year built: ___________

Original Manufacturer: ______________________________ Capacity: ____________

Date of last inspection: ____

Diameter: ________________________ Height: _______________________________

Type of construction: Welded: ______________ Riveted: _____________

Who is customer's insurance carrier? ____

Storage Tank Vocabulary

A. Altitude Valve
B. Booster Disinfection
C. Cathodic Protection
D. Elevated Storage
E. Elevated Tank
F. Emergency Storage
G. Ground-level tank
H. Hydropneumatic System
I. Overflow Level
J. Reservoir
K. Riser
L. Standpipe
M. Tank

______1. An electrical system for preventing corrosion to metals, particularly metallic pipes and tanks.
______2. A system using an airtight tank in which air is compressed over water (separated from the air by a flexible diaphragm). The air imparts pressure to water in the tank and the attached distribution pipelines.
______3. A structure used in a water system to contain large volumes of water or other liquids.
______4. The maximum height that water or liquid will rise in a receptacle before it flows over the overflow rim.
______5. A valve that automatically shuts off water flow when the water level in an elevated tank reaches a preset elevation then opens again when the pressure on the system side is less than that on the tank side.
______6. Storage volume reserved for catastrophic situations, such as supply-line break or pump-station failure.
______7. (a) Any tank or basin used for the storage of water. (b) A ground-level storage tank for which the diameter is greater than the height.
______8. A ground-level water storage tank for which the height is greater than the diameter.
______9. In the distribution system, storage of water in a tank whose bottom is at or below the surface of the ground.
______10. In any distribution system, storage of water in a tank supported on a tower above the surface of the ground.
______11. The vertical supply pipe to an elevated tank.
______12. A water distribution storage tank that is raised above the ground and supported by posts or columns.
______13. The practice of adding additional disinfectant in the distribution system.

Storage Tank Review Questions

1. List 9 reasons for providing water storage in a distribution system.
   -
   -
   -
   -
   -
   -
   -
   -
   -

2. List the 4 types of distribution storage tanks and a description of each.
   -
   -
   -
   -

3. What is the difference between operating storage and emergency storage?

4. Why should vent openings on storage tanks be screened?

5. What is the purpose of an altitude valve?

6. How often must storage tanks be inspected according to the Regulations for Public Water Systems and Drinking Water Quality for the State of Tennessee?

7. After disinfection, what must be done before a tank is put back in service?

8. Name four things that should be considered when determining the type and the site for a new storage tank.
   -
   -
   -
   -

9. Why should the overflow pipe on a storage tank never be directly connected to a sewer or storm drain?

10. How are storage tanks protected from corrosion?

Storage Tank Review Questions

1.
   - Equalizing pressure and demand
   - Increasing operating convenience
   - Leveling out pumping requirements
   - Decreasing power costs
   - Providing water during source or power failure
   - Providing adequate water for fire fighting
   - Providing surge relief
   - Increasing detention time
   - Blending water source

2.
   - Elevated – tank on tower, provides pressure, minimizes pressure variations
   - Standpipe – tank on ground, taller than diameter, stores large volumes of water at low pressure, safer than elevated tank, may require pump
   - Ground-level reservoir – diameter greater than height, requires pump
   - Hydro-pneumatic – 2/3 water, 1/3 air; air helps maintain pressure, usually used with wells; small tanks

3. Emergency storage is not considered to be potable water – for emergencies only, e.g. fire protection.
   Operating storage is directly connected to distribution system, fills and empties by distribution pressure.

4. To keep out birds, insects, animals, etc.

5. To keep tank from overflowing

6. Professionally every 5 years

7. Bacteriological samples must be taken and must pass.

8. Water demand; Hydraulics, terrain; Purpose of tank; Public opinion

9. That would be a cross connection

10. Cathodic protection, coatings

Storage Tank Vocabulary

1. C
2. H
3. M
4. I
5. A
6. F
7. J
8. L
9. G
10. D
11. K
12. E
13. B

Section 12

Taste and Odor

Taste and Odor Control

California State University: Sacramento
Water Treatment Plant Operation

1

Taste and Odor Classifications

- Objectionable Taste Classifications

Sweet	Sour	Bitter	Salty

- Objectionable Odor Classifications

Aromatic	Fishy	Grassy
Musty	Septic	Medicinal

- sMCL Odor = 3 TON (threshold odor number)
- sMCL Color = 15 color units
- sMCL pH = 6.5 - 8.5

2

Taste and Odor Problems

- Consumer uses three senses to evaluate water
  - Sight (color)
  - Smell (odor)
  - Taste (objectionable)
- Leads to consumers purchasing bottled water or switching to alternative water supplies
- Loss of public confidence in water utility
- Funding restrictions
- Increased public relations problems
- Key to success is to prevent tastes and odors from every developing

3

Common Causes of Tastes & Odors

- Geosmin
  - Natural byproduct of blue green algae and certain bacteria in the soil (Actinomycetes)
  - Associated with earthy odors in water
- 2-Methylisoborneol (MIB)
  - Natural byproduct of blue green algae and Actinomycetes
  - Imparts a musty odor to water
- Chlorine
  - Most common disinfectant and most common source of T&O
  - Complaints range from bleach to chlorinous and medicinal tastes and odors

4

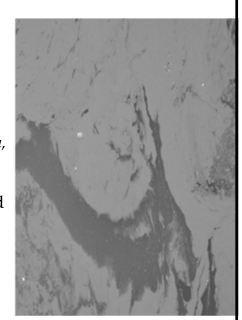
Common Causes of Tastes and Odors

- Chloramines
  - Made by combining ammonia and chlorine
  - Monochloramine – rarely causes T&O
  - Dichloramine – swimming pool or bleach odor detected at 0.9-1.3 mg/L
  - Trichloramine – geranium-like odor at 0.02 mg/L or higher
- Aldehydes
  - Caused by oxidation of amino acids and nitriles
  - Fruity odor in ozonated waters
- Phenols and Chlorophenols
  - Chlorine reacts with phenols to form chlorophenols
  - Pharmaceutical and medicinal tastes and odors most common

5

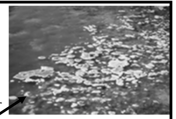
Natural Causes of Tastes and Odors – Biological Growth

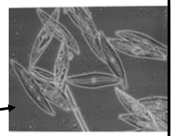
- *Actinomycetes* – group of bacteria identified as sources of earthy-musty odor
  - Geosmin and MIB are byproducts
- Algae is a major cause of tastes and odors
  - Blue-green algae (*Cyanophyta*)
    - Most common odor producer
      - *Anabeana, Aphanizomenon, Oscillatoria, Microcystis*
      - Earthy-musty to septic
        - Dependent on species, density, and physiological state
    - Grow into blooms that float on top of water



Natural Causes of Tastes and Odors – Biological Growth

- Algae is a major cause of tastes and odors
  - Yellow-green algae (*Chyrsophyceae*)
    - *Dinobryon, Mallomonas, Synura*
    - Large numbers not necessary to produce odors ranging from cucumbery to fishy
  - Diatoms (*Bacillariophyceae*)
    - *Asterionella, Cyclotella,* and *Tabellaria* produce fishy odors
    - *Melosira* & *Fragellaria* produce musty odors
  - Dinoflagellates (*Pyrrophyta*)
    - *Ceratium* & *Peridinium* produce rotten, septic, or fishy odors in large quantities





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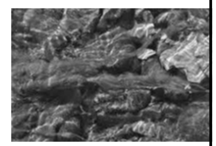
Natural Causes of Tastes and Odors – Biological Growth

- Planktonic algae and periphyton (attached algae) are significant sources of geosmin and MIB
- Sulfate-reducing bacteria are anaerobic bacteria that reduce sulfate to hydrogen sulfide
  - Results in rotten egg odor
  - Can occur in when bottom of stratified lake becomes anaerobic

Planktonic algae



Periphytonic algae

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Natural Causes of Tastes and Odors – Biological Growth

- As microbial populations grow and multiply, metabolic byproducts may deteriorate the T&O quality
  - Amount of byproduct produced is minimal (ng/L)
- As microbial population dies off, T&O issues increase due to natural decomposition

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Natural Causes of Tastes and Odors – Environmental Conditions

- Pollutants
  - Microorganisms that feed off the organic material (pollutants) cause oxygen depletion following nutrient enrichment from runoff
  - Increased nutrient concentrations allow for rapid microbial growth
    - Microbes consume dissolved oxygen in water faster than it can be replaced creating an oxygen-poor condition

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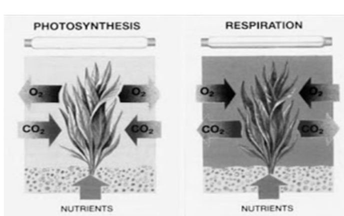
Natural Causes of Tastes and Odors – Environmental Conditions

- Blooms of photosynthetic algae can affect oxygen concentrations
  - Photosynthesis converts carbon dioxide and inorganic substances into oxygen using sunlight
  - Respiration consumes oxygen and produces carbon dioxide during the night



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Natural Causes of Tastes and Odors – Environmental Conditions

- Diurnal Dissolved Oxygen Cycle
  - Large algal blooms produce oxygen faster than it can escape during the day (photosynthesis)
    - The water then becomes supersaturated with oxygen especially during the afternoon hours
    - DO and temperature are inversely proportionate
  - At night, algae consume the oxygen faster than it can be replenished (respiration)
    - By early morning, nearly all dissolved oxygen has been consumed

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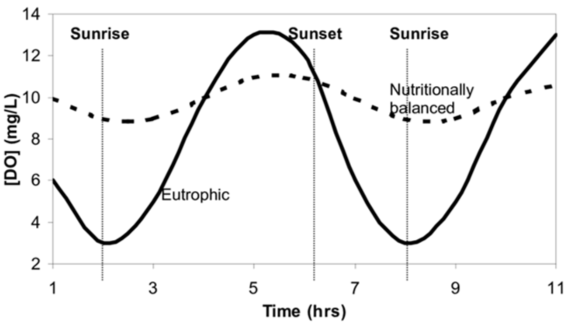
Diurnal Dissolved Oxygen Cycle



Human Causes of Tastes and Odors

- Municipal Wastewaters
  - Directly adds odoriferous compounds to water such as phenols and aromatic hydrocarbons
  - Adds nutrients that result in T&O causing algal blooms
  - Major source of nutrients that cause eutrophication
    - Phosphorus and nitrogen
- Industrial Wastes
  - NPDES – National Pollutant Discharge Elimination System permit designates pollutant discharge limits for those entities that discharge to Waters of the State
- Household Plumbing
  - Age and type of plumbing materials affect T&O

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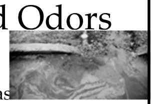
Human Causes of Tastes and Odors



- Urban Runoff
  - Oils, grease, gasoline, and other residues are was local receiving waters from roadway storm drainage systems during first big rain after a dry period
    - If complaints slow down after storm, this may be the cause
    - Can contain nitrates
- Agricultural Wastes
  - Fertilizers, microbial contaminants (*Cryptosporidium* & *Giardia*), pesticides, and herbicides
  - High density animal feeding and dairy operations can lead to heavy nutrient loading of water
    - Discharges require NPDES permit

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Human Causes of Tastes and Odors

- Treatment Plant and Distribution System Conditions
  - Debris and sediments transported to the plant accumulate over a period of time
  - Taste and odor causing conditions can occur in a treatment plant that is not kept clean
  - Filamentous algae growth in basins can lead to geosmin and MIB production
  - If odors are detected in the finished water but not in the raw water, conduct a sensory profile of treatment plant to pinpoint location of algal growth
  - Distribution system flushing should be used to flush out accumulated debris in the mains to prevent bacterial growth leading to T&O

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Locating Taste and Odor Sources

- Raw Water Sources
  - Any part of system used to store, transport, or regulate untreated water can lead to taste and odor due to lack of chlorine residual
  - Sample locations should provide water that is representative
    - Outlet works of major reservoirs & regulating basins
    - Inlets and outlets of transmission channels & pipelines
    - Plant influent upstream from any chemical additions
  - Analyze for plankton levels and predominant type, turbidity, pH, taste threshold test, threshold odor number (TON), geosmin, and MIB
    - Different results between sampling points may be due to conditions contributing to the T&O problem

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Locating Taste and Odor Sources

- Treatment Plant
  - Visually inspect basin and filter walls, channels, and weirs for blue-green algae attaching to surfaces
    - *Oscillatoria* and *Phormidium*
    - Can produce geosmin and MIB
  - Yearly dewatering operations allow inspection and cleaning of suspected or potential problem facilities

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Locating Taste and Odor Sources

- Distribution System
  - Main causes of T&O are microbiological activity, disinfection residuals and their byproducts, organic or mineral compounds, external contaminants from cross connections
  - Dead ends, low-flow zones, and areas subject to variable flows may have higher T&O complaints
    - Flush frequently and keep records of customer complaints (5 years)
  - Cross connections must be prevented to minimize contamination due to backflows

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Taste and Odor Treatment

- Two Categories of T&O Treatment
  - Removed by coagulation/flocculation/sedimentation, degasification, and adsorption
  - Destruction by oxidation
- Coagulation/Flocculation/Sedimentation
  - Use jar tests to determine if coagulation dosage is effective
  - Chlorination of raw water may lead to increased odor levels
    - May produce chlororganics
  - Chlorination of settled water upstream of the filters may improve T&O

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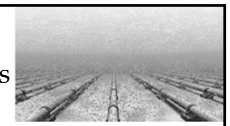
Aeration Processes and Systems

- Effective in removing volatile gases and compounds
  - Volatile – capable of being evaporated or changed to a vapor at low temperatures
  - Volatile compounds = objectionable odor
  - Non-volatile compounds = objectionable tastes
- Degasification removes volatile dissolved gases from water
- Oxidation (through aeration) is effective in removing inorganic compounds
  - Not effective in removing nonvolatile organic compounds

Aeration Processes & Systems



- Aeration Treatment Designs
  - Air into water – air is pumped into water flow
  - Water into air – water is distributed through the air
  - Air stripping – combines both methods
- Air Blowers
  - Compressors that supply air to water
  - Degasification accomplishes best gas transfer with very small bubbles
  - Compressor must be able supply very high pressures
  - Overall not very effective for T&O control

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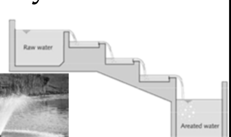
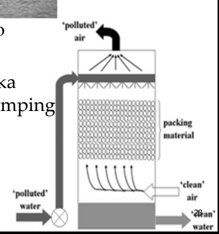
Aeration Processes and Systems

- Cascades
  - Termed waterfall devices
  - Series of concrete steps over which the water flows
- Spray Aerators
  - Spray water through air
  - Efficiency depends on air-to-water ratio
- Air Stripping (packed tower)
  - Water flows over a support medium (aka packing) contained in a tower while pumping air through the packing in the opposite direction
    - Minimum air-to-water ratio: 25:1
    - Maximum air-to-water ratio: 80:1





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Oxidative Processes

- Chlorine
- Potassium Permanganate
- Ozone
- Chlorine Dioxide

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Oxidative Processes

- Chlorine
  - Treats many raw water issues
    - Fishy, grassy, or flowery odors
    - Iron and sulfide
  - Effectiveness depends on type of odor, problem severity, applied dosage, contact time
  - Superchlorination at the intake followed by dechlorination
    - Powdered or granular activated carbon
  - Chlorinating phenolic compounds will increase odors
    - Produces chlorophenolic compounds

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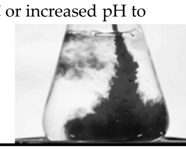
Oxidative Processes

- Potassium Permanganate
  - Strong chemical oxidizer able to destroy many organic compounds as well as oxidize iron, manganese, and sulfide
  - Permanganate ion is reduced changing colors from purple to yellow or brown forming manganese dioxide (MnO_2)
    - MnO_2 can then be settled or filtered out
    - Pink water should be absent on top of filter
  - Feed permanganate at intake to allow longer contact time and to allow operator to monitor feed rate
    - Overdose can be counteracted by PAC or increased pH to precipitate manganese



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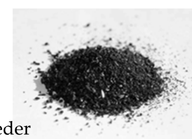
Oxidative Processes



- Potassium Permanganate
  - Dosage ranges from 0.1 to 5 mg/L
    - Typical dosage is 0.3 to 0.5 mg/L
  - Dry, crystalline product feed with dry feeder
  - Store in dry and well ventilated area to prevent caking and clogging of the feeder
  - Ventilation and PPE are a must to protect operators from dust and equipment from corrosion
  - Never store permanganate in same room as activated carbon
    - Both are highly flammable

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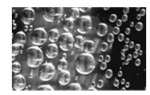
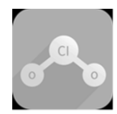
Oxidative Processes



- Ozone (O_3)
  - Must be generated onsite by passing dry air or oxygen through a high energy ozonator
  - Advantages over chlorine:
    - Stronger oxidant
    - Less objectionable byproducts produced (DBPs)



- Chlorine Dioxide (ClO_2)
  - Strongly oxidizing, unstable compound
  - Generated onsite using sodium chlorite and chlorine
  - Good for controlling phenolic tastes and odors and those caused by industrial pollution

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Adsorption Processes

- Adsorption – gathering of a gas, liquid, or dissolved substance on the surface of another material
  - Adsorbate: material being removed
  - Adsorbent: material responsible for removal
- Powdered activated carbon (PAC) and granular activated carbon (GAC) are primary adsorbents
  - Wood, coal, coconut shells, or bones activated using high temperature and high-pressure steam treatment
  - Activation significantly increases surface area by forming holes and crevices resulting in particles with a very porous structure
  - Phenol number or Iodine number indicates the adsorption capacity of the carbon
    - Higher number = greater adsorption capacity

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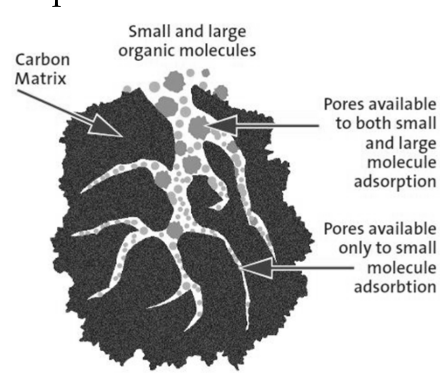
Adsorption Processes



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Adsorption Processes

- Powdered Activated Carbon
  - May be applied any point before filtration
  - Less effective after chlorination
    - Reaction neutralizes affect of carbon and chlorine
  - Thorough mixing and long contact time improves effectiveness
  - Feed Systems
    - Dry-type feeder – small scale applications if used only for short-term, occasional incidents
    - Slurry feeder – more common with larger facilities or those that use PAC regularly

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Adsorption Processes

- Powdered Activated Carbon
  - Feeder Systems
    - Carbon slurry tanks require constant mixing
    - Do not allow suction side of carbon intake to extend into drain sump in slurry tank
    - PAC is hydrophobic (dislikes water) so does not mix well with water
    - Fill PAC storage tank ¼ to 1/3 full of water before adding PAC
    - Operate tank mixers during loading
    - Load into hopper slowly enough to allow complete mixing and wetting of the carbon
      - Improper mixing can lead to cake formation on water surface

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Adsorption Processes

- Powdered Activated Carbon
  - Dose Determination
    - Use jar tests to determine necessary doses
      - Jar test trials should mimic plant conditions
    - Use TON test to determine dosage
      - Can indicate PAC alone is insufficient or if results don't change above a certain dosage
    - Olfactory fatigue – condition in which a person can no longer detect an odor after prolonged exposure
    - Feed equipment requires more maintenance, cleaning and inspections to ensure proper dosage
      - Valves and lines can easily become clogged with carbon leading to a decreased feed rate

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Adsorption Processes

- Powdered Activated Carbon
  - Filtration Considerations
    - Overfeeding can lead to caking on top of filters
      - Remedied by optimizing the settling process
        - This will increase physical removal of T&O components PAC can pass through filters
      - Determine carbon penetration by filtering 1 liter of filter effluent through membrane filter

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Adsorption Processes

- Powdered Activated Carbon
  - Handling
    - Dust collectors must be clean and functional at the start of any loading operations
    - Operators must wear PPE during loading: goggles, dust masks, and gloves at the very minimum
    - PAC tanks are confined spaces
      - Powdered carbon will active remove oxygen from the air
    - Store bags of PAC off the floor
      - Carbon is combustible but will smoke be produced
      - Do not stack bags more than 3 or 4 high
      - Do not store near potassium permanganate or HTH

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Granular Activated Carbon

- Made up of larger particles than PAC
- Placed in a stationary bed instead of fed as a slurry
- 2 considerations that make carbon contactors different than conventional filters
  - Empty Bed Contact Time (EBCT)
    - Time that the water is actually in media bed
    - EBCT must be long enough to provide adequate contact time as the water is passed through media
  - Regeneration interval of the carbon
    - Varies with type of material being removed and volume of water treated
    - Accomplished same way as initial activation

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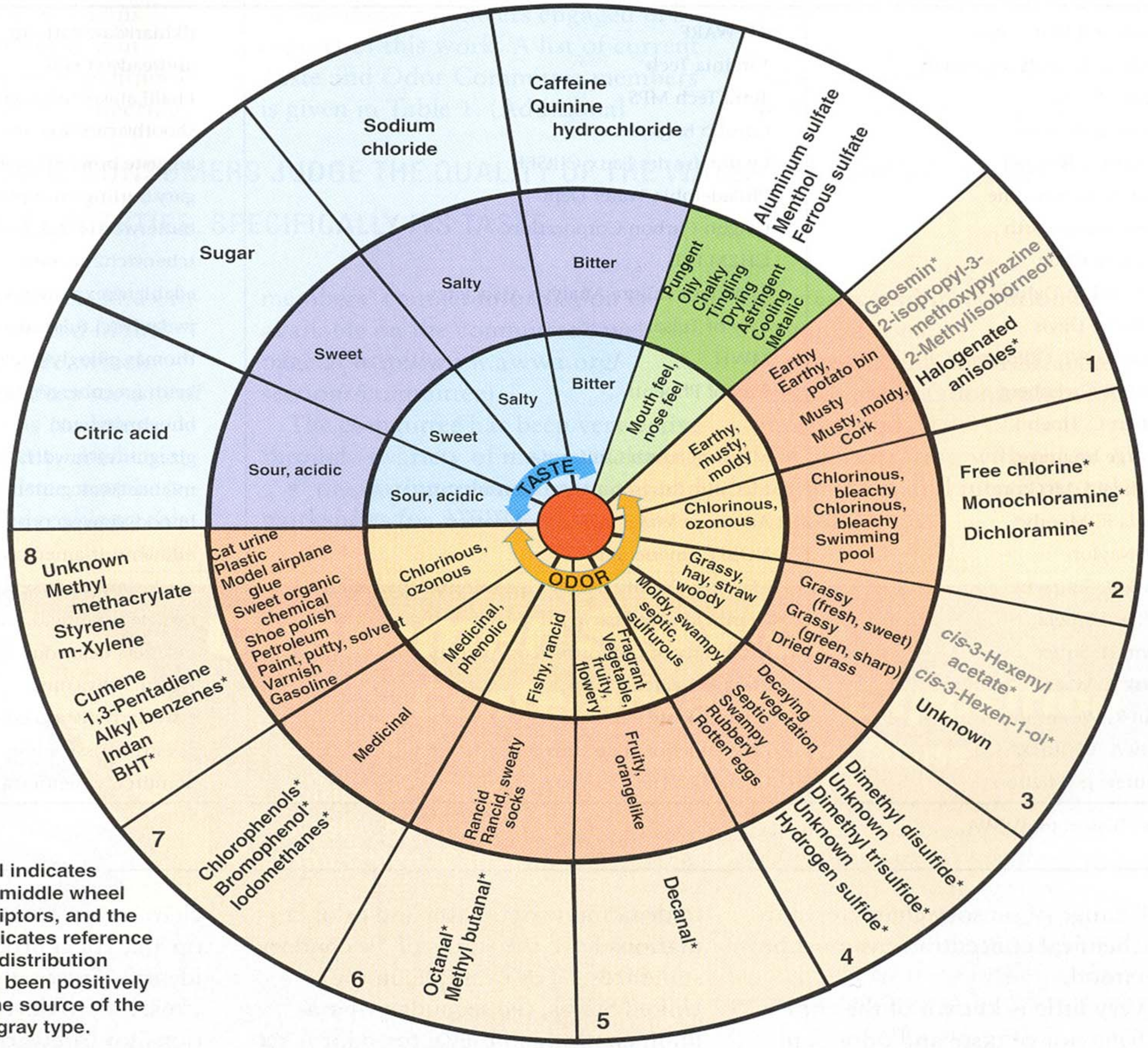
Examples of Customer Complaints

Customer Complaint	Possible Cause
Red water or reddish-brown staining of fixtures and laundry	Corrosion of iron pipes or presence of natural iron in raw water
Bluish stains on fixtures	Corrosion of copper lines
Black water	Sulfide corrosion of copper or iron lines or precipitations of natural manganese
Foul tastes and/or odors	Byproducts from microbial activity
Loss of Pressure	Excessive scaling, tubercule (buildup from pitting corrosion), leak in system from pitting or other type of corrosion
Lack of hot water	Buildup of mineral deposits in hot water system (can be reduced by setting thermostats to under 140°F [60°C])
Short service life of household plumbing	Rapid deterioration of pipes from pitting or other types of corrosion

FIGURE 1 Wheel identifying distribution system–generated tastes and odors



The inner wheel indicates categories, the middle wheel indicates descriptors, and the outer wheel indicates reference standards. The distribution system has not been positively confirmed as the source of the compounds in gray type.

*Presence confirmed in water

Source: D. Khiari et al, 2002. *Distribution Generated Taste-and-Odor Phenomena.* AwwaRF Report, AWWA Bookstore catalog no. 90897. AWWA, Denver.

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