Health Consultation

SPRINGDALE CREEK APARTMENTS, NORTH END
2510 JACKSON AVENUE
MEMPHIS, SHELBY COUNTY, TENNESSEE

EPA FACILITY ID: TND007024664

SEPTEMBER 5, 2007

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared By:

Tennessee Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

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Foreword

This document summarizes an environmental public health investigation performed by Environmental Epidemiology of the State of Tennessee Department of Health. Our work is conducted under a Cooperative Agreement with the federal Agency for Toxic Substances and Disease Registry. In order for the Health Department to answer an environmental public health question, several actions are performed:

Evaluate Exposure: Tennessee health assessors begin by reviewing available information about environmental conditions at a site. We interpret environmental data, review site reports, and talk with environmental officials. Usually, we do not collect our own environmental sampling data. We rely on information provided by the Tennessee Department of Environment and Conservation, U.S. Environmental Protection Agency, and other government agencies, businesses, or the general public. We work to understand how much contamination may be present, where it is located on a site, and how people might be exposed to it. We look for evidence that people may have been exposed to, are being exposed to, or in the future could be exposed to harmful substances.

Evaluate Health Effects: If people could be exposed to contamination, then health assessors take steps to determine if it could be harmful to human health. We base our health conclusions on exposure pathways, risk assessment, toxicology, cleanup actions, and the scientific literature.

Make Recommendations: Based on our conclusions, we will recommend that any potential health hazard posed by a site be reduced or eliminated. These actions will prevent possible harmful health effects. The role of Environmental Epidemiology in dealing with hazardous waste sites is to be an advisor. Often, our recommendations will be actions items for other agencies. However, if there is an urgent public health hazard, the Tennessee Department of Health can issue a public health advisory warning people of the danger, and will work with other agencies to resolve the problem.

If you have questions or comments about this report, we encourage you to contact us.

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Background and Statement of Issues

During a telephone call on May 18, 2007, the Tennessee Department of Environment and Conservation (TDEC), Division of Remediation (DoR) requested assistance from the Tennessee Department of Health (TDH). They requested that Environmental Epidemiology (EEP), under our Cooperative Agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR), determine if concentrations of semi-volatile pesticides in soil at the Springdale Creek Apartments present a health hazard from inhalation of ambient air or from vapor intrusion into apartments. The TDEC DoR is addressing this site under authority of the *Hazardous Waste Management Act Part 2*, and consults with the Memphis Shelby County Health Department and the Tennessee Department of Health in making site decisions to protect human health at this site.

The Springdale Creek Apartments complex encompasses 15 acres located at 2510 Jackson Avenue, between North Hollywood Street and Cypress Creek. The Springdale Creek Apartments site is located in Cypress Creek Sub-Area III; a major portion of Sub-Area III (EPA Facility ID: TND981015456) is currently under investigation and cleanup under authority of the Resource Conservation and Recovery Act (RCRA). See Figure 1 for a site map of the apartment complex.

During construction of Springdale Creek Apartments, the utility, Memphis Light, Gas, and Water (MLGW), sampled the soil at the apartment complex for pesticides, metals, and polychlorinated biphenyls (PCBs) on May 19, 2004. An environmental firm further investigated the Springdale site for the property owners. The southern portion of the Springdale site was contaminated with lead, polynuclear aromatic hydrocarbons, the polycyclic biphenyl Aroclor 1248, total petroleum hydrocarbons, and volatile organic compounds from an automobile junkyard operating on the southern portion of the property from 1937 until 2001. Chlorinated pesticides were also found in the northwest corner of the southern end of the property. After the contamination was discovered, construction was halted until the site was characterized and the southern portion cleaned up. At the time of this report, the southern end of the property has been remediated and institutional controls put in place to protect occupants of the apartments. Ten finished apartment buildings on the southern side of Springdale Creek Apartments have been rented and inhabited.

Soil sampling revealed that the northern end of the apartment complex was contaminated with pesticides. This end of the property is nearest Cypress Creek. Six partially finished apartment buildings are located in the northern portion of the site, which is contaminated with chlorinated and cylcodiene pesticides.

Cypress Creek originates near the center of Memphis and runs north and northwest for eight miles before emptying into the Wolf River. Major channelization and widening was performed prior to 1944. In the 1950s, a levee system and a pumping station were constructed to prevent flooding of Cypress Creek during storm events. A section of the creek upstream of the pumping station was widened to act as a surge basin. Prior to 1963, the creek was used to dispose of sanitary sewage and manufacturing wastewater. Velsicol Chemical Corporation (Velsicol) was among the industries, including Buckeye Chemical and Buckman Laboratory, which discharged industrial wastewater to the creek. In the 1960s, a concrete liner was put in place and some of the creek channel straightened. During the construction of the concrete liner, sediments from

the creek bottom and banks were removed and then placed in staging piles. After construction of the channel walls, the staged sediments/soils were used as backfill material to bring the adjacent banks to grade with the new concrete channel walls. This included the area where the Springdale Creek Apartments were constructed. The *Health Consultation: Cypress Creek Sub-Area III Memphis, Shelby County, Tennessee EPA Facility ID: TND981015456, dated* July 31, 2006, detailed a potential health hazard in some residential back yards.

Discussion

Pathways of Exposure, Data, Soil Screening Levels

To determine whether persons have been, are, or are likely to be exposed to contaminants, EEP evaluates the environmental and human components that could lead to human exposure. An exposure pathway contains five elements:

1. a source of contamination,
2. contaminant transport through an environmental medium,
3. a point of exposure,
4. a route of human exposure, and
5. a receptor population.

An exposure pathway is considered complete if there is evidence that all five of these elements have been, are, or will be present.

Possible pathways of exposure at the Springdale Creek Apartments include incidental ingestion of contaminated soil, dermal contact with soil, and inhalation of vapors from the emission of pesticides from the soil into the outdoor ambient air or into the indoor air in the apartments. Ingestion of shallow contaminated groundwater will not occur in Memphis since municipal treated water is available from a deeper aquifer.

A passive soil gas survey on the southern side of the Springdale Creek Apartment site also measured soil gas at a few points on the north side of the property. The passive soil gas survey measured mass of constituents in soil gas and was used by DoR to help understand the distribution of constituents in the vapor phase and whether there were hot spots that required further evaluation. Several constituents identified on the north side in this sampling included carbon tetrachloride, chloroform, tetrachloroethylene, and 1,4-dichlorobenzene. Dieldrin, endrin, heptachlor, and hexachlorobutadiene were also tentatively identified compounds in soil gas on the north side (GORE).

The probability of an increased health risk from the inhalation of pesticide vapors at the northern end of the Springdale Creek Apartments site will be explored in this health consultation. Table 1 summarizes soil sampling and analysis for pesticides at the northern end of Springdale Creek Apartments. The 183 soil samples were taken from 0 to 72 inches depth, with most samples taken at 0 to 24 inches. Soil samples with high pesticide concentrations were sometimes found

at deeper depths; the highest concentrations appeared in soil taken from two to four feet in depth. These findings suggest the past use of creek sediment as fill material.

Because detection limits were very high for many of the samples on the north end, averages, medians, and reported highs and lows shown in Table 1, EEP used one-half the detection limit as the concentration for those data reported as less than the detection limit. Although analyses included lindane isomers, chlordane, DDT and breakdown products, endosulfan isomers, heptachlor and heptachlor epoxide, methoxychlor, and toxaphene, the chemicals that are probably at highest concentration and that were the chemicals of concern in other parts of Sub-Area III are aldrin, dieldrin, and endrin. When the word, endrin, is used in this consultation it will refer to the sum of endrin, endrin aldehyde, and endrin ketone, unless otherwise noted.

Table 1. Summary statistics for chemicals of concern in soil, northern end of Springdale Creek Apartments, Memphis, Shelby County, Tennessee. Concentrations are reported in parts per million (ppm).

Concentrations in Soil	*Aldrin*	*Dieldrin*	*Total Endrin*
Mean concentration, ppm *	60.4	62.1	1,246.3
Median, concentration, ppm *	0.9	1.0	27.3
Low concentration, ppm *	0.000025	0.00005	0.00015
High concentration, ppm *	4,540	4,990	97,300
Samples below the detection limit	65%	80%	8% endrin 83% endrin aldehyde 10% endrin ketone
Total endrin = endrin + endrin aldehyde + endrin ketone For data points with concentrations reported less than the detection limit, ½ the detection limit was used as the concentration.			

The high detection limits for many of the samples made the data of limited usefulness for determining true means and distributions. Laboratory detection limits ranged as follows:

Aldrin	0.00005 to 1,990 ppm
Dieldrin	0.001 to 4,990 ppm
Endrin	0.0001 to 6.3 ppm
Endrin aldehyde	0.0001 to 400 ppm
Endrin ketone	0.0001 to 15.1 ppm

The U.S. Environmental Protection Agency (EPA) has published guidance for developing soil screening levels (OSWER Part 2 2002) and has calculated generic soil screening levels (SSLs) for direct inhalation of volatiles (OSWER Appendix A 2002). In addition, the EPA Office of Research and Development's National Center for Environmental Assessment has developed a computer program, EMSOFT, to provide an average emission flux from soil over time (OSWER Part 3 2002). If the computer program is used, more modeling is needed to determine the dispersion of the chemicals into ambient air.

EPA has calculated generic SSLs for the carcinogenic effects of aldrin and dieldrin. Human health benchmarks for the non-carcinogenic effects through the inhalation route of exposure are not available. EPA did not calculate a SSL for the inhalation of endrin because of the lack of non-carcinogenic human health benchmarks and because endrin is not classifiable as to its carcinogenicity (IRIS). The generic SSLs are based on a variety of assumptions that do not necessarily represent the Springdale Creek Apartments site conditions. These assumptions are listed in Appendix 1.

Appendix 2 presents the equations that can be used to calculate site-specific SSLs and the values for parameters used by EEP in calculating site-specific SSLs. The parameters were chosen for soil characteristics of loess; however, the soil in areas filled in with creek sediment may not have the same physical characteristics as loess (personal communication, Ron Clendening, TDEC, Division of Geology, May 24, 2007).

Comparisons of EPA calculated generic and EEP calculated site-specific SSLs are presented in Table 2. The SSLs were calculated to provide protection to public health for a 1×10^{-6} excess caner risk level. Again, no human benchmark levels for non-carcinogenic effects were available for the inhalation of aldrin or dieldrin. SSLs calculated for non-cancer effects would be most helpful, since the evidence for the human carcinogenicity of these pesticides is unclear.

Table 2. Comparison of generic soil screening levels and site-specific soil screening levels for an excess cancer risk of 1×10^{-6}, Springdale Creek Apartments, Shelby County, Tennessee.

	Generic SSLs [1]	***Site-specific SSLs*** [2]
Aldrin	3 mg/kg	0.3 mg/kg
Dieldrin	1 mg/kg	1 mg/kg

[1] Assumes physical characteristics of loam; loam is soil composed of sand, silt, manure, and clay in relatively even concentration (OSWER 2002)

[2] Assumes physical characteristics of loess; loess is a fine, silty, windblown type of unconsolidated deposit

The concentrations measured in soil are much higher than either the generic SSLs or the site-specific SSLs.

During soil removal activities at the southern end of the site, air monitoring for fugitive dusts and concentrations of pesticides was conducted. In addition, indoor air sampling was done in one apartment of buildings 5, 6, 8, 10, and 15 (EnSafe 2006). Figure 1 shows the locations of these buildings. Concentrations of pesticides in indoor air were below the detection limits. However, the laboratory detection limits were above 0.02 $\mu g/m^3$ for aldrin and dieldrin; this concentration represents theoretical a risk of 1 excess cancer in 10,000 people.

Toxicology

Aldrin/Dieldrin

Aldrin and dieldrin are two closely related organochlorine insecticides. They were used in agriculture and to control mosquitoes from the early 1950s until 1989, when their manufacture in the United States was discontinued. Aldrin and dieldrin are not very water soluble, but readily bind to sediment and rarely leach into deeper soil layers and groundwater. Evaporation from moist soil surfaces can occur. They take decades to break down in the environment, particularly in oxygen deprived deeper soil, resulting in persistent soil residues and varying degrees of uptake in a wide range of crops. Aldrin converts rapidly to dieldrin in biological systems of soils, plants, and animals. Dieldrin accumulates in fatty tissues, uterine tissues, breast milk, and can cross the placental barrier (ATSDR 2002, Liu et al. 1997).

In chronic-duration animal studies the liver was the most sensitive target organ for aldrin and dieldrin toxicity, although the central nervous system is also an important target of toxicity. Other effects in animals that may be associated with exposure to aldrin or dieldrin include kidney toxicity, immune effects, fetal toxicity, subtle neurological effects, and decreased reproductive function. However, these effects have not been observed in all studies, and they have occurred at higher doses (ATSDR 2002).

Longer-term exposure to aldrin and dieldrin in occupational settings, where concentrations were typically much higher, has been associated with central nervous system effects. A few case reports have attributed liver and kidney toxicity and hemolytic anemia to oral exposure to aldrin or dieldrin. These effects were not observed in larger occupational studies, suggesting that they are likely to be rare.

Cyclodiene pesticides inhibit gamma-aminobutyric acid (GABAergic) neurotransmission by blocking the chloride ion channel of the GABA A receptor ($GABA_A$)[1]. The central nervous system effects of cyclodiene pesticides are caused by this inhibition of the neurotransmission. It also has implications for developing fetuses and infants (Devlin 2002).

Fetuses may be affected through transplacental exposure. Fetuses may bioconcentrate aldrin and dieldrin, and infants may absorb the pesticides in mothers' milk (ATSDR 2002).

Aldrin and dieldrin are associated with liver cancer in mice, but not in other animals. The International Agency for Research on Cancer (IARC) has categorized aldrin and dieldrin as Group 3 (unclassifiable as to human carcinogenic potential) chemicals. That means that the IARC does not consider the evidence strong enough to consider aldrin and dieldrin human

[1] GABA is one of two major inhibitory neurotransmitters in the central nervous system acting through the GABA receptor on all parts of the brain except the spinal cord and brainstem. There are 2 main forms of the GABA receptor. $GABA_A$ subunits combine to form a chloride ion channel, while $GABA_B$ subunits act with a protein to increase conductance in a potassium ion channel. The GABA receptor is composed of two or more subunits. The alpha-$GABA_A$ unit binds with a variety of pharmaceutical agents, while the beta-$GABA_A$ subunit binds with GABA (Devlin 2002).

carcinogens. Based on the finding of liver tumors in mice, EPA classified both aldrin and dieldrin as B2 probable human carcinogens. The EPA has calculated inhalation unit risks from oral dose response data for aldrin and dieldrin. These values are shown below in Table 3.

Table 3. Health screening values for aldrin and dieldrin for cancer risks.

	Aldrin	***Dieldrin***
Oral slope factor, (mg/kg-day) $^{-1}$	17	16
Drinking water unit risk (µg/L-day) $^{-1}$	4.9×10^{-4}	4.6×10^{-4}
Inhalation unit risk (µg/m ^{3}) $^{-1}$	4.9×10^{-3}	4.6×10^{-3}

Endrin

Endrin is a solid, white, almost odorless substance that was used as a pesticide to control insects, rodents, and birds. Endrin has not been produced or sold for general use in the United States since 1986.

Endrin is well absorbed through ingestion, inhalation, and dermal routes of exposure. The central nervous system is the primary target site for endrin toxicity. Acute ingestion of endrin in amounts much greater than what has been measured along Cypress Creek have led to convulsions and death. Less severe symptoms include headache, convulsions, dizziness, nausea, vomiting, nervousness, and confusion. No long-term health effects have been noted in occupationally exposed workers. Birth defects, especially abnormal bone formation, have been seen in some laboratory animal studies (ATSDR 1996).

In studies using rats, mice, and dogs, endrin did not produce cancer. The EPA has determined that endrin is not classifiable as to its human carcinogenicity because the available information is inadequate (ATSDR 1996).

Other Pesticide Characteristics

Reports have indicated that the pesticides identified are volatile and can infiltrate buildings from soil. An assessment of the environmental contamination of a residential community built on a thick layer of harbor sludge in the Netherlands found that the maximal combined daily intake of aldrin, dieldrin, isodrin (not found at the site), and telodrin (not found at the site) by soil ingestion, inhalation of contaminated indoor air, and diet exceeded the allowable daily intake by a factor of three. In the referenced study, the total indoor air concentrations of the compounds in the living rooms of homes built on contaminated soil were 10 times higher than outdoor air levels (ATSDR 2002). Two of the apartment buildings in the southern portion (now remediated and under institutional controls) and at least three buildings in the northern portion of the Springdale Creek Apartments are built on soil with highly elevated levels of pesticides (about 40 ppm to 9000 ppm total pesticide). The highest concentrations appeared in soil taken from two to four feet in depth.

Child Health Considerations

The many physical differences between children and adults demand special emphasis. Because of their larger surface-to-volume ratio, children have a higher metabolic rate and respiration rate. Therefore, their exposure to contaminants in the air is greater than that of an adult. The Toxicology section above suggests that children might be more at risk from exposure to aldrin and dieldrin than are adults. In addition, fetuses may bioconcentrate aldrin and dieldrin. Birth defects, especially abnormal bone formation, have been seen in some laboratory animals during studies of endrin toxicity (ATSDR 2002).

It has been hypothesized that prenatal exposure to cyclopentadiene pesticides could alter expression of $GABA_A$ receptors and have long-term consequences on brain development. $GABA_A$ receptors develop at the same time and in the same place in the rat brain as the nervous system pathways that are sensitive to the receptor. Liu et al. (1997) presented evidence that dieldrin selectively alters the development of $GABA_A$ receptors in rat embryonic brainstem cultures.

Summary

Limited passive soil gas sampling at this site indicated that several pesticides have volatilized into soil gas. Soil sampling showed that high levels of aldrin, dieldrin, and endrin are present in the soil on the north end of Springdale Apartments. In addition, generic and site-specific soil screening levels (SSLs) indicate that the concentrations of aldrin and dieldrin in soil at the north side of Springdale Creek Apartments may be high enough to pose a health hazard from inhalation of ambient air and from inhalation of indoor air contaminated through vapor intrusion. However, both the generic SSLs and the site-specific SSLs may not represent the true conditions at the site. The SSLs are for protection from carcinogenic risks, while the human carcinogenicity of aldrin and dieldrin is unclear. No human health comparisons are available for the inhalation of aldrin, dieldrin, nor endrin. No health comparison values are available for inhalation of endrin. Many reported concentrations of aldrin, dieldrin, endrin, endrin aldehyde, and endrin ketone in soil were above the detection limits of the laboratory, making most of the data qualitatively useful but not quantitatively useful. Previous indoor air sampling at the site used laboratory detection limits for aldrin and dieldrin that were above the theoretical risk of 1 excess cancer in 10,000 people.

Conclusions

1. The possibility of the inhalation of aldrin, dieldrin, and endrin at the north side of Springdale Creek Apartments exists for exposures from ambient air.

2. The possibility of the inhalation of aldrin, dieldrin, and endrin at the north side of Springdale Creek Apartments exists for exposures from vapor intrusion into apartments.

3. The lack of non-carcinogenic human health benchmarks for the inhalation of aldrin, dieldrin, and endrin restricts the ability to predict true risks from the inhalation route of exposure.

4. The inhalation of aldrin, dieldrin, and endrin at the north side of Springdale Creek Apartments presents an indeterminate public health hazard. While calculations indicate the possibility of a health hazard from inhalation of ambient air or indoor air, confidence in the calculations is low.

Recommendations

1. Measure indoor air concentrations for aldrin, dieldrin, endrin, and constituents previously identified in soil gas at Springdale Creek Apartments where soil concentrations and/or soil gas concentrations indicate or may indicate the potential for migration of pesticides or other potentially harmful constituents into indoor air. TDEC- DoR, TDH, and the Memphis and Shelby County Health Department will work cooperatively to determine constituents to be analyzed, required detection limits, locations of measurements, and to see that measurements are made

2. Measure ambient air concentrations for aldrin, dieldrin, endrin, and constituents previously identified in soil gas at the north side Springdale Creek Apartments. TDEC- DoR, TDH, and the Memphis and Shelby County Health Department will work cooperatively to determine constituents to be analyzed, required detection limits, locations of measurements, and to see that measurements are made.

Public Health Action Plan

1. EEP will continue to work with DoR on public health issues at the Springdale Creek Apartments

2. EEP will ask for assistance from ATSDR in obtaining non-carcinogenic human health benchmarks for aldrin, dieldrin, and endrin. It is unlikely that an actual Minimal Risk Level could be established quickly, but EEP needs assistance in reasonably interpreting the health risk from exposure to these pesticides in air.

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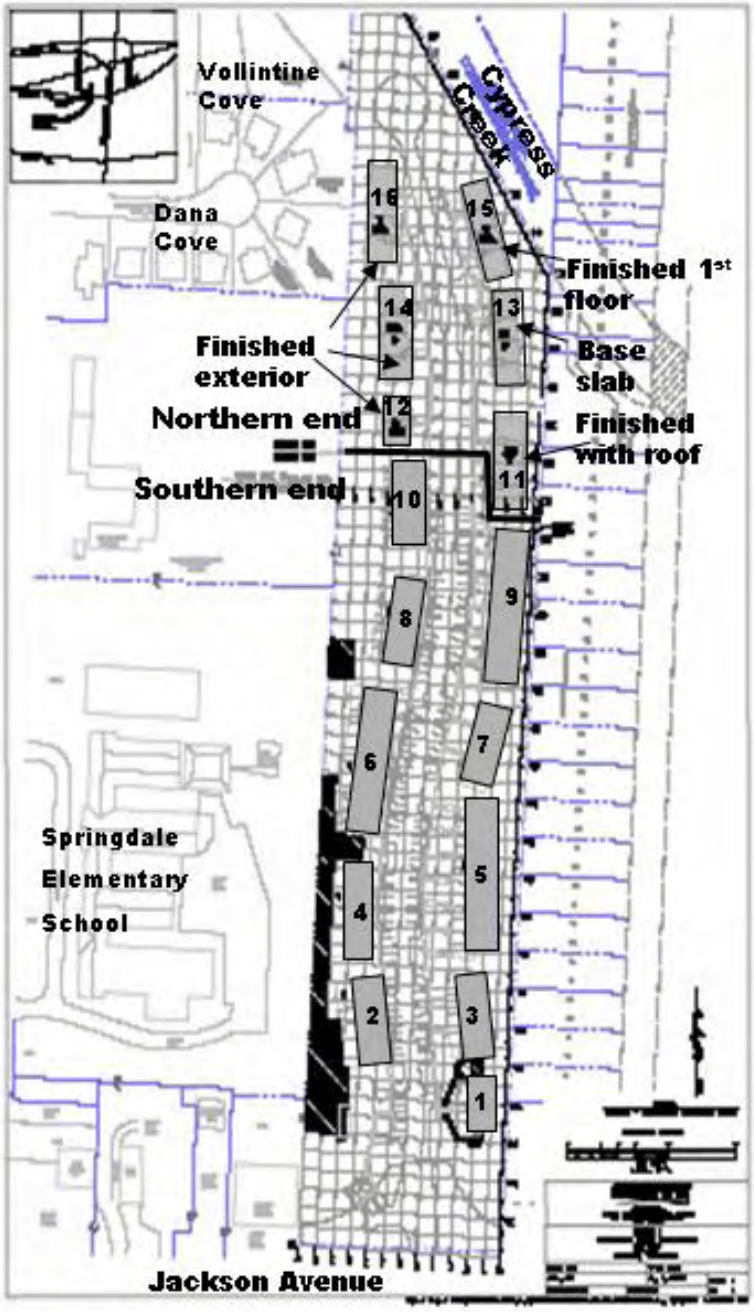
Figure 1: Site map of Springdale Creek Apartments, Memphis, Shelby County, Tennessee.



Appendix 1. Default parameters and assumptions for generic soil screening levels for aldrin and dieldrin for the inhalation of volatiles pathway of exposure (OSWER 2002, Appendix A).

Parameter	*Inhalation pathway*	*Default*
Source Characteristics		
Continuous vegetative cover	●	50 percent
Roughness height	○	0.5 cm for open terrain; used to derive $U_{t,7}$
Source area (A)	●	0.5 acres
Soil Characteristics		
Soil texture	○	Loam
Dry soil bulk density (ρ_b)	●	1.5 kg/L
Soil porosity (n)	●	0.43
Vol. soil water content (θ_w)	●	0.16
Vol. soil air content (θ_a)	●	0.28
Soil organic carbon (f_{oc})	●	0.006
Soil pH	○	6.8 (not applicable at Springdale)
Mode soil aggregate size	○	0.5 mm; used to derive $U_{t,7}$
Threshold windspeed @ 7m ($U_{t,7}$)	●	11.32 m/s
Meteorological Data		
Mean annual windspeed (U_m)	●	4.69 m/s (Minneapolis, MN)
Air dispersion factor (Q/C)	●	90th percentile conterminous U.S.
Volatilization Q/C	●	68.81; Los Angeles, CA; 0.5 acre source
Human Health Benchmarks		
Aldrin, unit risk (URL) ($\mu g/m^3$)$^{-1}$	●	4.9E-03
Dieldrin, unit risk (URL) ($\mu g/m^3$)$^{-1}$	●	4.6E-03
● Indicates input parameters directly used in SSL equations.		
○ Indicates parameters/assumptions used to develop SSL input parameters.		

Appendix 2. Equations and variables used to calculate Springdale Creek Apartments site-specific soil screening levels for the inhalation of aldrin and dieldrin.

Abbreviation	*Variable name*	*Value used*

$$SSL(mg/kg) = \frac{TR \times AT \times 365(days/year)}{URF \times 1{,}000(\mu g/mg) \times EF \times ED \times {}^{1}\!/_{VF}}$$

SSL	Soil screening level	
TR	Target cancer risk	1E-06
AT	Averaging time	70 years
URF	Unit risk factor, $(\mu g/m^3)^{-1}$	Aldrin: 4.9E-03 Dieldrin: 4.6E-03
EF	Exposure frequency	350 days/year
ED	Exposure duration	30 years

$$VF(m^3/kg) = {}^{Q}\!/_{C} \times \frac{(3.14 \times D_A \times T)^{1/2}}{2 \times \rho_b \times D_A} \times 10^{-4}(m^2/cm^2)$$

VF	Soil-to-air volatilization factor, m^3/kg	
Q/C	A measure of dispersion, g/m^2-sec per kg/m^3	46.37; Atlanta, GA; 10 acre source
T	Exposure interval, sec	9.5E08 (30 years)
ρ_b	Dry soil bulk density for loess, mid-value	$1.4\ g/m^3$
ρ_s	Soil particle density	$2.68\ g/cm^3$

$$D_A = \frac{\left(\theta_a^{10/3} \times D_i \times H' + \theta_w^{10/3} \times D_w\right)/n^2}{(\rho_b \times K_d) + \theta_w + (\theta_a \times H')}$$

D_A	Apparent diffusivity, cm^2/sec	
θ_a	Air-filled soil porosity, unitless	
n	Total soil porosity, unitless	
θ_w	Water-filled soil porosity, unitless	0.15
D_i	Diffusivity in air, cm^2/sec	Aldrin: 1.32E-02 Dieldrin: 1.25E-02
D_w	Diffusivity in water, cm^2/sec	Aldrin: 4.86E-06 Dieldrin: 4.74E-06
K_d	Soil-water partition coefficient, cm^3/g	$K_d = K_{oc} \times f_{oc}$
K_{oc}	Soil organic carbon-water partition coefficient, L/kg	Aldrin: 48,685 Dieldrin: 25,546
f_{oc}	Organic carbon content of soil	0.006
H'	Dimensionless Henry's Law constant	Aldrin: 6.97E-03 Dieldrin: 6.19E-04

$$\theta_a = n - \theta_w$$

$$n = 1 - (\rho_b/\rho_s)$$

Certification

This Health Consultation: Springdale Creek Apartments, North End was prepared by the Tennessee Department of Health, Environmental Epidemiology under a Cooperative Agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It was prepared in accordance with the approved methodology and procedures that existed at the time the health consultation was begun. Editorial review of this document was performed by the Cooperative Agreement partner.

Technical Project Officer, CAT, CAPEB, DHAC, ATSDR

The Division of Health Assessment and Consultation, ATSDR has reviewed this public health consultation and concurs with the findings.

Team Leader, CAT, CAPEB, DHAC, ATSDR