Health Consultation

DNR Triangle Gravel Pit
Olympia, Thurston County, Washington

September 30, 2006

Prepared by:
Washington State Department of Health
under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

DOH 334-108 September 2006

Forward

The Washington State Department of Health (DOH) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on specific health issues so that DOH can respond to requests from concerned residents or agencies for health information on hazardous substances. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time of this health consultation, and should not necessarily be relied upon if site conditions or land use changes in the future.

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Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Aquifer	An underground formation composed of materials such as sand, soil, or gravel that can store and/or supply groundwater to wells and springs.
Cancer Risk	A theoretical risk for developing cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.
Cancer Risk Evaluation Guide (CREG)	The concentration of a chemical in air, soil or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a *comparison value* used to select contaminants of potential health concern and is based on the *cancer slope factor* (CSF).
Cancer Slope Factor	A number assigned to a cancer causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Comparison value	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dermal Contact	Contact with (touching) the skin (see route of exposure).
Dose (for chemicals that are not radioactive)	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental Media Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on ATSDR's *minimal risk level* (MRL).
Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
Groundwater	Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Maximum Contaminant Level (MCL)	A drinking water regulation established by the federal Safe Drinking Water Act. It is the maximum permissible concentration of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system. MCLs are enforceable standards.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.

Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
No apparent public health hazard	A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Plume	A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.
Reference Dose Media Evaluation Guide (RMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The RMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Surface Water	Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].
Volatile organic compound (VOC)	Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Summary and Statement of Issues

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the Washington Department of Natural Resources (DNR). The purpose of this health consultation is to evaluate the potential health hazard posed by lead contamination in soil at the DNR Triangle Gravel Pit (Triangle Pit) in Thurston County, Olympia, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background

The DNR Triangle Pit is located near the junction of Waddell Creek and Sherman Roads in the Capitol State Forest east of Olympia, Washington (See figure 1). Capitol State Forest is part of the state trust lands. These state trust lands provide income to trusts beneficiaries in Washington State through forest management activities, while also providing habitat for many native plants and animals, and allowing recreational and educational opportunities for visitors.

The Triangle pit was developed as a gravel mine by the DNR. Recreational target shooters frequent the pit. Years of use of the pit as a shooting area has resulted in a buildup of lead, including bullets and bullet fragments, and other contaminants related to shooting activities. In addition to recreational shooting, there is limited use by off road vehicles (ORV (dirt bike or all-terrain vehicle)) within the pit area (See figure 2).

In April 2004, Thurston County Public Health and Social Services Department (TCHD) collected a limited number of surface (0 -1 inch) and subsurface soil samples from the DNR Pit. However, Table 1 shows the range of surface soil only [1]. Lead levels from those samples ranged from 825 milligrams per kilogram (mg/kg) to 9290 mg/kg. Copper ranged from 106 mg/kg to 590 mg/kg. Note: mg/kg is also equal to parts per million (ppm).

Table 1. Concentrations of inorganic compounds detected in soil (0 -1 inch) in 2004 and their respective comparison values at the DNR triangle gravel pit in Olympia, Thurston County, Washington.

Inorganic

Compounds	Maximum Concentration (ppm)	Range of Concentration (ppm)	EPA Cancer Class	Comparison Value (ppm)	Comparison Value Reference
Copper	590	106 - 590	D	2000	IM EMEG
Lead	9290	825 - 9290	B2	250	

MTCA

IM EMEG - ATSDR's Intermediate Environmental Media Evaluation Guide (child)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
MTCA – Washington State Department of Ecology: Model Toxics Control Act

In May 2005, Landau Associates (Landau) were hired by DNR to conduct a preliminary investigation of shallow soil (0 to 18 inches) [2]. Landau conducted further investigation of the site to define the vertical (0 to 24 inches) and lateral extent of the lead contaminated soil in June 2005. Sixty-three soil samples were collected from 43 sample locations at the site. Only soil particles less than two millimeters in diameter were provided for laboratory analysis. However, the report did not indicate whether lead shots or bullet fragments were removed before sample analysis. The results indicated a maximum lead contamination of 58,500 ppm (See table 2). About 10 % (six samples) of the 63 soil samples collected were analyzed for polycyclic aromatic hydrocarbons (PAHs). The maximum concentration for the 10 % of soil samples analyzed for PAHs are shown in Table 2 below.

Table 2. Maximum concentrations of contaminants detected in soil (0-6 inches) in 2005 and their respective comparison values at the DNR Triangle Pit site in Olympia, Thurston County, Washington.

Compounds	**Maximum Concentration (ppm)**	**Comparison Value (ppm)**	**EPA Cancer Class**	**Comparison Value Reference**	**Contaminant of Concern**
Lead	58,500	250	B2	MTCA	Yes
Dibenzofuran	0.021	290	D	Region 9	No
2-Methynaphthalene	0.019	200	IN	RMEG	

No

Naphthalene
0.013U
1000
C
RMEG
No

Acenaphthene
0.2
3000

RMEG
No

Anthracene
0.3
20000
D
RMEG
No

Benzo(a)anthracene
2.7
0.62
B2
Region 9
cPAH

Acenapthylene
0.013U
2000*

No

Dibenzo(a,h)anthracene
0.57
0.062
B2
Region 9
cPAH

Chrysene
3.3
62
B2
Region 9
cPAH

Benzo(b)fluoranthene
2.2
0.62

B2
Region 9
cPAH

Benzo(k)fluoranthene
1.3
6.2
B2
Region 9
cPAH

Benzo(a)pyrene
4.0
0.062
B2
Region 9
cPAH

Fluoranthene
2.0
2000
D
RMEG
No

Fluorene
0.065
2000
D
RMEG
No

Indeno (1,2,3-cd)- pyrene
1.3
0.62
B2
Region 9
cPAH

Benzo(g,h,I)perylene
2.3
2000*
D

No

Phenanthrene
1.0
2000*
D

No

Pyrene

2.8
2000
D
RMEG
No

RMEG - ATSDR's Reference Dose Media Evaluation Guide (child)
U- data qualifier: The compound was analyzed for, but was not detected at the given reporting limit.
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
C - EPA: Possible human carcinogen (no human, limited animal studies)
D - EPA: Not classifiable as to health carcinogenicity
Region 9 – EPA: Preliminary Remediation Goals
cPAH - carcinogenic Polycyclic Aromatic Hydrocarbons
MTCA – Washington State Department of Ecology: Model Toxics Control Act
* Fluoranthene RMEG value was used as a surrogate

Discussion

The following discussion addresses lead and carcinogenic polycyclic aromatic hydrocarbons (cPAHs) as contaminants of concern in soil for this site. In order for any contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm, and there must be a completed route of exposure to people. Lead and cPAHs are evaluated below since they exceed their health comparison values. Human patterns of use and site-specific conditions are accounted for in the evaluation.

Lead Exposure Pathways

For most people, the majority of exposure to soil is expected to occur at home. Exposure can also occur at childcare facilities, schools, parks, the workplace, and elsewhere. Although contact with soil at the Triangle Pit may be infrequent, there is concern because of the very high lead levels found there. In general, exposure to contaminants in soil can occur by swallowing it (ingestion exposure), breathing it (inhalation exposure) or getting it on the skin (dermal exposure). During recreational activities at the Triangle Pit, people are likely to be exposed to contaminants in the soil. Actions that reduce exposure to soil contaminants include wearing breathing protection, wearing eye protection, wearing clothing that completely covers the skin, and washing up after playing at the Triangle Pit. The closest residence to the Triangle Pit is less than a mile away. It is possible for groundwater in the area to become contaminated, because of dissolved lead from the site and travel offsite. However, since there is no groundwater data available, this pathway will not be evaluated.

Ingestion exposure (swallowing)

Ingestion of contaminated soil is expected to account for most of the exposure at the Triangle Pit. Over time, swallowing even small amounts of soil contaminated with lead could lead to a variety of health problems. Most people inadvertently swallow small amounts of soil and dust (and any contaminants they contain). Young children often put hands, toys, pacifiers, and other things in their mouths, and these may have dirt or dust on them that can be swallowed. Adults may ingest soil and dust through activities such as gardening, mowing, construction work, dusting, and in this case, recreational activities.

Pica behavior is a persistent eating of non-food substances (such as dirt or paper). In a small percentage of children, pica behavior has been found to result in the ingestion of relatively large amounts of soil (one or more grams per day). Compared to typical children, those who swallow large amounts of contaminated soil may have added risks from short-term exposure. There is a strong possibility a pica child could be unsupervised at the gravel pit. Young children are allowed to play at the site unsupervised while their parents or older siblings ride.

Inhalation exposure (breathing)

Although people can inhale suspended soil or dust, airborne soil usually consists of relatively large particles that are trapped in the nose, mouth, and throat and are then swallowed, rather than breathed into the lungs.

Skin exposure (dermal)

Harmful effects from skin contact with the contaminated soil are unlikely. The concentrations of the contaminants are not expected to cause skin problems, such as irritation or rashes, from dermal contact. Metals, such as lead, are not absorbed well through the skin. Therefore, skin contact is unlikely to lead to increased levels of lead in the body.

Lead – Occurrence, Health Concerns, and Risks

Lead is a naturally occurring chemical element that is normally found in soil. In Washington, normal background concentrations rarely exceed 20 ppm [3]. However, the widespread use of certain products (such as leaded gasoline, lead-containing pesticides, and lead-based paint) and the emissions from certain industrial operations (such as smelters) has resulted in significantly higher levels of lead in many areas of the state.

Elimination of lead in gasoline and solder used in food and beverage cans has greatly reduced exposure to lead. Currently, the main pathways of lead exposure in children are ingestion of paint chips, contaminated soil and house dust, and drinking water in homes with old plumbing.

Children less than seven years old are particularly vulnerable to the effects of lead. Compared to older children and adults, they tend to ingest more dust and soil, absorb significantly more of the lead that they swallow, and more of the lead that they absorb can enter their developing brain. Pregnant women and women of childbearing age should also be aware of lead in their environment, because lead ingested by a mother can affect the unborn fetus.

Health effects

Exposure to lead can be monitored by measuring the level of lead in the blood. In general, blood lead rises 3-7 µg/dl for every 1,000 ppm increases in soil or dust concentration [5]. For children, the Centers for Disease Control and Prevention (CDC) has defined an elevated blood lead level (BLL) as greater than or equal to 10 micrograms of lead per deciliter of blood (µg/dl) [6]. However, there is growing evidence that damage to the central nervous system resulting in learning problems can occur at blood lead levels less than 10 µg/dl. About 2.2 percent of children in the U.S. have blood lead levels greater than 10 µg/dl.

Lead poisoning can affect almost every system of the body and often occurs with no obvious or distinctive symptoms. Depending on the amount of exposure a child has, lead can cause behavior and learning problems, central nervous system damage, kidney damage, reduced growth, hearing impairment, and anemia [7].

In adults, lead can cause health problems such as high blood pressure, kidney damage, nerve disorders, memory and concentration problems, difficulties during pregnancy, digestive problems, and pain in the muscles and joints [7]. These have usually been associated with blood lead levels greater than 30 µg/dl. The National Toxicology Program report has listed lead as a potential carcinogen [4].

Because of chemical similarities to calcium, lead can be stored in bone for many years. Even after exposure to environmental lead has been reduced, lead stored in bone can be released back into the blood where it can have harmful effects. Normally this release occurs relatively slowly. However, certain conditions, such as pregnancy, lactation, menopause, and hyperthyroidism can cause more rapid release of the lead, which could lead to a significant rise in blood lead level [8].

Health risk evaluation – The IEUBK model

To evaluate the potential for harm, public health agencies often use a computer model that can estimate blood lead levels in children younger than seven years of age who are exposed to lead-contaminated soil. This model (developed by the EPA and called the Integrated Exposure Uptake Biokinetic Model, or IEUBK model) uses the concentration of lead in soil to predict blood lead levels in children [9]. It is intended to help evaluate the risk of lead poisoning for an average group of young children who are exposed to lead in their environment. The IEUBK model can also be used to determine what concentration of lead in soil could cause an unacceptable risk of elevated blood lead levels in an average group of young children. It is often used in this way to set soil cleanup levels for lead. It is important to note that the IEUBK model is not expected to accurately predict the blood lead level of a child (or a small group of children) at a specific point in time. In part, this is because a child (or group of children) may behave differently, and therefore have different amounts of exposure to contaminated soil and dust, than the average group of children used by the model to calculate blood lead levels. For example, the model does not take into account reductions in exposure that could result from community education programs. Despite this limitation, the IEUBK model is a useful tool to help prevent lead poisoning, because of the information it can provide about the hazards of environmental lead exposure.

For children who are regularly exposed to lead-contaminated soil, the IEUBK model can estimate the percentage of young children who are likely to have blood lead concentrations that exceed a level that may be associated with health problems (usually 10 μg/dl).

Soil lead concentrations and estimated blood lead levels

The IEUBK model was used to estimate the percentage of children that could have elevated blood lead levels if they play frequently in areas with lead contamination and exhibit typical behaviors that result in ingestion of soil. The percentage was calculated using the 95 % upper confidence limit (UCL) of the soil lead concentrations (3638 ppm). Except for the soil lead concentration, model default parameters were used [9].

For children less than seven years old who have daily exposure to soil containing 3,638 ppm lead, IEUBK model calculations (win Version 1.0 build 255) indicate that about 96 % will have blood lead levels greater than 10 μg/dl. The model also predicts that the average blood-lead levels of children under seven who play frequently in this area would be 22 μg/dl. However, this is unlikely unless the site becomes residential in the future.

A more realistic exposure scenario would be a time-weighted average (TWA) approach. This exposure scenario is based on one day a week at the site and six days a week at home with a default level of 200 ppm (apportioning exposure across location according to hours awake). Also taken into consideration are the climatic conditions and a five-month period of access to the site (dry months). This exposure scenario yielded an estimated weighted soil lead concentration of 220 ppm for use in the model. Based on this scenario, the model indicates that about 1.5 % will have blood lead levels greater than 10 μg/dl and predicts an average blood lead level of 3.6 μg/dl for children under seven years of age.

Off Road Vehicles (ORV) Users

Mechanical disturbances of soil from people engaging in short-term activities with ORV (dirt bike or all-terrain vehicle) produce large quantities of dust. Also taken into consideration are the climatic conditions and a five-month period of access to the site (dry months - a one day per week ORV user exposure scenario). Exposure to lead via ingestion, inhalation and dermal routes were evaluated, since this activity is common in the area. To evaluate possible effects from these exposure routes, the UCL (3638 ppm) in the soil was used to calculate the TWA concentration for lead (see Appendix A). A TWA scenario similar to the one above would apply to ORV users. Based on the scenario, the model indicates that about 1.9 % will have blood lead levels greater than 10 μg/dl and predicts an average blood lead level of 3.8 μg/dl for children under seven years of age.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are generated by the incomplete combustion of organic matter, including oil, wood, and coal. They are found in materials such as creosote, coal, coal tar, and used motor oil. Base on structural similarities, metabolism and toxicity, PAHs are often grouped together when one is evaluating their potential for adverse health effects. The EPA has classified some PAHs as probable human carcinogens (B2), as a result of *sufficient* evidence of carcinogenicity in animals and *inadequate* evidence in humans [10]. That group of PAHs is known as cPAH.

Benzo(a)pyrene is the only cPAH for which EPA has derived a cancer slope factor. Benzo(a)pyrene cancer slope factor was used as a surrogate to estimate the total cancer risk of cPAHs in soil. It should be noted, benzo(a)pyrene is considered the most carcinogenic of the cPAHs. The use of its cancer slope factor as a surrogate for total cPAH carcinogenicity may overestimate risk. To address this issue, DOH made an adjustment for each cPAH based on the relative potency to benzo(a)pyrene [10].

Dietary sources make up a large percentage of PAH exposure in the US population, and smoked or barbecued meats and fish contain relatively high levels of PAHs. The majority of dietary exposure to PAHs for the average person comes from ingestion of vegetables and grains (cereals) [11].

Non-cancer effects

Non-cancer, chronic effects from PAH exposure include respiratory, dermal, and eye irritation, photosensitivity, reproductive problems and immune system defects [10]. To evaluate possible noncancer effects from ingestion exposure, the Toxic Equivalency Factor (TEF) for benzo(a)pyrene was used to calculate Total Toxicity Equivalents (TEQ) to obtain the cPAH concentration (5.2 ppm) in the soil. An exposure dose was calculated and then compared to the Lowest Observed Adverse Effect Level (LOAEL), 10 milligrams/kilogram/day (mg/kg/day) and for intermediate oral exposure to benzo(a)pyrene [10]. This LOAEL is based on induced reproductive effects in the progeny of mice exposed to benzo(a)pyrene.

Exposure dose calculations for cPAH and LOAEL comparison value are provided in Appendix A (Table A2). The LOAEL used for benzo(a)pyrene is 10 mg/kg/day, which is over 300,000 times greater than the exposure dose for children. Therefore, no non-cancer effects are expected to occur.

Cancer effects

The EPA classifies PAHs as a Group B2 probable human carcinogen. This means that there is sufficient evidence of carcinogenicity in animal studies, but inadequate evidence in human epidemiological studies. Cancer risk is estimated by calculating an exposure dose (Appendix A) similar to that described above and multiplying it by a cancer potency factor, also known as the cancer slope factor. Some cancer potency factors are derived from human population data. Others are derived from laboratory animal studies involving doses much higher than are encountered in the environment. Use of animal data requires extrapolation of the cancer potency obtained from these high dose studies down to real-world exposures. This process involves much uncertainty.

Current regulatory practice assumes that there is no "safe dose" of a carcinogen and that a very small dose of a carcinogen could give a very small cancer risk. Cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer risk. The validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. More recent guidelines on cancer risk from EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise.

Cancer Risk

Cancer risk estimates do not reach zero no matter how low the level of exposure to a carcinogen. Terms used to describe this risk are defined below as the number of excess cancers expected in a lifetime:

Term		# of Excess Cancers
low	is approximately equal to	1 in 10,000
very low	is approximately equal to	1 in 100,000
slight	is approximately equal to	1 in 1,000,000
insignificant	is less than	1 in 1,000,000

This document describes cancer risk that is attributable to site-related contaminants in qualitative terms like low, very low, slight and no significant increase in cancer risk. These terms can be better understood by considering the population size required for such an estimate to result in a single cancer case. For example, a low increase in cancer risk indicates an estimate in the range of one excess cancer case per ten thousand persons exposed over a lifetime. A very low estimate might result in one excess cancer case per several tens of thousands exposed over a lifetime and a slight estimate would require an exposed population of several hundreds of thousands to result in a single case. DOH considers cancer risk insignificant when the estimate results in less than one cancer per one million exposed over a lifetime. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. Cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower.

EPA has derived a cancer potency factor based on these studies so that cancer risk to humans can be quantified. Cancer risk is the likelihood, or chance, of getting cancer. Based upon the estimated Total Toxicity Equivalents (TEQ) for benzo(a)pyrene, the cPAH level was calculated (5.2 ppm). A person's cancer risk would increase by about 3 in 1,000,000 (3 excess cancers in a population of 1,000,000 people exposed) (See Appendix A - Table A3) and a lifetime cancer risk of about 5 in 1,000,000. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. This estimated risk is slight to very low. Thus, we conclude that there is not a public health concern.

Children's Health Concerns

The potential for exposure and subsequent adverse health effects often increases for younger children compared with older children or adults. ATSDR and DOH recognize that children are susceptible to developmental toxicity that can occur at levels much lower than those causing other types of toxicity. The following factors contribute to this vulnerability:

- Children are more likely to play in contaminated outdoor areas.
- Children often bring food into contaminated areas, resulting in hand-to-mouth activities.
- Children are smaller and receive higher doses of lead exposure per body weight.
- Children are shorter than adults, therefore they have a higher possibility of breathing in dust and soil.
- Fetal and child exposure to lead can cause permanent damage during critical growth stages.

These unique vulnerabilities of infants and children demand special attention in communities that have contamination of their water, food, soil or air. Children's health was considered in the writing of this health consultation and the exposure scenarios treated kids as the most sensitive population being exposed.

Conclusions

No apparent public health hazard exists currently for children, or adults exposed in a one day per week TWA exposure scenario to contaminants present at the pit, specifically to high concentrations of lead present in soil. However, lead pellets in the soil may pose a health threat to young children if they ingest them.

No apparent public health hazard exists currently for children, or adults exposed in a one day per week, (20 days per year) ORV user exposure scenario to contaminants present at the site.

If the site becomes residential properties, a future public health hazard exists for children exposed to contaminants present at the pit, specifically to high concentrations of lead present in the soil.

An indeterminate health hazard exists for groundwater used as a source of drinking water in the area from exposure to lead migrating from the site. Dissolved lead can percolate into ground water and travel offsite.

Recommendations

1. DOH recommends DNR post warning signs to inform the public of the lead contamination from the shot pellets, to avoid accidental ingestion of the pellets and soil.

2. DOH recommends DNR sample groundwater at the Triangle Pit for lead.

Public Health Action Plan

Action Planned

1. DOH will follow up with DNR to assist in developing messages and make sure that signs indicating the hazards at the site are posted.

2. DOH will coordinate with DNR to obtain groundwater-sampling results. DOH will evaluate groundwater-sampling results.

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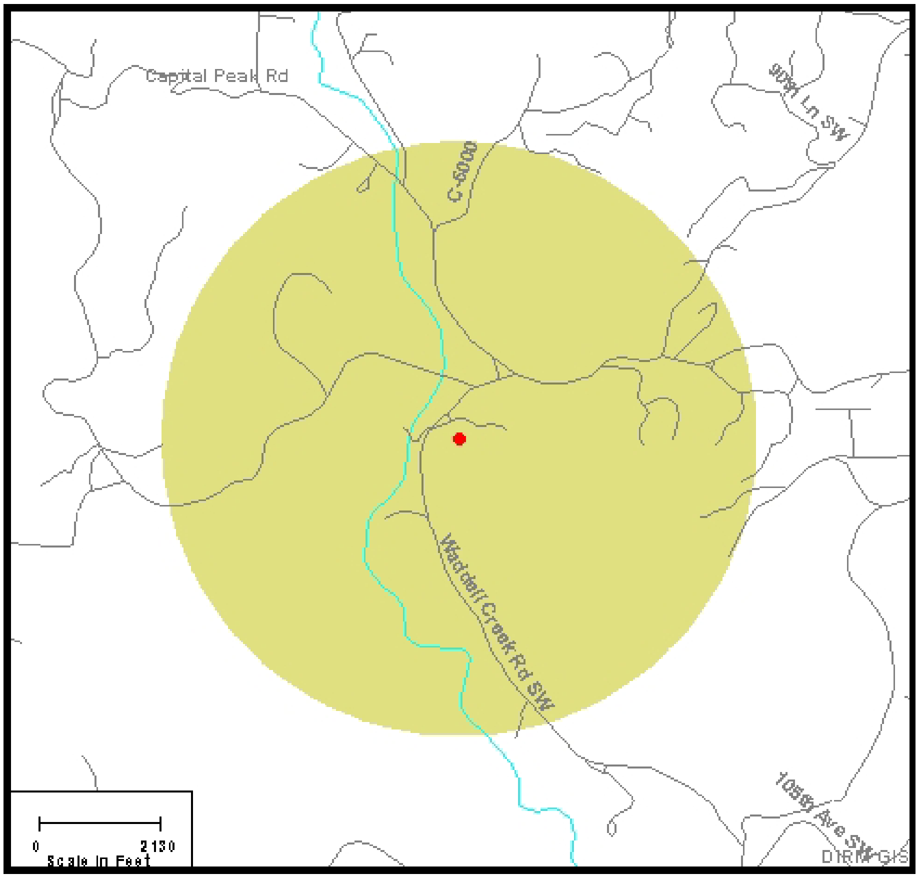
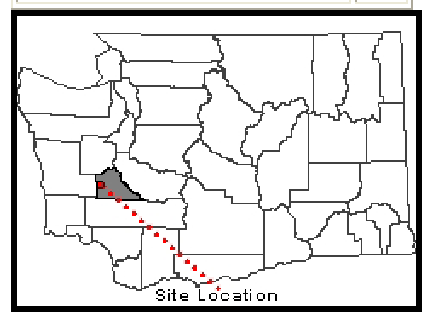
Figure 1. Demographic Statistics Within One Mile of the Site* - Olympia, Thurston County, Washington.



Thurston County

Total Population	65
White	62
Black	0
American Indian, Eskimo, Aleut	0
Asian or Pacific Islander	0
Other Race	0
Hispanic Origin	2
Children Aged 6 and Younger	7
Adults Aged 65 and Older	3
Females Aged 15 - 44	14
Total Aged over 18	48
Total Aged under 18	17
Total Housing Units	23



*** Calculated using the area proportion technique. Source: 2000 U.S. CENSUS**

Figure 2: 2003 Arial photograph showing the DNR triangle pit in Capitol Forest, Olympia, Thurston County, Washington.

Appendix A

This section provides calculated exposure doses and assumptions used for exposure to chemicals in soil at the DNR Pit site. Three different exposure scenarios were developed to model exposures that might occur. These scenarios were devised to represent exposures to a child (0-5 yrs), an older child, and an adult. The following exposure parameters and dose equations were used to estimate exposure doses from direct contact with chemicals in soil

Exposure to chemicals in soil via ingestion, inhalation, and dermal absorption.

Total dose $_{(non\text{-}cancer)}$ = Ingested dose + inhaled dose + dermally absorbed dose

Ingestion Route

$$Dose_{(non\text{-}cancer\ (mg/kg\text{-}day)} = \frac{C \times CF \times IR \times EF \times ED}{BW \times AT_{non\text{-}cancer}}$$

$$Cancer\ Risk = \frac{C \times CF \times IR \times EF \times CPF \times ED}{BW \times AT_{cancer}}$$

Dermal Route

$$Dermal\ Transfer\ (DT) = \frac{C \times AF \times ABS \times AD \times CF}{ORAF}$$

$$Dose_{(non\text{-}cancer\ (mg/kg\text{-}day)} = \frac{DT \times SA \times EF \times ED}{BW \times AT_{non\text{-}cancer}}$$

$$Cancer\ Risk = \frac{DT \times SA \times EF \times CPF \times ED}{BW \times AT_{cancer}}$$

Inhalation of Particulate from Soil Route

$$Dose_{non\text{-}cancer\ (mg/kg\text{-}day)} = \frac{C \times SMF \times IHR \times EF \times ED \times 1/PEF}{BW \times AT_{non\text{-}cancer}}$$

$$Cancer\ Risk = \frac{C \times SMF \times IHR \times EF \times ED \times CPF \times 1/PEF}{BW \times AT_{cancer}}$$

Table A1. Exposure Assumptions for exposure to cPAH in soil, at DNR Triangle Gravel Pit Capitol Forest, Thurston County, WA.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	mg/kg	Maximum detected value
Conversion Factor (CF)	0.000001	kg/mg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Ingestion Rate (IR) – adult	100	mg/day	Exposure Factors Handbook [12]
Ingestion Rate (IR) – older child	100		
Ingestion Rate (IR) - child	200		
Exposure Frequency (EF)	20	Days/year	One days a week for five months
Exposure Duration (Ed)	30 (5, 10,15)	years	Number of years at one residence (child, older child, adult yrs).
Body Weight (BW) - adult	72	kg	Adult mean body weight
Body Weight (BW) – older child	41		Older child mean body weight
Body Weight (BW) - child	15		0-5 year-old child average body weight
Surface area (SA) - adult	5700	cm^2	Exposure Factors Handbook
Surface area (SA) – older child	2900		
Surface area (SA) - child	2900		
Averaging $Time_{non-cancer}$ (AT)	1825	days	5 years
Averaging $Time_{cancer}$ (AT)	27375	days	75 years
Cancer Potency Factor (CPF)	7.3	$mg/kg\text{-}day^{-1}$	Source: EPA
24 hr. absorption factor (ABS)	0.13 0.001	unitless	Source: EPA (Chemical Specific) PAH Lead
Oral route adjustment factor (ORAF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Adherence duration (AD)	1	days	Source: EPA
Adherence factor (AF)	0.2	mg/cm^2	Child, older child
	0.07		Adult
Inhalation rate (IHR) - adult	15.2	m^3/day	Exposure Factors Handbook
Inhalation rate (IHR) – older child	14		
Inhalation rate (IHR) - child	8.3		
Soil matrix factor (SMF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Particulate emission factor (PEF)	1.45E+7	m^3/kg	Model Parameters

Lead Exposure TWA scenario used in the IEUBK model –
PbS_{home} = 200 ppm (Soil lead default value for home)
Dry months = 5
F_{site} = Frequency at site 1/10 of waking hours
F_{home} = Frequency at home
PbS = Soil lead concentration
EF_{site} = Exposure Frequency at site during the dry months
EF_{home} = Exposure Frequency at site during the wet months
PbS_{total} = Soil lead concentration by apportioning total exposure

Apportioning exposure across location according to hours awake

Exposure frequency during dry days

$$F_{site} = \frac{1.2 \text{ hr/day} \times 1 \text{ day/ week}}{12\text{hr/day} \times 7 \text{ days/week}}$$

$$F_{home} = (1 - F_{site})$$

Weighted soil concentration from home and site
$$PbS_{dry} = (PbS_{home} \times F_{home}) + (PbS_{site} \times F_{site})$$

Exposure during wet days

$$F_{home} = \frac{12 \text{ hr/day} \times 7 \text{ days/ week}}{12\text{hr/day} \times 7 \text{ days/week}} = 1$$

$$PbS_{wet} = (PbS_{home} \times F_{home}) = 200 \text{ ppm}$$

Apportioning exposure across location according to wet and dry months

$$EF_{site} = (\text{dry months/ 12 months})$$

$$EF_{home} = (1 - EF_{site})$$

$$PbS_{total} = (PbS_{wet} \times EF_{home}) + (PbS_{dry} \times EF_{site}) = 220 \text{ ppm}$$

Off Road Vehicles usage Lead Soil Exposure Route

Lead Exposure TWA scenario used in the IEUBK model –
PbS_{home} = 200 ppm (Soil lead default value for home)
Dry months = 5
F_{site} = Frequency at site 1/5 of waking hours
F_{home} = Frequency at home
PbS = Soil lead concentration
EF_{site} = Exposure Frequency at site during the dry months
EF_{home} = Exposure Frequency at site during the wet months
PbS_{total} = Soil lead concentration by apportioning total exposure

Apportioning exposure across location according to hours awake

Exposure frequency during dry days

$$F_{site} = \frac{2.4\ \text{hr/day} \times 1\ \text{day/ week}}{12\text{hr/day} \times 7\ \text{days/week}}$$

$$F_{home} = (1 - F_{site})$$

Weighted soil concentration from home and site
$$PbS_{dry} = (PbS_{home} \times F_{home}) + (PbS_{site} \times F_{site})$$

Exposure during wet days

$$F_{home} = \frac{12\ \text{hr/day} \times 7\ \text{days/ week}}{12\text{hr/day} \times 7\ \text{days/week}} = 1$$

$$PbS_{wet} = (PbS_{home} \times F_{home}) = 200\ \text{ppm}$$

Apportioning exposure across location according to wet and dry months

$$EF_{site} = (\text{dry months}/\ 12\ \text{months})$$

$$EF_{home} = (1 - EF_{site})$$

$$PbS_{total} = (PbS_{wet} \times EF_{home}) + (PbS_{dry} \times EF_{site}) = 241.87\ \text{ppm}$$

Soil Exposure Route– cPAH Non-cancer

Table A2. Non-cancer hazard calculations resulting from exposure to cPAH in soil samples from DNR Triangle Gravel Pit Capitol Forest, Thurston County, WA.

Contaminant	TEQ Concentration (ppm) (mg/kg)	Scenarios	Estimated Dose (mg/kg/day)			Total Dose	LOAEL (mg/kg/day)	LOAEL / Total Dose
			Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates			
cPAH	5.2	Child	3.80E-6	2.51E-5	1.09E-8	2.89E-5	10E+0	346,020
		Older Child	6.95E-7	9.17E-6	6.71E-9	9.87E-6		1,013,171
		Adult	3.96E-7	3.59E-6	4.15E-9	3.99E-6		2,506,265

Soil Exposure Route – cPAH Cancer

Table A3. Cancer risk resulting from exposure to cPAH in soil samples from DNR Triangle Gravel Pit Capitol Forest, Thurston County, WA.

Contaminant	TEQ Concentration (ppm)	EPA cancer Group	Cancer Potency Factor (mg/kg-day^{-1})	Scenarios	Increased Cancer Risk			Total Cancer Risk
					Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates	
cPAH	5.2	B2	7.3	Child	1.85E-6	6.97E-7	5.29E-9	2.56E-6
				Older Child	6.76E-7	5.10E-7	6.53E-9	1.19E-6
				Adult	5.78E-7	3.00E-7	6.06E-9	8.84E-7

Lifetime cancer risk: 2.56E-6 + 1.19E-6 + 8.84E-7 = 4.63E-6

Certification

This DNR Triangle Gravel Pit Health Consultation was prepared by the Washington State Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodology and procedures existing at the time the health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

Robert B. Knowles
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Agency for Toxic Substances and Disease Registry

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

Team Lead, CAPEB, DHAC
Agency for Toxic Substances and Disease Registry