Health Consultation

Evaluation of Soil Contamination
Robertson Elementary School
2807 W. Lincoln Avenue
Yakima, Washington

September 30, 2006

Prepared by

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

Washington State Department of
Health

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Foreword

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

Acute	Occurring over a short time [compare with **chronic**].
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.
Absolute bioavailability	Is the amount of a substance entering the blood via a particular route of exposure (e.g., gastrointestinal) divided by the total amount administered (e.g., soil lead ingested).
Bioavailability	The fraction of lead or arsenic that is absorbed and enters the blood by whatever portal-of-entry compared with the total amount of lead or arsenic acquired.
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.
Chronic	Occurring over a long time (more than 1 year) [compare with **acute**].
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**].
Geographic information system (GIS)	A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contamination within a community in relation to points of reference such as streets and homes.
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.

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.
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 EMEG 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].

Purpose

The Washington State Department of Health (DOH) prepared this health consultation at the request of the Washington State Department of Ecology (Ecology) for Robertson Elementary School. The purpose of the health consultation is to evaluate whether the contaminants found in the soil of the school playgrounds pose a health concern to children and residents in the nearby community. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background and Statement of Issues

Elevated concentrations of arsenic (As) and lead (Pb) exist in soil from historical (pre 1948) use of lead arsenate pesticide, particularly in apple and pear orchards in Eastern Washington. [1] Elevated levels of lead and arsenic are present in soils of Robertson Elementary School, Yakima - Washington.

The Robertson School is located in a residential area on the Central perimeter of Yakima, Yakima County, Washington, and consists of nearly 11 acres (Figure 1). There are a total of 571 students in the Robertson Elementary School (kindergarten through grades 5, the age range corresponds to 5 to 12 years old). The Yakima School District owns this property, which historically was used as an orchard land where pesticides containing lead and arsenic were used. The school yard consists of several play areas, sport fields, landscaped grounds, and parking/access areas. Play areas are generally well-maintained, with good grass cover, gravel, or other barrier to native soil. Some small patches of native soil, including parts of the baseball field, surrounding fences, building corners, and general playground areas contain exposed soil (Figures 2, 4, 5, and 6).

Composite surface soil sampling (0-12 inches) at Robertson Elementary School was conducted on February and March 2005 by the state Department of Ecology. Samples collected from the school playgrounds were analyzed using field portable x-ray fluorescence (FPXRF). FPXRF performance was checked twice with calibration, blank and reference readings during sample collection. All the readings were below detection limit. More recently, Ecology sampled soils within 0 to 3, 3 to 6, 6 to 9 and 9 to 12 inches (May 2006). Soil lead and arsenic concentrations were above background levels in both surface and subsurface samples. DOH used mean and UCL 95^{th} % values of Pb and As from both sampling dates to assess children's exposure to contaminated soils at Robertson Elementary School.

Concentrations from 0 – 12 inches were selected for assessment rather than data from selected depths for several reasons. First, the distribution of contaminants in the school's playgrounds is not homogeneous across the site with hot spots found throughout the area in surface and sub-surface soil. Also, the distribution of contaminant concentrations varied with depth from site to site, with some areas having higher concentrations at the surface and others with higher concentrations at lower depths. For example, some areas with exposed soil had elevated levels of lead and arsenic while other areas with exposed soil presented lower levels. In the same way, some grass areas presented high levels of contaminants and 3 feet down the levels were insignificant. Many studies have concluded that the redistribution of surface-applied Pb and As within orchard soils is limited; decades after the application of arsenical pesticides, the highest concentrations of Pb and As generally remain in the top 10 inches of contaminated soils.[2] Thus, samples composited over the 0 – 12 inch depth are likely to reflect exposure conditions at this site considering uncertainties associated with contaminant distribution.

Arsenic levels at the 55 sample locations ranged from 9.7 to 60.8 mg/kg. Samples at almost all locations exceeded the ATSDR health standards for arsenic (20 mg/kg for non-cancer and 0.5 mg/kg for cancer values), and the Washington state MTCA Method A soil cleanup level for unrestricted land use (20 mg/kg). The cleanup standards and cleanup actions comply with state and federal laws to be protective of human health and the environment. At none of the sample locations, the concentration of arsenic exceeded Ecology's interim action level for arsenic (100 mg/kg). Ecology's interim action levels apply to low- to moderate-level soil contamination dispersed over a large geographic area covering several hundred acres to many square miles. For schools, childcare centers, and residential land uses, in general, Ecology considers total arsenic concentrations of between 20 and 100 milligrams per kilogram (mg/kg) and total lead concentrations of between 250 and 500 mg/kg to be within the low-to-moderate range.[3] Lead concentrations ranged from 12.1 to 437.9 mg/kg, and levels at 11 of the 69 sample locations exceeded the MTCA Method A cleanup level for unrestricted land use for lead (250 mg/kg). At none of the sample locations, lead concentrations exceeded Ecology's interim action level of 500 mg/kg.

Interim Remedial Actions

In general, the grass cover is in good condition and well-watered during the spring and summer months; this helps reduce exposure to the contaminated soil. Many areas at the school remain with bare soil through-out the school year. These include areas surrounding trees and fence lines, baseball field, and general playground areas. Top dressing and re-seeding or re-sodding is done if money is available. Resilient material such as gravel and/or wood bark cover is replaced annually or as needed if sooner. The irrigation system operates from April through mid-October, and mostly every day; there is not irrigation during the winter months, because of low water flow. An increase in moisture during the fall and winter months is expected. Areas around playground equipment are covered with gravel up to 12 inches deep, and access areas surrounding the playgrounds are paved.

Elementary school play areas

The children who attend the school use almost all of the school grounds as play areas, and members of the community use the school yard for various activities. Soils with elevated levels of lead and arsenic still remain on-site, and although grass has grown on top of most of the contaminated soils, the effectiveness of this grass cover in reducing exposure has not been evaluated. While grass cover is expected to reduce exposure compared to bare soil, some exposure to the contaminated soil is still likely to occur.[4]

Historical use of lead and arsenic

Lead arsenate was the primary insecticide used to control the codling moth and other insects in Washington deciduous tree fruit orchards between 1905 and 1947.[1] After 1948, lead arsenate use dropped drastically and was replaced by DDT.[5] No sampling for DDT has occurred at this site, and there are not plans to sample for DDT in the future.[6] According to the Washington State Department of Ecology DDT was used only for a short period of time and studies in temperate climates show that half of the DDT initially present usually disappears in about 5 years. By the mid-1960s, DDT was found to cause cancer and eventually was banned.[7] Lead and arsenic are expected to remain in the top of the soil for centuries, and very little leaches through the soil.[8] Most schools in Eastern and Central Washington were built in historic orchard lands shortly after farmers ended the use of lead arsenate. Contaminant levels can vary greatly between orchards, and from location to location within a single orchard. The highest levels are often found on ground where the chemicals were mixed. While some properties have been tested, a comprehensive study to find the level and extent of contamination throughout central and eastern Washington has not been conducted.

Increased concern for human health risks arises when old orchard lands are converted to other land uses such as schools or residential areas where children are likely to be exposed to contaminants in the soil. The DOH has not found any reliable studies that have investigated whether or not health problems increase in people who live in areas with past lead arsenate pesticide use.

Site visit

On March 20, 2006, staff from DOH Office of Environmental Health Assessments and Ecology met to conduct site visit for some of the schools scheduled for the summer 2006 cleanup. A site visit was conducted at Robertson Elementary School to observe conditions and evaluate potential for exposure to lead and arsenic in soils. Playground areas are covered with gravel. Some patches of soil are exposed in the soccer, baseball and general playground areas and along the playground fences and trees (Figures 2, 3, 4, 5, and 6). The current irrigation system has helped to keep a healthy grass cover over contaminated soil during the spring and summer months. In general, DOH found well-watered lawns on most school grounds; this helps to reduce exposure to the contaminated soil.

School officials told DOH that they have not tried to educate teachers, parents, children, and the surrounding community about ways to prevent and reduce exposure to the contaminated soils. Following soil safety and preventive measures can help teachers, parents, and community members to minimize potential health risks from elevated lead and arsenic levels that may be present at the schools and their yards at home.

Discussion

This discussion will focus on potential health impacts from exposure to lead and arsenic in soil at the Robertson Elementary School. Since many areas at the school remain with bare soil through out the school year, estimates of health risk in this document refer to risks that are currently present at the school if the exposed soil is not replaced with clean soil. Risks would increase if the covers are not well maintained.

Lead and arsenic are the only identified contaminants of concern at the Robertson Elementary School. At many locations on the property, levels of arsenic and lead exceeded the ATSDR health comparison values for arsenic (20 mg/kg for non-cancer and 0.5 mg/kg for cancer values), the MTCA Method A cleanup levels for unrestricted land use (i.e., 20 mg/kg for arsenic and 250 mg/kg for lead) and Ecology's interim action levels for schools (i.e., 100 mg/kg for arsenic and 500 mg/kg for lead) (Table 1). Contaminant concentrations exceeding these comparison values do not necessarily pose health threats but are evaluated further to determine whether they are at levels of human health concern.

No comprehensive study has been undertaken to find the levels or extent of contamination in soil on properties currently and formerly used as orchards in Yakima. Studies to correlate health problems in children with lead and arsenic exposure from old orchard lands have not been conducted.

Current exposures to Lead and Arsenic at Robertson School

The presence of chemicals above cleanup levels does not necessarily represent a threat to public health. People must be exposed to the chemicals which must enter the body before they can cause harm. Potential exposure pathways are inhalation, ingestion, and dermal absorption (through the skin). Metals are not readily absorbed through the skin, so dermal absorption of lead and arsenic is not a significant concern at the concentrations found at Robertson Elementary School. Ingestion of contaminated soil is expected to be the primary route of exposure for metals, particularly with young children. Metals in dust or soil can be ingested accidentally by hand-to-mouth activity. Pica behavior, that is, intentionally eating non-food items, may increase this exposure for some children. Pica is most common in children 1 to 2 years old, but some older children and adults also have the behavior. The potential for high levels of lead and arsenic in dust from old orchard land is not just limited to the school property, but is also possible at residences in the area. Ingestion or inhalation of wind-blown soil or dust are additional pathways of exposure to lead and arsenic in the Yakima area. Children are considered a sensitive population because they tend to ingest more soil and dust than adults and because they tend to absorb more of the lead they ingest.

The risk of harm depends on the amount and type of exposure people have to the lead and arsenic. At Robertson Elementary School exposures are difficult to estimate, because they are influenced by children's behaviors and by the levels of contaminants at areas where children spend time, neither of which have been characterized very well. When such uncertainties exist, it is common practice to estimate exposures using the 95 percent upper confidence limit (95 percent UCL) of the mean of the measured sample concentrations in order to protect public health. An alternative is to use the mean of the measured sample concentrations, but that may not reliably reflect the full extent of the exposure for many children. For Robertson Elementary School, risks will be calculated for both the mean and the 95 percent UCL of lead and arsenic.

Using the 95 percent UCL instead of the mean value is considered acceptable in this case, because of the uncertainty regarding arsenic and lead levels surrounding the school fields. There are many areas of exposed soil in the baseball and general playground fields, and along the fence and tree areas. The 95 percent UCL may be the most appropriate estimate of soil lead and arsenic levels to ensure protection of the health of the children from current and past exposures.
While grass cover cannot be considered an adequate long-term barrier to exposure, it is expected to provide some exposure reduction until a long-term solution is implemented for this site (i.e., removal of most of the contaminated soil).

Past exposures at Robertson Elementary School

Incidental ingestion of contaminated surface soil is the predominant lead and arsenic exposure pathway at contaminated playgrounds in the school. An additional exposure pathway of lead and arsenic is also the inhalation of wind-blown soil or dust from the school playgrounds. It is unknown whether past exposures (incidental or inhalation) have occurred at Robertson Elementary School. Nonetheless, if conditions were similar today or worse, past exposure could have occurred. The DOH is not aware of past school playground conditions to determine whether past exposure has occurred.

Lead

Lead is a naturally occurring element normally found in soils. Background soil lead concentrations in the Yakima Basin range between 2 mg/kg and 17 mg/kg.[9] 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 have resulted in substantially 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 people's exposure to lead. Currently, the main pathways for lead exposure in children are ingestion of chips and dust from leaded paint, contaminated soil and house dust, and drinking water in homes that have plumbing materials containing lead.

Table 1. Range values of contaminants detected in soil and their respective comparison values (CV) at Robertson Elementary School, Yakima, Washington.

Contaminant	N	Range in (mg/kg)	95% UCL (mg/kg)	Mean (mg/kg)	Non-Cancer CV (mg/kg)	Cancer C V (mg/kg)	MTCA Method A (mg/kg)	Ecology Interim Action Levels (mg/kg)
Lead	69	12.1 – 437.9	169	144	NA	NA[c]	250	500
Arsenic	55	9.7 – 60.8	31	27.6	20[a]	0.5[b]	20	100

a- EMEG – ATSDR's Reference Dose Media Evaluation Guide (child)
b- CREG – ATSDR's Cancer Risk Evaluation Guide (child)
c- Lead and lead compounds are reasonably anticipated to be human carcinogen [10]
NA – Not applicable

Children six years old and younger are particularly vulnerable to the effects of lead. Compared with older children and adults, they tend to ingest more dust and soil, and absorb more of the lead they swallow. Because children's brains are developing rapidly, they may be more sensitive to the neurological effects of lead than adults. Pregnant women and women of childbearing age should also be aware of lead in their environment, because lead ingested by a mother can affect her unborn fetus.

Health effects

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.[11]

Exposure to lead can be monitored by measuring the level of lead in the blood. One estimate suggests that blood lead (PbB) rises 3-7 micrograms of lead per deciliter (µg/dL) for every 1,000 ppm lead increase in soil or dust concentration.[12] For children, the Center for Disease Control and Prevention (CDC) has defined an elevated blood lead level (BLL) as greater than or equal to 10 µg/dL.[13] However, evidence is growing that damage to the central nervous system resulting in learning problems can occur at blood lead levels less than 10 µg/dL. Deficits in cognitive and academic skills associated with lead exposure occur at blood lead concentrations lower than 5 µg/dL .[14,15,16] About 2.2 % of children in the United States have blood lead levels greater than 10 µg/dL.

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.[11] These have usually been associated with blood lead levels greater than 30 µg/dL.

In the 11th Report on Carcinogens (2004), the National Toxicology Program (NTP) of the U.S. National Institutes of Health concluded that "exposure to lead and lead compounds is reasonably anticipated to be human carcinogens".[10] In arriving at its conclusion, the NTP relied upon studies on laboratory animals and workers exposed to high levels of lead. The laboratory animals developed brain, kidney, and lung cancer. The workers inhaled high levels of lead fumes or accidentally ingested lead dust. The worker studies did not account for diet, smoking, and exposure to other cancer-causing agents. The worker study showed weak evidence for increased risk for lung, stomach, or bladder cancer. The workers were exposed to lead at 50 to 5000 micrograms per cubic meter (ug/m^3) in air and had 40 to 100 micrograms lead per deciliter (ug/dl) in blood. For the school, these exposures do not fit the types and amounts of exposures for school children and nearby residential users of the playgrounds.

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 substantial rise in blood lead level.[17] Understandably, most if not all of these conditions would not apply to elementary school children, and possibly some for nearby residential playground users.

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 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.[18] It is intended to help evaluate the risk of lead poisoning for an average child who is exposed to lead in their environment. Lead poisoning refers to the blood that exceeds 10 micrograms of lead per deciliter. Above 10 micrograms of lead per deciliter is toxic according to the CDC. 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. The IEUBK is often used in this way to set soil cleanup levels for lead. It is important to note that the IEUBK model may not (or, is not expected to) predict accurately the blood lead level of a child (or a small group of children) at a specific time. In part, this is because an individual child (or group of children) may behave differently than the average group of children the model uses to calculate blood lead levels and, therefore, have different amounts of exposure to contaminated soil and dust. 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 it can provide reasonable estimates of the hazards of environmental lead exposure.

For children with regular exposure 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 toxicological level of concern such as the CDC guideline of 10 µg/dL.

Soil lead concentration and estimated Blood Lead Levels (BLLs)

The IEUBK model was used to estimate the percentage of children that could have elevated BLLs if they play frequently in areas that have lead contamination and exhibit typical behaviors that result in soil ingestion. For the reasons described in the section on exposure (page 9), two different percentages were calculated: one using the 95% UCL of the mean of the soil lead concentrations measured at the school, and one using the mean concentration. The 95 percent UCL may overestimate the risks, because most children in the community are likely to have regular exposure to soil levels at school that are less than the 95% UCL. On the other hand, potential exposure of these same kids at homes with lead arsenate-contaminated soil is not considered and so the model could underestimate BLLs. Nonetheless, these estimates are useful in determining the potential hazard for children who may be exposed to these contaminated areas.

The IEUBK model was designed to estimate the distribution of BLLs in children 0 to 84 months of age, based on these assumptions:

- Intake of all potential sources of lead including air, water, diet, soil, and indoor air dust at the school added to incremental intakes of lead at home.
- Uptake of lead from those media into the bloodstream.
- Distribution of lead to tissues and organs.
- Excretion of lead.

The maximum concentration of lead detected in surface soil (0-12 inches) was 437.9 mg/kg. The calculated mean and 95% UCL soil lead concentration (0-12 inches) were 144 mg/kg and 169 mg/kg respectively (Table 1).

DOH used a school exposure scenario to account for lead intake resulting from exposure to soil and dust. The following assumptions were considered as reasonable to run the IEUBK Model:

1. Children may be exposed to lead in soil and dust at the school facility as well as at home (located outside the site). For exposure at home, DOH used the default value (200 mg of lead/kg soil) that is built into the model for use when there are no site-specific data.

2. A child plays at school 5 days per week and stays at home 2 days per week.[a] The IEUBK model is recommended for exposure durations that exceed a minimum frequency of one

[a] Exposure to lead in soil at Robertson Elementary School is assumed to occur for 5 full days/week for 9 months (for a total of 180 days, which equals 6 months that corresponds to the instructional school calendar). However, the IEUBK Model was not designed to model exposures that may occur only part of the year; therefore, the modeled exposure frequency was set at 5 days/week, year around.

day per week and duration of 3 consecutive months.[19,20] Three months is considered as the minimum duration of exposure that is appropriate for modeling exposures that occur no less than once every 7 days.[20] Exposure to lead in soil at Robertson Elementary School is expected to occur more than three months and more than once a day every 7 days.

3. The concentrations of lead at the school facility are 169 mg/kg (95% UCL) and 144 mg/kg (mean value). Based on the percentage of time spent at school, these were converted to the total weighted soil lead concentrations of 187.3 mg/kg and 177.04 mg/kg respectively (Appendix, A). The soil lead concentration by apportioning total exposure (exposure at home and during school) is 193.65 and 188.52 mg/kg respectively, which are below the state cleanup level of 250 mg/kg.

4. For soil and dust ingestion, the IEUBK default bioavailability values of 30% were used. Bioavailability is not constant. The values cited apply for low lead intake rates. Absolute bioavailability decreases as lead intake increases and uptake saturation is reached.[19]

Using these assumptions, the model predicts an approximate 0.2 percent risk that a child (school-age range of 60 to 84 months) exposed to the lead-contaminated soil with a concentration of the 95 percent UCL will have a blood lead level greater than 10 µg/dL (Appendix A, Table A1). For comparison, the model predicts 0.2 percent (age range 60 – 84 months) will have a blood lead level greater than 10 µg/dL when exposed to the state cleanup level of 250 mg/kg.

Using the mean lead value as opposed to the 95% UCL, the model predicts similar BLLs for children within the school-age range of 60 to 84 months, with about 0.2 percent exceeding 10 µg/dL (Appendix A, Table A2).

As mentioned previously, there is much uncertainty associated with estimating the true average concentration at the site and therefore the most appropriate estimate of soil lead levels to ensure protection of the health of the children is the 95 percent UCL.[21]

The health risks from such level of exposure at this school are very low. The IEUBK model uses the school-age range of 60 to 84 months; however, a great portion of the children in Robertson ES is older than 84 months. Under similar environmental conditions with similar lead exposures, the model tends to predict lower blood lead levels with increasing age. DOH assumes that lead levels are not a health risk to either age group and that children at Robertson Elementary School (K-5 grades) are unlikely to get sick when they are exposed to soil contaminated with lead at the levels observed at the school.

Arsenic

Arsenic is a naturally occurring element in the earth's soil. Background soil arsenic concentration in the Yakima Basin ranges from 0.9 mg/kg to 29 mg/kg.[9] EPA classifies the inorganic form of arsenic as a human carcinogen. Ingested arsenic is typically absorbed by the intestines and enters the bloodstream where it is distributed throughout the body. Inhaled arsenic is quickly absorbed by the lungs and enters the bloodstream. Arsenic is poorly absorbed through the skin, so skin contact with contaminated soil is not normally an important pathway for harmful exposure.

Noncancerous effects

Long term exposure to arsenic has been shown to increase people's risk of developing several types of health problems including cardiovascular disease, diabetes mellitus, lung disease and liver disease. To evaluate possible noncancerous effects from ingestion exposure to the 95% UCL or the mean level of arsenic in site soil (Table 1), an exposure dose was calculated and compared with ATSDR's minimal risk level (MRL) and EPA's oral reference dose (RfD). RfDs and MRLs are doses below which adverse noncancerous health effects are not expected to occur. A level of uncertainty exists when defining an MRL or RfD, because of uncertainty about the quality of data on which it is based. To account for this uncertainty, "safety factors" are used to set RfDs and MRLs below toxic effect levels that have been measured (e.g., Lowest Observed Adverse Effect Level [LOAEL]). This approach provides an added measure of protection against the potential for adverse health effects to occur. For acute oral exposure to arsenic, the MRL is 0.005 milligrams per kilogram per day (mg/kg/day). For chronic oral exposure to arsenic, the MRL is 0.0003 mg/kg/day.

The maximum concentration of arsenic (60.8 mg/kg) in the soil exceeds the ATSDR health comparison values of 20 mg/kg for children. The mean soil arsenic concentration is 27.6 mg/kg. The 95 % UCL surface soil (0-12 inches) arsenic concentration is 31 mg/kg. An exposure scenario of five days a week at the site with exposure to 31 and 27.6 mg/kg was used in dose calculations in Appendix B (Table B1). A child (age 5 to 12 years old) would receive an exposure dose of 0.0000779 mg/kg/day and 0.0000697 mg/kg/day respectively, Appendix B (Table B2), which is lower than the acute MRL of 0.005 mg/kg/day and the chronic MRL of 0.0003 mg/kg/day. An adult teacher would be exposed to approximately 0.0000136 mg/kg/day of arsenic, Appendix B (Table B2), which is lower than both the acute MRL and chronic MRL.

Estimated doses for children and adults are below the acute MRL, so short-term non-cancerous health effects are unlikely to occur from exposures at Robertson Elementary School. If the chronic estimated dose for a child does, however, exceed the chronic MRL or RfD it does not necessarily indicate that harmful effects are likely, but suggests that further toxicologic evaluation should be conducted. This involves comparing the estimated doses at the site with occupational and/or environmental exposures known to cause harmful effects. For a child, the estimated exposure dose is about 10 times below the No Observed Adverse Effect Level (NOAEL) (0.0008 mg/kg/day) identified in chronic studies and 180 times below the LOAEL (0.014 mg/kg/day).[22] Studies have not found non-cancer effects in people exposed to arsenic in drinking water at chronic doses of 0.0004 to 0.01 mg/kg/day, doses which exceed those estimated here. Also, most studies of arsenic toxicity have examined people exposed to arsenic in water, which is usually better absorbed than arsenic in soil. Non-cancer effects are, therefore, unlikely to occur in children or adults exposed to arsenic on soil at Robertson Elementary School.

Cancerous effects

Arsenic has been shown to increase people's risk of developing several types of cancer including lung, bladder, skin, kidney and liver cancer. This document describes cancer risk that is attributable to site-related contaminants in qualitative terms like high, low, very low, slight and no significant increase in cancer risk. These terms can be better understood by considering the population size required for site-related exposures to result in a single cancer case. For example, a low increase in cancer risk indicates an increased risk of about one cancer case per ten thousand persons exposed over a lifetime. A very low risk is about one cancer case per several tens of thousands exposed over a lifetime and a slight risk would require an exposed population of several hundreds of thousands to result in a single case. DOH considers cancer risk to be not significant when the estimated result is 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.

EPA classifies arsenic as a Group A (known human) carcinogen by the oral and inhalation routes. The 95% UCL for arsenic in the soil (31 mg/kg) exceeds the ATSDR Cancer Risk Evaluation Guide (CREG) of 0.5 mg/kg. An exposure dose was calculated for a child over a 5-year exposure period with five days a week exposure at the site (180 days per year). The calculated theoretical increased cancer risk for such an exposure is estimated at about 5 additional cancers in a population of 100,000 persons (school-age children of 5 to 12 years old) (Appendix B, Table B3). DOH considers this to be a low increased cancer risk over a short period of time (6 months -180 days - corresponds to the school instructional calendar). The cancer risk for an adult teacher or neighborhood adult playground user would be approximately 2 cancers in a population of 1 million persons, also considered a low increased cancer risk.

The true cancer risks at this site cannot be determined due to variability and uncertainty in several parameters. The calculated risks are estimates based on available information and could be higher or lower than the true risk.

Uncertainty

Although there is some uncertainty surrounding the magnitude of the carcinogenic potential of arsenic, there is a strong scientific basis for choosing a slope factor that is different from the value (1.5 per mg/kg-day) currently listed in the EPA IRIS database. Several recent reviews of the literature have evaluated bladder and lung cancer endpoints instead of skin cancer (which is the endpoint used for the current IRIS value):

- National Research Council (2001) [23]
- EPA Office of Drinking Water (2001) [24]
- Consumer Product Safety Commission (2003) [25]
- EPA Office of Pesticide Programs (2003) [26]

- California Office of Environmental Health Hazard Assessment (2004) [27]
- EPA IRIS Review Draft for the SAB (2005) [28]

Information provided in these reviews allows the calculation of slope factors for arsenic which range from 0.4 to 23 per mg/kg-day (but mostly greater than 3.7). The recent EPA IRIS review draft presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg-day. The slope factor calculated from the work by the National Research Council is about 21 per mg/kg-day. These slope factors could be higher if the combined risk for all arsenic-associated cancers (bladder, lung, skin, kidney, liver, etc.) were evaluated. For this Health Consultation, DOH used a slope factor of 5.7 per mg/kg-day, which appears to reflect EPA's most recent assessment.

Exposure reduction actions

The use of a sprinkler system to promote better grass cover in some areas has likely helped reduce exposure. However, grass may not be reliable or permanent barrier to prevent contact with soil contaminated with lead and arsenic. While grass cover seems to limit or reduce exposure compared to bare soil, some studies indicate that exposure to contaminated soil may occur even when grass is present.[4] In terms of exposure reduction activities, DOH believes that interim remedial activities such as maintenance of grass and gravel cover and irrigation systems are unlikely to provide an effective, permanent barrier to limit exposure. Risks may arise if the covers are not well maintained over the long-term.

Child Health Considerations

Children's school and residential exposure scenarios were evaluated in this document to determine if children's exposure were of public health concern. ATSDR and DOH recognize infants and children are susceptible to developmental toxicity that can occur at levels much lower than those causing other types of toxicity. Infants and children are also more vulnerable to exposures than adults. The following factors contribute to this vulnerability at this site:

- 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 metals exposure per body weight.
- Children are shorter than adults, therefore they have a higher possibility to breathe 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 with 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 children as the most sensitive population being exposed.

It is expected that children will be present throughout the school year and may use the outdoor playgrounds and other facilities even when school is not in session. Children's activities on the school property and residential homes may result in frequent, significant exposure to soil contaminants. The implementation of interim remedial actions at the site will help reduce or prevent children from making contact with the contaminated soil that remains on-site. However, children, who are most susceptible to the contamination, may also be exposed at home where potentially high levels of lead and arsenic may be present in the soil.

Conclusions

Based on available information contained in this Health Consultation, DOH has reached the following conclusions:

1. Concentrations of arsenic and lead in soil at Robertson Elementary School exceed health-based comparison values including MTCA cleanup levels.

2. Although some students and staff are likely to be exposed to contaminated soil on the property, the health risks from this exposure, while not zero, are expected to be relatively low. Based on the magnitude of the risk and ATSDR's health guidelines for their conclusion category ranking system, DOH concludes that Robertson Elementary School should be classified as *no apparent public health hazard*. However, because arsenic concentrations and estimated cancer risks exceed the goals specified by the health-based MTCA soil arsenic cleanup level, recommendations to reduce exposure are considered prudent public health practice and are provided to further minimize exposure.

3. Ecology has chosen to be proactive and reduce risks to children by remediating soil lead and arsenic contamination. DOH supports this decision because reduction of exposure by cleaning up releases of hazardous materials is preferable to treating preventable illnesses after they occur. This cleanup effort for schools is part of the Governor's "Healthy Washington" initiative. DOH is working in partnership with Ecology to address environmental cleanup actions and long-term health risks when children play in contaminated soils.

4. Data are unavailable for additional exposure scenarios such as those at home and child day cares for the same children who attend this school. It is likely that some homes near the school were built on old orchard lands and the yards could have elevated levels of arsenic and lead. The full extent of soil contamination in residential areas that Robertson Elementary School serves is unknown, because these areas have not been sampled. Consequently, DOH is unable to evaluate the added risks from lead and arsenic contamination in residential areas that may have been built on old orchard lands.

5. Data are unavailable for additional exposure scenarios such as those at home and child day cares for the same children who attend this school. Homes built on old orchard lands can potentially have elevated levels of DDT in the soil. DOH is unable to evaluate the added risks from DDT contamination in residential areas that may have been built on old orchard lands.

Recommendations

1. The *no apparent public health hazard* conclusion category was selected based on information indicating relatively low health risks from exposure to lead and arsenic that is occurring or has occurred in the past. However, because arsenic concentrations are higher than Washington's health-protective cleanup levels, recommendations to reduce exposure may be considered prudent public health practice.

2. DOH recommends discouraging children from playing in areas that have bare soil or that are known to have higher concentrations of lead and arsenic.

3. DOH recommends exposure reduction health education efforts for families living within the footprint of old orchard lands.

4. DOH recommends residents test their soil in homes built in former orchard lands.

5. DOH recommends soil testing in child day cares built on former orchard lands.

6. Since the presence of DDT is unknown in historic orchards soil DOH recommends investigating a pilot project regarding soil testing for DDT in schools and/or residential homes built on former orchard lands.

Public Health Action Plan

1. The Department of Ecology is available to assist the school district with the implementation of remedial activities to reduce exposure of kids to contaminants on-site.

2. DOH, Yakima Health District and school officials will conduct outreach and education activities, as appropriate, to provide concerned citizens with health education information. These activities may include a poster presentation to be displayed at a public location, site-specific fact sheets, or attendance at public meetings. Materials and activities will be appropriate for the age and education level of the intended audience.

3. Exposure to contaminants at the school and residential properties can be reduced if children and adults follow the soil safety guidelines below.

    - Use plenty of soap and water

- Wash your hands after playing or working outside, especially before eating.
- Launder heavily soiled clothing separately.
- Wash children's toys, bedding and pacifiers frequently.

- Garden safely

  - Wear gloves while gardening and wash vegetables before eating them.
  - Cover up exposed soil in your yard by growing grass on it or cover with mulch.
  - Avoid muddy soil that cling to clothing, toys, shoes, hands or feet.

- Mop, dust and vacuum

  - Wash anything that has come in contact with soils before entering your home.
  - Implement regular damp mopping to avoid breathing indoor housedust.
  - Vacuum carpets and rugs frequently, plus wet mop and/or wet dust all other surfaces in your home.
  - Remove shoes before entering your home to avoid tracking soil into your house.

- Keep pets clean

  - Wipe down pets before you let them inside.
  - Keep your pets clean. Brush and bathe them regularly.
  - Restrict your pets to areas of your home that are free from carpeting and upholstery. Give pets their own sleeping spots.

- Eat a healthy diet

  - Eat healthy. Foods that contain the daily recommended amounts of iron and calcium help to decrease the absorption of lead.
  - Prevent children from eating dirt.

This information will be distributed to parents and community residents living within the school boundaries of Robertson Elementary School. The school district and DOH will notify them about these simple steps to reduce and limit exposure to soils at school and at home.

4. DOH will be available to consult on the appropriateness and efficacy of future remedial actions.

5. DOH will analyze aerial photos from historical orchard lands (1940's) to identify how the footprint of former orchard lands match residences within the school boundaries. Once susceptible populations and/or people living in old orchard lands are identified within the school boundaries, DOH will coordinate efforts with school officials to implement outreach and health education activities.

6. DOH will work with Ecology and the Yakima Health District to determine the value and

need for additional efforts such as blood lead screening for children and residential soil sampling.

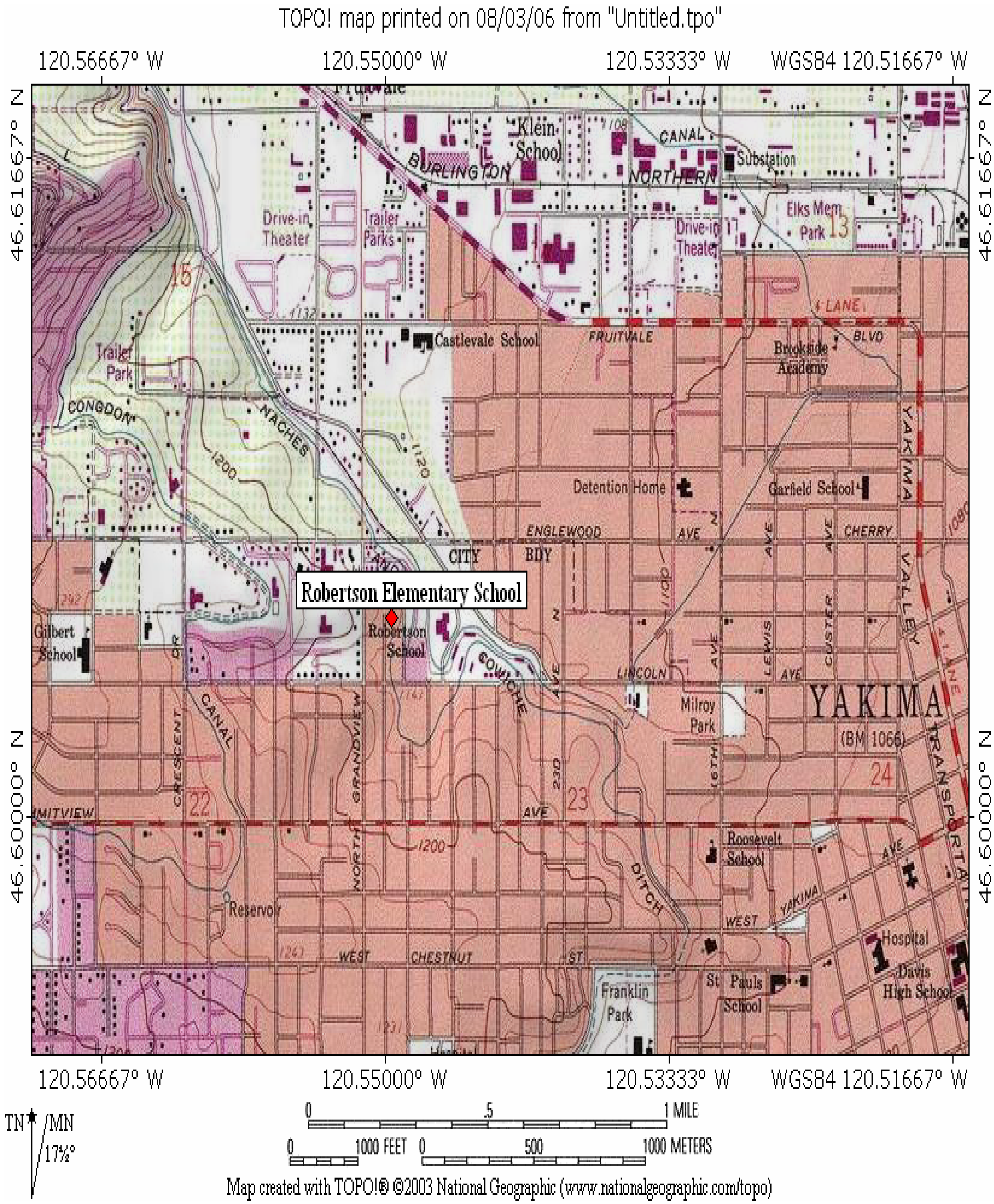

Figure 1. Map of Robertson Elementary School, Yakima, Washington.

Figure 2. Exposed soil along soccer field, Robertson Elementary School, Yakima, Washington.

Figure 3. Playground field at Robertson Elementary School, Yakima, Washington.

Figure 4. Robertson Elementary School playfields, Yakima Washington.

Figure 5. Robertson Elementary School playfields, Yakima Washington.

Figure 6. Exposed soil along trees, Robertson Elementary School, Yakima Washington.

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Appendix A

This section provides inputs and calculations for the IEUBK model. The following inputs to the model were used to account for exposures at Robertson School and residential areas.

The fraction of hours the child is awake and potentially exposed for each location was calculated as follows:

Apportioning exposure across locations according to hours awake:

Exposure frequency during school

$$F_{school} = \frac{8 \text{ hours/day x 5 days/week}}{14 \text{ hours/day x 7 days/week}} = \frac{40}{98} = 0.41$$

Eight hours/day indicates the amount of time a child spends at school (indoor area and playing in the school grounds).

Exposure frequency at home

$$F_{home} = \frac{14 \text{ hours/day x 7 days/week}}{14 \text{ hours/day x 7 days/week}} = 1$$

Apportioning exposure across location according to school and non-school months

EF_{school} = (*school months/ 12 months) = 6/12 = 0.5

* The traditional calendar for Yakima Public Schools for 2005 and 2006 instructional calendar corresponds to 180 days.

EF_{home} = (1- EF_{school}) = 1 - 0.5 = 0.5

The home fraction was calculated by subtracting the fraction of hours spent at other locations from 1.0; thus, the remaining time spent at home is:

$$F_{home} = (1.0 – 0.41) = 0.59$$

Deriving a weighted soil concentration from school and home DOH used the following equation:

$$PbS_w = (PbS_{school} \text{ x } F_{school}) + (PbS_{home} \text{ x } F_{home})$$

Where:

PbS_w = Weighted soil lead concentration from home and site (mg/kg).

PbS_{school} = 95% UCL concentration at school and/or mean value at school
F_{school} = Fraction of daily outdoor time spent at school
PbS_{home} = Average soil lead concentration at home (ppm), (equals the default value of 200 mg/kg set by EPA).
Instructional calendar for Yakima Public School = 180 days
F_{home} = Fraction of daily outdoor time at local background soil lead concentration (equals 1 minus F_{school}).
PbS = Soil lead concentration
EF_{home} = Exposure frequency at site during vacation time and no school days
EF_{school} = Exposure frequency at site during the school (instructional calendar)
PbS_{total} = Soil lead concentration by apportioning total exposure

$$PbS_w = (169 \text{ mg/kg} \times 0.41) + (200 \text{ mg/kg} \times 0.59)$$
$$PbS_w = (69.3 \text{ mg/kg}) + (118 \text{ mg/kg})$$
$$PbS_w = 187.3 \text{ mg/kg}$$

Soil lead concentration by apportioning total exposure

$$\begin{aligned} PbS_{total} &= (PbS_{home} \times EF_{home}) + (PbS_{school} \times EF_{school}) \\ &= (200 \times 0.5) + (187.3 \times 0.5) \\ &= 100 + 93.65 \\ &= 193.65 \text{ mg/kg} \end{aligned}$$

The weighted soil lead concentration using the 95% UCL results in 187.3 mg/kg. The soil lead concentration by apportioning total exposure corresponds to 193.65 mg/kg. 193.65 mg/kg was used to run the IEUBK Model. The IEUBK indoor dust lead levels of 200 mg/kg were used as the default or constant value to run the model (Table A1).

The weighted soil lead concentration using the mean value results in (Table A2):

$$PbS_w = (144 \text{ mg/kg} \times 0.41) + (200 \text{ mg/kg} \times 0.59)$$
$$PbS_w = (59.04 \text{ mg/kg}) + (118 \text{ mg/kg})$$
$$PbS_w = 177.04 \text{ mg/kg}$$

Soil lead concentration by apportioning total exposure:

$$\begin{aligned} PbS_{total} &= (PbS_{home} \times EF_{home}) + (PbS_{school} \times EF_{school}) \\ &= (200 \times 0.5) + (177.04 \times 0.5) \\ &= 100 + 88.52 \\ &= 188.52 \text{ mg/kg} \end{aligned}$$

Table A1. IEUBK input parameters and 95% UCL blood lead concentration values that exceed 10µg/dL within different age ranges at Robertson Elementary School, Yakima, Washington.

IEUBK input parameters	Values used for Robertson School	
Derived total weight soil concentration (PbS_{total})		**193.65** [a]
PbS_{school}	169 mg/kg	
PbS_{home}	200 mg/kg	[b]
f_{school}	0.41	
f_{home}	0.59	
EF_{school}	0.5	
EF_{home}	0.5	
Exposure period	180 days	

[a] This is the total weighted soil lead concentration based on the calculated 95% UCL soil lead concentration (169 mg/kg).
[b] Corresponds to indoor dust lead levels (constant value).

IEUBK Output [*]		
Age range (months)	**GM PbB**	**% > 10 µg/dL**
0-84	3.1	0.70
6-12	3.5	1.37
12-24	3.9	2.38
24-36	3.6	1.61
36-48	3.5	1.19
48-60	2.9	0.39
60-72	2.4	0.13
72-84	2.2	0.06

GM PbB: Blood lead geometric mean
[*] Corresponds to the 95% UCL soil lead concentration values that exceed 10µg/dL at Robertson School.

Children's intake of lead from soil and dust sources exhibit blood lead levels greater than 10µg/dL for different age ranges at the school (Table A1).

Table A2. IEUBK input parameters and mean blood lead concentration values that exceed 10µg/dL within different age ranges at Robertson Elementary School, Yakima, Washington.

IEUBK input parameters	Values used for Robertson School	
Derived total weight soil concentration (PbS *total*)		**188.52** [a]
PbS_{school}	144 mg/kg	
PbS_{home}	200 mg/kg	[b]
f_{school}	0.41	
f_{home}	0.59	
EF_{school}	0.5	
EF_{home}	0.5	
Exposure period	180 days	

[a] This is the weighted total soil lead concentration based on the mean soil lead concentration (144 mg/kg).
[b] Corresponds to indoor dust lead levels (constant value).

IEUBK Output *		
Age range (months)	**GM PbB**	**% > 10 µg/dL**
0-84	3.1	0.66
6-12	3.5	1.31
12-24	3.9	2.28
24-36	3.6	1.54
36-48	3.4	1.14
48-60	2.8	0.37
60-72	2.4	0.13
72-84	2.2	0.06

GM PbB: Blood lead geometric mean
[*] Corresponds to the mean soil lead concentration values that exceed 10 µg/dL at Robertson School.

Children's intake of lead from soil and dust sources exhibit blood lead levels lower than 10µg/dL for different age ranges at the school (Table A2).

Appendix B

This section provides calculated exposure doses and assumptions used for exposure to chemicals in soil at the Robertson Elementary School site. Three different exposure scenarios were developed to model exposures that might occur at the site. These scenarios were devised to represent exposures to 1) a child (5-12 yrs old) and 2) an adult teacher. 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 $_{\text{(non-cancer)}}$ = Ingested dose + inhaled dose + dermally absorbed dose

Ingestion Route

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

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

Dermal Route

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

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

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

Inhalation of Particulate from Soil Route

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

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

Table B1. Exposure Assumptions for exposure to arsenic in soil at Robertson Elementary School site – Yakima, Washington.

Parameter	Value	Unit	Comments
Concentration (C)	31 and 27.6	mg/kg	95% UCL detected value, and mean value respectively
Conversion Factor (CF)	0.000001	kg/mg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Ingestion Rate (IR) – adult	50	mg/day	Exposure Factors Handbook [29]
Ingestion Rate (IR) – older child (5-6 yrs. old)	200		
Ingestion Rate (IR) – child (7-12 yrs. old)	100		
Exposure Frequency (EF)	180	days/year	Average days in school year
Exposure Duration (Ed)	(5-6, and 7-12)	years	Number of years at school (child, elementary school age child, adult - teacher).
Body Weight (BW) - adult	70	kg	Adult mean body weight
Body Weight (BW) – older child (5-6 and 7-12 yrs. old)	21 and 35		Older child mean body weight [29]
Body Weight (BW) – child (0.5 -4 yrs. old)	12		0.5-4 year-old child average body weight
Surface area (SA) - adult	5700	cm^2	Risk Assessment Guidance (EPA) [30]
Surface area (SA) – older child	2900		
Surface area (SA) - child	2900		
Averaging Time$_{non\text{-}cancer}$ (AT)	730, 2190, 5293	days	8 years (K-5 grades), and adult
Averaging Time$_{cancer}$ (AT)	27375	days	75 years
Cancer Potency Factor (CPF)	5.7E+00	$mg/kg\text{-}day^{-1}$	CPF are presented in Table B3
24 hr. absorption factor (ABS)	0.03	unitless	Source: EPA Chemical Specific Arsenic – 0.03 Inorganic – 0.001 Organic – 0.01
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 [29]
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

Soil Route of Exposure – Non-cancer

Table B2. Non-cancer hazard calculations resulting from exposure to arsenic in soil at Robertson Elementary School site (School-age children) – Yakima, Washington.

Contami_ nant	Concen tration (mg/kg)	Scenarios	Estimated Dose (mg/kg/day)			Total Dose	MRL (mg/kg/day)	Hazard quotient
			Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates			
Arsenic	27.6 [a]	Child 5-6	1.30E-04	1.13E-05	2.12E-08	1.41E-04	3E-4	0.47
		Child 7-12	3.89E-05	6.77E-06	2.25E-07	4.59E-05		0.15
		Adult	9.72E-06	2.33E-06	2.04E-07	1.23E-05		0.04
	31.0 [b]	Child 5-6	1.45E-04	1.26E-05	2.38E-08	1.58E-04		0.53
		Child 7-12	4.34E-05	7.54E-06	2.53E-07	5.12E-05		0.17
		Adult	1.08E-05	2.59E-06	2.29E-07	1.36E-05		0.04

[a] corresponds to the mean concentration value
[b] corresponds to the 95% UCL concentration value

Soil Route of Exposure – Cancer

Table B3. Cancer risk resulting from exposure to contaminants of concern in soil samples from Gilbert Elementary School site (School-age children) at – Yakima, Washington.

Contaminant	Concentra tion mean (mg/kg)	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	
Arsenic	27.6	A	5.7	Child 5-6	1.97E-05	1.71E-06	5.64E-08	2.15E-05
				Child 7-12	1.77E-05	3.09E-06	1.71E-07	2.10E-05
				Adult	1.07E-05	2.56E-06	2.32E-07	1.35E-05

Contaminant	Concentra tion UCL 95% (mg/kg)	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	
Arsenic	31.0	A	5.7	Child 5-6	2.20E-05	1.91E-06	6.34E-08	2.40E-05
				Child 7-12	1.98E-05	3.44E-06	1.92E-07	2.34E-05
				Adult	1.19E-05	2.86E-06	2.61E-07	1.50E-05

Certification

This Evaluation of Soil Contamination at Robertson Elementary School, Yakima Washington Public Health consultation was prepared by the Washington State Department of Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodologies and procedures existing at the time the health consultation were initiated. Editorial review was completed by the Cooperative Agreement partner.

Technical Project Officer, CAPEB, DHAC

The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

Team Lead, CAT, CAPEB, DHAC, ATSDR