Health Consultation

Assessment of Soil Exposures to Dioxins and Heavy Metals in the Community Adjacent to the Stericycle Medical Waste Incinerator

NORTH SALT LAKE, DAVIS COUNTY, UTAH

Prepared by
Utah Department of Health

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Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

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NORTH SALT LAKE, DAVIS COUNTY, UTAH

Prepared By:

Environmental Epidemiology Program
Office of Epidemiology
Utah Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

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SUMMARY

INTRODUCTION	The Environmental Epidemiology Program (EEP) at the Utah Department of Health (UDOH), as part of a cooperative agreement with the Agency for Toxic Substance and Disease Registry (ATSDR), prepared this health consultation to evaluate possible human health hazards that may occur from exposure to soil potentially contaminated with dioxins and heavy metals in the vicinity of the Stericycle medical waste incinerator in North Salt Lake, Utah. In May 2013, the Utah Department of Air Quality (DAQ) issued a Notice of Violation to Stericycle for multiple pollutant emissions limit exceedances. DAQ issued an amended Notice of Violation in August 2013 to explicitly cover each day of emissions violation. During emission tests occurring between 2011 and 2013, the Stericycle incinerator exceeded their permitted emission limits for dioxins and dioxin-like compounds, nitrogen dioxides, and hydrogen chloride gas. By April 2013, the facility had reduced emissions of all monitored pollutants to levels in compliance with their operating permit. To respond to community concerns regarding the health effects from exposure to soil potentially contaminated with pollutants released by the incinerator, the EEP and the Davis County Health Department (DCHD) independently conducted investigative sampling of soil from residential, public use, and undeveloped properties adjacent to the facility. Samples collected by both agencies were tested for dioxins and dioxin-like compounds. Additionally, samples collected by the EEP were tested for eight heavy metals regulated by Stericycle's permit issued under the federal Resource Conservation and Recovery Act (RCRA) (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). A separate letter health consultation document addressing concerns regarding the potential health effects from inhalation exposure to contaminants released by the incinerator was released on February 20, 2014 and is available on the EEP's website (http://www.health.utah.gov/enviroepi/appletree/SouthDavisCounty/Stericycle_Air_Emissions_LHC.pdf).

CONCLUSION 1	The Utah Environmental Epidemiology Program (EEP) concludes exposures to arsenic in residential soils, vicinity playground sand, and non-residential soils are not expected to harm the health of adults, children, or children with soil-pica (a rare behavior).
BASIS FOR DECISION	The arsenic concentration in sand from the Caleb Drive playground exceeded the Agency for Toxic Substances and Disease Registry (ATSDR) chronic environmental media evaluation guide (EMEG) for children and the acute EMEG for children who have soil-pica behavior. Exposure dose estimates for adults and children without soil-pica behavior are below the ATSDR chronic minimal risk level (MRL) for arsenic. Exposure dose estimates for children with soil-pica are below the ATSDR acute MRL.
NEXT STEPS	Parents are advised to monitor young children for excessive hand-to-mouth behavior and ingestion of playground sand. Residents are advised to take steps to limit their and their children's exposure to playground sand, particularly in young children at higher risk for soil-pica behavior.
CONCLUSION 2	The EEP concludes that exposures to chromium in residential soils, vicinity playground sand, and non-residential soils are not expected to harm the health of adults, children, or children with soil-pica. This conclusion includes the very conservative assumption that all chromium detected is in the more toxic hexavalent form.
BASIS FOR DECISION	Total chromium concentrations in residential soil, given an assumption of all Cr(VI), exceeded the ATSDR intermediate EMEG for children with soil-pica. Exposure dose estimates for children with soil-pica behavior did not exceed the ATSDR intermediate MRL for hexavalent chromium. Independent soil sampling by the U.S. Geological Survey suggests that total chromium levels in residential soil are at or below typical background levels for the region.
NEXT STEPS	Parents are advised to monitor young children for excessive hand-to-mouth behavior and ingestion of soil. The EEP recommends that area residents limit their exposure to residential soil, particularly in young children at higher risk for soil-pica behavior.
CONCLUSION 3	The EEP concludes that exposures to barium, cadmium, lead, mercury, selenium, silver, and dioxins/furans in residential soil and vicinity playground sands is not expected to harm people's health.

BASIS FOR DECISION	Concentrations of barium, cadmium, chromium, lead, mercury, selenium, silver, and dioxins in soil and sand are below the applicable ATSDR chronic comparison values.
NEXT STEPS	While soil lead levels were low, the best available science indicates that there is no safe level of lead exposure, especially for children. The EEP recommends that residents limit their exposure to lead containing materials. The EEP will provide residents with health information, education, and outreach regarding the health effects associated with exposure to these substances. Residents with concerns about lead exposure are encouraged to consult with their health care provider and can find further information at the EEP's website: http://www.health.utah.gov/enviroepi/healthyhomes/lead/
FOR MORE INFORMATION	If you have concerns about your health, you should contact your primary health care provider. For questions or comments related to this health consultation, you may contact the EEP at (801) 538-6191 or APPLETREE@utah.gov.

STATEMENT OF ISSUES

The Environmental Epidemiology Program (EEP) at the Utah Department of Health (UDOH) prepared this health consultation to evaluate the health risks for exposure to soil potentially contaminated with dioxins and dioxin-like compounds (henceforth collectively referred to as dioxins), as well as toxic metals, in the vicinity of the Stericycle medical waste incinerator. The EEP evaluates the human health risks of exposure to environmental contaminants in Utah through a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

The mission of ATSDR is to serve the public by applying the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures related to toxic substances. The State of Utah Governor's Office has requested that the EEP conduct this health consultation to identify public health hazards posed by the contaminants to the surrounding area. The assessment process serves as a mechanism to help ATSDR and state health departments determine where public health actions should be addressed and for whom.

The objective of this health consultation is to determine if measured levels of dioxins and toxic metals in soil in the vicinity of the Stericycle incinerator pose a health hazard to residents.

BACKGROUND

Stericycle, Inc. is a large national provider of regulated waste disposal services. In the early 1990s, BFI Medical Waste, Inc. began planning a medical waste incinerator at 90 North 1100 West in North Salt Lake, Davis County, UT. The North Salt Lake Planning Commission gave its final approval to BFI's site plan in August 1991, and construction of the incinerator proceeded shortly thereafter (KUER, 2013). In November 1999, Stericycle acquired BFI, and with it the incinerator (DSHW, 2005. See **Appendix A, Map 1**). This facility accepts medical waste from a variety of markets throughout North America, primarily the Pacific coast and intermountain states (DSHW, 2005). The permitted capacity for the incinerator is 1,850 pounds of waste per hour (DSHW, 2006). In the 2011 calendar year, Stericycle received 7,223 tons of medical waste for incineration at the North Salt Lake facility, 84% of which originated outside of Utah (DSHW, 2012).

The types of waste the Stericycle facility is permitted to accept include (DSHW, 2006):

- Non-hazardous medical waste, including laboratory waste, glassware, and sharps;
- Surgical specimens and tissues, animal tissues and carcasses, blood, and body fluids;
- Infectious wastes from veterinaries, mortuaries, research, and industry;
- Expired and unused pharmaceuticals and contraband;
- Outdated consumer commodities, proprietary packaging, and records;
- Recalled medical equipment and supplies;
- Agriculture waste, and municipal solid waste contaminated with infectious waste;
- Other non-hazardous waste approved by the Director that is appropriate for a medical waste incinerator.

Several types of waste are specifically not accepted by the incinerator, including radioactive waste, full chemotherapy drug containers, complete human remains and cadavers, recognizable fetal remains, compressed gas cylinders, and chemical materials regulated as hazardous under the federal Resource Conservation and Recovery Act (RCRA) or Utah Administrative Code subsection 19-6-102 (9) and section R315-2-3 (DSHW, 2005).

Incineration of medical waste produces a number of potentially hazardous pollutants, and Stericycle is required to comply with all relevant Federal and State regulations regarding air emissions as outlined in their Title V operating permit issued by the Utah Division of Air Quality (DAQ), Department of Environmental Quality (DEQ). Currently, Stericycle is required to monitor the emission levels of nine pollutants: cadmium, carbon monoxide (CO), dioxins, hydrogen chloride gas (HCl), lead, mercury, nitrogen oxides (NO_x), particulate matter (PM), and sulfur dioxide (SO_2) (DAQ, 2009). Testing of emissions at the stack (a 'stack test') is mandated every three years for PM, CO, and HCl, and every five years for dioxins, SO_2, NO_x, lead, cadmium, and mercury. These stack tests must use conditions representative of normal operating procedures. If a test indicates emissions of a pollutant are exceeding permitted levels, annual testing for that pollutant is required until levels are in compliance for a three year period (DAQ, 2009). The Stericycle incinerator utilizes several types of air pollution control systems, including a multi-pass dry reactor to control potential emissions of dioxins/furans and mercury by injection of carbon, an electrostatic precipitator to remove particulate matter, and a wet absorber tower using sodium hydroxide to remove acid vapors (DSHW, 2005).

Operating Permit Violations

On May 28, 2013, DAQ issued a Notice of Violation and Order to Comply to Stericycle for multiple violations of the pollutant emission limits specified in its operating permit (DAQ, 2013a). On August 28, 2013, DAQ issued an amended Notice of Violation to explicitly cover each day of emissions exceedance (DAQ, 2013b). The violations identified by DAQ occurred between 2011 and 2013 and include:

- Emissions exceeding the permit limits for dioxins;
- Emissions exceeding the permit limits for NO_x on multiple occasions;
- Emissions exceeding the permit limits for HCl;
- Failure to report these emission exceedances to DAQ in the requisite time frame;
- Failure to maintain normal operating conditions during the December 2011 stack test;
- Failure to include the test results demonstrating these emission exceedances in the requisite annual and semi-annual monitoring reports.

Appendix B, Table B1 lists the permitted emission limits for the Stericycle incinerator, stack test dates and results, and dates and levels of emission exceedances. A separate letter health consultation addressing concerns regarding the potential health effects from inhalation exposure to contaminants released by the incinerator was released on February 20, 2014. This document is available on the EEP's website (http://www.health.utah.gov/enviroepi/appletree/SouthDavisCounty/).

Site Description

The Stericycle incinerator facility consists of 22,080 square feet of office, processing, and storage space situated on a 5.23 acre parcel of land in the City of North Salt Lake. The perimeter is enclosed with a ten-foot pre-cast cement wall (DSHW, 2005). Prior to 2001, the area north of the facility was zoned for industrial and manufacturing purposes and was largely undeveloped. However, the city of North Salt Lake rezoned this area for mixed purpose use, and development began on a residential subdivision in 2003 (KUER, 2013). The Stericycle incinerator lies centrally within census tract 1270.02, and residential properties begin in the northern portion of that tract and continue for approximately two miles north into neighboring tracts 1270.03 and 1270.04. In 2010, these census tracts had populations of 6,738 (1270.02), 5,159 (1270.03), and 7,756 (1270.04) (USCB, 2014). Immediately east and south of the facility is a mix of industrial and undeveloped properties, which largely changes to residential properties after 1.5 and 2.5 miles, respectively. The land west is mainly undeveloped land and nature areas.

There are three controlled-access highways located within 1.5 miles of the incinerator: Interstate 15, Interstate 215, and State Route 67. Motor vehicle traffic on these routes is considerable; the average annual daily traffic in 2012 in the vicinity of the facility was 135,135 vehicles for Interstate 15, 34,110 for Interstate 215, and 20,240 for State Route 67 (UDOT, 2012). The incinerator is approximately 650 feet from State Route 67, and residential properties to the north lie within 200 feet of the highway. Additionally, there are five oil refineries operating within four miles of the Stericycle incinerator with a combined processing capacity of approximately 175,500 barrels of oil per day (Salt Lake Tribune, 2012).

Community Concerns

Community members living in the vicinity of the Stericycle incinerator have expressed concerns regarding the potential health effects of exposure to soil contaminated by pollutants released from the facility. These apprehensions have intensified in light of Stericycle's violations of their air quality operating permit. The governor's office contacted the EEP in September 2013 and directed this assessment on October 24, 2013. The majority of concerns conveyed to the EEP have focused on the potential health effects of exposure to dioxins emitted from the incinerator.

ENVIRONMENTAL DATA

Plume Deposition Analysis

In October 2013, the Davis County Health Department (DCHD) requested that DAQ perform a plume deposition analysis of operations at the Stericycle medical waste incinerator to identify optimal areas for soil sampling of dioxins and heavy metals. The analysis provided a deposition gradient of settling particles in the area surrounding the incinerator, and were based on predicted maximum emission outputs simulated for a 20-year period, actual stack testing data, physical characteristics of the stack, emission temperature, emission velocity, and a five-year historical record of meteorology monitored near the site. The parameters used in the analysis are described in **Appendix D**.

Maps 2, 3, and 4 in **Appendix A** show the predicted isopleths of the contaminant deposition gradient out to one, two, and four kilometers (kms) from the Stericycle incinerator, respectively. In this situation, an isopleth is a gradient line on a map connecting all points that have the same predicted pollutant deposition level. The gradient reflects the weather patterns known to occur in this area, where air flows are most often from either the north-northwest or south. Modeling indicated that the highest deposition level would be 0.00663 g/m^2 approximately 110 meters north-northwest of the incinerator, indicated by the innermost, orange isopleth. Pollutant deposition would continue to decline further from the facility, denoted by isopleths progressing from orange to green, blue, and finally purple. This is consistent with the incinerator's main stack design, where emissions are released below the roofline and are subject to severe building downwash.

Soil Sampling

Both the EEP and DCHD have conducted soil sampling in the vicinity of the Stericycle incinerator. The EEP collected six composite soil samples from five sites in November 2013. The sampling locations are marked in **Appendix A, Map 5**. Three samples (A-C) were soil from the backyards of three residences close to the incinerator, and three samples (D soil, D sand, and E sand) were either soil or sand from two local playgrounds. All samples were from the top three inches of substrate. Samples A and B were located in the innermost isopleth, and the remaining samples were within the third innermost isopleth. All samples were sent to TestAmerica Laboratories, Inc. (West Sacramento, California) for analysis of dioxin levels. Additionally, all samples were also sent to the Utah Public Health Laboratory to test for eight heavy metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver).

DCHD collected six soil samples in October 2013. Five samples were within the maximum predicted extent of the deposition plume shown in **Appendix A, Map 4**, and a sixth control sample was taken approximately 23 miles from the incinerator in Hooper, UT. All samples were from soils in undeveloped fields. The sampling locations are marked on **Appendix A, Map 6**. Samples were submitted to ALS Environmental (Houston, Texas) for analysis of dioxin content.

In December 2013, the EEP received the results of testing for eight heavy metals from the six soil samples collected near the incinerator. The EEP received dioxin content test results for the same samples in January 2014. DCHD shared the results of dioxin content testing from their soil samples with the EEP in November 2013. All soil sample test results are shown in **Table 1**.

The arsenic concentration in sand from EEP sample site D (playground on Caleb Drive) exceeded comparison values (CVs) for children and children exhibiting soil-pica behavior. It is not known from where this sand originated before being brought to the park. Arsenic levels in all other soil samples were below the relevant CVs. Total chromium concentrations in all four EEP soil samples exceeded the hexavalent chromium [Cr(VI)] CV for children with soil-pica. A CV for total chromium has not been established, and chromium exists in most environments as a mix of valence states. In most soils, chromium will be present predominantly in the less toxic trivalent [Cr(III)] state (ATSDR, 2012b). Total chromium levels in both EEP playground sand samples were below the relevant CVs. Concentrations of barium, cadmium, lead, mercury, selenium, silver, and dioxins were below all applicable CVs. Comparison values are defined in the Exposure Pathway Analyses section below as well as in **Appendix D**.

Given that sand used in playgrounds is typically brought in from outside sources during construction, it is unlikely that the elevated arsenic concentration found in playground sand at EEP sample site D is associated with local arsenic releases. This is supported by the fact that the arsenic concentration in soil from sample site D, taken approximately 10 feet away from the playground sand, was below the detection limit of the laboratory instrumentation..

Table 1. Soil sample test results for dioxins and eight RCRA regulated metals.

		Arsenic (ppm)	**Barium (ppm)**	**Cadmium (ppm)**	**Total Chromium (ppm)**	**Lead (ppm)**	**Mercury (ppm)**	**Selenium (ppm)**	**Silver (ppm)**	**Dioxins (TEQ) (ppt)**
Comparison Values	Child c-EMEG	15	10,000	5	45*	400 (TSCA)	NA	250	250 (RMEG)	50
	Pica Child i-EMEG	10 (a-EMEG)	400	1	10*	400 (TSCA)	NA	NA	NA	40
	Adult c-EMEG	210	140,000	70	630*	400 (TSCA)	NA	3,500	3,500 (RMEG)	700
EEP Sites	A	<8.5	130.4	<1.7	17.1	15.9	<0.06	<8.5	<1.7	2.60
	B	9.4	151.5	<1.6	16.9	16.3	<0.05	<8.1	<1.6	2.60
	C	<7.3	129.5	<1.5	16.9	19.7	<0.05	<7.3	<1.5	0.62
	D (Soil)	<7.7	122.5	<1.5	17.8	17.7	<0.05	<7.7	<1.5	1.20
	D (Sand)	**20.8**	44.6	<1.4	6.8	<7.1	<0.05	<7.1	<1.4	0.05
	E (Sand)	<7.2	47.7	<1.4	4.9	<7.2	<0.05	<7.2	<1.4	0.06
DCHD Sites	1	NT	NT	NT	NT	NT	NT	NT	NT	1.64
	2	NT	NT	NT	NT	NT	NT	NT	NT	0.86
	3	NT	NT	NT	NT	NT	NT	NT	NT	0.67
	4	NT	NT	NT	NT	NT	NT	NT	NT	0.72
	5	NT	NT	NT	NT	NT	NT	NT	NT	1.14
	Control	NT	NT	NT	NT	NT	NT	NT	NT	0.17

Shaded values: Contaminant level exceeds at least one adult or non-pica child CV.

***:** Chromium CVs are for hexavalent chromium.
ppm: Parts per million.
ppt: Parts per trillion.
NA: Not available/applicable.
NT: Not tested.
a-EMEG: Acute EMEG.
i-EMEG: Intermediate EMEG.
c-EMEG: Chronic EMEG.
TSCA: Toxic Substances Control Act.

EXPOSURE PATHWAY ANALYSES

Chemical contamination of the environment can harm people's health, but only if they have contact with those contaminants (exposure). Without such exposure, there can be no harm to health. If there is exposure, the risk of harm is determined by the quantity of contaminants a person is in contact with (concentration), how often they contact them (frequency), how long they contact them (duration), and the health risk of the contaminant (toxicity).

To determine if residents, visitors, and workers are exposed to contaminants related to a site, ATSDR evaluates the environmental and human components that lead to exposure. An exposure pathway consists of five elements (ATSDR, 2005):

1. A source of contamination;
2. An environmental medium, such as air, water, or soil, that can hold or move the contamination;
3. An exposure point where people come into contact with the contaminated medium;
4. An exposure route, like ingesting contaminated soil or water or breathing contaminated air;
5. A population who could be exposed to the contamination, such as local residents.

These five elements largely determine to what extent exposures may have occurred, may be occurring, or may occur in the future at and around a site. ATSDR categorizes an exposure pathway as either *completed*, *potential,* or *eliminated*. In a *completed* exposure pathway, all five elements exist and indicate that exposure to a contaminant has occurred in the past, is occurring, or will occur in the future. In a *potential* exposure pathway, at least one of the five elements has not been confirmed, but it may exist. Exposure to a contaminant may have occurred in the past, may be occurring, or may occur in the future. An exposure pathway can be *eliminated* if at least one of the five elements is missing and will never be present (ATSDR, 2005).

When an exposure pathway is identified, CVs for air, soil, or drinking water are used as guidelines for selecting contaminants that require further evaluation. A CV is a concentration of a substance, calculated by ATSDR or the U.S. Environmental Protection Agency (EPA), in air, water, food, or soil that is unlikely to cause harmful health effects in exposed people. It should be stressed that comparison values are screening tools, not thresholds of toxicity. While levels at or below a CV may reasonably be considered to pose no risk, it does not necessarily follow that concentrations above a CV would be expected to cause harmful health effects. Rather, levels above a CV indicate the need for further evaluation (ATSDR, 2005). The potential for exposed persons to experience adverse health effects depends on many factors, including:

- The amount of each chemical to which a person is or has been exposed;
- The length of time that a person is exposed;
- The route by which a person is exposed (inhalation, ingestion, or dermal absorption);
- The health condition of the person;
- The nutritional status of the person;
- Exposure to other chemicals (such as cigarette smoke or chemicals in the work place).

The CVs used in this report are environmental media evaluation guides (EMEGs) and reference media evaluation guides (RMEGs) determined by ATSDR. An EMEG, based on an ATSDR minimal risk level (MRL), is a concentration of a substance in water, soil, or air to which humans may be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing adverse, non-cancer health effects. For EMEGs, an acute time period is 14 days or fewer, intermediate is 15 days to one year, and chronic is over one year (ATSDR, 2005). An RMEG is similar to an EMEG, but is based on a reference dose (RfD) developed by EPA and applies to chronic exposures. As ATSDR CVs for lead contamination of soil are not available, the EPA hazard standard for lead in soil from the Toxic Substances Control Act (TSCA) was used. Under the TSCA standard, lead is considered a hazard when equal to or exceeding 400 ppm in bare soil in children's play areas (EPA, 2001). A cancer risk evaluation guide (CREG) for arsenic is available, but as it is lower than normal background levels (typically 1 – 40 ppm), the listed EMEG is the recommended CV (ATSDR, 2007). A more detailed discussion of arsenic, including background levels, can be found in the Toxicological and Health Effects Evaluation section of this document.

ATSDR has developed a hierarchy of CVs for use in screening human exposure data (ATSDR, 2005). In general, hierarchy 1 guidelines such as CREGs and chronic EMEGs are preferred due to their conservative assumptions regarding exposure. If those are not available, hierarchy 2 guidelines such as intermediate EMEGs are selected. If there are no CVs from the preceding hierarchy levels, values from additional sources may be used (such as the TSCA lead standards in this report). The EEP has chosen the most conservative comparison value available for each pollutant. The CVs for children are used when available to protect sensitive populations.

Compared to ingestion, ATSDR generally considers the risk from dermal exposure (absorption through the skin) to chemicals in soil to be a minor contributor to the overall exposure dose (ATSDR, 2005). This is particularly true of chemicals that bind to organic matter in soil, as this makes them less available for dermal absorption. Furthermore, only the fraction of the contaminant that is in direct contact with the skin is amenable to absorption.

Completed Pathways

Arsenic contamination of the sand in the playground on Caleb Drive (sand from EEP sample site D) has resulted (or will result) in exposures by the ingestion and dermal routes in the past, present, and future. The arsenic concentration in the playground sand exceeds the ATSDR chronic EMEG of 15 ppm for children, as well as the acute EMEG of 10 ppm for children exhibiting soil-pica behavior. The exposure pathway for arsenic is detailed in **Table 2**.

Table 2. Exposure pathway for arsenic in Caleb Drive playground sand.

Source	Environmental Medium	Exposure Point	Exposure Route	Exposed Population	Time Frame	Status
Playground sand	Playground sand	Caleb Drive playground	Ingestion and skin contact	People who play in and use the playground	Past	Complete
					Current	Complete
					Future	Complete

While concentrations of total chromium in residential soil tested in the vicinity of the Stericycle incinerator (EEP sample sites A – C and soil from site D) are well below the child and adult chronic EMEGs for Cr(VI) (45 and 630 ppm, respectively), they exceed the intermediate Cr(VI) EMEG of 10 ppm for children exhibiting soil-pica behavior. Past, present, and future exposures to chromium may have occurred in children who frequently ingest unusually high amounts of residential soil. The exposure pathway for chromium is described in **Table 3**.

Table 3. Exposure pathway for chromium in residential soil.

Source	Environmental Medium	Exposure Point	Exposure Route	Exposed Population	Time Frame	Status
Residential soil	Residential soil	Residential area near the Stericycle incinerator	Ingestion and skin contact	People who play in and use areas with bare soil	Past	Complete
					Current	Complete
					Future	Complete

Health Guidelines

The health guidelines used in this report are ATSDR's MRLs, which are estimates of the daily human exposure to a hazardous substance that are likely to be without appreciable risk of adverse, non-cancer health effects over a specific duration (ATSDR, 2013). As with CVs, the duration can be acute (14 days or less), intermediate (15 days to one year), or chronic (greater than one year). These substance specific estimates are intended to be used as screening levels, and are used to identify contaminants and potential health effects that may be of concern. MRLs are not intended to define clean-up or action levels for governmental or other agencies (ATSDR, 2013). It is also important to note that health guideline values are not absolute levels at which adverse health effects from exposure will occur. They are values at which action should be taken and are not necessarily harmful to all people if exceeded (ATSDR, 2005).

ATSDR uses the no-observed-adverse-effect-level (NOAEL) / uncertainty factor (UF) approach to derive MRLs for hazardous substances (ATSDR, 2013). A NOAEL is the highest dose of a substance that produces no statistically or biologically significant increases in the frequency or severity of adverse effects. While effects may be produced at this level, they are not considered to be adverse, or to be precursors to adverse effects. A UF is a mathematical adjustment applied to a health guideline for reasons of safety when knowledge is incomplete. For example, UFs are applied to NOAELs to derive MRLs to account for variations in people's sensitivity to a contaminant and differences between animals and humans. Most MRLs contain some degree of uncertainty due to a lack of precise toxicological information on the people who might be most sensitive to the effects of hazardous substances (e.g., infants, the elderly, and nutritionally or immunologically compromised people).

When NOAELs are not available, a lowest-adverse-effect-level (LOAEL) may be used, which is the lowest dose that produces statistically or biologically significant increases in the frequency or severity of adverse effects. If neither the NOAEL nor LOAEL are available, the benchmark dose (BMD) can be used. The BMD is a dose that produces a predetermined change in the response rate of an adverse effect compared to background. The lower limit of the benchmark dose (the BMDL) is a characterization of the dose or concentration corresponding to a specified increase in the probability of a specified response. A $BMDL_{10}$ is the lower confidence limit of the estimated dose corresponding to an increase of 10% in the probability of the specified response relative to the probability of that same response at dose zero. A $BMDL_{2sd}$ is an estimate of the dose associated with a change of two standard deviations from the control; the use of two standard deviations takes into consideration the normal variability in a population.

Human data are used when possible, but MRLs must often be based on animal studies because relevant human studies are lacking or not available. Without evidence to the contrary, ATSDR assumes that humans are more sensitive than animals to the effects of hazardous substances. The resulting human MRL may be as much as 100 times lower than levels shown to be non-toxic in laboratory animals (i.e., an animal-based NOAEL divided by a UF of 100) (ATSDR, 2013).

Proposed MRLs undergo a rigorous review process. They are reviewed by the Health Effects/MRL Workgroup within the ATSDR Division of Toxicology and Human Health Sciences, an expert panel of external peer reviewers, the ATSDR wide MRL Workgroup (with participation from other federal agencies, including EPA), and are submitted for public comment through the toxicological profile public comment period.

Exposure Dose Estimates

The contaminants of concern for this health consultation were dioxins, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Arsenic at one sample site (sand at EEP sample site D) exceeded the chronic EMEG for children and the intermediate EMEG for children with soil-pica. Total chromium at four sites (soil at EEP sample sites A – D) exceeded the intermediate Cr(VI) EMEG for children with soil-pica. Concentrations of the other contaminants at these and all other EEP and DCHD sample sites were below the relevant CVs, indicating that no further analysis is warranted.

The exposure pathways for arsenic and chromium described previously were assessed using doses calculated from the highest contaminant concentrations (maximums) associated with each pathway (20.8 ppm for arsenic and 17.8 ppm for chromium). The calculated exposure doses were then compared with the appropriate health guidelines for arsenic and hexavalent chromium in soil.

The EEP estimated potential exposure doses for adults, children, and children with soil-pica using the ATSDR equations for soil ingestion and soil dermal exposure as implemented in the ATSDR Exposure Dose Calculator (ATSDR, 2008). All calculations assumed 180 days per year of contact with soil and playground sand (an exposure factor of 0.493) to account for lack of exposure during winter and other inclement weather. Exposure in infants was not assessed as they are unlikely to have meaningful contact with playground sand or residential soil. Standard ATSDR parameters were used in the calculations, which are listed in **Appendix C**.

For known or possible carcinogens, EPA has developed cancer slope factors (CSF) as an estimate of a substance’s potential to cause additional cancer cases in a population. A CSF is an upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime of exposure to a substance (EPA, 2012b). The CSF is used to calculate a lifetime cancer risk, which is an estimate of the number of excess (or additional) cancer cases predicted to occur if a population was exposed to a substance at site-specific levels. EPA has set a target cancer risk range of 10^{-4} to 10^{-6}, within which the agency strives to manage risks (EPA, 1991). These values do not include the U.S. average lifetime risk of cancer of 0.41 (i.e., approximately 41% of people will be diagnosed with cancer at some point during their lifetime) (NCI, 2013). It is important to note that estimated excess cancer risks only apply at the population level and do not predict an individual's risk of developing cancer.

Equations and example calculations for determining potential exposure doses and excess cancer risks by oral ingestion and dermal absorption can be found in **Appendix C**.

Arsenic: Non-Cancer Evaluation

ATSDR has developed a chronic MRL for inorganic arsenic of 0.0003 milligrams per kilogram bodyweight per day (mg/kg/day), based on hyperpigmentation, keratosis, and possible vascular complications in humans (ATSDR, 2007). This MRL is derived from a NOAEL of 0.0008 mg/kg/day for dermal effects in a study of a Taiwanese farming population exposed to arsenic in well water (Tseng, 1977), with a UF of three to take human variability into account.

Potential exposure doses to arsenic in sand from the Caleb Drive playground for children and adults are presented in **Table 4**. Exposure doses for children with soil-pica are discussed in the Soil-Pica Behavior section below. The EEP concludes that the potential exposure pathways for incidental ingestion and skin contact with playground sand is not expected to harm the health of children or adults since the exposure doses are below the ATSDR chronic MRL. The potential health implications of oral and dermal exposure to arsenic are discussed in the Toxicological and Health Effects Evaluation section below.

Table 4. Potential exposure doses to arsenic from playground sand.

Arsenic (ppm)	Chronic MRL (mg/kg/day)	Exposure Route	Potential Child Exposure Dose (mg/kg/day)	Potential Adult Exposure Dose (mg/kg/day)
20.8	3.00×10^{-4}	Ingestion	1.28×10^{-4}	1.46×10^{-5}
		Dermal	1.55×10^{-5}	5.22×10^{-6}
		Total	1.44×10^{-4}	1.98×10^{-5}

ppm: Parts per million.
mg/kg/day: Milligrams per kilogram body weight per day.
MRL: Minimal risk level.

Arsenic: Cancer Risk Evaluation

The EEP evaluated the excess lifetime cancer risk for residential arsenic oral and dermal exposures using the child and adult exposure doses listed above. Childhood exposure was considered to be between the ages of 1 and 13 years, and adult exposure was between the ages of 13 and 70 years. The lifetime excess cancer risk for oral and dermal exposure to the highest sampled concentration of arsenic (20.8 ppm) was 6.22 x 10^{-5}, which is within EPA's target risk range of 10^{-4} to 10^{-6}.

Chromium: Non-Cancer Evaluation
ATSDR has established a chronic MRL for hexavalent chromium of 0.0009 mg/kg/day. As the available human data on chronic exposure were inadequate, the MRL is based on non-cancerous lesions in mice (ATSDR, 2012b). This MRL is derived from a $BMDL_{10}$ of 0.09 mg/kg/day of Cr(VI) for diffuse epithelial hyperplasia in the duodenum of female mice (NTP, 2008). A UF of 100 was applied to reach the MRL: ten for extrapolation from animals to humans and ten for human variability.

Potential exposure doses to total chromium in residential soil from the neighborhood near the Stericycle incinerator for children and adults are presented in **Table 5**. Exposure doses for children with soil-pica are discussed in the Soil-Pica Behavior section below. The EEP concludes that the potential exposure pathways for incidental ingestion and skin contact with residential soil is not expected to harm the health of children or adults, as the exposure doses are below the ATSDR and chronic MRL.

Table 5. Potential exposure doses to total chromium from residential soil.

Total Chromium (ppm)	Cr(VI) Chronic MRL (mg/kg/day)	Exposure Route	Potential Child Exposure Dose (mg/kg/day)	Potential Adult Exposure Dose (mg/kg/day)
17.8	9.00 x 10^{-4}	Ingestion	1.10 x 10^{-4}	1.25 x 10^{-5}
		Dermal	1.32 x 10^{-5}	4.47 x 10^{-6}
		Total	1.23 x 10^{-4}	1.70 x 10^{-5}

ppm: Parts per million.
mg/kg/day: Milligrams per kilogram body weight per day.
MRL: Minimal risk level.

The cancer risk endpoint from chromium exposure was not estimated as the carcinogenic potential of hexavalent chromium via ingestion has not been determined due to a lack of sufficient epidemiological and toxicological data (EPA, 1998a). The EEP believes that the non-cancer endpoints used in this document (i.e., chronic and intermediate MRLs) are protective of health in this situation as the soil concentrations of chromium are relatively low, soil-pica behavior is rare, and very conservative assumptions were used to estimate the potential exposure doses. The potential health implications of oral and dermal exposure to chromium are discussed in the Toxicological and Health Effects Evaluation section below.

Soil-Pica Behavior
Soil-pica behavior (also called simply soil-pica) is the recurrent ingestion of unusually high amounts of soil (ATSDR, 2000). Soil-pica is distinct from the common causes of incidental soil ingestion, which include mouthing behavior, contacting dirty hands, and eating dropped food. People with soil-pica often ingest on the order of 1,000 – 5,000 mg of soil per day, compared to the standard values used by ATSDR in dose calculations for adults and children of 100 mg and 200 mg, respectively (ATSDR, 2000; ATSDR, 2008; LaGoy, 1987). While information on the

prevalence of soil-pica is extremely limited, it is thought to be rare. Groups known to be at higher risk include children aged six years and younger and individuals who are developmentally delayed (EPA, 2011). As ingestion is typically of surface soil, soil-pica behavior is of public health concern as it can lead to substantial exposure to harmful substances in already sensitive populations. However, the EEP has no evidence to suggest that children with soil-pica reside in the community near the Stericycle incinerator.

In the few studies that are available investigating the frequency and annual rates of soil-pica, the behavior often appears to be episodic in nature (meaning it occurs only occasionally) (EPA, 1998c; EPA, 2009). In one study of 12 children identified by their parents as being pre-disposed to soil-pica, only one child displayed the behavior during the two week observation period (Calabrese et al., 1997). Another estimated that 33 percent of children may ingest more than 10 grams of soil on 1 - 2 days per year, and that 16 percent of children are expected to ingest more than one gram of soil on 35 - 40 days per year (Stanek and Calabrese, 1995). These data suggest that acute and intermediate MRLs are most appropriate for comparison with estimated exposure doses.

Arsenic

ATSDR has calculated an acute MRL for inorganic arsenic exposure of 0.005 mg/kg/day, derived from 220 human poisoning cases in Japan that showed several transient effects at a LOAEL of 0.05 mg/kg/day (ATSDR, 2007; Mizuta et al., 1956). These temporary effects lasted two to three weeks in most cases, and included facial swelling, nausea, vomiting, abdominal pain, and diarrhea. A UF of 10 was applied to account for the use of a LOAEL. Data in the literature are inadequate to derive an intermediate duration oral MRL for inorganic arsenic (ATSDR, 2007).

Potential exposure doses to arsenic in sand from the Caleb Drive playground for children with soil-pica behavior are presented in **Table 6**. The EEP concludes that the potential exposure pathways for ingestion and skin contact with playground sand is not expected to harm the health of children or adults since the exposure doses are below the ATSDR acute MRL. It is important to note that soil-pica behavior is rare even in higher risk groups (e.g., young children). Furthermore, the exposure dose calculations assume a child with soil-pica is consuming the full 5,000 mg of sand from the Caleb Drive playground on each of the 180 days of exposure per year.

Chromium

ATSDR has derived an intermediate MRL for hexavalent chromium of 0.005 mg/kg/day, based on a $BMDL_{2sd}$ of 0.52 mg/kg/day of Cr(VI) for anemia in male rats (NTP, 2008). A UF of 100 was applied, ten for extrapolation from animals to humans and ten for human variability. Data in the literature were inadequate to derive an acute duration oral MRL for Cr(VI) (ATSDR, 2012b).

Potential exposure doses to total chromium in residential soil for children with soil-pica behavior are presented in **Table 6**. The EEP concludes that the potential exposure pathways for ingestion and skin contact with residential soil is not expected to harm the health of children or adults since the exposure doses are below the ATSDR intermediate Cr(VI) MRL. The exposure dose calculations assume that all chromium in the soil is in the most toxic hexavalent state, which is very unlikely to be true. This extremely conservative assumption is designed to protect sensitive populations, and is in addition to the conservative UFs applied in the Cr(VI) BMDL calculations. The majority of chromium is likely to be in the less toxic Cr(III) state in most soils (ATSDR, 2012b). Again, it is important to recognize that soil-pica behavior is rare even among higher risk groups and that the exposure dose calculations assume a child with soil-pica is consuming the full 5,000 mg of soil from the Caleb Drive playground on each of the 180 days of exposure per year.

Table 6. Potential exposure doses to arsenic and chromium among children with soil-pica behavior.

	Soil Concentration (ppm)	MRL (mg/kg/day)	Exposure Route	Potential Soil-Pica Child Exposure Dose (mg/kg/day)
Arsenic	20.8	5.00×10^{-3} Acute	Ingestion	3.20×10^{-3}
			Dermal	1.55×10^{-5}
			Total	3.22×10^{-3}
Chromium	17.8	5.00×10^{-3} Cr(VI) Intermediate	Ingestion	2.74×10^{-3}
			Dermal	1.32×10^{-5}
			Total	2.75×10^{-3}

ppm: Parts per million.
mg/kg/day: Milligrams per kilogram body weight per day.
MRL: Minimal risk level.

Background Arsenic and Chromium Levels in Surface Soil

In 2007, the U.S. Geologic Survey (USGS) of the Department of the Interior initiated a low-density geochemical and mineralogical survey of soils in the lower 48 states as part of the North American Soil Geochemical Landscapes Project (USGS, 2013). The sampling procedure included testing the top five centimeters of soil, and seven sample sites were located within 40 miles of the Stericycle incinerator (**Map 7**). Sampling concluded in 2010, and the chemical and mineralogical analyses were completed in May 2013. In addition to analyzing a number of geological parameters, the concentration of 43 major and trace elements were determined, including arsenic and chromium. The arsenic and chromium concentrations at the seven sites near the incinerator are shown in **Table 7**.

Among these seven USGS sample sites, soil concentrations of arsenic ranged from 3.1 - 12.8 ppm, with an average of 6.4 ppm. Of the two EEP sample sites with arsenic concentrations above the detection threshold, only the playground sand sample that exceeded the CV was above the USGS background arsenic range. Soil concentrations of chromium ranged from 18 - 49 ppm, with a mean of 32.3 ppm. All six EEP soil samples had total chromium concentrations below the lower bound of the USGS background chromium range. These data suggest that, aside from arsenic in the Caleb Drive playground sand sample, the soil levels of arsenic and total chromium in the vicinity of the Stericycle incinerator are similar to or below average background levels for the area.

Table 7. Arsenic and chromium soil levels at USGS sample sites near the Stericycle incinerator.

Site	Distance from Stericycle (mi)	Latitude	Longitude	Land Type	Arsenic (ppm)	Chromium (ppm)
USGS 1	14.9	41.0579	-111.9053	Residential	5.7	27
USGS 2	16.6	40.6139	-112.0324	Shrubland	11.3	49
USGS 3	28.3	40.9792	-111.4296	Grassland	3.2	25
USGS 4	31.0	40.5546	-111.4887	Shrubland	3.1	32
USGS 5	31.0	41.2664	-112.1401	Grassland	4.2	32
USGS 6	37.7	41.1821	-111.3737	Mixed Forest	4.6	43
USGS 7	40.3	40.7989	-112.7065	Bare Rock, Sand, or Clay	12.8	18
				Average:	6.4	32.3

TOXICOLOGICAL AND HEALTH EFFECTS EVALUATION

Arsenic

Arsenic is a naturally occurring element that is widely distributed in the Earth's crust. It has properties of both metallic and non-metallic substances, though it is usually referred to as a metal. Most arsenic found in the environment is combined with other elements, such as oxygen, chlorine, and sulfur, to form inorganic arsenic compounds. Arsenic combined with carbon and hydrogen forms organic arsenic compounds. Typically, both inorganic and organic arsenic compounds are white or colorless powders with no smell or taste, making it difficult to detect their presence without specialized tests (ATSDR, 2007). Inorganic arsenic is the form of most concern, but the tests used by scientists to determine the levels of arsenic in the environment do not determine the specific form of arsenic that is present, so it can be unclear what type a person may be exposed to.

All arsenic intentionally used in the US is imported, as it is no longer produced domestically. As of 2007, approximately 90% of all arsenic produced was used in copper chromated arsenate as a preservative for wood (referred to as "pressure-treated" wood) (ATSDR, 2007). By December 31, 2003, the use of copper chromated arsenate in residential structures was phased out, although it can still be used in industrial applications. In the past, a major source of arsenic contamination was the use of inorganic arsenic compounds in pesticides; their use has been discontinued as well, although certain organic arsenic pesticides are still in use. Arsenic is also utilized in semiconductor manufacturing, as an additive in certain animal feeds, and to make alloys with other metals, principally in lead-acid automotive batteries (ATSDR, 2007).

As arsenic and arsenic compounds naturally occur in the environment, most people are exposed to some arsenic by eating food, drinking water, and breathing air. The incidental ingestion of arsenic-containing soil can also result in exposure, particularly in children. Skin contact with arsenic-containing soil is usually of lesser concern as only a small amount will go through the skin (ATSDR, 2007). Arsenic levels in soil range from roughly 1 – 40 ppm with an average of 3 – 4 ppm, although this can vary widely based on the type of rock and soil present at a particular site and the past use of that land. Areas with arsenic-rich geological deposits, mining and smelting sites, and areas where arsenic pesticides were used can have much higher concentrations. Small amounts of arsenic can also be released into the atmosphere from coal-fired power plants and incinerators, as coal and waste products often contain some arsenic (ATSDR, 2007).

Both inorganic and organic forms of arsenic leave the body through urine. Most will be gone within a few days, although some may remain for several months or longer (ATSDR, 2007).

Inorganic forms of arsenic have been recognized as a poison for thousands of years. Large oral doses can be fatal, though it should be noted that lethal concentrations are typically greater than 60,000 ppb in water, which is 10,000 times greater than arsenic levels in 80% of US drinking water (ATSDR, 2007). Lower levels of inorganic arsenic (e.g., 300 – 30,000 ppb in water) may result in stomachache, nausea, vomiting, diarrhea, decreased blood cell production, abnormal heart rhythm, and impaired nerve function (a “pins and needles” sensation). Long term exposure to inorganic arsenic can result in a characteristic pattern of skin changes, including darkened patches and the appearance of small “corns” or “warts” on the palms, soles, and torso (ATSDR, 2007). These are not actual warts, which are caused by a virus, but bear a superficial resemblance. Very little is known about the effects of exposure to organic arsenic compounds in humans, though animal studies show that they are less toxic than inorganic forms.

EPA, the US Department of Health and Human Services (DHHS), and the International Agency for Research on Cancer (IARC) have determined that inorganic arsenic is a human carcinogen. Several studies have shown that ingestion of inorganic arsenic can increase the risk of skin, liver, bladder, and lung cancer. Inhalation of inorganic arsenic can also increase the risk of lung cancer (ATSDR, 2007).

As with many chemical exposures, children may have an increased risk of exposure and adverse health effects. This is attributable to a variety of factors, including lower body weight, reduced variety of foods and beverages, and increased incidental ingestion of contaminated soils due to playing in and around soil and hand- and object-to-mouth contact. Intentional soil ingestion may also be an important source of exposure in children exhibiting soil-pica behavior. Children exposed to inorganic arsenic generally have many of the same health effects as adults (ATSDR, 2007).

Chromium

Chromium is a naturally occurring element found in rocks and soil. It often combines with other elements to form a variety of compounds, which can be gas, liquid, or solid. No taste or odor is associated with chromium compounds. While it is released into the environment from both natural and anthropogenic sources, the largest contributors are industrial, primarily metal processing and welding, tannery facilities, textile production, and the production of chrome-based pigments and chromate (ATSDR, 2012b). Chromium is also used in the wood preservative copper chromated arsenate, and can be released from the burning of fossil fuels like natural gas, oil, and coal. Total chromium levels in soil in the U.S. range from 1 - 2,000 ppm, with an average of 37 ppm.

Chromium can exist in a variety of oxidation states, the most common of which are the +0 state [Cr(0); metallic chromium], the +3 state [Cr(III); trivalent chromium], and the +6 state [Cr(VI); hexavalent chromium] (EPA, 1998b). Trivalent chromium chemistry is dominated by the formation of stable complexes with both organic and inorganic compounds. Hexavalent chromium compounds tend to be strongly oxidizing (EPA, 1998a). Depending on the conditions present, chromium can change states in the environment, and the oxidation state governs its behavior in the environment and the human body. Most chromium in soil probably occurs as insoluble Cr(III) oxide, as organic matter in soil will convert soluble Cr(VI) compounds into Cr(III) oxide. The processes by which chromium is lost from soil are physical, primarily through water runoff and wind transport of dust (EPA, 1998a; EPA, 1998b).

While the primary route of non-occupational exposure is through food, the general public can also be exposed to chromium by inhalation of ambient air, drinking water, and skin contact with soil or certain consumer products contaminated with chromium. People working in chromium-related industries can be exposed to chromium concentrations two orders of magnitude (or 100 times) greater than the general population (ATSDR, 2012b). It is estimated that only a small fraction of ingested chromium is absorbed (less than 10%), with Cr(VI) compounds having the greatest absorption efficiency (EPA, 1998a). Both trivalent and hexavalent chromium can penetrate the skin to some extent, particularly if open wounds are present (ATSDR, 2012b). After absorption, chromium is found in nearly all tissues, with the highest amounts found in the liver, kidneys, and bones. Most chromium will exit the body via urine within a week, although some may remain for several years or longer (ATSDR, 2012c).

In general, Cr(III) is much less toxic to humans than Cr(VI). Trivalent chromium is an essential nutrient in small amounts, and the chronic EMEG for soil exposure to Cr(III) is over 1,600 times greater than that same CV for Cr(VI) (ATSDR, 2012b). It should be noted that the tests for the eight metals discussed in this assessment are total metals analyses and do not differentiate between different forms of the metals, including chromium. As the component makeup of chromium at the test sites is unknown, the EEP has taken the most conservative and health protective approach and assumed that all chromium is in the most toxic Cr(VI) state.

The primary health effects associated with exposure to Cr(VI) are respiratory, gastrointestinal, immunological, hematological, and reproductive (ATSDR, 2012b; ATSDR, 2012c). Breathing high concentrations of Cr(VI) (at least 60 times higher than background levels) can cause irritation to the lining of the nose, nose ulcers, and breathing problems, including asthma, cough, shortness of breath, and wheezing. In animal studies, the main effects of oral exposure are irritation and ulcers in the stomach and small intestine and anemia. Skin contact with certain Cr(VI) compounds can cause skin ulcers, an allergic sensitization consisting of severe redness and swelling has been noted in some individuals exposed to both Cr(III) and Cr(VI) compounds. Damage to sperm and the male reproductive system has also been observed in laboratory animals after exposure to Cr(VI).

EPA, DHHS, and IARC have determined that breathing hexavalent chromium compounds can be carcinogenic in humans (ATSDR, 2012b; EPA, 1998a). Inhalation of Cr(VI) has been shown to cause lung cancer among workers in industrial settings. In laboratory animals, tumors of the stomach, intestinal tract, and lung have been observed after exposure to Cr(VI) compounds.

However, the carcinogenic potential of hexavalent chromium via oral exposure cannot be determined due to a lack of sufficient epidemiological and toxicological data (EPA, 1998a).

While there are no studies that have specifically examined the effects of chromium exposure in children, it is likely that they would have the same health effects as adults. It is also unknown whether children are more sensitive than adults to the effects of chromium (ATSDR, 2012b; ATSDR, 2012c).

Dioxins and Dioxin-Like Compounds

The EEP does not expect soil concentrations of dioxins and dioxin-like compounds near the Stericycle incinerator to cause adverse health effects as the levels at all sample sites are considerably below all relevant CVs. Nevertheless, an evaluation of the toxicology and potential health implications is presented below as a response to community concerns.

Dioxins and dioxin-like compounds are a group of chlorinated chemicals with similar structures and chemical properties that includes polychlorinated dioxins, furans, and some polychlorinated biphenyls (PCBs). They have very low solubility in water and tend to stick to soil, ash, plant leaves, and other surfaces with high organic content (ATSDR, 1998). They are often collectively referred to as dioxins, as they are usually found in the environment as a mixture of several of these chemicals. Aside from small amounts for research purposes, dioxins are not intentionally produced and have no known use. Sources of environmental dioxins include the chlorine bleaching process of pulp in paper mills, contaminants in the manufacture of some organic chemicals, emissions from oil- and coal-fired power plants, and emissions from municipal and industrial solid waste incinerators (ATSDR, 1995; ATSDR, 1999). Dioxins can also be found in cigarette smoke and exhaust from both gasoline and diesel fuelled vehicles. Typical soil concentrations in industrialized areas of the U.S. range from 1 – 10 ppt (ATSDR, 1998).

Dioxins formed during combustion are associated with small particles in the air. Sunlight and atmospheric chemicals will break down a very small portion, but most of the dioxins are deposited relatively close to the emission source and bind strongly to soil (if on land) or sediment (if in water) (ATSDR, 1998). Certain types of bacteria and fungi in soil can also break down dioxins, but the process is extremely slow and dioxins will typically persist for decades (ATSDR, 1998).

Not all dioxins have the same toxicity or ability to cause adverse health effects. However, it is likely that all dioxins that do cause adverse health effects do so through a similar biologic mechanism of action. The available science indicates that the health effects resulting from exposure to multiple dioxins are additive. The most toxic and well-studied member of the group is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). The World Health Organization (WHO) developed toxic equivalency factors (TEF) to compare the toxicity of other dioxins relative to that of TCDD. The levels of other dioxins measured in environmental or biologic samples are multiplied by a TEF to produce a TCDD toxic equivalent (TEQ) concentration. The resulting TEQs for all dioxins measured in a sample are then added together to determine the total dioxin TEQ concentration for that sample. In 2005, the WHO International Programme on Chemical Safety expert panel re-evaluated the TEFs for dioxins, furans, and some PCBs (ATSDR, 2012a; Van den Berg et al., 2006). The TEFs used in this document, and the TEQs calculated from them, utilize this most recent information. A summary of the 1998 and 2005 WHO TEF values is presented in **Appendix B, Table B2**.

As dioxins are contaminants or byproducts of processes that produce a number of toxic substances, people exposed to dioxins are also usually exposed to many other harmful substances at the same time. This makes it difficult to separate the effect of dioxin exposure from that of these other substances (ATSDR, 1998). Nevertheless, there have been many studies examining the health effects of exposure to dioxins, particularly TCDD. The most noted health effect in people exposed to large amounts of TCDD (e.g., at least ten times greater than background levels) is chloracne (ATSDR, 1998; ATSDR, 1999). Chloracne is a severe skin disease characterized by acne-like lesions, especially on the face and upper body. The lesions heal within several months after exposure ends in mild cases, but can persist for many years in more severe instances. Other skin effects have been noted following exposure to high levels of TCDD, including red skin rashes, discoloration, and excessive body hair (ATSDR, 1998).

Exposure to high levels TCDD may also result in liver damage, as indicated by changes in blood, urine, and the liver's ability to metabolize hemoglobin, lipids, sugars, and proteins (ATSDR, 1998). Most of these effects were considered mild and were reversible, although in some people they can last for many years. Slight increases in the risk of diabetes and abnormal glucose tolerance were reported in some people. The majority of these studies were of occupational exposures or exposures following industrial accidents. In both situations, dioxin levels are typically much higher than those measured near the Stericycle incinerator. For example, altered liver enzyme values (an indicator of liver damage) were observed in individuals residing in an area of Seveso, Italy (the site of a well-studied 1976 industrial accident) where highly contaminated soil had a TCDD content of roughly 80 ppb (80,000 ppt) (ATSDR, 1998; EPA, 1994). It is important to bear in mind that the soil concentration that resulted in adverse health effects at Seveso were orders of magnitude higher than those found in the North Salt Lake residential areas near Stericycle (80,000 ppt at Seveso vs. 2.6 ppt in North Salt Lake). Severe liver toxicity, which is consistently reported in studies of TCDD exposure in rodents, has not been observed in humans (EPA, 2012a). Studies in animals suggest that TCDD can also cause reproductive damage, including altered sex hormone levels, decreases in fertility, reduced production of sperm, and increased rates of miscarriages. Overall, studies of oral TCDD exposure in animals indicate that the effects that occur at the lowest doses are immune, endocrine, and developmental (ATSDR, 1998).

DHHS and IARC have determined that TCDD is a human carcinogen. The classification of TCDD as a human carcinogen was unusual in that it was deemed to cause an increase in the risk of cancers at all sites rather than at a few specific locations. This judgment was supported by both studies in animals and epidemiologic data from humans (Steenland et al., 2004). As of the writing of this document, there are no comparison values for the risk of cancer due to dioxin exposure. Therefore, the EEP cannot determine if exposures to dioxins in the soil in the vicinity of the incinerator could increase the risk of cancer.

Very few studies have examined how dioxins specifically affect the health of children. Chloracne occurred at a lower body burden than adults, suggesting that children may be more sensitive. This effect still only appeared after exposure to dioxin levels much higher than background, and the reason for the apparent increased sensitivity remains unclear. It is likely that other effects of exposure to high concentrations of dioxins will be similar between children and adults. There is also no information to suggest that there are difference between children and adults in the absorption and excretion of dioxins or their location in the body (ATSDR, 1998).

CHILD HEALTH CONSIDERATIONS

In communities faced with air, water, or food contamination, the many physical differences between children and adults demand special emphasis. Children may be at greater risk than adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults and they breathe dust, soil, and vapors close to the ground. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. The recurrent ingestion of relatively large amounts of soil in children exhibiting soil-pica behavior may also considerably increase their exposure. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Adults need as much information as possible to make informed decisions regarding their children's health.

This health consultation takes into account the unique vulnerabilities of children by using child-specific comparison values and exposure factors, such as body weights, intake rates, and skin exposure areas. The resulting exposure doses for children are correspondingly higher than adult doses and represent the basis for the public health conclusions and recommendations.

CONCLUSIONS

This Health Consultation presents an evaluation of the past, present, and potential future exposures to residential soil and playground sand in the community adjacent to the Stericycle incinerator. On the basis of soil sampling performed by the EEP and DCHD and likely exposure pathways, the EEP concludes the following:

> **Arsenic:** Oral and dermal exposures to arsenic in residential sand and soil are not expected to harm people's health. Only playground sand at EEP sample site D exceeded the CVs for children. For adults and children without soil-pica, the estimated exposure doses were below the chronic MRL. Excess cancer risk was within the EPA target risk range of 10^{-4} to 10^{-6}. Estimated exposure doses for children with soil-pica did not exceed the acute MRL.
>
> Of the two EEP sample sites with arsenic levels above the detection threshold, only playground sand from EEP sample site D was above the background arsenic concentration range as determined by USGS soil sample data. This suggests that sand from sample site D is not representative of typical soil arsenic background levels in the vicinity of the Stericycle incinerator, which are likely to be at or below those determined from USGS data.
>
> **Chromium:** Oral and dermal exposures to chromium in residential sand and soil are not expected to harm people's health. Although residential soil samples exceeded the Cr(VI)

CV for children with soil-pica, total chromium concentrations were below the CVs for adults and children without soil-pica. Estimated exposure doses for children with soil-pica did not exceed the intermediate MRL.

Despite the fact that total chromium concentrations in residential soil near the incinerator exceeded the CVs, they are likely to be at or below typical background levels for the region based on USGS soil sampling data.

Barium, cadmium, lead, mercury, selenium, silver, and dioxins: Concentrations of these contaminants in residential soil and playground sand were below relevant CVs, and are not expected to harm people's health. However, while soil lead levels were low, the best available science indicates that there is no safe level of lead exposure, especially for children.

RECOMMENDATIONS

Based upon evaluation of soil and playground sand concentrations of arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, and dioxins in the community adjacent to the Stericycle medical waste incinerator, the EEP makes the following recommendations:

- While the arsenic concentration in playground sand from EEP sample site D (Caleb Drive playground) is above the chronic CV for children, exposure dose estimates indicate that exposure would not be expected to harm the health of children. Based on the often episodic nature typical of soil-pica behavior, exposure is not expected to harm the health of children with soil-pica. However, as the CV was exceeded, the EEP recommends that community residents take steps to reduce exposure. Parents are advised to monitor young children for excessive hand-to-mouth behavior and ingestion of playground sand. Residents are advised to take steps to limit their exposure to playground sand, particularly in young children that are at higher risk for soil-pica behavior.
- While soil lead levels were well below the CV, the best available science indicates that there is no safe level of lead exposure, especially in children. Therefore, the EEP recommends that residents take actions to limit their exposure to lead containing materials.

PUBLIC HEALTH ACTION PLAN

Actions Undertaken

- In October 2013, DAQ performed a plume deposition analysis of emissions from the Stericycle incinerator to identify optimal areas for soil sampling.
- DCHD conducted soil sampling of undeveloped areas within the predicted emissions plume from the incinerator in October 2013.
- DAQ performed an air dispersion modeling analysis in November 2013 to identify the maximum predicted off-property annual air concentrations of pollutants released by the incinerator.
- In November 2013, the EEP conducted soil sampling of residential and playground areas in the community adjacent to the incinerator. Informational material about the soil

sampling was distributed at this time to homeowners who agreed to have their property sampled.

- On February 20, 2014, the EEP released a letter health consultation addressing community concerns about inhalation exposures to air emissions from the Stericycle incinerator. This document is available on the EEP's website (http://www.health.utah.gov/enviroepi/appletree/SouthDavisCounty/).

Actions Underway or Planned

- The EEP will remain available to address public health questions or concerns regarding these issues for residents, visitors, and the general public following this report's final release.
- The EEP will collaborate with DCHD to provide health education and outreach to the community, as well as participating in community and public health meetings. Information will also be available through the EEP's website: http://www.health.utah.gov/enviroepi/appletree/SouthDavisCounty/
- The EEP will provide continued support to city, county, and state agencies on interpreting sampling data and adverse health outcomes.

REPORT PREPARATION

This Public Health Consultation for soil exposures near the Stericycle medical waste incinerator was prepared by the Environmental Epidemiology Program at the Utah Department of Health under a cooperative agreement with ATSDR. It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

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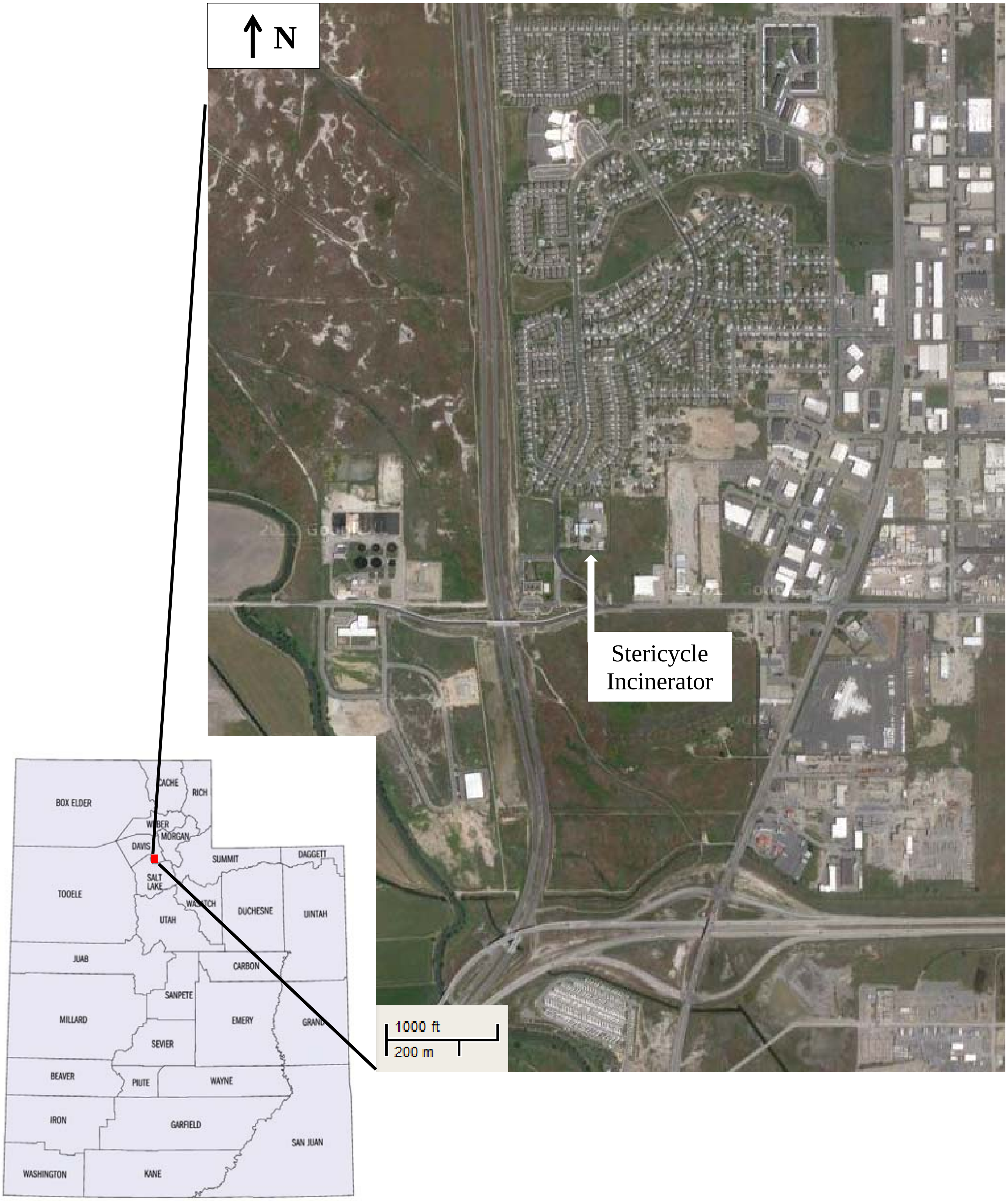
APPENDIX A

Maps

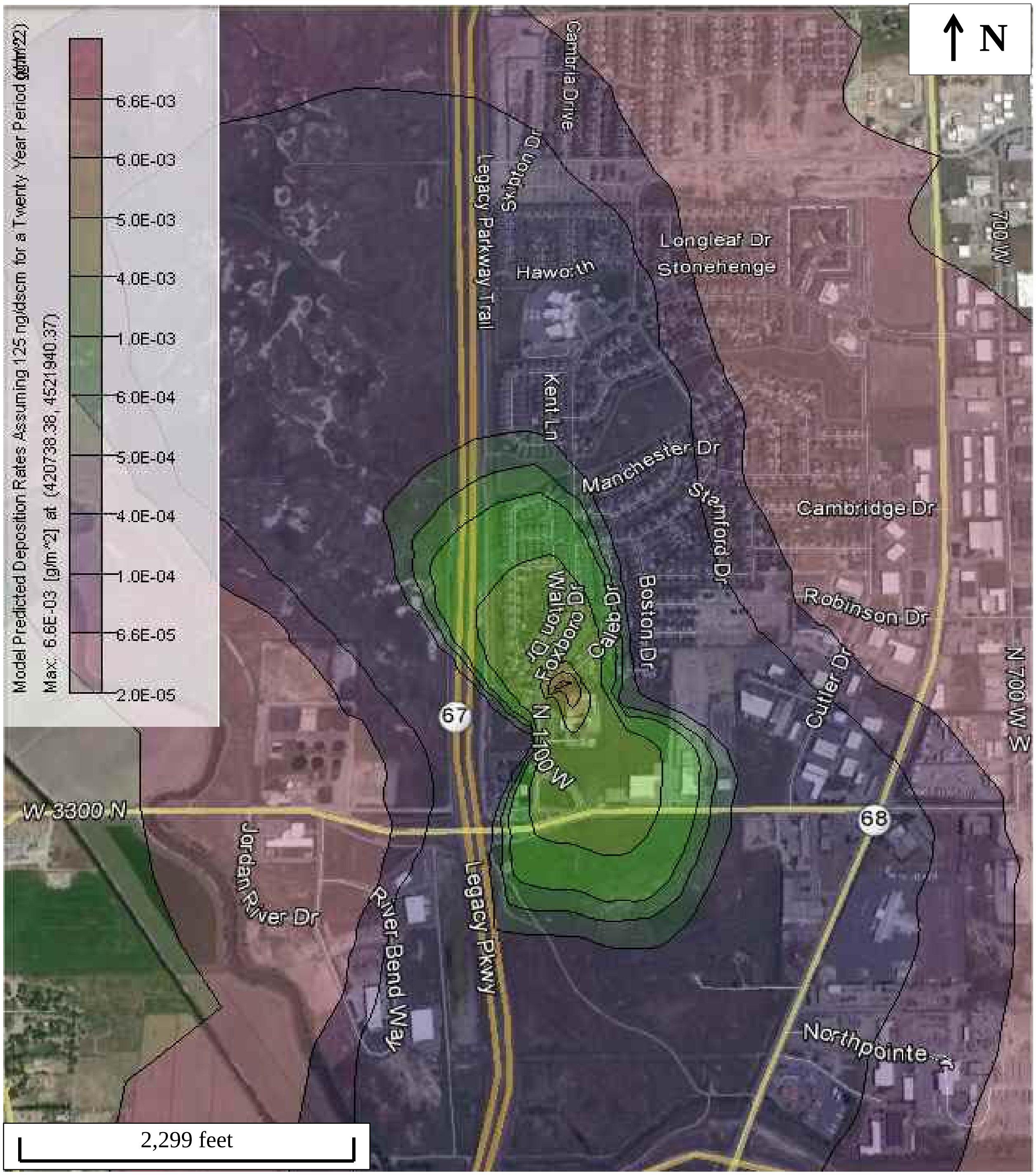
Map 1. Location of the Stericycle medical waste incinerator at 90 North 1100 West in North Salt Lake, UT.



Map 2. Pollutant deposition gradient out to one kilometer from the Stericycle incinerator. Map courtesy of DAQ.

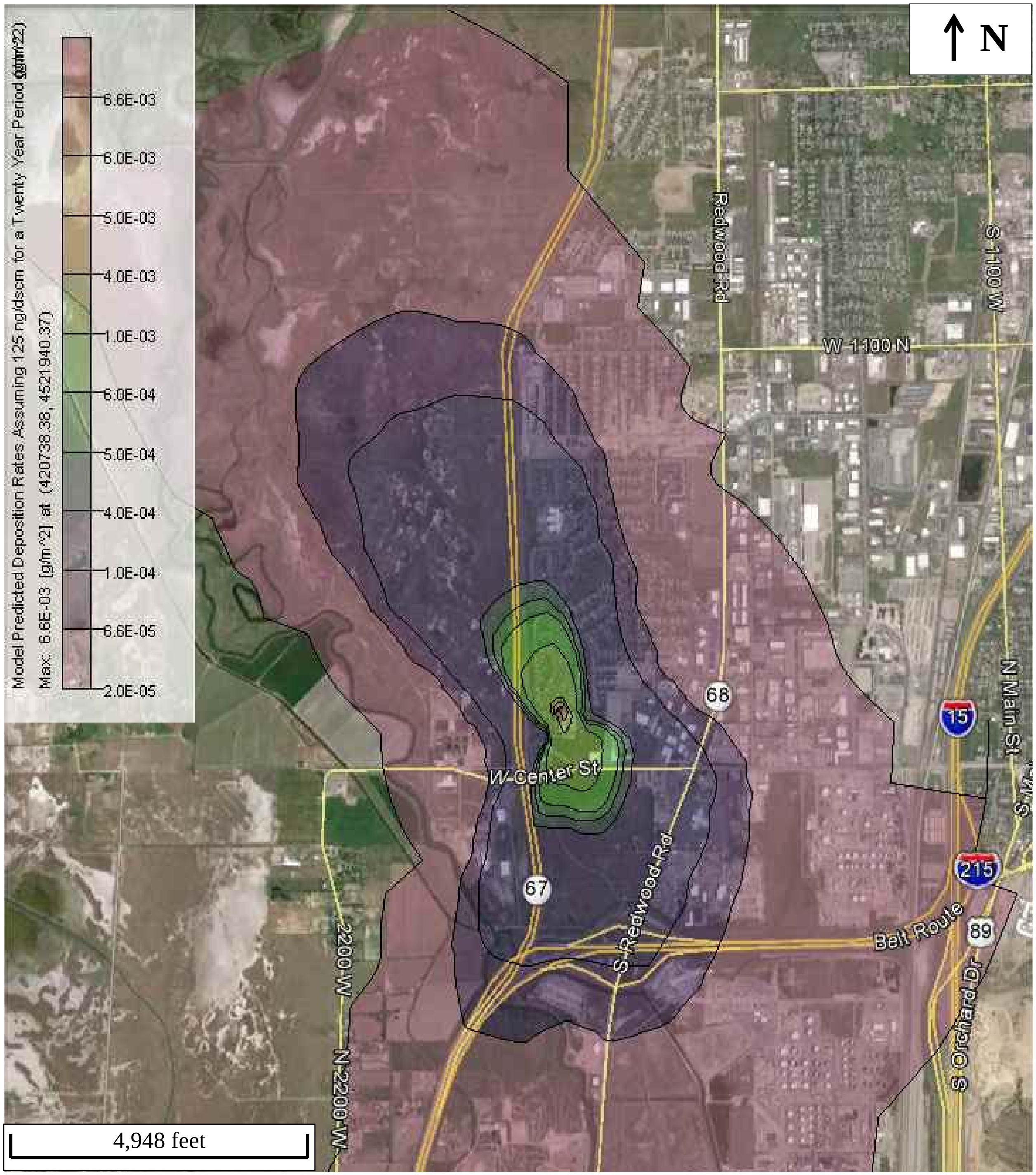
The innermost, orange isopleth denotes the greatest predicted pollutant deposition. Isopleths progressing outward from orange to green, blue, and finally purple indicate decreasing predicted concentrations.

Map 3. Pollutant deposition gradient out to two kilometers from the Stericycle incinerator. Map courtesy of DAQ.



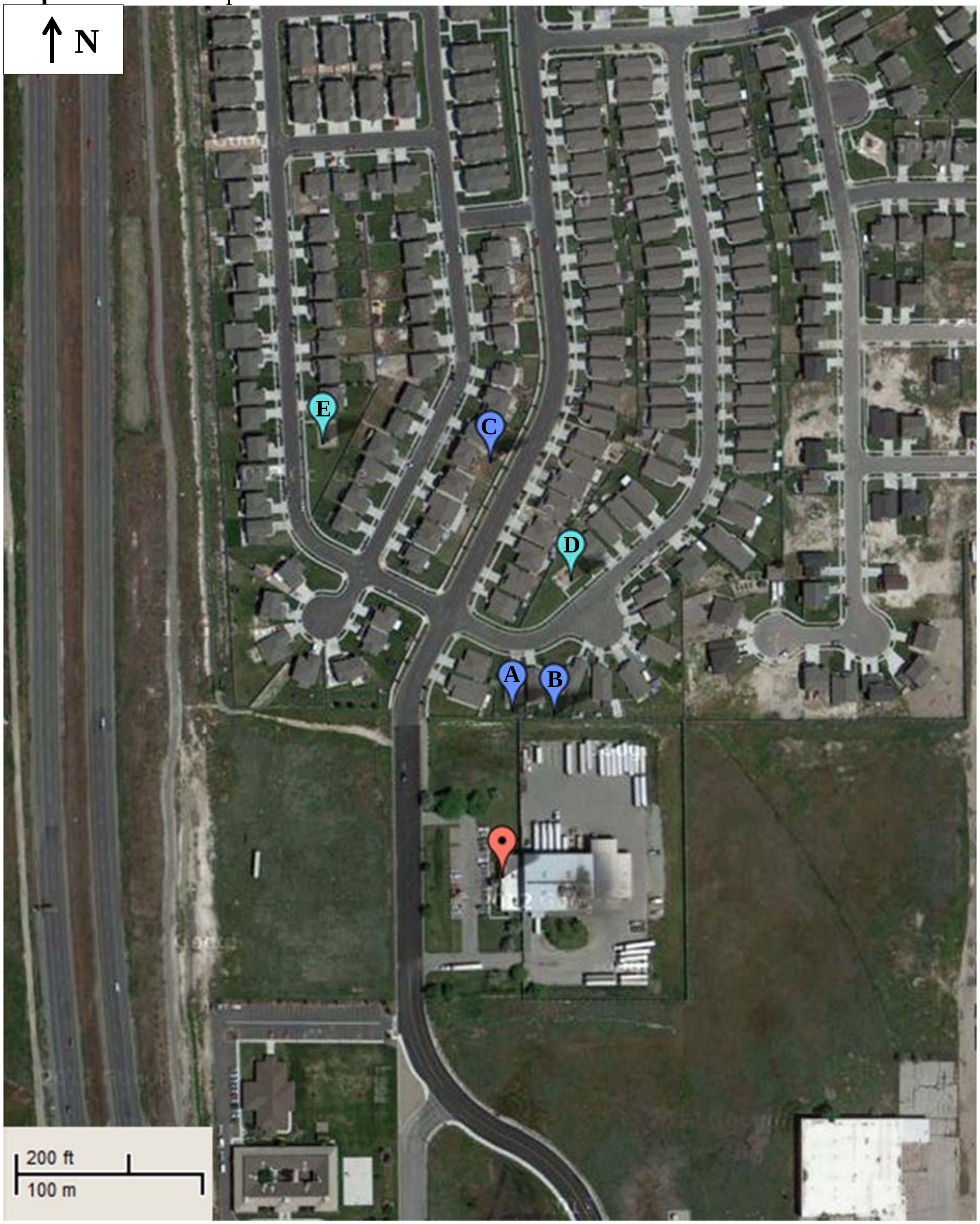
The innermost, orange isopleth denotes the greatest predicted pollutant deposition. Isopleths progressing outward from orange to green, blue, and finally purple indicate decreasing predicted concentrations.

Map 4. Pollutant deposition gradient out to four kilometers from the Stericycle incinerator. Map courtesy of DAQ.



The innermost, orange isopleth denotes the greatest predicted pollutant deposition. Isopleths progressing outward from orange to green, blue, and finally purple indicate decreasing predicted concentrations.

Map 5. EEP soil sample sites.



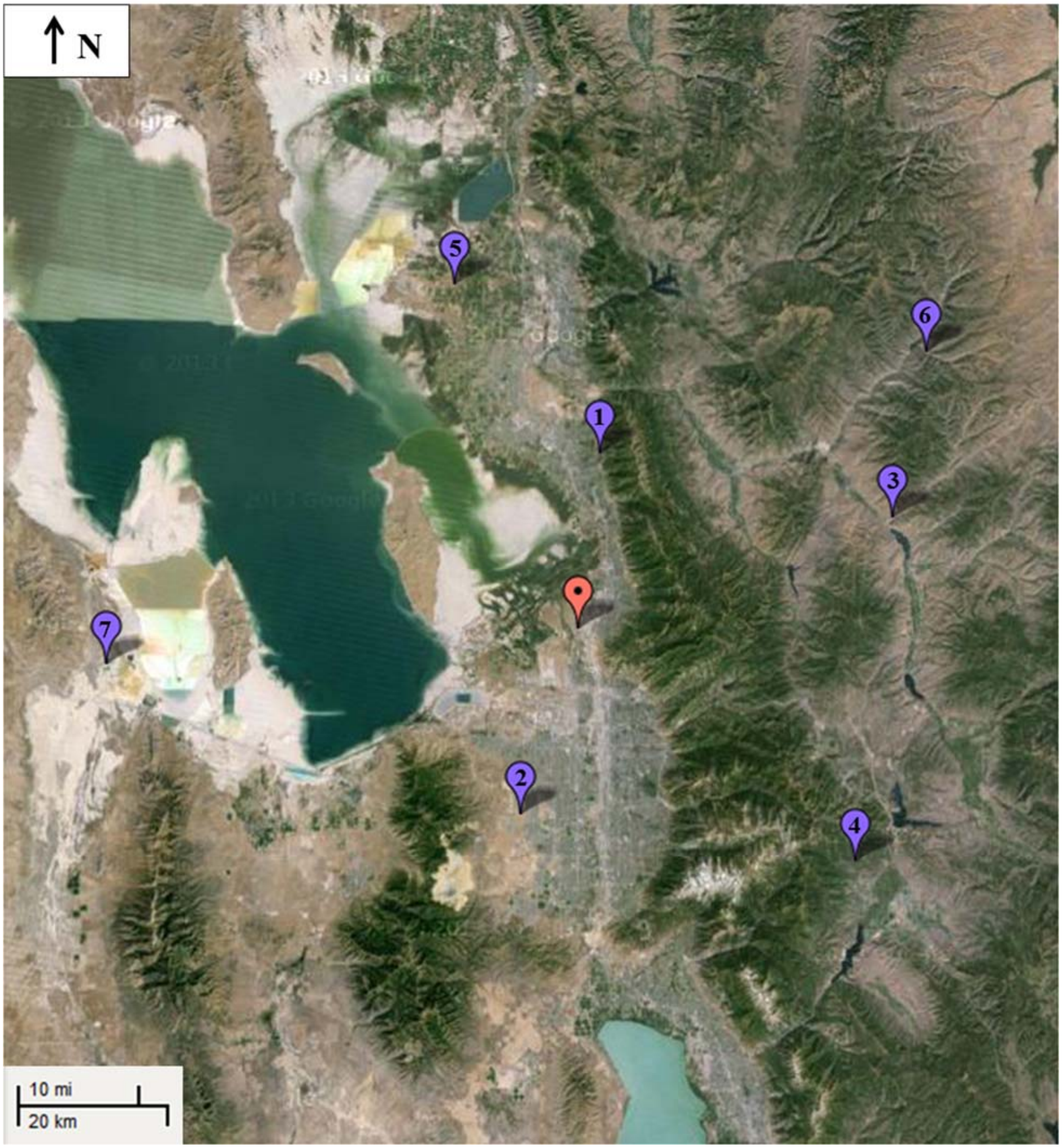
Red marker: Stericycle incinerator.
Dark blue markers: EEP residential sample sites.
Light blue markers: EEP playground sample sites.

Map 6. DCHD soil sample sites.

Right-hand panel is zoomed in on the sample sites in the circled area.

Red marker: Stericycle incinerator.
Green markers: DCHD sample sites.
Yellow marker: DCHD control sample site.

Map 7. USGS soil sample sites.



Red marker: Stericycle incinerator.
Purple markers: USGS sample sites.

APPENDIX B

Tables

Table B1. Emissions limits, stack test dates, and test results for the Stericycle incinerator.

Pollutant	Test Frequency (years) [a]	Test Date	Result	Limit
Cadmium (mg/dscm)	5	10/18/2006	0.001	0.16
		12/28/2011	0.001	0.16
		1/25/2013	0.003	0.16
Carbon Monoxide (ppmdv)	3	11/11/2009	20	40
		11/8/2012	2	40
		1/25/2013	5	40
		4/10/2013	3	40
Dioxins/Furans (ng/dscm)	5	10/18/2006	2	125
		12/28/2011	**616.4**	**125**
		2/15/2012	2	125
		1/25/2013	6	125
Dioxins/Furans (TEQ) (ng/dscm)	5	10/18/2006	0.1	2.3
		12/28/2011	**11.7**	**2.3**
		2/15/2012	0.1	2.3
		1/25/2013	0.3	2.3
Hydrogen Chloride (ppmdv)	3	11/11/2009	6	100
		11/8/2012	0.03	100
		1/25/2013	**143.4**	**100**
		4/10/2013	5	100
Lead (mg/dscm)	5	10/18/2006	0.004	1.2
		12/28/2011	0.001	1.2
		1/25/2013	0.02	1.2
Mercury (mg/dscm)	5	10/18/2006	0.004	0.55
		12/28/2011	0.04	0.55
		1/25/2013	0.005	0.55
Nitrogen Oxides (ppmdv)	5	10/18/2006	250	250
		12/28/2011	**336**	**250**
		9/13/2012	**438**	**250**
		1/25/2013	122	250
		4/10/2013	177	250
Particulate Matter (mg/dscm)	3	11/11/2009	2	34
		11/8/2012	25	34
		1/25/2013	20	34
Sulfur Dioxide (ppmdv)	5	10/18/2006	6	55
		12/28/2011	1	55
		1/25/2013	10	55

[a] Required test frequency in the absence of an emissions violation.
dscm: dry standard cubic meter (m^3).
ppmdv: parts per million dry volume.

Table B2. WHO toxic equivalency factors for various dioxins and dioxin-like compounds.

Compound	WHO 1998 TEF	WHO 2005 TEF
2,3,7,8-tetrachlorodibenzo-*p*-dioxin	1	1
1,2,3,7,8-pentachlorodibenzo-*p*-dioxin	1	1
1,2,3,4,7,8-hexachlorodibenzo-*p*-dioxin	0.1	0.1
1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin	0.1	0.1
1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin	0.1	0.1
1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin	0.01	0.01
octachlorodibenzo-*p*-dioxin	0.0001	0.0003
2,3,7,8-tetrachlorodibenzofuran	0.1	0.1
1,2,3,7,8-pentachlorodibenzofuran	0.05	0.03
2,3,4,7,8-pentachlorodibenzofuran	0.5	0.3
1,2,3,4,7,8-hexachlorodibenzofuran	0.1	0.1
1,2,3,6,7,8-hexachlorodibenzofuran	0.1	0.1
1,2,3,7,8,9-hexachlorodibenzofuran	0.1	0.1
2,3,4,6,7,8-hexachlorodibenzofuran	0.1	0.1
1,2,3,4,6,7,8-heptachlorodibenzofuran	0.01	0.01
1,2,3,4,7,8,9-heptachlorodibenzofuran	0.01	0.01
octachlorodibenzofuran	0.0001	0.0003
3,3’,4,4’-tetrachlorobiphenyl (PCB 77)	0.0001	0.0001
3,4,4’,5-tetrachlorobiphenyl (PCB 81)	0.0001	0.0003
3,3’,4,4’,5-pentachlorobiphenyl (PCB 126)	0.1	0.1
3,3’4,4’5,5’-hexachlorobiphenyl (PCB 169)	0.01	0.03
2,3,3’,4,4’-pentachlorobiphenyl (PCB 105)	0.0001	0.00003
2,3,4,4’,5-pentachlorobiphenyl (PCB 114)	0.0005	0.00003
2,3’,4,4’,5-pentachlorobiphenyl (PCB 118)	0.0001	0.00003
2’.3.4.4’.5-pentachlorobiphenyl (PCB 123)	0.0001	0.00003
2,3,3’,4,4’,5-hexachlorobiphenyl (PCB 156)	0.0005	0.00003
2,3,3’,4,4’,5’-hexachlorobiphenyl (PCB 157)	0.0005	0.00003
2,3’,4,4’,5,5’-hexachlorobiphenyl (PCB 167)	0.00001	0.00003
2,3,3’,4,4’,5,5’-heptachlorobiphenyl (PCB 189)	0.0001	0.00003

PCB: polychlorinated biphenyl.

APPENDIX C

Exposure Dose Calculations

Exposure dose (ED) calculation for soil ingestion (ATSDR, 2005):

ED = (C x IR x EF x BF x CF) / BW

Where:
ED = exposure dose (mg/kg/day)

C = Contaminant concentration (mg/kg)

IR = Intake rate of contaminated soil
- 200 mg/day for a child
- 5,0000 mg/day for a soil-pica child
- 100 mg/day for an adult

EF = Exposure factor (unitless)
- 1.0 = daily exposure for 365 days a year

BF = Bioavailability (unitless)
- 1.0

CF = Conversion factor
- 1.0E-06 kg/mg

BW = Body weight (kg)
- 16 kg for a child (1-6 years)
- 70 kg for an adult

Example from **Table 4.** Calculating the potential child exposure dose of arsenic from ingesting playground sand.

C = 20.8 ppm or 20.8 mg/kg

IR = 200 mg/day

EF = 180 days/year = 180/365 = 0.493

BF = 1.0

CF = 0.000001 kg/mg

BW = 16 kg

ED = (C x IR x EF x BF x CF) / BW

ED = (20.8 mg/kg x 200 mg/day x 0.493 x 1.0 x 0.000001 kg/mg) / 16 kg

ED = 0.000128 mg/kg/day = 1.28E-04 mg/kg/day

Exposure dose (ED) calculation for soil dermal contact (ATSDR, 2005):

ED = (C x A x AF x EF x CF) / BW

Where:
ED = exposure dose (mg/kg/day)

C = Contaminant concentration (mg/kg)

A = Total soil adhered (mg) = Exposed skin area x soil adherence concentration

- Exposed skin area
    - Head = 13.45% of total
    - Torso = 33.3% of total
    - Arms = 13.55% of total
    - Hands = 5.21% of total
    - Legs = 27.45% of total
    - Feet = 7.10% of total

Total surface area:

- Child (1-11 years) = 8,750 cm^2
- Adolescent (12-17 years) = 15,235 cm^2
- Adult (18-70 years) = 19,400 cm^2

- Soil adherence concentration = 0.2 mg/cm^2 (children) or 0.07 mg/cm^2 (adults)

AF = Bioavailability factor (unitless)

- 0.1

EF = Exposure factor (unitless)

- 1.0 = daily exposure for 365 days a year

CF = Conversion factor

- 1.0E-06 kg/mg

BW = Body weight (kg)

- 30 kg for a child (1-11 years).
- 50 kg for adolescents (12-17 years)
- 70 kg for an adult (18-70 years)

Example from **Table 4.** Calculating the potential child exposure dose of arsenic from skin contact with playground sand.

C = 20.8 ppm = 20.8 mg/kg

A = [(13.55% (Arms) + 5.21% (Hands) + 7.10% (Feet)) x 8,750 cm^2] x 0.2 mg/cm^2 = (25.86% x 8,750 cm^2) x 0.2

= 2,262.75 cm^2 x 0.2 mg/cm^2 = 452.55 mg

AF = 0.1

EF = 180 days/year = 180/365 = 0.493

CF = 0.000001 kg/mg

BW = 30 kg

ED = (C x A x AF x EF x CF) / BW

ED = (20.8 mg/kg x 452.55 mg x 0.1 x 0.493 x 0.000001 kg/mg) / 30 kg

ED = 0.0000155 mg/kg/day = 1.55E-05 mg/kg/day

Excess cancer risk calculations for oral and dermal exposure to arsenic

Cancer risk = ED x Oral Slope Factor x (Exposure Years/70)

The child and adult exposure doses (EDs) for oral exposure and the child, adolescent, and adult EDs for dermal exposure to arsenic as calculated above were used. They are:

- Oral exposure doses
  - Child (1-13 years): 1.28E-04 mg/kg/day
  - Adult (13-70 years): 1.46E-05 mg/kg/day
- Dermal exposure doses
  - Child (1-11 years): 1.55E-05 mg/kg/day
  - Adolescent (11-17 years): 1.59E-05 mg/kg/day
  - Adult (17-70 years): 5.22E-06 mg/kg/day

The oral slope factor for arsenic is 1.5 per mg/kg/day (ATSDR, 2007).

<u>Oral exposure in children:</u>

Cancer risk = 1.28E-04 mg/kg/day * 1.5 * (12/70) = 3.30E-05

<u>Oral exposure in adults:</u>

Cancer risk = 1.46E-05 mg/kg/day * 1.5 * (57/70) = 1.79E-05

<u>Dermal exposure in children:</u>

Cancer risk = 1.55E-05 mg/kg/day * 1.5 * (10/70) = 3.31E-06

<u>Dermal exposure in adolescents:</u>

Cancer risk = 1.59E-05 mg/kg/day * 1.5 * (6/70) = 2.04E-06

<u>Dermal exposure in adults:</u>

Cancer risk = 5.22E-06 mg/kg/day * 1.5 * (53/70) = 5.93E-06

<u>Total cancer risk:</u>

3.30E-05 + 1.79E-05 + 3.31E-06 + 2.04E-06 + 5.93E-06 = 6.22E-05

APPENDIX D

Plume Deposition Analysis Parameters

The following design and inputs were used in the plume deposition analysis conducted by DAQ:

- AERMOD modeling system version 13350;
- National Weather Service surface and upper air meteorology monitored at the Salt Lake City International Airport from 2006 through 2010;
- Site: Stericycle medical waste incinerator, North Salt Lake, Utah: UTM Easting 420776, Northing 4521837, elevation 4,229 feet;
- Evaluated the area out to four kilometers (km) from the site location;
- Particle evaluated: TCDD, density of 1.8 grams per cm^3, 1 - 8 µm in diameter;
- Emission rate based on the permitted limit of 125 ng/m^3, with temperatures and flow rates based on February 2013 stack testing data;
- Emissions were simulated for a 20-year period.
- Deposition based on emission at permitted limits over 20 years of operation.

APPENDIX E

Glossary

ATSDR	Agency for Toxic Substances and Disease Registry.
BMD	Benchmark dose. The dose that produces a predetermined change in the response rate of an adverse effect compared to background.
$BMDL_{10}$	Benchmark dose level, 10%. The lower confidence limit of the estimated dose corresponding to an increase of 10% in the probability of the specified response relative to the probability of that same response at dose zero.
$BMDL_{2sd}$	Benchmark dose level, two standard deviations. An estimate of the dose associated with a change of two standard deviations from the control; the use of two standard deviations takes into consideration the normal variability in a population.
CSF	Cancer slope factor. An upper bound calculated by EPA on the increased cancer risk from a lifetime of oral exposure to a substance. Approximates a 95% confidence limit.
CDC	The Centers for Disease Control and Prevention.
cm^2	Square centimeter.
cm^3	Cubic centimeter.
Cr(III)	Trivalent chromium, in the +3 oxidation state.
Cr(VI)	Hexavalent chromium, in the +6 oxidation state.
CREG	Cancer risk evaluation guide. An estimate of the concentration of a contaminant that would be expected to cause no more than one excess case of cancer in a million persons exposed every day, 24 hours a day, for their lifetimes.
CV	Comparison value. A concentration calculated by ATSDR or EPA of a substance in air, water, food, or soil that is unlikely to cause harmful health effects in exposed people.
DAQ	Division of Air Quality, within the Utah Department of Environmental Quality.
DCHD	Davis County Health Department.
DEQ	Utah Department of Environmental Quality.
Detection Limit	The lowest concentration of a substance that can reliably be distinguished from a concentration of zero.
DHHS	United States Department of Health and Human Services

dscm	Dry standard cubic meter of gas.
DSHW	Division of Solid and Hazardous Waste, within the Utah Department of Environmental Quality.
EEP	Environmental Epidemiology Program, within the Utah Department of Health.
EMEG	Environmental media evaluation guide, based on ATSDR's MRL. A concentration of a substance in water, soil, and air to which humans may be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing adverse, non-cancer health effects. Acute is 14 days or less, intermediate is 15 days to one year, and chronic is over one year.
EPA	United States Environmental Protection Agency.
Exposure Dose	The measured or calculated dose to which a population is likely to be exposed considering all sources and routes of exposure.
IARC	The International Agency for Research on Cancer.
Isopleth	A line on a map connecting all points that have the same value of some measureable quantity. In this report, the lines connect all points having the same predicted average deposition of pollutant particles.
kg	Kilograms. One kilogram is equal to 2.205 pounds.
km	Kilometers. One kilometer is equal to 0.62 miles.
LOAEL	Lowest-adverse-effect-level. The lowest dose of a substance that produces statistically or biologically significant increases in the frequency or severity of adverse effects.
m^2	**Square meter.**
m^3	Cubic meter.
mg	Milligrams. One thousandth of a gram.
mg/kg/day	Milligrams per kilograms of body weight per day.
mi	Miles.

MRL Minimal risk level. 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, non-cancerous effects. MRLs are calculated for a route of exposure over a specified time period. Acute is 14 days or less, intermediate is 15 days to one year, and chronic is over one year.

NOAEL No-observed-adverse-effect-level. The exposure level of a substance that produces no statistically or biologically significant increases in the frequency or severity of adverse effects. Effects may be produced at this level, but they are not considered to be adverse, nor precursors to adverse effects.

ng Nanograms. One billionth of a gram.

ppm Parts per million.

ppmdv Parts per million by dry volume.

ppt Parts per trillion.

RCRA Resource Conservation and Recovery Act. Originally enacted in 1976, it is the principle federal law governing the disposal of solid and hazardous waste.

RfD Reference dose. An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans, including sensitive subgroups.

RMEG Reference dose media evaluation guide, based on EPA's RfD. A concentration of a substance in water, soil, or air to which humans may be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing adverse, non-cancer health effects. Acute is 14 days or less, intermediate is 15 days to one year, and chronic is over one year.

Soil Ingestion The consumption of soil. This may results from a number of behaviors, including mouthing, contacting dirty hands, eating dropped foods, and consuming soil directly.

Soil-pica The recurrent ingestion of unusually high amounts of soil, often on the order of 1,000 - 5,000 mg/day (5 - 25X normal). Groups at risk of soil-pica include children aged six years and younger and developmentally delayed individuals.

TCDD 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. The most toxic type of dioxin/furan.

TEF Toxic equivalency factor. Expresses the toxicity of the various dioxins and furans in terms of the most toxic type, TCDD.

TEQ Toxic equivalent. A single number expressing the toxicity of a mixture of dioxins and furans in terms of their TEFs.

TSCA Toxic Substances Control Act. A law providing EPA with authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances. Some substances are generally excluded from TSCA, including food, drugs, cosmetics, and pesticides.

UDOH Utah Department of Health

µg Micrograms. One millionth of a gram.

µm Micrometers. One millionth of a meter. Also referred to as microns.

UF Uncertainty factor. UFs are mathematical adjustments for reasons of safety when knowledge is incomplete. For example, UFs are applied to no-observed-adverse-effect-levels to derive minimal risk levels, thus accounting for variations in people's sensitivity to a contaminant and differences between animals and humans.

USGS U.S. Geologic Survey.

WHO World Health Organization.