Health Consultation

Follow-up Report for the Assessments of Soil and Air Exposures to Stericycle Medical Waste Incinerator Emissions

North Salt Lake
Davis County, Utah

October 5, 2015

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

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

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members.

You may contact the Environmental Epidemiology Program, Utah Department of Health at
801-538-6191
or
Visit our Home Page at: http://health.utah.gov/enviroepi/appletree

HEALTH CONSULTATION

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Prepared By:

Environmental Epidemiology Program
Bureau of Epidemiology
Utah Department of Health
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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 follow-up health consultation for the studies aimed at assessing the potential health effects associated with exposures to emissions from the Stericycle medical waste incinerator located in North Salt Lake, Utah (UDOH, 2013; 2014a; 2014b; 2015. See **Map 1, Appendix A**). The purpose of this report is to:

- Provide an estimation of excess cancer risk due to inhalation of dioxins using the best available toxicological assessment values;
- Provide a cumulative excess cancer risk estimate for all contaminants exceeding cancer-based screening levels at this site;
- Provide an assessment of exposure to the multiple chemicals emitted from the incinerator;
- Provide verification that new medical waste incinerator emission standards have been adopted at the Stericycle North Salt Lake facility; and
- Provide an estimation of potential health impacts of Stericycle facility bypass events.

In May 2013, the Utah Division of Air Quality (DAQ), within the Department of Environmental Quality, 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 pollutants released by the incinerator, the EEP has carried out the following public health studies:

- A Health Consultation addressing the 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;

- A Letter of Health Consultation was completed on February 20, 2014, addressing concerns regarding the potential health effects from inhalation exposure to contaminants released by the incinerator;

- A Cancer Incidence Statistical Review of the residential area adjacent to the incinerator; and

- An Adverse Birth Outcomes study of the residential area adjacent to the incinerator.

These studies are available on the EEP's webpage dedicated to this issue: (http://www.health.utah.gov/enviroepi/appletree/SouthDavisCounty)

CONCLUSION 1	The EEP concludes that inhalation exposure to dioxins released from the Stericycle medical waste incinerator is not expected to result in significant excess cancer risk or adverse, non-cancer health effects.
BASIS FOR DECISION	While modeled residential exposures to dioxins during Stericycle's violation of their operating permit exceeded the EPA's cancer-based regional screening level, cumulative exposure from the first development of the neighboring community in 2003 to 2014 is 2.52E-06 (or a little over one in one million). This value falls on the lower end of EPA's acceptable target cancer risk range of 1.0E-04 to 1.0E-06 (1 in 10,000 to 1 in one million) for environmental contaminants. Furthermore, modeled residential exposures did not exceed available non-cancer comparison values (CVs) for dioxins.
NEXT STEPS	No further actions are recommended.
CONCLUSION 2	The EEP concludes that exposures to the mixture of chemicals emitted from the incinerator stack is not expected to result in adverse non-cancer health effects.
BASIS FOR DECISION	Based upon the highest recorded stack testing (including the permit violation period) data, modeled residential pollution concentrations yield Hazard Quotients (HQ) that indicate a Hazard Index (HI) less than one (<1). Therefore, this mixture of pollutants is not expected to result in additive toxicological effects leading to non-cancer adverse health effects.
NEXT STEPS	No further actions are recommended.
CONCLUSION 3	The EEP concludes that current emissions regulations, effective October 2014, are expected to be adequately protective of human health for both cancer and non-cancer adverse health effects.
BASIS FOR DECISION	Based upon the most current stack testing data, modeled residential pollution concentrations are below both cancer and non-cancer based CVs. Further, HQ analysis indicates a HI less than one (<1). Therefore, stack pollutants alone or in mixture are not expected to result in additive toxicological effects leading to cancer or non-cancer adverse health effects.
NEXT STEPS	No further actions are recommended.

CONCLUSION 4	The EEP concludes that excess cancer risks from all contaminants that exceeded cancer-based CVs at this site (arsenic in soil and dioxins in air) are not expected to result in significant excess cancer risk.
BASIS FOR DECISION	The additive excess cancer risk posed by all contaminants in all media for which data has been acquired that exceed cancer-based CVs is 6.47E-05. This value is within EPA's acceptable target cancer risk range of 1.0E-04 to 1.0E-06 (1 in 10,000 to 1 in one million).
NEXT STEPS	As many types of cancer and chronic disease are often preventable, residents are encouraged to make healthy life choices. These can include quitting smoking, maintaining a healthy diet and weight, avoiding too much sun exposure, and getting enough physical exercise.
CONCLUSION 5	The EEP concludes that the most sensitive individuals (those with severe respiratory disorders) may experience minor adverse health effects associated with sulfur dioxide when exposed to bypass event smoke plumes and should take steps to reduce these exposures. Furthermore, all individuals should reduce their exposure to bypass event smoke as much as reasonably possible.
BASIS FOR DECISION	Based upon the modeled data for bypass event smoke exposure, predicted estimates for all listed contaminant concentrations are well below established National Institute for Occupational Safety and Health (NIOSH) values for immediately dangerous contaminant levels; however, modeled sulfur dioxide concentrations exceed available health-based acute exposure levels.
NEXT STEPS	Though this toxicological evaluation concludes that it is unlikely that severe adverse health effects will occur due to exposure to bypass event smoke, the EEP recommends that residents (especially children and those with existing respiratory conditions) exercise reasonable caution and avoid direct exposure to incinerator smoke plumes during bypass events. Actions and precautions include the following: • Move indoors if you may be in direct contact with a smoke plume outdoors; • Close windows and doors once indoors;

- Turn off non-filtering air-handling devices that bring outdoor air inside (window fans, window A/C units, some evaporative coolers) until the smoke plume dissipates;
- Regularly maintain all home heating, ventilation, and air conditioning (HVAC) filters; and
- Consider a portable home air purifier unit with carbon and HEPA filtration.

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 PURPOSE

The Environmental Epidemiology Program (EEP), Utah Department of Health (UDOH), has created this follow-up report for the studies aimed at assessing the potential health effects associated with exposures to emissions from the Stericycle medical waste incinerator located in North Salt Lake, Utah (UDOH, 2013; 2014a; 2014b; 2015. See **Map 1, Appendix A**). The purpose of this report is to:

- Provide an estimation of excess cancer risk due to inhalation of dioxins using the best available toxicological assessment values;
- Provide a cumulative excess cancer risk estimate for all contaminants exceeding cancer-based screening levels at this site;
- Provide an assessment of exposure to the multiple chemicals emitted from the incinerator;
- Provide verification that new medical waste incinerator emission standards have been adopted at the Stericycle North Salt Lake facility; and
- Provide an estimation of potential health impacts of Stericycle facility bypass events.

For a complete statement of issues and background including the Stericycle operating permit violations, site description, and community health concerns please see the Stericycle Soil Dioxins and Heavy Metals Health Consultation (UDOH, 2015).

DIOXIN INHALATION EXPOSURE

Currently, neither the Agency for Toxic Substances and Disease Registry (ATSDR) nor the U.S. Environmental Protection Agency (EPA) have established comparison values (CVs) for inhalation exposure to dioxins due to a lack of adequate toxicological data. A CV is a concentration of a substance in air, water, food, or soil below which the substance is unlikely to cause harmful health effects in exposed people (ATSDR, 2005). If a contaminant exceeds an established CV, it indicates that further investigation is necessary. In the absence of relevant CVs, there is no basis to determine whether concentrations of toxic substances are likely to harm people's health.

In an effort to provide an evaluation of the inhalation health risks due to dioxin emissions from Stericycle's North Salt Lake facility, the EEP has employed an existing EPA regional screening level (RSL) for dioxin air concentrations. There are significant limitations associated with the current dioxin air RSLs as detailed below, yet these are the best established values available.

EPA's regional offices sometimes develop RSLs for contaminants, including those for which the agency as a whole has not determined CVs. RSLs are risk-based concentrations for substances that combine assumptions about exposure with toxicity data (EPA, 2013a). RSLs are considered by EPA to be protective of human health, including sensitive groups (e.g., children), and are intended for site screening and initial cleanup goals at Superfund sites when national federal screening levels have not been adequately determined. Like other CVs, RSLs do not indicate a health effect level or cleanup standards; rather, they are generic screening values used to help identify areas, contaminants, and conditions that require further attention (EPA, 2013a).

For dioxins, EPA regions 3, 6, and 9 (the Mid-Atlantic, South Central, and Pacific Southwest regions, respectively) have developed both carcinogenic and non-carcinogenic RSLs for dioxins in residential air (EPA, 2013a). Both RSLs are based on the toxic equivalency (TEQ) for dioxins, which expresses the toxicity of the many types of dioxin in terms of the most toxic form: 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). The cancer-based RSL for TCDD is 7.4E-08 micrograms per cubic meter (µg/m^3) while the non-cancer RSL is 4.2E-05 µg/m^3 (**Table 1**). Both RSLs assume chronic (long-term) exposure. The cancer-based RSL assumes a target cancer risk of 1.0E-06, or one excess cancer case in a million exposed people. Contaminant concentrations below this value present a cancer risk so small that further investigation is not considered meaningful.

The dioxin RSLs were developed from an inhalation reference concentration (RfC) of 4.0E-05 µg/m^3 developed by the California Environmental Protection Agency (CalEPA) (CalEPA, 2000; EPA, 2013a). An RfC represents the estimated concentration of a particular chemical (with uncertainty spanning perhaps a factor of ten) that will not result in an adverse non-cancer health effect over a life-time exposure.

Limitations to Consider

As the available human data were inadequate, the dioxin RfC calculated by CalEPA was derived from a 1978 study of long-term, dietary exposure to TCDD in rats (CalEPA, 2000; Kociba et al., 1978). While the study duration was reasonably long (two years) and sample size was high (50 rats per treatment group per gender), there are several issues that limit the applicability of the study (and thus the derived RSLs) to human exposure. These issues include differences in species (rats to humans) and exposure route (ingestion to inhalation). Different species often have different reactions to a given substance, and it can be extremely difficult to accurately predict toxic reactions from one species to the next. For example, while it takes several thousand times more TCDD to kill a hamster than a guinea pig, there is very little difference in sensitivity between the two species when it comes to reproductive effects of TCDD (ATSDR, 1998). Furthermore, both the severity and type of reaction a substance produces may be affected by the route of exposure. Factors like the fraction of a dose of a substance that is actually absorbed, the rate at which it is absorbed, and the frequency of exposure can vary significantly by exposure route (e.g., eating vs. breathing) (ATSDR, 2005). Finally, the study only examined exposure to TCDD by itself, while in the environment most humans are exposed to a variable mix of dioxins and dioxin-like compounds, of which TCDD is rarely the main component (ATSDR, 1998). Despite these weaknesses, the RSLs derived by the regional EPA offices and CalEPA are the best CVs currently available for inhalation exposure to dioxins.

Dioxin Exposure Estimation

The EEP requested that the Utah Division of Air Quality (DAQ), in the Department of Environmental Quality (UDEQ), extend the previously conducted air dispersion modeling analyses (described in UDOH, 2014b). The new analyses estimated the maximum annual residential air concentration of dioxins based on five different conditions:

1. The highest recorded dioxins emission that was <u>not</u> in violation of Stericycle's operating permit;
2. The maximum dioxins emission limit specified by Stericycle's previous operating permit through DAQ;
3. The dioxins emission when the incinerator was in violation of their operating permit;
4. The most recent dioxin stack test data following compliance with new federal and state medical waste incinerator emission standards (effective October 2014); and
5. The maximum dioxins emission limit specified by Stericycle's current operating permit.

As described previously, the highest concentration of dioxins is predicted to be approximately 110 meters north-northwest of the incinerator stack (**Maps 2 & 3** in **Appendix A**). The results of the updated analyses are presented in **Table 1**.

The maximum predicted residential dioxin concentrations for the above conditions are all below the non-carcinogenic RSL; thus, the EEP would not expect adverse non-cancer health effects from inhalation exposure to dioxins released from the Stericycle incinerator. The maximum predicted dioxin concentrations derived from the previous permit limit and the period of violation both exceed the cancer-based RSL, indicating that further evaluation into the potential for carcinogenic health effects due to inhalation of dioxins is necessary.

EPA has set a target range for excess cancer risk due to an environmental contaminant of 1.0E-04 to 1.0E-06 (1 case in 10,000 exposed people to 1 case in one million exposed people) (EPA, 1991). These target values do not include the U.S. average lifetime risk of developing any type of cancer, which is 0.396 (NCI, 2015). In other words, almost 40% of U.S citizens (or 3,960 cases in 10,000 people) will be diagnosed with some type of cancer during their lifetime. In general, this risk is slightly higher for men (42.1%) and slightly lower for women (37.6%). 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. Furthermore, the EEP uses conservative (i.e., very protective of human health) assumptions regarding exposures to contaminants in order to protect sensitive populations, such as children and pregnant women.

The EEP assessed the excess cancer risk resulting from inhalation exposure to dioxins emitted from the Stericycle incinerator. The timeframe used for exposure evaluation is from development of the neighborhood next to the incinerator to the present day (2003 to 2014, for a total of 11 years) (KUER, 2013). Prior to 2003, chronic exposure would have been unlikely as the land was largely undeveloped.

In 2011, Stericycle exceeded the dioxins emission allowed under their operating permit. Stack tests in 2006 and 2012 showed dioxin levels well under the permit limit (**Table A1** in **Appendix A**). In estimating cancer risk, the EEP assumed that dioxin emissions remained at the permit violating level (1.17E-02 $\mu g/m^3$ TEQ at the stack) for the six years between the 2006 and 2012 stack tests. For the remaining five years, the dioxin emissions were assumed to be at the highest recorded non-violation level (3.00E-04 $\mu g/m^3$ TEQ at the stack). The estimated excess cancer

Table 1. Stericycle incinerator stack concentrations, maximum predicted annual residential air concentrations, and regional screening levels for dioxins.

Pollutant	Stack Concentration (µg/m³) [a]	Maximum Predicted Residential Air Concentration (µg/m³)	Carcinogenic RSL	Non-Carcinogenic RSL
1) Dioxins TEQ [b]	3.00E-04	1.95E-08	7.40E-08	4.20E-05
2) Dioxins Old Permit Limit TEQ [c]	2.30E-03	1.49E-07		
3) Dioxins Violation TEQ [d]	1.17E-02	7.60E-07		
4) Current Dioxin TEQ (2014) [e]	8.8E-06	5.72E-10		
5) Current Dioxin Permit Limit TEQ (2014) [f]	5.40E-05	3.50E-09		

[a] Concentration of dioxin at the Stericycle incinerator stack.
[b] The highest non-violation measured dioxin emission.
[c] The maximum dioxin emission limit listed in Stericycle's previous operating.
[d] Dioxin emission when Stericycle was in violation of their operating permit.
[e] Most current dioxin sampling data
[f] Maximum dioxin emission limit listed in Stericycle's current permit
µg: microgram.
m^3: cubic meter.

risk from inhalation exposure to the maximum residential air concentration of dioxins emitted from the Stericycle incinerator is 2.52E-06, which is on the lower end of the EPA excess cancer target risk range. The excess cancer risk calculations can be found in **Appendix B** of this report.

Similar to the cadmium emissions regulations discussed in the previous health consultation (UDOH, 2014b), the past dioxins emission limit allowed large medical waste incinerators to potentially release dioxins at a level that exceeded the cancer-based RSL but remain in compliance with air quality regulations (**Table 1**). This potential issue has been addressed by DAQ via new regulations effective October 2014 that lowered the dioxins emission limit from 2.30E-03 µg/m^3 TEQ to 5.40E-05 µg/m^3 TEQ (EPA, 2013b). The resulting maximum predicted residential air concentration near the incinerator is 3.50E-09 µg/m^3, significantly lower than the cancer-based RSL of 7.40E-08 µg/m^3. This emission standard and modeled exposure eliminates the need for cancer risk assessment for inhalation of dioxins past 2014.

EXPOSURE TO MULTIPLE CONTAMINANTS

To evaluate the exposure to multiple contaminants that affect the same organ systems, the concentration of the chemical is divided by the appropriate health-based guideline value to determine a hazard quotient (HQ). All HQs ≥ 0.1 are summed, the resulting value is the hazard index (HI). A HI ≥ 1.0, indicates a potential health hazard due to additivity of toxicity (ATSDR, 2004). **Table 2** lists the contaminants of concern emitted from the Stericycle North Salt Lake incinerator, the respective highest reported stack test data, highest modeled residential concentration, health-based guidance value, and hazard quotient. Calculations for modeled residential pollutant concentrations can be found in **Appendix C** of this report. As shown in the table, HQ values for HCl and NOx were ≥ 0.1. The combined HI for these contaminants is 0.92. Therefore, based upon the highest recorded stack testing data, the EEP finds it unlikely that adverse health effects would result from the mixture of chemicals emitted from the incinerator.

Table 2. Highest stack test data*, calculated multiple contaminant hazard index (2006-2013).

Pollutant	Highest Reported Stack Test	Highest Modeled Residential Concentration ($\mu g/m^3$)	Non-Cancer CV ($\mu g/m^3$)	Hazard Quotient (HQ) [Conc./CV]	CV Source
Cadmium (1/25/13)	0.003 (mg/dscm)	0.00012	0.01	0.012	ATSDR Chronic EMEG
Carbon Monoxide (11/11/09)	20 (ppmdv)	1.11	10,000	0.0001	NAAQS 8-Hour Primary Standard
Dioxins/Furans TEQ[V] (12/28/11)	11.7 (ng/dscm)	0.00000076	0.00004	0.018	CalEPA Chronic REL
Hydrogen Chloride[V] (1/25/13)	143.4 (ppmdv)	10.4	20	0.519	EPA RfC
Lead (1/25/13)	0.02 (mg/dscm)	0.00088	0.15	0.006	NAAQS 3 Month Avg. Primary Standard
Mercury (12/28/2011)	0.04 (mg/dscm)	0.0013	0.2	0.006	ATSDR Chronic EMEG
Nitrogen Oxides[V] (9/13/12)	438 (ppmdv)	40.1	99.73	0.402	NAAQS NO_2 Annual Primary Standard
Particulate Matter (11/8/12)	25 (mg/dscm)	1.02	150	0.007	NAAQS PM_{10} 24-Hour Primary Standard
Sulfur Dioxide (1/25/13)	10 (ppmdv)	1.15	26	0.044	ATSDR Acute EMEG
Hazard Index (HI) [Contaminants with HQ ≥ 0.1]				**0.92**	

*Source: UDEQ, 2013a; 2013b; 2013c
V: violation
mg: milligram
dscm: dry standard cubic meter (m^3)
ng: nanograms
m^3: cubic meter
ppmdv: parts per million dry volume
µg: micrograms
EMEG: environmental media evaluation guide
NAAQS: national ambient air quality standard
REL: reference exposure level
RfC: reference concentration

For comparison purposes, the EEP also evaluated the HI for multiple incinerator contaminants based upon the most current stack testing data (in compliance with new medical waste incinerator emission standards). Those results are listed on **Table 3.**

Table 3. Current stack test data*, calculated multiple contaminant hazard index (Oct.–Dec. 2014).

Pollutant	Highest Reported Stack Test	Highest Modeled Residential Concentration (μg/m^3)	Non-Cancer CV (μg/m^3)	Hazard Quotient (HQ)	CV Source
Cadmium[a]	0.0003 (mg/dscm)	0.000013	0.01	0.001	ATSDR Chronic EMEG
Carbon Monoxide	0.2 (ppmdv)	0.053	10,000	0.000005	NAAQS 8-Hour Primary Standard
Dioxins/Furans TEQ	0.0088 (ng/dscm)	0.00000000078	0.00004	0.000018	CalEPA Chronic REL
Hydrogen Chloride	0.1 (ppmdv)	0.0084	20	0.0004	EPA RfC
Lead	0.0003 (mg/dscm)	0.000018	0.15	0.0001	NAAQS 3 Month Avg. Primary Standard
Mercury	0.001 (mg/dscm)	0.000047	0.2	0.0002	ATSDR Chronic EMEG
Nitrogen Oxides	116 (ppmdv)	10.4	99.73	0.105	NAAQS NO_2 Annual Primary Standard
Particulate Matter	4 (mg/dscm)	0.18	150	0.001	NAAQS PM_{10} 24-Hour Primary Standard
Sulfur Dioxide	1.8 (ppmdv)	0.00067	26	0.0007	ATSDR Acute EMEG
Hazard Index (HI) [Contaminants with HQ ≥ 0.1]				**0.11**	

***Source**: UDEQ, 2014c
[a] Note that modeled cadmium concentrations are also *below* cancer risk evaluation guidelines (CREG) for cadmium of 0.00056 μg/m^3.
mg: milligram
dscm: dry standard cubic meter (m^3)
ng: nanograms
m^3: cubic meter
ppmdv: parts per million dry volume
μg: micrograms
EMEG: environmental media evaluation guide
NAAQS: national ambient air quality standard
REL: reference exposure level
RfC: reference concentration

CUMULATIVE EXCESS CANCER RISK FOR ALL SITE CONTAMINANTS

When multiple contaminants released from one source require assessment of cancer risk, the cumulative risk is considered to be additive (EPA, 1989). The additive excess cancer risk posed by all contaminants in all media for which data has been acquired that exceed cancer-based CVs is 6.47E-05 (**Table 4**). This value is comprised of the above mentioned estimated cancer risk for dioxin inhalation exposure and the estimated cancer risk for incidental ingestion and dermal exposure to soil arsenic as detailed in the soil assessment document for this site (UDOH, 2015). This value is within the EPA excess cancer target risk range of 1.0E-04 to 1.0E-06.

Table 4. Cumulative site-contaminant excess cancer risk.

Pollutant	Estimated Cancer Risk	EPA excess cancer target risk range
Dioxin (air/inhalation) - 11 years	2.52E-06	**1.0E-04 to 1.0E-06**
Arsenic (soil/ingestion and dermal) - lifetime	6.22E-05	
TOTAL	**6.47E-05**	

ADOPTION OF WASTE EMISSION STANDARDS

Stericycle's newest permit limits that follow the updated 2014 emission standards can be found in the August 2014 Approval Order (UDEQ, 2014a). Stericycle's compliance with this newest emission standard was verified by DAQ in December 2014 (UDEQ, 2014b; 2014c). The past and current emission limits and testing data can be found in **Table A1, Appendix A.**

BYPASS EVENTS

At the Stericycle North Salt Lake facility, an emergency bypass occurs in response to equipment malfunction or power outage that may result in severe damage to the emission filtration equipment or to the facility itself if emissions are not diverted to a bypass stack. When the bypass stack is opened, emissions from the incinerator vent directly to the atmosphere, bypassing some of the air pollution control equipment. Emissions will still pass through the incinerator's secondary combustion chamber, which controls some, but not all emissions.

During a bypass event, emissions from the facility change from white and transparent to thick and black. If the bypass event lasts longer than 10 minutes, it is common to witness the black smoke thin considerably to a lighter grey color. This is because the waste feed to the incinerator chamber is automatically shut off when the bypass stack is opened (UDEQ, 2014d). As the residual content of the incinerator chamber is consumed, the emitted smoke thins. Though the bypass events can last 20 - 30 minutes, the first 5 - 10 minutes of the event cause the most noticeable nuisance. Due to the infrequent and random nature of bypass events, and the highly variable nature of both the event duration and contents of the incinerator at the time of the bypass event, a realistic estimate of exposure hazards to bypass smoke is difficult to accurately predict. Based upon estimates of bypass event emission levels at the Stericycle site (UDEQ, 2014d), the EEP has estimated the contaminant content of bypass smoke for the contaminants listed in **Table 5.** Potential acute (short-term, from seconds up to 14 days) health effect levels (e.g., burning

Table 5. Estimation of bypass event pollution emissions and associated health comparison values.

Pollutant	**Maximum Predicted Residential Air Concentration (μg/m³)**	**Acute Exposure Health Comparison Values (μg/m³)**	**Source**	**NIOSH IDLH Acute Exposure Level (μg/m³)**
NOx	77.43	188	NAAQS 1-hour Primary Standard	37,600
PM/PM10	101.58	150	NAAQS 24-hour Primary Standard	5,000 [a]
SO_2	**47.2**	**26**	ATSDR Acute MRL	262,000
CO	2.18	40,250	NAAQS 1-hour Primary Standard	1,380,000
VOC	6.5	29 [b]	ATSDR Acute MRL Benzene	1,595,000
Lead	**1.58**	**0.15**	NAAQS 3-month Primary Standard	100,000
Hydrogen Chloride	728.65	2,100	CalEPA Acute REL	74,500
Hydrogen Fluoride	3.24	16	ATSDR Acute MRL	24,600
Cadmium	**0.12**	**0.03**	ATSDR Acute MRL	9,000
Mercury - total (elemental + inorganic compounds)	**2.33**	**0.6** [c]	CalEPA Acute REL	10,000
Mercury - elemental	0.47	0.6 [c]	CalEPA Acute REL	10,000
Dioxins/Furans	1.34E-05	4.20E-05	CalEPA Chronic REL/RfC [d]	NA

[a] No IDLH available, listed value is OSHA 8-hour time-weighted average
[b] Benzene values used for evaluation of general VOCs
[c] The CalEPA REL is based on elemental mercury exposures
[d] No acute health comparison or IDLH value available
IDLH: immediately dangerous to life or health
NAAQS: national ambient air quality standard
REL: reference exposure level
MRL: minimal risk level

sensation in eyes and nose, temporary dizziness, labored breathing etc.) in the most sensitive populations (e.g., infants, people with existing breathing or nervous system disorders, etc.) as well as values for health effects that would indicate an immediate danger to life or long-term health are also listed (**Table 5**). The calculations used to estimate maximum predicted residential air concentrations using reported Stericycle bypass event emission factors can be found in **Appendix C**. It is important to note that the listed uncontrolled emission factors are based directly on values developed by the EPA (EPA, 1993) before nation-wide hospital hazardous waste reduction programs (particularly addressing mercury, cadmium, and lead) were begun in 1998 (see below).

Although predicted estimates for all listed contaminant concentrations are well below established National Institute for Occupational Safety and Health (NIOSH) values for immediately dangerous contaminant levels, four of the pollutants (cadmium, mercury, sulfur dioxide, and lead) exceed available health-based acute exposure levels. These four contaminants are discussed below.

MRLs and RELs

ATSDR has developed minimal risk levels (MRLs) to provide health professionals with a reference of exposure levels to chemicals below which adverse health effects are not expected in the human population. MRLs are ideally based on the highest dose that results in a “not adverse” effect or “no observable adverse effect level” (NOAEL). There are certain chemicals that do not have an established NOAEL and the lowest dose with “minimal” or “less serious” health effects, or “lowest observable adverse effect level” (LOAEL), is used instead. MRLs are never based on serious health effects or cancerous effects. Minimal effects are those that reduce the ability of an organ or bodily system to deal with additional toxic challenge, but will not affect the function of that organ or system (e.g., itching, sneezing, running nose). Less serious health effects are those that will limit the function of the organ or system, but will not cause a person to be unable to function normally on the whole (e.g., labored breathing, cough, dizziness) (Wilbur, 1998). MRLs are derived from human studies when available, and animal studies when there is insufficient human data. When studies adequately identify a chemical dose that results in no effect, or a minimal or less serious adverse effect, that dose will be divided by a number of uncertainty factors (from as low as 10 in human studies, to as much as 3,000 in animal studies). This is done to sufficiently protect the most sensitive populations (infants, those with chronic health conditions, etc.). CalEPA reference exposure levels (RELs) are developed using the same principles as ATSDR MRLs (CalEPA, 2008).

Exposure to a level above the MRL or REL does not mean that adverse health effects will occur; rather, they are intended as a screening tool to help health professionals decide where to look more closely.

Sulfur Dioxide

Sulfur dioxide is a colorless gas with a pungent odor. It occurs as a byproduct or “off-gas” of incineration. Contact can cause eye and skin irritation. Breathing sulfur dioxide can result in nose, throat, and lung irritation. Breathing high concentrations of sulfur dioxide may result in labored breathing, inflammation of the airways, and lung damage (ATSDR, 1998b).

The acute inhalation MRL for sulfur dioxide was derived from studies in asthmatic people engaged in physical exercise. This study found that asthmatic subjects exposed to 262 $\mu g/m^3$ sulfur dioxide for 10 minutes during moderate exercise exhibited slight bronchorestriction (increased airway resistance). At this concentration, asthmatic subjects did not develop wheezing or shortness of breath (ATSDR, 1998b). The acute MRL of 26 µg/m^3 was determined by dividing the LOAEL of 262 µg/m^3 by 10 to be protective of the most sensitive population groups.

Based upon the modeled data for bypass event smoke exposure, the EEP concludes that the most sensitive individuals (those with severe respiratory disorders) may experience minor symptoms of sulfur dioxide exposure, such as nose, throat, and lung irritation.

Cadmium

Cadmium is a metal and is not destroyed during incineration. Cadmium in medical waste comes from plastic dyes (including hazard material “red bags” and containers), cadmium-containing batteries, and some electrical devices (WDOE, 2005). Breathing high levels of cadmium can severely damage the lungs. Eating food or drinking water with very high cadmium levels severely irritates the stomach, leading to vomiting and diarrhea. Long-term exposure to lower levels of cadmium in air, food, or water leads to a buildup of cadmium in the kidneys and possible kidney disease. Other long-term effects are lung damage and fragile bones (ATSDR, 2012).

The acute inhalation MRL for cadmium was derived from a study in rats, which found that rats given 100 µg/m^3 cadmium oxide (88 µg/m^3 cadmium) for 6 hours/day, 5 days/week, for 2 weeks developed mild inflammation in their lungs (measured by an accumulation in macrophage immune cells) (ATSDR, 2012). The acute MRL of 0.3 µg/m^3 was derived by dividing the LOAEL by a total of 300 to account for using an animal study, using a LOAEL, and to be protective of the most sensitive people.

Awareness of the hazards of cadmium in hospital waste has spurred several initiatives to reduce this chemical’s presence in the healthcare waste stream (NHDES, 2003; WDOE, 2005; UDSHW, 2015). These initiatives include using non-cadmium containing batteries and non-cadmium containing hazardous waste bags and containers. Furthermore, Stericycle Inc.’s red biohazard bags and liners are cadmium-free (WDOE, 2005; SH, 2015).

As the available EPA uncontrolled emission factors (EPA, 1993) used for modeling pre-date these cadmium reduction initiatives, it is very likely that the modeled data overestimate the actual cadmium emissions from the Stericycle North Salt Lake incinerator. Therefore, although estimated bypass emissions exceed available health-based standards, EEP concludes that it is unlikely that residents exposed to bypass event smoke will experience cadmium-related adverse health effects.

Mercury

Mercury is a metal and is not destroyed during incineration. Mercury in medical waste comes primarily from thermometers, sphygmomanometers (blood pressure monitors), and esophageal bougies (devices used to clear gastrointestinal restrictions) (EPA, 2002). Mercury exists in the environment in three forms: elemental, inorganic, and organic (ATSDR, 1999). Mercury pollution created by medical waste incinerators is approximately 2 - 20% elemental mercury and

80 - 98% divalent inorganic mercury compounds (mainly $HgCl_2$) (EPA, 1997; ATSDR, 1999; Pichtel, 2010). **Table 5** shows the highest estimated elemental mercury concentration (0.47 µg/m3), based upon 20% of the total mercury being in the elemental form.

Breathing elemental mercury vapors has a much greater toxic potential than inorganic compounds. Indeed, all inhalation studies that assess mercury toxicity are based upon elemental mercury (CalEPA, 2008; EPA, 1995). This is because elemental mercury is very lipid soluble (crosses animal cell walls easily) and poorly water soluble. Inorganic mercury compounds, in contrast, are very water soluble (WHO, 2003). Chemicals that are very poorly water soluble (such as elemental mercury, carbon monoxide, and hydrogen sulfide gas), penetrate deeply into the lungs and readily enter the blood stream. Chemicals that are very water soluble (such as inorganic mercury compounds, sulfur dioxide, and ammonia) dissolve in the upper airway and immediately cause mucus membrane irritation. This alerts the body that a hazard is present that must be avoided, mucus production and coughing occur, and the chemicals are prevented from entering the lungs (Casarett and Doull, 2013). In contrast, poorly lipid-soluble chemicals, such as inorganic mercury compounds, are not easily absorbed by the body and a much larger percentage is therefore harmlessly excreted as compared to elemental mercury (ATSDR, 1999).

Exposure to elemental mercury vapor can result in eye, skin, and respiratory irritation. The most serious effects of high concentration mercury vapor exposure are nervous system damage and developmental problems in infants. The current CalEPA acute REL is based upon studies of the offspring of pregnant rats exposed to elemental mercury vapor for one hour/day for six days during pregnancy. The mercury vapor exposure concentration in this study was 1,800 $\mu g/m^3$. Offspring of exposed rats showed decreased overall motor activity at three months of age compared to control animals. This decreased activity was not observed when the same offspring were again tested at 14 months of age. A combined uncertainty factor of 3,000 was used to derive the human health REL from this study, indicating substantial uncertainty to the applicability of the study’s results to human exposures.

In 1998, the American Hospital Association and the EPA began Hospitals for a Healthy Environment (H2E) which called for comprehensive pollution prevention in the healthcare sector. The H2E program became an independent, non-profit organization in 2006, and in 2008 was reorganized into Practice Greenhealth (Practice Greenhealth, 2014). One of the goals of this initiative was the virtual elimination of mercury waste in healthcare by 2005.

Mercury reduction initiatives have resulted in 75 percent reduction in mercury emissions in the U.S. between 1990 - 1993 and 2008. The sources accounting for the majority of this reduction over this timeframe are medical waste incinerators, municipal incinerators, and utility coal boilers. In 1990 - 1993, medical waste incinerators accounted for an estimated 51 tons of the total 246 tons of mercury emitted to the atmosphere by man-made sources. This amount fell to 0.2 tons/year in 2002, and to 0.1 tons/year in 2008 (EPA, 2013c).

Based upon the proportion of mercury emitted in its elemental form (2 - 20%), available medical waste incinerator emission factors pre-dating mercury reduction initiatives (EPA, 1993), and the subsequent reduction of mercury in hospital waste and incinerator emissions, the EEP concludes that actual mercury release during bypass events is far less than estimated calculations and finds that adverse health effects due to mercury in bypass smoke is unlikely to occur.

Lead

Lead is a metal and is not destroyed during incineration. Lead in medical waste comes from lead-containing batteries, radiation shielding (such as aprons), paint dyes, and autoclave indicator tape (WDOE, 2005).

The effects of lead are the same whether it enters the body through breathing or swallowing, and it can affect almost every organ and system in the body. The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system. It may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people and can cause anemia. Exposure to high lead levels can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high-levels of exposure to lead may cause miscarriage. High-level exposure in men can damage the organs responsible for sperm production.

Children are more vulnerable to lead poisoning than adults. A child who swallows large amounts of lead may develop blood anemia, severe stomachache, muscle weakness, and brain damage. If a child swallows smaller amounts of lead, much less severe effects on blood and brain function may occur. Even at much lower levels of exposure, lead can affect a child’s mental and physical growth. Exposure to lead is more dangerous for young and unborn children. Unborn children can be exposed to lead through their mothers. Harmful effects include premature births, smaller babies, decreased mental ability in the infant, learning difficulties, and reduced growth in young children. These effects are more common if the mother or baby was exposed to high levels of lead. Some of these effects may persist beyond childhood (ATSDR, 2007).

Lead exposure during bypass events

The best available science indicates that there is no safe level for lead exposure, especially for children. Currently, the best available air lead exposure guidelines were developed for the National Ambient Air Quality Standards (NAAQS). The highest residential concentration of lead during a bypass event indicates concentrations above this standard. As with cadmium and mercury, nationwide initiatives to reduce lead in healthcare waste have been in place since 1998. The most recent data on man-made lead emissions sources that include medical waste incinerators indicates a reduction from 1,010 tons/year in 1996, to 110 tons/year tons in 2008 (EPA, 2013d). Therefore, it is likely that estimated lead emissions during bypass events (based upon EPA, 1993) overestimate actual bypass event lead emissions.

As stated, the only residential guideline for lead air exposure comes from the NAAQS; however, this guideline is based on a rolling 3-month average, meaning it is most appropriately compared against three months of averaged air lead data. Therefore, this value is more appropriate for intermediate exposures (between 14 days to one year) rather than acute incidents like bypass events. To further evaluate this very short-term lead exposure, EEP has compared the estimated bypass lead exposure to the Occupational Safety and Health Administration (OSHA) 8-hour time weighted average (TWA) air lead action level of 30 µg/m^3. Values above the action level indicate the need for medical surveillance, exposure monitoring, and education (OSHA, 2015). To be protective of human variability (i.e., children's health), the EEP divided this TWA value by a standard uncertainty factor of 10 (EPA, 1993b; ATSDR, 1995). The estimated bypass lead emissions (1.58 µg/m^3) are below this modified action level (3 µg/m^3).

Therefore, based upon the likely overestimation of lead emission due to longstanding initiatives for lead waste reduction, and bypass event air lead estimation values falling below protective short-term action levels, the EEP concludes that it is unlikely that residents exposed to bypass event smoke will exhibit adverse health effects due to lead.

Lead exposure during typical incinerator operation

As stated, the best available science indicates that there is no safe level of lead exposure, especially for children. The EPA Superfund assessment guidance considers lead an unacceptable risk if predictive models indicate that greater than 5.0% of children between the ages of 6 - 84 months exceed a blood lead level (BLL) of 10 micrograms/deciliter (µg/dL) (EPA, 1998). In 2012, the CDC adopted a reference value of the 97.5th percentile of the BLL distribution among children 1 - 5 years old in the U.S. (currently 5 µg/dL) to identify children with elevated BLLs using data generated by the National Health and Nutrition Examination Survey (CDC, 2012).

To determine the percentage of children with elevated BLLs by CDC standards, the EEP used EPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK, 2015) to estimate BLLs of children between the ages of 0 - 60 months that would exceed 5 µg/dL within the community near the Stericycle incinerator. This model takes into account time spent indoors and outdoors; food and water consumption rates; biological absorption; and the lead concentrations in outdoor soil, indoor dust (estimated from outdoor soil), food, water, and air to estimate child blood lead levels. The lead concentration inputs for the model were as follows: the highest lead soil value found through sampling (19.7 ppm; UDOH, 2015), the estimated value for indoor dust based on outdoor soil (23.8 ppm), default values for consumption of lead from food (1.95 - 2.26 µg/day), default values for consumption of lead from water (4 µg/L, 0.20 - 0.59 L/day), and default values for intake of lead from air (0.1 µg/m^3). Although the default value for air lead concentration is above the concentrations calculated in **Tables 2 and 3**, multiple lead emission sources exist in this area; therefore, the default value is used to account for these added sources of air lead. Modeling indicates that the percentage of children expected to have BLLs above 5.0 µg/dL is 0.038%, with a geometric mean BLL of 1.03 µg/dL (**Table 6**). Therefore, based upon IEUBK modeling data, the EEP concludes that it is unlikely that outdoor environmental lead exposures in the incinerator area will result in adverse health effects in children.

Table 6. IEUBK-modeled child BLL for the community near the Stericycle incinerator.

Lead Exposure Route	**Lead Concentration**
Outdoor Soil	19.7 ppm
Indoor Dust	23.8 ppm
Food	1.95 - 2.26 µg/day (default)
Water	4 µg/L; 0.20 - 0.59 L/day (default)
Air	0.1 $\mu g/m^3$ (default)
Geometric Mean BLL (0 - 60 months old)	1.03 µg/dL
Percent above 5.0 µg/dL (0 - 60 months old)	0.038%

General Considerations

It is important to bear in mind that the bypass event values are estimates based upon historic meteorological data, the physical location of the facility, characteristics of the incinerator (e.g., stack height, gas temperatures), and assumptions by EPA as to the most likely by-products of incinerating the most likely type of waste in the type of incinerator used by Stericycle North Salt Lake (UDEQ, 2014d). Actual sampling data for these events is not available.

Though this toxicological evaluation concludes that it is unlikely that severe adverse health effects will occur due to exposure to bypass event smoke, the EEP recommends that residents (especially children and those with existing respiratory conditions) exercise reasonable caution and avoid direct exposure to incinerator smoke plumes during bypass events. Actions and precautions include the following:

- Move indoors if you may be in direct contact with a smoke plume outdoors.
- Close windows and doors once indoors.
- Turn off non-filtering air-handling devices that bring outdoor air inside (window fans, window A/C units and evaporative coolers) until the smoke plume dissipates.
- Regularly maintain all home heating, ventilation, and air conditioning (HVAC) filters.
- Consider a portable home air purifier unit with carbon and HEPA filtration.

UNCERTAINTIES AND LIMITATIONS

Risk evaluations often have limitations in the estimation of environmental exposures and related health risks due to uncertainties regarding exposure and toxicity. Typically, these estimates assume a "worst case scenario" of pollution and human exposure so as to be as protective of human health as possible. This section highlights the major assumptions and limitations specific to this evaluation that result in uncertainty.

- As stated previously, the direct applicability of the dioxin RSLs have substantial limitations. Indeed, neither ATSDR nor EPA have established a comparison value for dioxin inhalation due to the lack of adequate toxicological data. That said, the RSLs used here are the best available values for toxicological assessment.
- This evaluation assessed only the health risks associated with emissions from the Stericycle incinerator in North Salt Lake. There are alternate local sources for many of

the pollutants discussed in the UDOH Stericycle health studies. These include area refineries, factories, and high traffic freeways that may alter the overall health risks associated with a particular pollutant or combination of pollutants.

- While the air modeling results presented in this evaluation are based on historic meteorological and stack testing data and conservatively estimate residential air concentrations of pollutants using maximum permitted emissions, it is possible that the results over- or underestimate the true average annual air concentrations of pollutants.
- Estimates of bypass event smoke contaminant concentrations are further limited by the lack of actual sampling data and rely on EPA assumptions of the most common incinerator waste content and their incineration by-products as generated by the type of incinerator used by Stericycle North Salt Lake.

CONCLUSIONS

- Based on the available CVs, inhalation exposure to dioxins released from the Stericycle medical waste incinerator is not expected to result in adverse, non-cancer health effects. While modeled residential exposures to dioxins during Stericycle's violation of their operating permit exceeded the cancer-based RSL, cumulative exposure from the first development of the neighboring community to 2014 is not expected to result in substantial excess cancer risk.
- Based upon the highest recorded stack testing data, exposure to the mixture of chemicals emitted from the incinerator stack is not expected to result in adverse health effects.
- Compliance with new emissions regulations, effective as of October 2014, are expected to be adequately protective of human health for both cancer and non-cancer adverse health effects.
- Excess cancer risks from all contaminants that exceeded cancer-based CVs at this site (arsenic in soil and dioxin in air) are not expected to result in significant excess cancer risk.
- Exposures to bypass event smoke plumes may result in minor adverse health effects for those with severe respiratory disorders and should be reduced as much as possible.

In January 2014, the EEP reviewed the incidence of cancer among residents of portions of Bountiful, West Bountiful, Woods Cross, and North Salt Lake from 1976 to 2011 (UDOH, 2014a). Colon cancer, anal cancer among women, bone and joint cancer, cutaneous melanoma, breast cancer, and prostate cancer were elevated in the last analytical period (2006 - 2011). However, it is unlikely that elevated cancer rates in the study area can be attributed to environmental contaminants, as these cancer types are most often associated with behavioral and genetic factors and are frequently preventable. This study provides a base-line of the cancer incidence in the area and a starting point for potential future studies.

RECOMMENDATIONS

Based upon all soil and air studies at this site, the Environmental Epidemiology Program makes the following recommendations:

- Parents should watch for excessive hand-to-mouth behavior and soil-eating behavior in their young children playing in area playgrounds. Elevated arsenic levels were found in playground sand samples. These levels do not indicate an expected harm to children's health for typical child playground behavior (UDOH, 2015).
- Residents should take action to limit their exposure to lead containing materials. Soil lead levels were not elevated above health-based CVs; however, the best available science indicates that there is no safe level of lead exposure, especially for children (UDOH, 2015).
- Residents should take steps to limit direct exposure to black smoke plumes during bypass events as listed in this report. Although exposure to bypass event smoke is not expected to result in immediately dangerous health effects, the EEP recommends residents limit this exposure for themselves and their children as much as is reasonably possible.
- As many types of cancer and chronic disease are often preventable, residents are encouraged to make healthy life choices. These can include quitting smoking, maintaining a healthy diet and weight, avoiding too much sun exposure, and getting enough physical exercise.

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.
- The Davis County Health Department (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.
- In February 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/).

- In January 2014, the EEP conducted a cancer incidence statistical review for South Davis County. This document is available on the EEP's website (http://www.health.utah.gov/enviroepi/appletree/SouthDavisCounty/).
- In July 2015, the EEP released a health consultation addressing community concerns regarding soil dioxin and heavy metal contamination. This document is available on the EEP's website (http://www.health.utah.gov/enviroepi/appletree/SouthDavisCounty/).
- In July 2015, the EEP released this follow-up report to address community concerns regarding dioxin inhalation exposures, cumulative cancer risk, compliance with new federal and state emission standards, and exposures to bypass event smoke plumes.

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.

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CERTIFICATION

This Health Consultation, **Follow-up Report for the Assessments of Soil and Air Exposures to Stericycle Medical Waste Incinerator Emissions**, was prepared by the Utah Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time that this public health assessment was begun. Editorial review was completed by the Cooperative Agreement partner.

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Utah APPLETREE
ATSDR's Partnership to Promote Localized Efforts to Reduce Environmental Exposures

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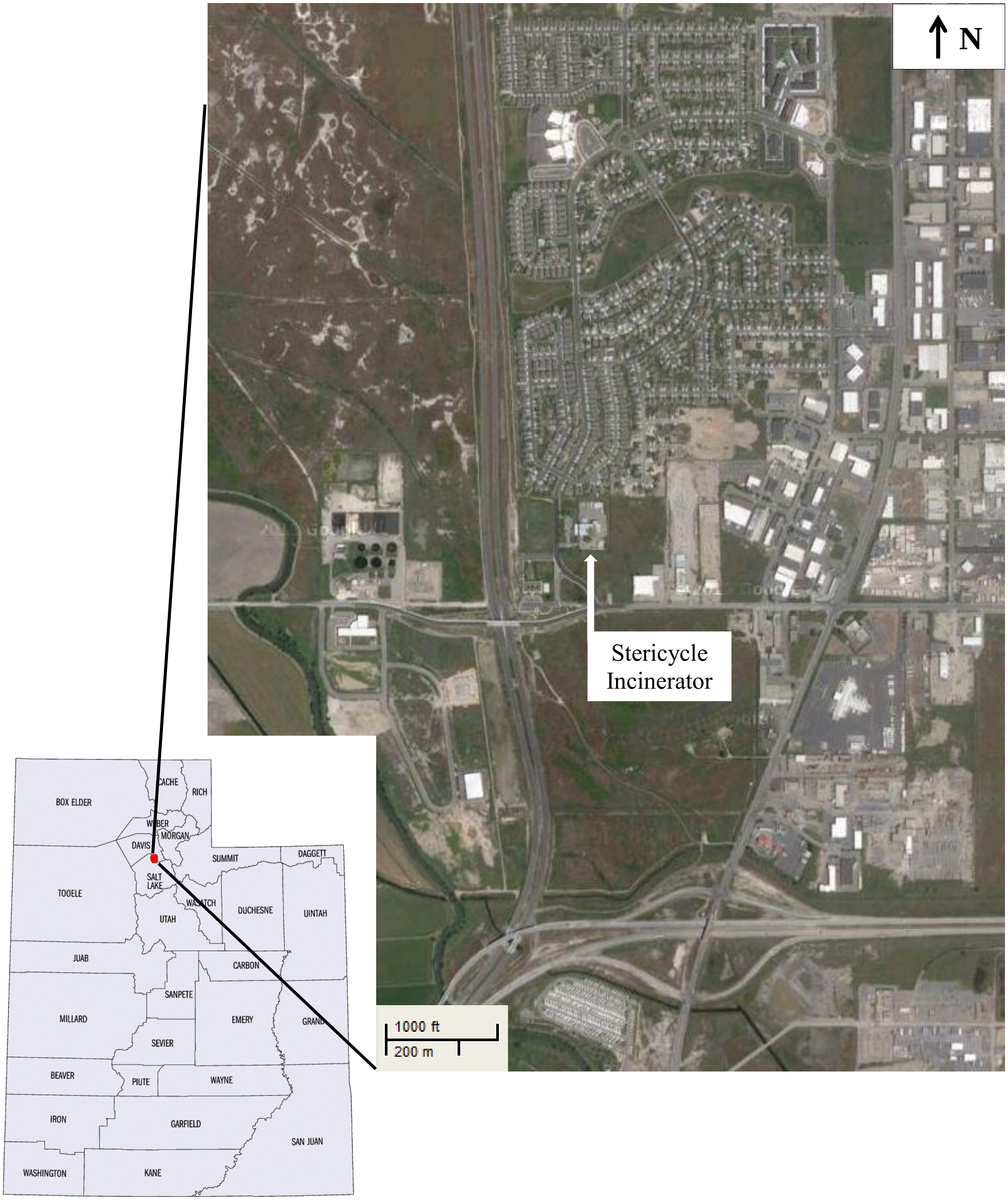
APPENDIX A: MAPS AND TABLES

Map 1: Location of the Stericycle medical waste incinerator in North Salt Lake.



Map 2: Pollutant concentration gradient out to four kilometers from the Stericycle incinerator. Map courtesy of DAQ.

The innermost, dark orange area denotes the highest predicted pollutant concentration. Bands progressing outward from orange to green to purple indicate decreasing predicted concentrations.

Map 3: Pollutant concentration gradient out to one kilometer from the Stericycle incinerator. Map courtesy of DAQ.

The innermost, dark orange area denotes the highest predicted pollutant concentration. Bands progressing outward from orange to green to purple indicate decreasing predicted concentrations.

Table A1. Emissions limits, stack test dates, and test results for the Stericycle incinerator, 2006 - 2014. Current test results and limits highlighted.

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
		10/1/2014	0.0003	0.04
Carbon Monoxide (ppmdv)	3	11/11/2009	20	40
		11/8/2012	2	40
		1/25/2013	5	40
		4/10/2013	3	40
		10/1/2014	0.2	11
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
		10/1/2014	0.4	9.3
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
		10/1/2014	0.0088	0.54
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
		10/1/2014	0.1	6.6
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
		10/1/2014	0.0003	0.036
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
		12/4/2014	0.001	0.018

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

Table A1. (cont.) Emissions limits, stack test dates, and test results for the Stericycle incinerator, 2006 - 2014. Current test results and limits highlighted.

Pollutant	Test Frequency (years) [a]	Test Date	Result	Limit
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
		10/1/2014	116	140
Particulate Matter (mg/dscm)	3	11/11/2009	2	34
		11/8/2012	25	34
		1/25/2013	20	34
		10/1/2014	4	25
Sulfur Dioxide (ppmdv)	5	10/18/2006	6	55
		12/28/2011	1	55
		1/25/2013	10	55
		10/1/2014	1.8	9

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

APPENDIX B: CANCER RISK CALCULATIONS

Excess Cancer Risk Calculations (ATSDR, 2005)

Cancer Risk = ED * IUR * (Exposure Years/70)

Where:
ED = Exposure Dose (µg/m^3). For these calculations, the ED is equivalent to the contaminant concentration.

IUR = Inhalation Unit Risk, an estimate of the theoretical increase in cancer cases in a population expressed in concentration units [(µg/m^3)$^{-1}$] to allow for comparison with site-specific air concentrations. The IUR for TCDD is 38 (EPA, 2013a).

Assumptions:
- 11 total years of exposure, from the 2003 construction of the subdivision adjacent to the incinerator to 2014.
  - Six years of exposure at the emission level when the incinerator was in violation of their operating permit.
    - The time period between the non-violating stack tests (in 2006 and 2012) that bracket the permit-violating stack test (in 2011).
  - Five years of exposure at the highest recorded emission level that did not violate Stericycle's operating permit.

Violation Cancer Risk: 7.59E-07 * 38 * (6/70) = 2.47E-06

Non-Violation Cancer Risk: 1.95E-08 * 38 * (5/70) = 5.29E-08

Total Cancer Risk: 2.47E-06 + 5.29E-08 = **2.52E-06**

APPENDIX C: AIR MODELING CALCULATIONS AND PARAMETERS

Highest <u>Historic</u> Predicted Residential Air Concentrations during Typical Operations

<u>Max Residential Air Concentration = (ER) * ECM</u>

<u>Where</u>
ER = Reported Emission Rate from emission testing analysis is in lbs./hr., then converted to grams/second. Sources of pollutant emissions rates are UDEQ, 2013a; 2013b; 2013c

ECM = Emission Rate Concentration Multiplier. The greatest residential ECM for this facility under normal controlled operations and averaged for annual exposure is calculated at 30.3 at a distance of 110 meters from incinerator.

The resulting product is the concentration in µg/m^3. This ECM was calculated for this site by DAQ using AERMOD modelling system version 13350 and design inputs as described in UDOH, 2014. Briefly, this multiplier is based upon physical characteristics of the facility (stack height, surrounding buildings, etc.) and temperature of gases and particles upon release. The following table shows the modeled calculations for predicting residential air concentrations based upon the highest historic stack test data taken under normal operating conditions.

Pollutant	**Highest lbs./hr.**	**grams/sec**	**Max Highest Conc. (µg/m^3)**
NOx	10.5	1.32E+00	4.01E+01
CO	2.90E-01	3.65E-02	1.11E+00
SO_2	3.00E-01	3.78E-02	1.15E+00
Dioxins/Furans TEQ	1.99E-07	2.51E-08	7.60E-07
Lead	2.30E-04	2.90E-05	8.78E-04
Cadmium	3.20E-05	4.03E-06	1.22E-04
Mercury	3.39E-04	4.27E-05	1.29E-03
PM	0.2664	3.36E-02	1.02E+00
HCl	2.72E+00	3.43E-01	1.04E+01

Highest Current Predicted Residential Air Concentrations during Typical Operations

Max Residential Air Concentration = (ER) * ECM

Where
ER = Reported Emission Rate from emission testing analysis is in lbs./hr., then converted to grams/second. Sources of pollutant emissions rates UDEQ, 2014c

ECM = Emission Rate Concentration Multiplier. The greatest residential ECM for this facility under normal controlled operations and averaged for annual exposure is calculated at 30.3 at a distance of 110 meters from incinerator.

The resulting product is the concentration in $\mu g/m^3$. This ECM was calculated for this site by DAQ using AERMOD modelling system version 13350 and design inputs as described in UDOH, 2014. Briefly, this multiplier is based upon physical characteristics of the facility (stack height, surrounding buildings, etc.) and temperature of gases and particles upon release. The following table shows the modeled calculations for predicting residential air concentrations based upon current stack test data taken under normal operating conditions.

Pollutant	**Current lbs./hr.**	**Grams/sec.**	**Highest Conc. ($\mu g/m^3$)**
NOx	2.73E+00	3.44E-01	1.04E+01
CO	1.38E-02	1.74E-03	5.27E-02
SO_2	4.53E-03	5.71E-04	1.73E-02
Dioxins/Furans TEQ	2.03E-10	2.56E-11	7.75E-10
Lead	4.70E-06	5.92E-07	1.79E-05
Cadmium	3.50E-06	4.41E-07	1.34E-05
Mercury	1.22E-05	1.54E-06	4.66E-05
PM	4.66E-02	5.87E-03	1.78E-01
HCl	2.20E-03	2.77E-04	8.40E-03

Maximum Predicted Residential Air Concentrations during Bypass Events

Max Residential Air Concentration = (EF*Fc) * ECM

Where
EF = Emission Factor for Pollutant, reported in lbs./ton of waste (UDEQ, 2014d).

Fc = Facility Waste Capacity (2,500 lbs./hour or 1.25 tons/hour). Multiplying the EF by 1.25 gives contaminant emission in lbs./hour. This product is then converted to grams/second before multiplying by the ECM.

ECM = Emission Rate Concentration Multiplier. The greatest residential ECM for this facility during uncontrolled (bypass) operations and calculated for instantaneous exposure 138.1 at a distance of 150 meters from the incinerator.

The resulting product is the concentration in $\mu g/m^3$. This ECM was calculated for this site by DAQ using AERMOD modelling system version 13350 and design inputs as described in UDOH, 2014. Briefly, this multiplier is based upon physical characteristics of the facility (stack height, surrounding buildings, etc.) and temperature of gases and particles upon release. The following table shows the modeled calculations for the listed contaminants for uncontrolled (bypass) events.

Pollutant	EF (lbs./ton)	Lbs./hr	grams/hr	grams/sec	$\mu g/m^3$
NOx	3.56E+00	4.45E+00	2.02E+03	5.61E-01	7.74E+01
PM/PM10	4.67E+00	5.84E+00	2.65E+03	7.36E-01	1.02E+02
SO_2	2.17E+00	2.71E+00	1.23E+03	3.42E-01	4.72E+01
CO	1.00E-01	1.25E-01	5.67E+01	1.58E-02	2.18E+00
VOCs	2.99E-01	3.74E-01	1.70E+02	4.71E-02	6.50E+00
Lead	7.28E-02	9.10E-02	4.13E+01	1.15E-02	1.58E+00
HCl	3.35E+01	4.19E+01	1.90E+04	5.28E+00	7.29E+02
Hydrogen Fluoride	1.49E-01	1.86E-01	8.45E+01	2.35E-02	3.24E+00
Cadmium	5.48E-03	6.85E-03	3.11E+00	8.63E-04	1.19E-01
Mercury	1.07E-01	1.34E-01	6.07E+01	1.69E-02	2.33E+00
Dioxins/Furans	6.14E-07	7.68E-07	3.48E-04	9.67E-08	1.34E-05

APPENDIX D: ACRONYMS AND DEFINITIONS

ATSDR Agency for Toxic Substances and Disease Registry.

BLL Blood lead level.

CalEPA California Environmental Protection Agency.

CDC The Centers for Disease Control and Prevention.

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. 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.

DCHD Davis County Health Department.

dscm Dry standard cubic meter of gas.

DAQ Division of Air Quality, within the Utah Department of Environmental Quality.

EEP Environmental Epidemiology Program, within the Utah Department of Health.

EMEG Environmental media evaluation guide. Concentrations of substances 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.

HCl Hydrogen chloride gas.

HI A hazard index is the sum of hazard quotients for substances that affect the same target organ or organ system. Because different pollutants can cause similar adverse health effects, it is often appropriate to combine HQs associated with different substances. If an HI is calculated to be equal to or less than 1.0, then adverse, non-cancer health effects over a lifetime of exposure are not expected. However, an HI greater than 1.0 does not necessarily suggest a likelihood of adverse effects due to the inherent conservative nature of the involved comparison values (e.g., EMEGs, RfCs, etc.).

HQ A hazard quotient is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected. If the HQ is calculated to be equal to or less than 1.0, then no adverse health effects are expected as a result of exposure. If the HQ is greater than 1, then adverse health effects are possible. The HQ cannot be translated to a probability that adverse health effects will occur and it is unlikely to be proportional to risk. It is especially important to note that an HQ exceeding 1 does not necessarily mean that adverse effects will occur.

IDLH Immediately dangerous to life or health. A NIOSH defined level of exposure to airborne contaminants that is likely to cause death or immediate or delayed permanent adverse health effects, or prevent escape from such an environment.

IEUBK Integrated Exposure Uptake Biokinetic Model for Lead in Children, developed by EPA to estimate blood lead levels in children.

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^3 Cubic meter.

mg Milligram. One thousandth of a gram.

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.

NAAQS National Ambient Air Quality Standards.

NAAQS Primary Standard An ambient air quality standard that provides public health protection, including the health of at-risk populations (e.g., asthmatics, children, and the elderly).

NIOSH National Institute for Occupational Safety and Health.

ng Nanogram. One billionth of a gram.

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.

NO_X Nitrogen oxides. A mixture of gases composed of nitrogen and oxygen, the most toxicologically significant of which are nitric oxide (NO) and nitrogen dioxide (NO_2).

OSHA Occupational Safety and Health Administration.

PM Particulate matter.

PM_{10} Particulate matter with a diameter of 10 micrometers or less.

ppm Parts per million.

ppmdv Parts per million by dry volume.

RfC Reference concentration. An EPA estimate of the continuous inhalation exposure that is likely to be without an appreciable risk of adverse effects during a lifetime.

RSL Regional screening levels are risk-based comparison values developed by EPA derived from standardized equations combining exposure information assumptions with EPA toxicity data. RSLs are intended to aid in deciding which contaminants warrant further investigation or site cleanup. Their usage is similar to ATSDR comparison values.

SO_2 Sulfur dioxide.

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

TEF Toxic equivalency for dioxins/furans. 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.

TWA Time-weighted average. A calculated exposure level that takes into account average levels of a substance and the time spent in a contaminated area.

UDEQ Utah Department of Environmental Quality.

UDOH Utah Department of Health.

μg Micrograms. One millionth of a gram.