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Summary of
Air Sample Results
for Residences Along Red Butte Creek

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Summary of Air Sample Results for Residences along Red Butte Creek

On behalf of Salt Lake City, air sampling was conducted along Red Butte Creek from June 18, 2010 to August 10, 2010. This report summarizes the data that were collected, and provides an interpretation of the results based on comparison to national health-based screening levels and to background levels for indoor and outdoor air. Sampling was conducted at the direction of the City in response to health and odor concerns from Red Butte Creek as a result of the June 12, 2010, oil spill and subsequent cleanup. Chemicals analyzed in the air were those considered by health agencies to be the most representative of health risks from air emissions from a petroleum spill. The results of the analyses were compared to national data on background levels and protective public health screening levels. With the exception of outdoor samples affected by cleanup crews on the creek and a location with exposed oil on the creek bank, the chemicals sampled were generally not detected at levels above background that would indicate a health concern for residents.

Air Sampling Procedures

Air sampling was conducted by IHI Environmental at the request of Salt Lake City. Samples were collected at properties along Red Butte Creek in response to residents' concerns or because of oil cleanup crews working in the creek. Sampling in June (18–24) and early July (1–9) used passive dosimeters (charcoal tubes), which absorbed chemicals in air over the sampling period. Dosimeters were set out the first day and collected the second day and sent to a laboratory for analysis of the amount of absorbed chemical. These samplers were useful for evaluating whether short-term exposures may be a concern during the cleanup of the creek, but were not able to detect lower levels of hydrocarbon chemicals near background levels and lower health-based screening levels protective of long-term exposures. Five residences were sampled using passive dosimeters. Air was sampled indoors and outdoors at each residence. One of these residences was sampled on three different days, but the results were similar. An additional dosimeter sample was collected at Miller Park near the cleanup crews.

Subsequent sampling in July (7–26) and August (4–10) was conducted with a more sensitive method using Summa canisters to collect air over an approximately 2-hour period. The air was then analyzed by a laboratory. Samples were collected using this method at six residences and at one location on the creek near the cleanup crews. Most residences had both indoor and outdoor air sampled, but one residence had only indoor air sampled and one had only outdoor air sampled. Some of the residents had two or more samples collected indoors and outdoors at different locations. Sampling using the Summa canisters was conducted during the day, except for one residence that had a subsequent outdoor sampling event on August 10 to capture potential emissions from the creek at night.

Data are also presented for a sampling event on October 28 and November 1, 2010 using Summa canisters at a location approximately 0.5 miles north of Liberty Lake. This sample location is more representative of the general local area because of its distance from Red Butte Creek and Liberty Lake. Sampling was conducted in this area as part of air monitoring prior to the draining and remediation of Liberty Lake. The sample on October 28 was collected during midday from 10:20 am to 12:20 pm and the sample on November 1 was collected from 7:15 am to 9:15 am, during the morning commute time.

Sample Results

Results of the air sample analysis from the laboratory were provided by IHI Environmental. Benzene, toluene, ethylbenzene, and xylenes were analyzed in all passive dosimeter samples. Hexane and naphthalene were also included in the analysis of samples from the last residence sampled using passive dosimeters on July 8-9. These specific chemicals were analyzed because they are generally considered to be of most concern for exposures to petroleum hydrocarbon emissions from crude oil and because they have established health-based levels to evaluate potential health concerns. Summa canister samples were analyzed for hexane, heptane, benzene, ethylbenzene, toluene, xylenes, and naphthalene.

Total hydrocarbons were also quantified in the passive dosimeter samples and volatile organic compounds (VOCs) were also quantified in Summa canister samples. These measures are general indicators of combined levels of a wide variety of chemicals emitted from petroleum as well as non-spill-related and natural sources. There are no applicable health-based levels for these general measures.

Evaluation of Passive Dosimeter Results

The passive dosimeter samples had no detectable levels for the specific chemicals at the limits of detection of this method (Table 1). A few results for total hydrocarbon compounds were detectable. The highest level was detected in an indoor air sample (810 parts per billion, ppb) for which the corresponding outdoor sample was undetectable at a much lower level (<79 ppb). Thus, the source of this hydrocarbon air level does not appear to be related to outdoor air. The next highest indoor air sample for total hydrocarbons was considerably lower (130 ppb) and slightly above the highest outdoor air sample (110 ppb; Table 1). Sample results for Miller Park, near the cleanup crews, were also undetectable for the specific chemicals, although the limits of detection were higher than for the residential samples. The total hydrocarbon level at Miller Park was higher than the highest outdoor residential air sample, likely reflecting emissions from the cleanup.

The passive dosimeter results were compared to short-term screening levels developed by the Agency for Toxic Substances and Disease Registry (ATSDR) for protection of public health for various exposure periods: short (less than 14 days), intermediate (14 to 364 days), and chronic (more than 1 year to a lifetime) (Table 1). Although the sampling investigation using this methodology was intended to evaluate short-term exposures during the cleanup phase (i.e., probably lasting only a day or a few days near any one home), chronic screening levels (e.g., for exposures lasting more than a year to a lifetime) were included because some chemicals lacked acute or intermediate screening levels. These screening levels are based on health endpoints other than cancer, which is less of a concern for short-term compared to long-term exposure. ATSDR uses these screening levels as indicators of whether additional investigation and assessment may be warranted. No such screening levels are available for total hydrocarbons. When individual chemicals were not detected, the limits of detection were compared to the health-based screening levels. When a chemical is not detected, any amount present would be below the limit of detection, but the specific amount, if any, is unknown.

Based on the limits of detection, air levels of the measured chemicals in indoor and outdoor air were below the acute screening levels (protective of short-term, or less than 14 days of exposure), likely below the intermediate screening levels (protective of medium-term, or 14 to 364 days of exposure), and possibly below the chronic screening levels (protective of noncancer effects for long-term, or 1 year to a lifetime). The detection limit for benzene was slightly above the intermediate screening level, whereas the detection limits for hexane, ethylbenzene, toluene, and xylenes were below all of the screening levels. Naphthalene could not be evaluated for short-term exposure because it lacked acute and intermediate screening levels and the chronic screening level (0.7 ppb) was lower than the limit of detection (<11 ppb). Levels of total hydrocarbons (which would also include the specific chemicals measured) were generally low compared to the screening levels for the specific chemicals of greater health concern. Thus, these results overall do not indicate health concerns for the relatively short-term exposure to the chemicals sampled during the cleanup of the creek.

Evaluation of Summa Canister Results

The Summa canister sampling methodology had lower limits of detection and thus air concentrations of chemicals were reported at lower levels than could be achieved using the passive dosimeters (Table 2). This more sensitive sampling methodology was in most cases used after the cleanup phase, with a few exceptions such as the sample taken near cleanup crews on the creek on July 7. Indoor and outdoor data for the residences summarized in Table 2 do not include the sample taken creekside near the cleanup crew or samples taken outdoors at a residence that had exposed oil remaining on the creek bank. Results for these samples are presented separately. Concentrations are higher overall for samples with an obvious emission source compared to the other outdoor residential samples (Table 2). The corresponding indoor air sample for the location with residual oil on the creek bank did not appear elevated compared to other residential samples and was therefore included in the summary of residential data.

Concentrations of individual chemicals were compared to lower health-based screening levels intended to be protective of long-term exposure by the general public (including children and other potentially sensitive subpopulations). Such levels have been developed by the U.S. Environmental Protection Agency (EPA), ATSDR, and the California Environmental Protection Agency. These screening levels are typically used as indicators of whether additional investigation and assessment may be warranted.

Because petroleum hydrocarbon compounds occur widely in indoor and outdoor air from fuel uses, consumer products, and building materials, comparison to background levels is also useful for understanding whether levels of these chemicals are possibly elevated as a result of emissions from the spill. This comparison is approximate because specific pre-spill measurements of these chemicals are unavailable for the properties sampled or for the Salt Lake City area.

Air levels of most chemicals measured at the properties do not indicate health risks above normal background risks. Indoor air samples of chemicals tended to be higher than outdoor air samples at the same location. This result is expected due to the many indoor sources of these chemicals from consumer products, building materials, and off-gassing of fuel from vehicles in attached garages. Measured indoor air levels of residences were within summaries of background indoor air levels in national surveys (Table 3; Figures 1a and 1b). Sample results were also below the health-based screening levels, except for the EPA Regional Screening Levels (RSLs) for benzene and ethylbenzene. RSLs for these two chemicals and naphthalene are based on protection at an increased cancer risk of one chance in a million, which is the most protective end of EPA's target lifetime risk range of 1 in 1,000,000 to 1 in 10,000. The RSLs are below or within background levels for these chemicals. The benzene and ethylbenzene levels measured were consistent with background levels, and did not exceed screening levels based on protection from noncancer effects. Naphthalene was not detected in the indoor air samples, although the detection limit was above the health-protective screening level based on cancer risk.

Outdoor sample concentrations for specific chemicals measured at residences were similar to concentrations in the local area samples and were within national background levels, with the exception of one detected sample of naphthalene (Table 4; Figures 1a and 1b). This detected sample also raised the mean level for the residential samples of naphthalene (Table 4). Benzene and ethylbenzene measurements exceeded the most stringent of the screening levels based on cancer risk, but were at background levels and did not exceed health screening levels based on noncancer effects.

Naphthalene was detectable at one of the four residences, although the detection limit was above background levels. The detection limit for naphthalene during the summer measurement period was also higher than the detection limit achieved by the laboratory in late October and early November for the local area sampling location. The detectable outdoor naphthalene sample at a residence on July 8 exceeded the naphthalene health screening level based on cancer risk, as well as one of the health screening levels based on noncancer effects. The corresponding indoor naphthalene level at this property on that date was undetectable. Cleanup was ongoing in the creek when this sample was taken, although not close to this residence. The sample may reflect emissions from turbulence caused by a small waterfall on the creek at this location. Although the measured naphthalene level outdoors likely was related to the oil spill, naphthalene is also present in air from common sources such as burning fossil fuels, wood, and cigarettes, and from its use in moth repellants. The measured concentration at 0.84 ppb is within reported air levels from other naphthalene sources (e.g., average of 0.86 ppb reported inside cars in traffic) and 100 times below the odor threshold of 84 ppb.[1]

[1] Agency for Toxic Substances and Disease Registry. 2005. Chapter 4 Chemical and physical information, Chapter 6 Potential for human exposure. In: Toxicological Profile for Naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene. Available at: http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=240&tid=43.

For outdoor samples with apparent emission sources (i.e., near cleanup crews or samples at a location with residual oil on the creek bank; Table 2), levels of the specific chemicals were generally at the upper end of background ranges (Table 4). VOC levels were also higher than in other samples (Table 2). Sample results for hexane, benzene, toluene, ethylbenzene, and xylenes did not exceed long-term health-based screening levels for noncancer effects, and thus would also not be a concern in comparison to short-term or intermediate-term health screening levels. Exposure to naphthalene for less than a year could not be evaluated because of the lack of established health-based screening levels for acute or intermediate exposure. The naphthalene level near the crews on the creek exceeded all long-term screening levels for cancer risk and noncancer effects for the general public. However, these health-protective screening levels assume 24-hour a day, long-term exposure, which is not the case for exposures near the crews or for the outdoor sample location near the residual oil on the bank.

Conclusions

Overall, air concentrations of chemicals measured at the properties do not indicate health concerns for exposures during the cleanup phase for the oil spill in the creek. Measurements using the more sensitive Summa canister method after the cleanup phase in mid July to August indicate health risks within background risks for even long-term exposure to the chemicals of concern for air emissions from oil. A possible exception is the elevated outdoor air levels for some chemicals at a location with residual oil remaining on the creek bank. A few samples taken near cleanup crews on the creek also showed elevated levels of some chemicals and total hydrocarbons or volatile organic compounds; however, levels are unlikely to be a concern for shorter-term exposures.

The attached question and answer sheet provides more information on how volatile emissions from petroleum spills are evaluated, and on the basis of the health-based screening levels and background air levels.

The conclusions of this summary report are limited to the air samples collected and resulting analysis. A more detailed health study including potential exposures shortly after the spill is being developed by the Salt Lake Valley Health Department and the Utah State Department of Health.

Table 1. Passive dosimeter air sample results in comparison to health-based screening levels (parts per billion)

	Hexane	Benzene	Toluene	Ethyl-benzene	Xylenes	Naphthalene	Total Hydrocarbons
Residence Indoor Data							
Number detected/number sampled[a]	0/1	0/5	0/5	0/5	0/5	0/1	3/5
Minimum	<63	<6.2	<59	<59	<59	<11	<53
Mean[b]	<63	<6.5	<62	<62	<62	<11	202
Maximum[c]	<63	<7.3	<70	<70	<70	<11	810
Residence Outdoor Data							
Number detected/number sampled[a]	0/1	0/5	0/5	0/5	0/5	0/1	1/5
Minimum	<63	<6.2	<59	<59	<59	<11	<53
Mean[b]	<63	<6.6	<63	<63	<63	<11	38
Maximum[c]	<63	<8.8	<85	<85	<85	<11	110
Miller Park (in area near crews)	NA	<10	<100	<100	<100	NA	190
ATSDR minimal risk level[d]							
Acute	--	9	1,000	10,000	2,000	--	--
Intermediate	--	6	--	700	600	--	--
Chronic	6,000	3	80	300	50	0.7	--

Note: The symbol "<" indicates that the result is less than the analytical limit of detection.
-- - not available
NA - not analyzed

[a] Number of residences with detectable results out of the number of residences sampled. Minimum and maximum values are for the total number of samples which is greater than the number of residences because of multiple samples for some residences

[b] Multiple results for indoor air or outdoor air at a residence were averaged before calculating the overall mean among residences for indoor or outdoor air data. Multiple results for a residence were generally similar. Undetected results were included at half the detection limit unless all samples were undetectable, then mean of detection limits is presented.

[c] Maximum detected value shown if available, or highest detection limit if no samples had detectable levels.

[d] Minimal risk levels by the Agency for Toxic Substances and Disease Registry (ATSDR) are protective of public health from noncancer health effects based on acute exposure (less than 14 days), intermediate exposure (14 days to 364 days), or chronic exposure (more than 1 year).

Table 2. Summary of Summa canister air sample results (parts per billion)

	Hexane	Heptane	Benzene	Toluene	Ethylbenzene	Xylenes[a]	Naphthalene	Total VOCs
Residence Indoor Data								
Number detected/number sampled[b]	4/5	4/5	4/5	5/5	4/5	5/5	0/5	5/5
Minimum	<0.13	<0.11	<0.10	0.72	<0.087	0.71	<0.50	100
Mean[c]	0.60	0.30	0.41	2.5	0.30	1.6	<0.50	154
Maximum[d]	1.4	0.71	0.60	4.7	0.78	3.9	<0.50	260
Residence Outdoor Data								
Number detected/number sampled[b]	3/4	1/4	3/4	4/4	1/4	4/4	1/4	4/4
Minimum	<0.13	<0.11	<0.10	0.76	<0.087	0.30	<0.50	80
Mean[c]	0.45	0.082	0.27	0.93	0.088	0.81	0.40	113
Maximum[d]	0.86	0.27	0.53	1.6	0.22	2.0	0.84	170
On creek near cleanup crews	0.97	0.51	1.4	7.0	1.4	12	3.4	710
Residual oil present (outdoor deck)	0.76	0.40	1.2	1.8	<0.087	0.25	<0.50	93
Residual oil present (creek bank)	0.80	0.62	1.8	7.8	1.1	7.6	1.3	490

Note: The symbol "<" indicates that the result is less than the analytical limit of detection and not detectable.

[a] Total xylenes includes results for m,p-xylene and o-xylene that were measured separately and summed. One-half of the detection limit was used for undetected results.

[b] Number of residences with detectable results out of the number of residences sampled. Minimum and maximum values are for the total number of samples which is greater than the number of residences because of multiple samples for some residences.

[c] Multiple results for indoor air or outdoor air at a residence were averaged before calculating the overall mean among residences for indoor or outdoor air data. Multiple results for a residence were generally similar. Undetected results were included at half the detection limit unless all samples were undetectable, then mean of detection limits is presented.

[d] Maximum detected value shown if available, or highest detection limit if no samples had detectable levels.

Table 3. Summary of Summa canister results for indoor air in comparison to chronic health-based reference levels and measured ranges of background levels (parts per billion)

	Hexane	Heptane	Benzene	Toluene	Ethylbenzene	Xylenes	Naphthalene
Minimum residence concentration	<0.13	<0.11	<0.10	0.72	<0.087	0.71	<0.50
Mean residence concentration	0.60	0.30	0.41	2.5	0.30	1.6	<0.50
Maximum residence concentration	1.4	0.71	0.60	4.6	0.78	3.9	<0.50
CalEPA reference exposure level[a]	2,000	--[b]	20	70	400	200	2
ATSDR minimal risk level[c]	600	--[b]	3	80	300	50	0.7
EPA regional screening level[d]	207	--[b]	0.1	1,383	0.2	168	0.01
Indoor background[e]							
Median	--	--	0.72	2.9	0.34	1.4	ND
75th percentile	--	--	1.1	5.6	0.57	2.2	ND
90th percentile	--	--	3.4	14	1.7	6.5	0.5

Note: The symbol "<" indicates that the result is less than the analytical limit of detection and not detectable.
Health-based reference levels are based on protection of the general public, including long-term exposure and sensitive subgroups.

-- - not available
ND - not detected; detection limits vary

[a] Reference exposure levels developed by the California Environmental Protection Agency (CalEPA) based on long-term noncancer health effects.

[b] Reference exposure levels and regional screening levels for hexane, which is more toxic, can be used to screen values for heptane.

[c] Minimal risk levels for chronic exposure developed by the Agency for Toxic Substances and Disease Registry (ATSDR) based on long-term noncancer health effects.

[d] Regional screening levels developed by the U.S. Environmental Protection Agency (EPA). The regional screening levels for benzene, ethylbenzene, and naphthalene are based on cancer risk, and are protective to a 1 in 1,000,000 cancer risk level. The hexane, toluene, and xylenes regional screening levels are based on noncancer health effects.

[e] MADEP. 2008. Residential typical indoor air concentrations. Massachusetts Department of Environmental Protection, Boston, MA.

Table 4. Summary of Summa canister results for outdoor air in comparison to chronic health-based reference levels and measured ranges of background levels (parts per billion)

	Hexane	Heptane	Benzene	Toluene	Ethylbenzene	Xylenes	Naphthalene
Minimum residence concentration	<0.013	<0.11	<0.10	0.76	<0.087	0.30	<0.50
Mean residence concentration	0.43	0.082	0.27	0.93	0.088	0.81	0.40
Maximum residence concentration	0.86	0.27	0.53	1.6	0.22	2.0	0.84
CalEPA reference exposure level[a]	2,000	--[b]	20	70	400	200	2
ATSDR minimal risk level[c]	600	--[b]	3	80	300	50	0.7
EPA regional screening level[d]	207	--[b]	0.1	1,383	0.2	168	0.01
Local area[e]							
Oct 28, 10:20 am to 12:20 pm	0.18	0.12	0.32	0.9	0.072	0.32	<0.05
Nov 1, 7:15 to 9:15 am	0.69	0.29	0.75	3.1	0.24	1.41	<0.05
National outdoor background[f]							
Annual average	0.28	0.1	0.309	0.78	0.081	0.31	0.012
Range	0.015−8.97	0.01−1.09	0.005−2.43	0.007−36.9	0.005−1.4	0.009−6.4	0.00001−0.04

Note: The symbol "<" indicates that the result is less than the analytical limit of detection and not detectable.
Health-based reference levels are based on protection of the general public, including long-term exposure and sensitive subgroups.
-- - not available

[a] Reference exposure levels developed by the California Environmental Protection Agency (CalEPA) based on long-term noncancer health effects.

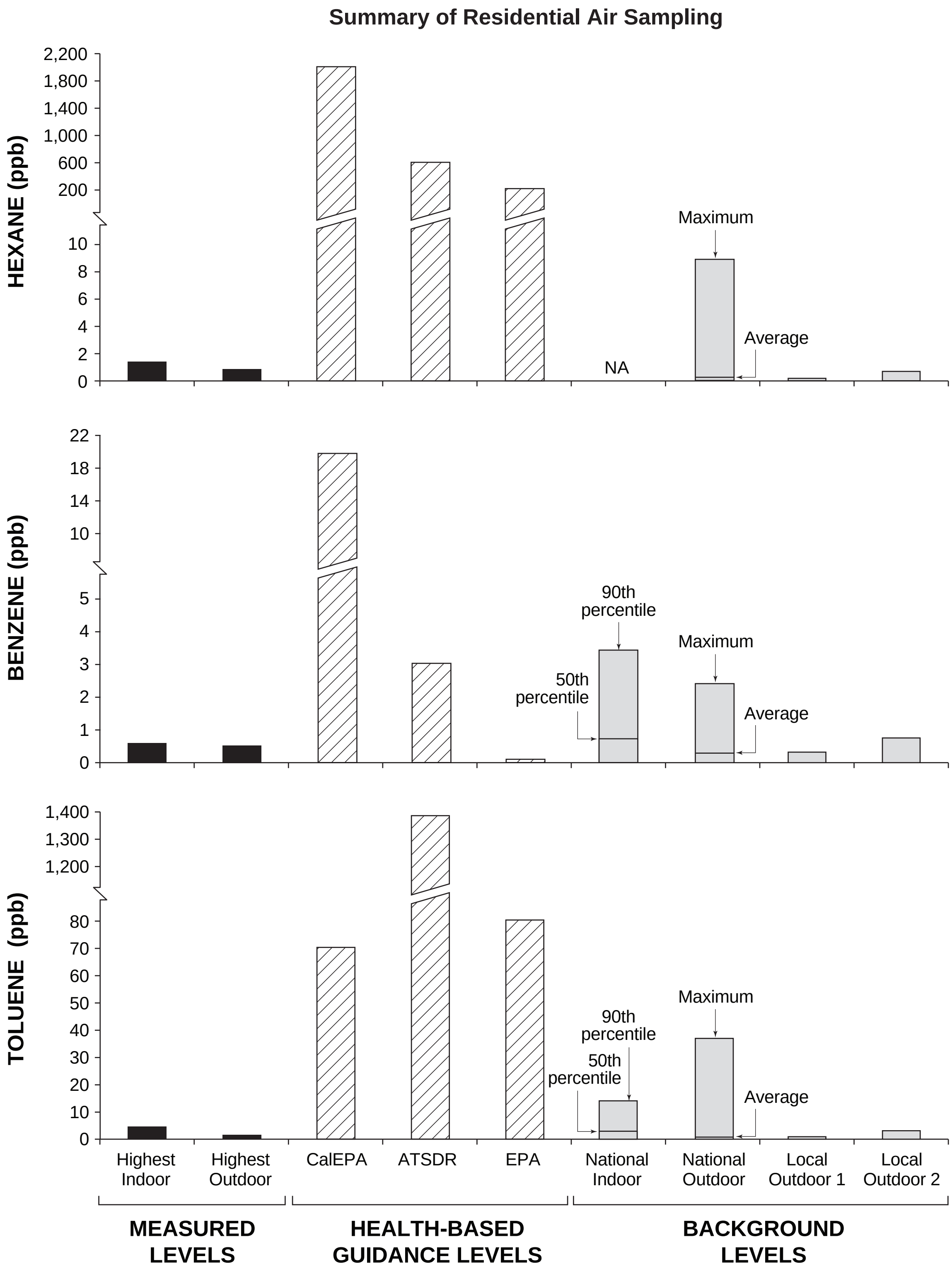
[b] Reference exposure levels and regional screening levels for hexane, which is more toxic, can be used to screen values for heptane.

[c] Minimal risk levels for chronic exposure developed by the Agency for Toxic Substances and Disease Registry (ATSDR) based on long-term noncancer health effects.

[d] Regional screening levels are developed by the U.S. Environmental Protection Agency (EPA). The benzene, ethylbenzene, and naphthalene regional screening levels are based on cancer and are protective to a 1 in 1,000,000 cancer risk level. The hexane, toluene, and xylenes regional screening levels are based on noncancer health effects.

[e] Measured near East 900 South and South 700 East, about a half mile north of the north end of Liberty Lake.

[f] U.S. EPA. 2008. 2007 National Monitoring Programs (UATMP and NATTS) Volume 1: Main Content (December 2008). EPA-454/R-08-008a. Available at: http://www.ntis.gov/search/product.aspx?ABBR=PB2009105239.

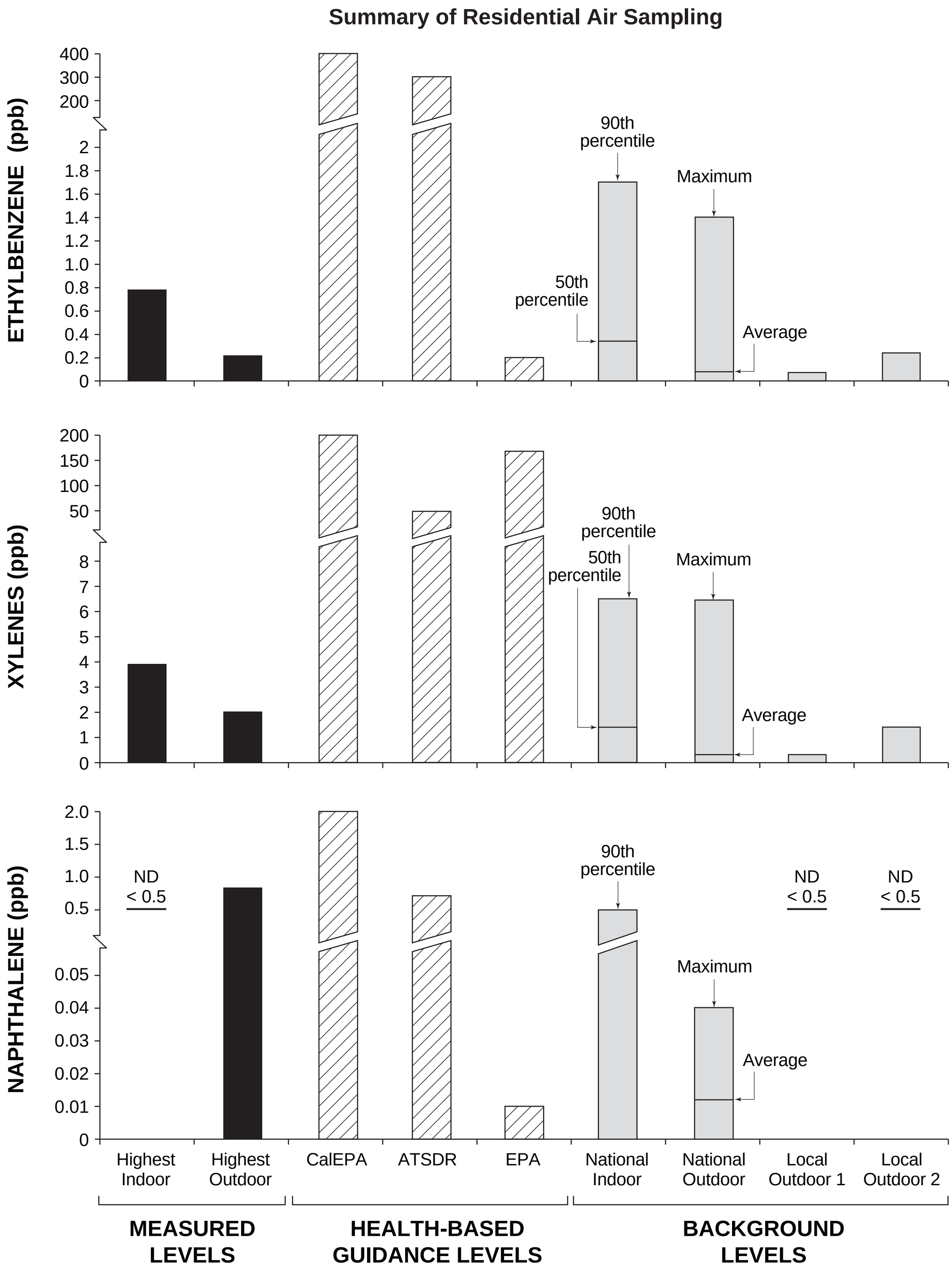


ppb – Parts per billion
NA – Not available
ATSDR – Agency for Toxic Substances and Disease Registry
CalEPA – California Environmental Protection Agency
EPA – U.S. Environmental Protection Agency

Notes: Measured concentrations from residential air sampling using Summa canisters (Table 2).

Health-based guidance levels are based on protection of the general public, including long-term exposure and sensitive subgroups.

Figure 1a. Comparison of measured air concentrations of hexane, benzene, and toluene to health-based guidance levels and background levels



ppb – Parts per billion
NA – Not available
ATSDR – Agency for Toxic Substances and Disease Registry
CalEPA – California Environmental Protection Agency
EPA – U.S. Environmental Protection Agency

Notes: Measured concentrations from residential air sampling using Summa canisters (Table 2).

Health-based guidance levels are based on protection of the general public, including long-term exposure and sensitive subgroups.

Figure 1b. Comparison of measured air concentrations of ethylbenzene, xylenes, and naphthalene to health-based guidance levels and background levels

Attachment A

Answers to Frequently Asked Questions on Air Sampling of Chemicals from the Red Butte Spill

Answers to Frequently Asked Questions on Air Sampling of Chemicals from the Red Butte Spill

What airborne chemicals come from crude oil?

Crude oil is a mixture of hundreds of chemicals that are called petroleum hydrocarbons because nearly all contain only carbon and hydrogen. The lighter, more volatile fraction of chemicals will be released into air from a spill. The amount of each chemical in air depends on its volatility and concentration in the oil, and to some extent the environmental conditions (e.g. temperature, wind speed). Highly volatile chemicals will initially reach higher air concentrations, but will decrease with dissipation in ambient air, breakdown in sunlight, and with depletion from the exposed oil. Less volatile chemicals will be emitted more slowly from the oil resulting in lower peak air concentrations. Among the volatile chemicals emitted from oil, some are simple, relatively short chains of carbon and hydrogen atoms (such as propane or butane). Others may have more branching of carbon connections, or can form more complex ring structures (like benzene, or double rings like naphthalene, a chemical also used in mothballs). In general, the larger, heavier carbon structures will be less likely to be released to air.

How do health professionals characterize the toxicity of these chemicals?

In characterizing the potential health effects of chemicals, health professionals review data from people exposed in the workplace or through accidents or intentional uses of these chemicals, as well as data from studies in animals and in isolated tissues or cells. To identify health-protective levels for use in evaluating air levels of chemicals for potential risks, a weight of evidence approach is used in which all information is considered to understand how an agent causes toxic effects and to identify the most sensitive endpoints (i.e., the effects occurring at the lowest doses). This analysis also considers particularly sensitive populations like children or people with asthma, and areas of uncertainty.

Health studies have focused on mixtures of petroleum hydrocarbons, such as gasoline, kerosene, mineral spirits, groups of similar hydrocarbon compounds, and on selected individual compounds of specific toxicological interest. In general, the more volatile oil fraction has had more well-characterized compounds than the heavier hydrocarbon fractions, although few individual compounds overall have been studied extensively. Many of the hydrocarbons are grouped into classes because of their similar chemical and toxicological properties. In general, individual chemicals with higher toxicity have been studied more extensively.

What are some of the effects of concern?

The simple, short-chain hydrocarbons, such as butane used in lighters, are readily absorbed into the bloodstream when inhaled, but they also are rapidly cleared from the body, causing little toxicity except at very high doses that may cause confusion, drowsiness, sleep, or asphyxiation if oxygen levels are depleted. Because these short-chain hydrocarbons are also flammable, risk of explosion hazard may be reached before serious toxicity occurs. High airborne levels of hydrocarbons with five to nine carbon atoms can cause irritation to the eyes and mucous membranes, central nervous system depression, and effects on hearing. Toxicity within this group tends to increase with hydrocarbon chain length, except for the compound with six carbons in a row, i.e., hexane.

Within the class of simple hydrocarbon chain compounds, hexane stands out as having unique effects at lower doses than the other chemicals in the class by affecting nerves in the extremities of the limbs. This chemical is thus typically evaluated independently from the rest of the simple chain hydrocarbons or can be used as a worst-case representative of the class.

The aromatic ring structure compounds are generally considered more toxic than the non-aromatic aliphatic (straight chain or branched chain) or alicyclic (forming a ring but not sharing electrons as in aromatic compounds) carbon compounds. Individual chemicals of toxicological concern for air sampling within the aromatic group are benzene, toluene, ethylbenzene, xylene, and sometimes naphthalene. Among these chemicals, repeated exposures to high levels of benzene have been found to affect the blood forming system thereby reducing immune cell counts in the blood, and increasing the risk of leukemia in both humans and animals. Ethylbenzene and naphthalene have not been associated with cancer in humans but have been shown to cause tumors in rats or mice exposed to high airborne levels over their lifetime. Xylene and toluene are not considered to be carcinogenic and thus are assessed based on their non-cancer effects, including adverse effects on the central nervous system, liver, and kidney with long-term exposure to elevated concentrations.

How do health effects from short-term versus long-term exposure differ?

Hydrocarbon compounds in both the aliphatic and aromatic classes are associated with immediate effects at sufficiently high airborne levels. Health effects that have been commonly reported in scientific studies include central nervous system depression, dizziness, headache, and abdominal effects such as nausea and vomiting. Thus, although air monitoring data right after the spill are limited, these reported effects, particularly in residents closest to the creek, are consistent with acute airborne exposures from petroleum hydrocarbon compounds. Hydrocarbon compound levels measured with time since the spill have indicated much lower levels that are not expected to be associated with these high dose effects.

The Salt Lake Valley Health Department and the Utah State Department of Health are undertaking a health study to assess health impacts of residents resulting from the spill. This study will also evaluate exposures since the spill and the potential for long-term health risks as a result of residents' short-term exposures.

In developing health-protective screening levels for air, much lower levels are needed to be protective of public health for long-term versus short-term exposure. Exposures to levels of hydrocarbons that may be tolerated for a short period without lasting effects would not be protective of repeated exposures over a long time period. Repeated exposures to such higher air levels can overwhelm the body's defenses, resulting in health effects. The Agency for Toxic Substances and Disease Registry (ATSDR; part of the Centers for Disease Control and Prevention) has developed different health-based screening levels (minimal risk levels, MRLs) for the general public depending on the length of the exposure period: acute (less than 14 days), intermediate (14 days to 364 days), and chronic (more than 1 year to a lifetime). The MRLs are based on protection from noncancer health effects, the primary concern for short-term exposures. By comparison, the U.S. Environmental Protection Agency (EPA) has developed criteria protective of noncancer effects that are protective of chronic exposure, defined as more than 6 years to a lifetime. EPA has also developed health criteria based on cancer risk for chemicals that may cause cancer.

At the Enbridge, Michigan, Oil Spill site, the health agencies used various short-term screening levels for decision-making in protecting public health after the spill. EPA used a screening level of 200 parts per billion (ppb) benzene in a single sample or an average of 60 ppb benzene[1] in three samples for determining whether residents needed to be evacuated from their homes. EPA used the ATSDR MRL for intermediate exposure (6 ppb benzene) to determine whether it was safe for residents at the Enbridge site to return to their homes. The 6 ppb level, which is considered safe for up to a year of exposure, was presumably used because levels were expected to continue to decrease over time.

The ATSDR short-term MRLs (acute and intermediate) were used to assess results from air sampling during the cleanup phase of Red Butte Creek using passive dosimeters. This sampling methodology has relatively high detection limits, but is generally sufficient for assessing whether short-term exposures may be a health concern. By contrast, health-based screening levels protective of long-term exposure over years are being used to evaluate the residential air sampling data after the cleanup of the Red Butte spill.

An exception to the general rule on lower risk for short- versus long-term exposures is for chemicals that have target effects at certain lifestages or periods of susceptibility, such as drugs or viruses that are known to cause birth defects if exposure occurs during fetal development. The available scientific and medical evidence has not shown petroleum hydrocarbons to specifically target the fetus or children, when exposures are at low doses that are safe for lifetime exposure. Still, uncertainty in the scientific data and children's potential susceptibility must be considered in setting health-protective levels.

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[1] Of the hundreds of chemicals monitored for after the Enbridge spill, benzene was the chemical that consistently was elevated above levels of concern. Air sampling by Salt Lake City in July and August after the Red Butte Spill has generally not found elevated levels of benzene.

If I can smell petroleum hydrocarbons is my health being harmed?

Many volatile hydrocarbon compounds in crude oil have strong odors. Obnoxious odors can make people feel ill and trigger various reactions. Sensitivity to odors and types of reactions vary greatly among individuals. Stimulation of nerves in the nose and the throat by strong odors or irritants can precipitate physiological changes in the body. These effects may include headache, nausea, sense of unease, stress, or other reactions that might be triggered by such stimuli. Highly unpleasant experiences may condition one to have similar reactions when the odors are again perceived, even at lower levels. Overall, health effects from odors can be distinguished from toxicological effects of chemicals in that the effects from odors should be alleviated once the odor is no longer perceived. Reactions to odors are also likely to attenuate with time.

Whether odor is a good sign of potential toxicity depends on the odor threshold of the specific compounds in relation to levels causing toxicity. Some chemicals may have strong odors at very low concentrations, but cause little toxicity in the body at these or even higher levels. Other chemicals may have little odor until levels are reached that are well above levels of concern for toxicity. People's ability to detect odors and their reaction to odors can also vary greatly.

For the individual chemicals of most concern analyzed in airborne emissions from crude oil (i.e., hexane, benzene, ethylbenzene, toluene, naphthalene, xylene), risk-based screening levels for protecting public health from continuous long-term exposure are many times below levels at which odors of these chemicals can be perceived. Consequently, sampling of air concentrations is necessary for evaluating whether levels of these chemicals are elevated and exceed health protective levels. Sampling in the community has indicated that hydrocarbon odors may be present even when these chemicals of concern are not elevated over background levels or the risk-based screening levels. Thus, sampling helps assess whether these odors are coming from these chemicals and whether they are present at levels of health concern.

Constituents analyzed—why are only a subset evaluated?

Analysis of air samples to assess potential health risks from volatile chemicals in crude oil focuses on a subset of compounds that are considered the most toxic chemicals in the mixture (e.g., benzene, ethylbenzene, toluene, xylenes, hexane, and naphthalene). These are the subset of chemicals that also have health effects guidance levels.

In addition, the total amount of volatile organic compounds (VOCs) or classes of hydrocarbon compounds may also be analyzed. "Total VOCs" is a measure of all volatile organic compounds containing carbon, but will include chemicals that are not petroleum-related as well, including from other commercial and household chemicals (e.g., disinfection byproducts from drinking water, consumer products) and compounds emitted by vegetation and other natural sources. Total VOCs is thus a general measure of the level of total volatile organic chemicals at different locations. Health-based reference levels, however, have not been established for VOCs because the composition of this measure, and hence, toxicity, can vary widely. The Massachusetts Department of Environmental Protection (MADEP) has also developed health-based screening levels for petroleum hydrocarbon classes in air such as C5-C8 aliphatics, C9-C12 aliphatics, C9-C10 aromatics based on studies of more toxic individual components (e.g., hexane for C5-C8 aliphatics) or on the most sensitive effects from studies of chemical mixtures in a class (e.g., C9-C12 aliphatics). For the MADEP screening levels, chemicals are grouped by the number of carbons they contain (e.g., C5-C8 refers to chemicals that contain five to eight carbons). The chemical laboratory used by Salt Lake City can analyze for these hydrocarbon ranges, although their analysis is relatively general and may included several other volatile compounds (e.g., alcohols, ketones, aldehydes) that do not commonly result from a crude oil spill.

Although not all chemicals in crude oil have been individually studied, a smaller set of chemicals are generally taken as representative of the potential toxicological properties of the types of chemical classes in petroleum. These chemicals are generally the focus of sampling and hazard evaluation. In addition, human exposures to petroleum compounds are common through the many uses of these products in society. Studies comprising our knowledge of overexposures to the chemicals of interest include cases involving exposure to a mixture of hydrocarbons or solvents, although only levels of the chemical of interest were quantified and associated with the toxic effects observed. Consequently, a general approach by health agencies has been that if the constituents of most concern are below health protective levels or within typical air levels for these compounds, the other volatile constituents from crude oil should also be below levels of health concern.

What are the screening levels based on?

Different health-based screening levels are available, depending on whether exposures are brief or long-term and on what population is being assessed. Both short-term and long-term screening levels for the general population, including sensitive subgroups, are much lower and more protective than for workers. Residential air sampling after the cleanup of the creek is being compared to long-term screening levels for the general population, to evaluate whether health concerns are currently present as a result of the spill. Such screening levels have been developed by EPA, the ATSDR, and state agencies such as the State of California Environmental Protection Agency. The most highly scrutinized, scientifically peer-reviewed, and widely accepted health-based screening levels for long-term exposure are those derived by EPA. In addition, EPA has adopted the lower, more stringent screening levels of states (e.g., California) for certain substances (e.g., ethylbenzene and naphthalene) for which EPA has yet to update their cancer risk assessment.

EPA uses health-protective methods to develop concentrations of chemicals in soil, water, and air that are associated with acceptable risk levels over a long-term exposure period. These concentrations, termed regional screening levels (RSLs), are intended to be used to identify areas that warrant additional sampling or evaluation. If an air concentration is higher than the respective RSL, it does not mean that health effects will actually occur. This is because the

RSLs are calculated using assumptions about exposure and about toxicity that should not underestimate risks, even for a highly exposed person. Consequently, the RSLs likely overestimate risks for nearly all individuals. For example, toxicity values are typically derived based on the most sensitive population, species, and endpoint studied. EPA used the higher end (i.e., assumed greater carcinogenicity) of their estimated cancer potency range for benzene in developing the RSL for this chemical. For ethylbenzene, the RSL based on cancer in animals was more stringent than that based on the most sensitive non-cancer effects from developmental toxicology studies.

Where data are not available for important endpoints, toxicity values are made more stringent to account for data limitations. EPA assumes that cancer risk observed at high doses can be extrapolated to low doses, even when evidence indicates that such effects would not occur at low doses. RSLs for residential air also assume that individuals are exposed to the air 24 hours per day, nearly every day of the year for decades.

Are these health-based levels protective of sensitive individuals like children?

Health agencies such as EPA and the ATSDR consider the available scientific evidence on chemicals in setting their health-based levels. This information may include epidemiological studies, poisoning cases, intentional abuse (e.g., sniffing of glue, paints, solvents, gasoline, aerosol propellants), medicinal use, experimental studies in animals including developmental and reproductive studies, studies of how the chemical causes toxicity in the body, and studies of mutagenic and genotoxic (i.e., toxicity to genetic material) effects in cells. Where the agency considers the data to be uncertain, additional “safety factors” are applied to make the levels more protective to account, for example, for insufficient data on developmental or reproductive effects. The magnitude of the safety factor is also based on the available science on variation in human sensitivity. If uncertainties are present, agencies will use a larger factor to incorporate greater protection.

EPA has also recently incorporated additional safety factors to increase the protection of its cancer risk assessments for certain chemicals, because of evidence that they act by a mutagenic mode of action that would be of particular concern for childhood exposures (i.e., under age 16). Sixteen chemicals to date have been designated in this category, but none are volatile petroleum hydrocarbons. If these factors were applied to the RSLs for the sampled chemicals that are assessed based on long-term cancer risk (benzene, ethylbenzene, and naphthalene), the effect would be a lowering of their RSL by 2.5 times. The RSLs for benzene and ethylbenzene based on a 1-in-a million target risk level are already below background levels in some cases, and thus include considerable health-protection.

For noncancer effects, additional concern for pesticides in the food supply prompted EPA, under the Food Quality Protection Act, to incorporate an additional 10-fold safety factor for some pesticide chemicals that have database uncertainties for protection of early life exposures. EPA is likely considering whether an additional safety factor is needed for protection of early life exposures in new assessments of other chemicals, but has not yet assessed whether it is needed for chemicals previously assessed. The effect of such an additional factor can be examined by lowering the screening levels based on non-cancer effects by 10 times (i.e., RSLs for hexane, toluene, and xylenes; Cal EPA Reference Exposure Levels; and ATSDR Minimal Risk Levels). Some chemicals already include such factors because of scientific uncertainty for protection of early life exposures. For example, EPA applied an additional factor of 10 to make the non-cancer toxicity criterion for ethylbenzene even more stringent. EPA selected developmental toxicity as the most sensitive non-cancer endpoint for ethylbenzene and then made the toxicity value 10 times more stringent, because of the lack of multi-generational toxicity studies in animals.

The magnitude of the interval by which the air sample results are below the screening levels also indicates the margin of exposure from potential health concerns.

What are the background air levels and what are they based on?

As noted above, health-based screening levels include many health-protective assumptions and safety factors in their calculations. In some cases, these calculations can result in levels that are below typical background levels in ambient outdoor air or indoor air. Hydrocarbons are present in air from vehicle emissions, fueling stations, industrial emissions, wood smoke, asphalt, and even natural compounds emitted by plants and trees. Cars parked in attached garages can contribute to indoor air levels of petroleum hydrocarbons. Volatile organic compounds include an even larger number of chemicals beyond those that just contain carbon and hydrogen. Indoor air may contain higher levels of volatile chemicals, including petroleum hydrocarbons, than outdoor air from glues, sealants, varnishes, paints, solvents, building materials, furnishings, and consumer products.

To help evaluate whether levels of chemicals in air are elevated because of the spill, the sample results can also be compared to typical background air levels from national data. Unfortunately, sampling for a definite signature is not possible because of the ubiquitous presence of these hydrocarbon chemicals in air. In addition, specific air levels of these chemicals in Salt Lake City are unavailable. However, if the sample results are within background ranges, elevated exposures from the spill are unlikely.

EPA has compiled annual indoor and outdoor air data collected from a network of monitors nationwide. EPA reports average sample concentrations as well as low to high ranges in levels. These monitors are predominantly outdoors and are not located near point sources of chemical emissions. The indoor data used for comparison were combined from eight surveys by a recent evaluation by MADEP. This evaluation excluded studies with unusually high sources or unrepresentative conditions for residential environments, high chemical detection limits, or older data. MADEP summarizes their compilation of indoor air background levels by reporting the median value (50 percent of the data are below and 50 percent are above this value), 75^{th} percentile level (75 percent of values are below and 25 percent above this value), 90^{th} percentile level (90 percent of values are below and 10 percent are above). ATSDR has also summarized various studies on levels of specific chemicals in indoor and outdoor air, although the data summarized included older studies when airborne levels of chemicals were higher. For example, benzene levels in gasoline were higher in the 1980's than they are currently.

Similarly, levels of organic solvents, such as ethylbenzene, toluene, and xylene, have been reduced in products.

Abbreviations and Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
Cal EPA	California Environmental Protection Agency
EPA	United States Environmental Protection Agency
MADEP	Massachusetts Department of Environmental Protection
ppb	parts per billion
RSL	Regional Screening Level
VOC	volatile organic compound

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