

Health Consultation

PUBLIC COMMENT RELEASE

SALEM-KEIZER SCHOOL DISTRICT SCHOOL BUSES

SALEM, OREGON

SEPTEMBER 9, 2008

COMMENT PERIOD END DATE: OCTOBER 7, 2008

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333**

Health Consultation: A Note of Explanation

An 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. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

You May Contact ATSDR Toll Free at
1-800-CDC-INFO

or

Visit our Home Page at: <http://www.atsdr.cdc.gov>

HEALTH CONSULTATION

PUBLIC COMMENT RELEASE

SALEM-KEIZER SCHOOL DISTRICT SCHOOL BUSES

SALEM, OREGON

Prepared By:

Oregon Department of Human Services
Environmental Health Assessment Program
Under Cooperative Agreement with the
The U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

This information is distributed by the Agency for Toxic Substances and Disease Registry for public comment under applicable information quality guidelines. It does not represent and should not be construed to represent final agency conclusions or recommendations.

TABLE OF CONTENTS

SUMMARY	3
PURPOSE AND HEALTH ISSUES	4
BACKGROUND	4
SITE DESCRIPTION AND HISTORY	4
SITE INVESTIGATIONS.....	4
COMMUNITY CONCERNS	5
DISCUSSION	7
DATA SAMPLING & ANALYSIS	7
IDENTIFICATION OF CONTAMINANTS OF CONCERN	9
TABLE 1. IDENTIFICATION OF CONTAMINANTS OF CONCERN	11
PATHWAY ANALYSIS AND PUBLIC HEALTH IMPLICATIONS	12
<i>Completed Exposure Pathways</i>	12
<i>Potential Exposure Pathways</i>	13
<i>Non-Cancer and Cancer Risks for Exposure Pathways</i>	13
CHILD HEALTH CONSIDERATIONS	18
CONCLUSIONS	19
RECOMMENDATIONS:	19
PUBLIC HEALTH ACTION PLAN	20
PUBLIC REVIEW	21
REFERENCES	23
APPENDIX A – COMPARISON VALUES	26
APPENDIX B -DOSE CALCULATION FOR PHENOL RESIDUES ON SEAT CUSHIONS	27
APPENDIX C – TABLE OF EVENTS	28
APPENDIX D	31
ATSDR’S GLOSSARY OF ENVIRONMENTAL HEALTH TERMS	31

Summary

The Oregon Public Health Division Environmental Health Assessment Program (EHAP) was asked by the Salem-Keizer School District to conduct this Health Consultation (HC). The purpose of this HC is to evaluate the public health risk for children who may or may not have come into contact with contaminants found on several school buses in the Salem-Keizer School District (SKSD). Following a fire that destroyed and/or damaged several school buses parked in the SKSD Hawthorne Ave. bus barn, bus drivers began reporting health symptoms from driving affected school buses.

EHAP was unable to find any reports of children's health complaints from parents or from children themselves. Therefore, EHAP considers the complaints registered by the drivers as proxy for potential health effects in the children. Children spend much less time per day on the buses than drivers do, and so their exposure to contaminants on buses is also much less. However, EHAP recognizes that children may be more vulnerable from exposure to contaminants than adults.

All the data analyzed in this HC were collected by Oregon Occupational Safety and Health Division (OR-OSHA) in evaluating potential occupational exposures for the bus drivers.

In an attempt to characterize the nature and degree of the contamination that would impact children's health, the Environmental Health Assessment Program (EHAP) reviewed all the data available from OR-OSHA's original complaint inspection, as well as from their follow-up health consultation. The equipment used by OR-OSHA was intended to determine if these chemicals were present, not to quantify the chemicals. Several data collection and monitoring events occurred over a 17-month period (see Appendix C).

In this HC, EHAP could not determine whether phosgene and sulfur dioxide are health hazards because we were unable to measure the levels of these contaminants. The instruments used for analysis could not accurately measure contaminants at the lower levels where health effects in children might occur, making this an *indeterminate health hazard*.

EHAP determined that carbon monoxide, benzene, particulate matter, diesel exhaust, limonene, undecane, and phenol pose *no apparent public health hazard*. This was because the measured levels were either too low to cause health effect in children or, as in the case of limonene and undecane, they have low toxicity.

EHAP concluded that isocyanates and other fire-related residues pose an *indeterminate health hazard* to children who ride the affected school buses. This determination was due to uncertainties as to the amount of fire-residue substances, the length of time they could potentially persist on the buses, and whether or not the children riding the buses could have been exposed to them.

Purpose and Health Issues

EHAP is part of the Oregon Department of Human Services (DHS) Public Health Division. EHAP evaluates the human health risks of exposure to environmental contaminants throughout Oregon in cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). EHAP developed this health consultation to evaluate exposure to potential contaminants on specific school buses in Oregon's Salem-Keizer School District and to determine, based on available data, whether riding the buses poses a health hazard to children. The potential for past, current, and future exposure to residual contaminants in several school buses that were involved in a fire, is the concern that prompted the request for this consultation.

Background

Site Description and History

On December 17, 2006, a fire broke out in the main school bus facility in the Salem-Keizer School District, located at 998 Hawthorne Ave in Salem, Oregon. The fire destroyed seven buses and heavily damaged five that were parked directly across from the destroyed buses. The metal canopy that sheltered the buses sustained heavy fire damage as well. At the time of the fire, the school district was closed for winter break. The cause of the fire has been labeled undetermined by the Salem Fire Department.

The school district's contracted industrial hygiene consultant, Wise Steps, Inc., oversaw the initial cleaning and repair of the buses between December 19 and December 29, 2006. ServiceMaster cleaned the interiors of buses that were located underneath the canopy at the time of the fire using HEPA-vacuums, detergents, and water. ServiceMaster also treated buses with ozone in order to eliminate odors. Salem Auto Body & Paintworks restored and cleaned the exterior of the five heavily damaged buses.

After returning from winter break, some of the bus drivers began reporting health problems including nausea, headaches, burning noses and throats, a cough, and trouble breathing. Additional cleanings were conducted on specific buses on January 5, 8, and 26, 2007 based on drivers' complaints.

Site Investigations

The Environmental Safety Specialist from the SKSD contacted OR-OSHA because several bus drivers reported health problems. In February 2007, OR-OSHA opened a complaint inspection after several drivers filed formal complaints. During the investigation, OR-OSHA reviewed cleaning procedures, service reports, and MSDS sheets for cleaning products and deodorizers. They concluded that the school district took appropriate measures when cleaning the buses after the fire, and no further actions were recommended. The investigator's review did not identify any substances resulting from the fire that would cause the persistent health effects that the drivers continued to report.

Due to bus drivers' continued health complaints, the school district requested a consultation with OR-OSHA in November 2007. In response to this request, OR-OSHA

agreed to conduct a health consultation that was based solely on current symptoms and current occupational exposures that may be responsible for the bus drivers' health effects. It was agreed that the consultation branch of OR-OSHA would not consider fire-related data in their report because the investigative branch had already reached a conclusion regarding the fire.

In December 2007, sample collection began for OR-OSHA's health consultation, which is detailed in the table of events (appendix C). SKSD then contacted EHAP in January 2008, to request that the program conduct a separate health consultation to review data collected by OR-OSHA and Wise Steps, Inc. EHAP agreed to conduct a health consultation for the SKSD that would address health concerns for children riding the school buses.

On April 1, 2008, EHAP conducted a site visit to the bus barn where the fire took place. Team members rode on one of the problematic buses, spoke with several bus drivers, and examined the area where the fire broke out. The barn lot itself is sandwiched between an interstate highway (I-5), and a busy city throughway. The entire facility is fenced in, with a one-way lane for vehicles to enter and exit the lot. Thirty-eight buses fit side to side, and nose to nose under a canopy. Several other buses are parked in an area outside the canopy. The driver's dispatch area and lunch room is located adjacent to the covered bus area at the far side of the canopy from the fire's point of origin. Drivers sit inside and wait between routes, eat lunch, and take care of business details.

While riding bus #11, EHAP staff noted a faint smoke odor and noticed that the ceiling was a metal mesh with holes approximately .5 cm in diameter. In the outdoor canopy area, EHAP staff noted a new section of canopy had replaced the fire-damaged portion. Streaks of black discoloration were still visible on the underside of original sections of the canopy, though it was evident that pressure washing had removed most of the soot.

EHAP had conversations with several bus drivers about their routes, their health concerns, and if they knew of any children who had health complaints. Their concerns are documented in the community concerns section of this report.

Community Concerns

Several school bus drivers indicated they had lingering health problems that they associated with driving certain school buses that had been on the lot at the time of the fire. At 17 months post-fire, some drivers characterized their health problems as stemming from a "past" exposure that had left them with multiple chemical sensitivities, allergies, and respiratory effects – some with asthma. Some drivers said they could no longer walk down the cleaning supply aisle in the grocery store without experiencing symptoms. Some had given up their desired school bus routes and transferred to less desirable routes to avoid buses that brought out their symptoms. Some drivers voiced a general mistrust in the school district and its contractor's thoroughness in cleaning the buses after the fire. One driver indicated more drivers didn't want to come forward with their complaints because of a general mistrust in state agencies, after previously unsatisfying results left them feeling frustrated and defeated.

Reported symptoms and health effects included tiredness and fatigue; occupational asthma (medically diagnosed); bronchial & flu-like symptoms; a chemical taste and smell that persists; burning sore throat; itchy, burning eyes – as though grit and particles are in them; very dry mouth and nose; a persistent cough; sensitization to chemicals/smells/perfumes; new allergies; dizziness; headache; and nausea. Drivers consistently reported that their acute symptoms dissipated after a few days/weeks away from problematic buses, but symptoms returned once they began driving those buses again.

One driver reportedly had to pull over during his elementary school route and radio in to the dispatch for someone to come and get him because he was having difficulty breathing.

Many of the drivers felt that their symptoms were consistent with exposure to a class of chemicals known as isocyanates, and wonder why they were not tested for after the fire. Some drivers speculated that perhaps there was mold in the ceilings, heaters and defrosters that was causing their symptoms, while others thought the seat pads were the source of exposure. Many drivers reported that their symptoms were exacerbated when the bus heaters were on and kids were bouncing up and down on the seats. Heaters in many of the buses are under the seats, and drivers feel their symptoms were triggered when the seats heated up. Most of the affected buses had seats that contain post-1990's flame retardant seat material and the driver's seats were made of cloth, instead of vinyl, which was the predominant material before the 90's.

One driver indicated that “glass-like” particles fell from the holes in the bus ceiling and could be seen when the sun shone through the windows. The SKSD director of transportation indicated that the ceilings on most of the affected buses are a metal mesh with a vapor barrier and insulation on the inside. This type of ceiling was found in newer buses as an innovation designed to minimize noise inside the buses.

Drivers had observed black soot when dusting and cleaning their buses, and said they had seen the roof-top vents dripping rain-soaked soot when left open. After wiping down their buses, some drivers said they returned the next day to find black soot covering everything again. One driver mentioned that he parked his car in the fenced-in bus lot while he worked, and continued to wipe down black soot inside his car every day, 17 months after the fire.

A few drivers reported that children on their buses had complained about headaches, tight chests, “weird” smells, and asthma attacks. One driver indicated that she took some children on a swim trip and, after sitting on the seats in their swimsuits, the children developed itchy, red, and irritated skin. The driver said one girl cried because it hurt. She said she saw glass-like particles on the seats – consistent with those she had seen falling out of the ceiling.

The drivers had listed 27 buses as being problematic to drive, which included numbers 10-31 (except 17), 41- 43, 142 and 143.

Discussion

This section of the report describes the data collection that took place, the process used to identify contaminants of concern, and an evaluation of exposure pathways and public health implications. All data were collected by either OR-OSHA or Wise Steps, Inc. EHAP's evaluation and interpretation of the data is independent of the organizations that collected it.

Data Sampling & Analysis

Microscopic analysis of particles:

To determine if the air intake filters contained residual particulate matter from the fire that could be responsible for health symptoms, OR-OSHA removed the air intake filter from the school bus that was parked directly across from the fire's point of origin (# 22). OSHA was trying to determine if there was contamination inside the intake filter that may be responsible for the drivers' reported symptoms. It was thought that bus #22 was likely to have the most contaminated intake filter, and would be a good measure for the others. A microscopic analysis of particulate matter found inside the filter identified particles consistent with a fire, but did not identify any chemicals or specify the size of particles. EHAP concluded that this analysis was not useful in identifying the cause of symptoms, and did not use these data in this report.

Wise Steps, Inc. collected particles from the air inside of 10 buses, half of which had been in the fire and half of which had not. Air was sampled using personal air monitoring equipment that pulled air through a particulate-collecting filter at a rate of 2 liters per minute for about 10 and a half hours. Microlab Northwest (a third party laboratory) removed the filters and analyzed them under a microscope in order to determine how much of the debris in the filters could be attributed to the fire. The analysis identified some particles that were consistent with an uncontrolled bus fire and other particles that would be expected in any city roadway environment. When examining the amount of light being blocked by the particulate matter in the filters, the lab did not find a link between involvement in the fire and the amount of total particles in the filter. In fact, the bus that had the most light-blocking particles, bus # 17, was not on the lot when the fire occurred. Bus drivers had also identified bus #17 as a "non-problem" bus.

Because this method did not test for any chemicals or quantify particles with any size discrimination that is relevant to human health, it was not useful in identifying causes of health effects. Therefore, EHAP could not use these data in this health consultation.

Particulate-bound organics sampling

One potential source of chemical exposure on the buses could be from inhaling contaminated dust. In an attempt to identify particles that might be responsible for health effects, OR-OSHA collected dust from inside one bus (#16) in fiberglass filters while the

floors were being swept. The collected dust particles were then washed with solvents to dissolve any organic chemicals that may have been bound to them.

The following chemicals were identified:

Benzene, tetramethyl heptadecane, heptadecane, docosane, nonodecane, butyl palmitate, octadecyl acetate, butyl octadecanoate, eicosane, butyl hexadecanoate, tetratetracontane, heneicosane, 3-hydroxy-2,4,4-trimethyl pentyl 2-methyl-propanoate, and 2,2-dimethyl-1-(2-hydroxy-1-methyl-ethyl) propyl 2-methyl-propanoate.

All of these chemicals fit within one or more of the following source categories:

- Diesel and gasoline fuels
- Food products
- Cosmetics
- Fragrances
- Food additives

Neither the chemicals nor the amount of dust collected were quantified (measured). Benzene is the only chemical associated with serious health effects that was identified, but because these data did not allow EHAP to determine the amount of benzene that a person would be exposed to via dust, EHAP did not use these data in the health consultation.

Wipe Test/Phenols

Some of the detergents used to clean the school buses after the fire, and on a regular basis by the bus drivers, contain phenols. Phenols can cause chemical sensitization in humans[2]. A person who becomes sensitized will experience negative health effects from exposure to phenol and other chemicals in the future, at lower exposure levels than are required by the average person[2].

One bus (#41) was tested for phenols. Air and seat surfaces were tested for phenols. Both the air sampling and seat-wipe data were used in this health consultation.

Real-Time Air Sampling

Particulate matter can contribute to symptoms similar to those experienced by some bus drivers, and may cause health problems for children who are exposed to it. OR-OSHA acquired real-time air monitors with the capacity to measure particulate matter 10 micrometers in diameter and smaller, without determining the exact size of particulates within that range. In addition to particulate matter, the real-time air monitors also measured temperature, humidity, carbon dioxide, carbon monoxide, and total volatile organic compounds (VOCs). The advantage of these real-time monitors was that they could measure multiple contaminants at the same time, and the data was immediately available online to drivers, OSHA, and school district staff.

These monitors were installed on buses 16, 17, 31, 41, 124, and 159. In addition, one outdoor reference monitor was placed at the Gaffin Road bus lot to measure ambient air, and one indoor reference monitor was placed in the bus driver's break room at the

Hawthorne bus lot, which is the lot where the fire broke out. Temperature, humidity and carbon dioxide on school buses are expected to fluctuate over the course of the day depending on the use and outside weather and are not associated with symptoms matching those of drivers. However, some VOCs can act as respiratory irritants and have health effects that are particularly serious for children. VOCs were analyzed individually and quantitatively by another method (snap-shot sampling) that is more accurate. For this report, EHAP did not use the data on VOCs measured by the real-time monitoring system, but chose to use the more accurate snap-shot method (see below). In addition, carbon monoxide is a very toxic gas that reduces the blood's ability to carry oxygen, and EHAP used the carbon monoxide measurements from the real-time monitors in this health consultation.

Snap-shot air sampling

Certain gases cause respiratory irritation and symptoms matching those described by some of the bus drivers. The real-time monitoring equipment, mentioned above, was not able to measure all of these irritant gases. Therefore, OR-OSHA took snap-shot air samples on several buses and measured for several individual irritant gases. These included ozone, nitrogen oxides, phosgene, sulfur dioxides, and certain VOCs, including benzene, xylenes, toluene, limonene, and undecane. EHAP used these data in this health consultation.

Diesel Exhaust

Diesel exhaust has been linked to respiratory irritation, cancer, and other heart and lung problems[3]. Buses that run on diesel produce large amounts of diesel exhaust. To determine whether diesel exhaust was present in sufficient concentrations to cause adverse health effects, OR-OSHA collected air samples from buses and analyzed them for diesel particulate matter (DPM). OR-OSHA used the sampling and analytical method recommended by the National Institute of Occupational Health and Safety (NIOSH) known as the NIOSH 5040 method. These data include the concentration of DPM in the air, and EHAP used them in this report, comparing them to specific concentrations (“comparison values”) known to be low enough that they are protective of children.

Identification of Contaminants of Concern

EHAP uses the following criteria to identify contaminants of concern:

- Contaminant concentrations (estimated dose in the case of phenol)
- Comparison of contaminant concentrations, limits of detection, or doses against health-based comparison values (CV)
- Community concern

EHAP uses comparison values (CVs) that were established by the Agency for Toxic Substances and Disease Registry (ATSDR). These values are used whenever possible because they are protective of the health of the most vulnerable of people, including children. In the absence of ATSDR comparison values, EHAP uses CVs established by

the Environmental Protection Agency (EPA) that are based on human health effects among the general public.

In this HC, air contaminants were considered ‘contaminants of concern’ (COC) if their measured concentrations were above the CV levels on one or more of the school buses. In many instances, contaminants were not detected at all. In these cases, EHAP compared the equipment’s limit of detection against the CVs. The limit of detection (LD) is the actual limitation of the equipment used when measuring a contaminant.

For example, we knew that sulfur dioxide was not detected on the school buses. However, upon closer examination, we noted that the equipment used did not measure anything below 100 ppb. Because we knew that health effects could occur near 100 ppb, we wanted to know whether sulfur dioxide levels were just below 100 ppb or far below. Because the equipments’ detection limit was not adequate, we could not tell what the actual levels were, so we chose sulfur dioxide as a contaminant of concern and recommend obtaining a more accurate reading to use in our conclusions.

Other conditions that would cause us to identify a substance as a COC, are if there are no health-based standards that exist for that contaminant, (limonene and undecane were identified as COC for that reason). Also, if the community is concerned about a specific contaminant, EHAP chooses that contaminant to evaluate further, even if the contaminant does not exceed a CV. An example in this HC is isocyanates.

The contaminants of concern that EHAP identified for the SKSD school buses are:

- Benzene
- Phosgene
- Sulfur Dioxide
- Limonene
- Undecane
- Diesel exhaust
- Carbon Monoxide
- Particulate Matter
- Isocyanates and other fire-related residues
- Phenol

Table 1 summarizes the comparisons of chemical contaminants with their CVs. Contaminants that are bolded are contaminants of concern, and the concentrations or LDs that are bolded indicate numbers that exceed the health protective comparison values. All of the contaminants and measurements in Table 1 represent concentrations in the air.

In addition to air testing, phenol was also measured on the seat surfaces from wipe tests. Appendix B summarizes the method used to estimate a phenol dose to a child from contact with the seats. The estimated dose was 0.35 milligrams-phenol per kilogram-body weight per day (mg/kg/day). The CV for phenol is something known as a ‘reference dose’ (RfD) established by the EPA. The RfD is 0.3 mg/kg/day, so the estimated dose slightly exceeds the CV.

Table 1. Identification of contaminants of concern

Bus #	Benzene (ppb)	Toluene (ppb)	Xylene (ppb)	Limonene (ppb)	Undecane (ppb)	Ozone (ppb)	Sulfur dioxide (ppb)	Phosgene (ppb)	Phenol (ppb)	Nitrogen oxides (ppb)	Diesel Particulate Matter (µg/m ³)			Carbon monoxide (ppm)	Particulate (µg/m ³)
											Outside bus	Center of bus	Near driver		
11	ND	11.7	ND	ND	ND	--	--	--	--	--	30	--	17	--	--
14	ND	12.5	ND	5.1	ND	--	--	--	--	--	<1.5	4	2	--	--
16	--	--	--	--	--	ND	ND	ND	--	ND	--	--	--	3	109
17	ND	8.8	ND	ND	ND	--	--	--	--	--	1.6	2.7	1.8	4	15
24	ND	9.9	ND	ND	ND	--	--	--	--	--	5.7	<1.4	4.8	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	2	81
41	ND	5.0	ND	ND	ND	ND	ND	ND	ND	ND	7.8	4.2	3.3	4	119
55	ND	13.9	ND	ND	ND	--	--	--	--	--	12	--	4.5	--	--
124	--	--	--	--	--	--	--	--	--	--	--	--	--	2	146
159	--	--	--	--	--	--	--	--	--	--	--	--	--	2	43
169	ND	6.1	ND	ND	ND	--	--	--	--	--	7.1	--	5.1	--	--
172	ND	4.8	ND	ND	ND	--	--	--	--	--	<1.7	2.3	<2	--	--
Hawthorn Barn	--	--	--	--	--	--	--	--	--	--	4.3	--	--	--	--
Gaffin Rd. Barn	--	--	--	--	--	--	--	--	--	--	<1.4	--	--	10	150
LD	4		4	2	2	25	100	50	49	40					
Screening Standards															
MRL	3	80	50	---	---	---	10	---	20 [§]	---	---	---	---	---	---
CREG	0.03	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NAAQS	---	---	---	---	---	75	---	---	---	53	---	---	---	9	150 [¶]
RfC	---	---	---	---	---	---	---	0.07	---	---	5	5	5	---	---
ppb = parts per billion															
ppm = parts per million															
ND = Not detected															
"--" = Not tested															
LD = Limit of detection															
MRL = Minimal Risk Level (standard set by the Agency for Toxic Substances and Disease Registry (ATSDR))															
CREG = Cancer Risk Guide (standard set by ATSDR)															
NAAQS = National Ambient Air Quality Standard (Set by the EPA)															
RfC = Reference concentration (Set by the EPA)															
"---" = No standard or irrelevant standard															
[§] This MRL is based on acute exposures lasting less than 14 days															
[¶] Standard for particulate matter 10 microns in diameter (may not be relevant to measured samples)															
[*] Standard for nitrogen dioxide															

OR-OSHA did not test for isocyanates in the air or on any surfaces. Isocyanates dissipate very rapidly after a fire, and they did not expect to be able to detect them. However, several community members have expressed concerns that their symptoms match many of those associated with exposure to isocyanates. Therefore, EHAP considers isocyanates a contaminant of concern. All of the contaminants of concern identified in this section were carried forward for further evaluation.

Pathway Analysis and Public Health Implications

Five elements of an exposure pathway were evaluated to determine whether people are being exposed to benzene, phosgene, sulfur dioxide, diesel exhaust, carbon monoxide, particulate matter, isocyanates, and phenols on SKSD school buses. If all the criteria are met for the five elements, then the exposure pathway is considered “completed”. The five elements for a completed exposure pathway are:

- 1) A contaminant source or release
- 2) A way for the chemical to move through the environment (air, soil, water, etc.) to a point of exposure
- 3) Exposure point or area where people can come into contact a contaminant
- 4) Route of exposure (eating, breathing, touching, etc.)
- 5) A population that comes in contact with the contaminant

Completed Exposure Pathways

Completed exposure pathways for contaminants of concern on SKSD school buses include inhaling contaminants from the air in and around the buses, touching the seats (skin exposure to phenol), as well as swallowing small amounts left on children’s hands if they weren’t washed before eating.

It is not clear whether contaminants measured in the air on buses originated from inside the buses or from the outside air. Concentrations of contaminants measured in outside air were often higher than concentrations measured inside the buses, so it seems plausible that the outdoor air is the source of these contaminants of concern. This would be consistent with the placement of the bus barn, which is housed between Interstate-5 and a major city thoroughfare. The public health implications of exposures to contaminants of concern in the air are discussed later in this section.

Phenol is a component of cleaning agents that have been used to clean the buses on a regular basis. While phenols typically degrade rapidly in the environment (within a day or so)[2], regular application by staff cleaning the buses could have created a situation where phenols are consistently present on seats and other interior surfaces. Children riding the buses could come into skin contact with phenols on these surfaces, and phenol can easily be absorbed through the skin[2]. If children put their hands into their mouths after touching such surfaces without washing in between, they could also swallow small amounts of phenol.

Potential Exposure Pathways

Isocyanates and other potential fire residues could have been generated during the fire and absorbed or deposited into porous surfaces such as seat cushions and ceiling insulation in the buses. If isocyanate residues were deposited, it is unknown whether or not those deposited residues could be released from those surfaces to come into contact with children riding the bus. Therefore, EHAP considers this exposure to be a potential pathway, because of the uncertainty stemming from a lack of data and knowledge about fire residues and how long they persist in a setting like a school bus and whether or not they come into contact with children after they've been deposited.

It is unlikely that isocyanates would have been present in the air on buses at the time when students and drivers returned from winter break, because of the instability of isocyanates in the air. There were at least 10 days between the time of the fire and when drivers and children began using the buses again. However, other unidentifiable residues from the fire could have still been present even after subsequent cleanings if those residues were in ceiling insulation or seat foam.

Non-Cancer and Cancer Risks for Exposure Pathways

Non-cancer risks for contaminants of concern (COC) in the air on buses were assessed by comparing possible air concentrations on the buses with concentrations that have been associated with health effects in humans and/or animals.

Cancer risks for COC in air were calculated by multiplying the highest possible concentration of contaminants by something called the 'Inhalation Unit Risk' (IUR) for those contaminants. IURs are established by the EPA as comparison values that are protective of sensitive individuals' health, including children.

A cancer risk is usually expressed as a certain number of additional cancer cases in a population that has been in contact with some type of contamination. This health consultation report describes cancer risk in terms like "high", "low", "very low", or "slight" cancer risks. A "low" increase in cancer risk means there would be about one additional cancer case for every ten thousand people that were exposed to a contaminant over a lifetime. A "very low" risk would mean about one additional cancer case for several tens of thousands of people exposed over a lifetime, and a "slight" risk would require several hundreds of thousands of exposed people, before we would expect a single additional cancer case.

It is important to remember that these calculations are theoretical, and assume that a person breathes, drinks, eats, or touches a given chemical at a given dose all day long, every day for a lifetime. Using this way of determining cancer risk, the children riding one of the fire-affected school buses 2 hours each day, 177 days/year, for 10 years, would not have even a slight risk of developing cancer. Also, an *increased risk of cancer does not mean that a person will get cancer if exposed*. These risk numbers are used by public health officials to make decisions about appropriate measures to reduce exposures.

Completed Pathways

Benzene

Non-cancer health effects have usually been observed in people who are chronically exposed (for several years) to concentrations of benzene above 560 ppb[4]. No benzene was detected on any bus, but the equipment used to measure benzene on the school buses could not measure below 4 ppb. Therefore, the highest possible concentration of benzene on the buses is still 140 times below any concentration that has been shown to cause non-cancer health effects. EHAP does not expect any non-cancer health effects due to benzene exposure from SKSD school buses.

Increased incidence of cancer, specifically AML, has been observed in people exposed to 300 ppb for 18 months or longer[4]. This is 75 times higher than the possible concentrations on buses (4 ppb). The cancer risk that is theoretically estimated for benzene at the maximum concentration possible on the buses (4 ppb) is 1 additional cancer out of 10,000 people exposed. EHAP considers this to be a low cancer risk. In addition, the actual concentration of benzene on the buses is not known and could be much lower than 4 ppb, due to detection limitations. Because this calculation assumes that children breathe the air on the buses all day every day for their entire lives, their actual risk is much lower. EHAP concludes that benzene exposures present ***no apparent public health hazard*** for children riding the school buses.

Limonene and Undecane

Limonene and undecane are VOCs that were detected during the data collection process, but for which no health-based comparison values exist. This means that there is no way of knowing whether the levels found on the school buses are high or low. However, because of the nature of these chemicals, we anticipate no negative health effects.

Limonene is considered safe by the Food and Drug Administration and it is naturally found in citrus fruits and concentrated in cleaning products and air fresheners. It has a citrus scent. At higher concentrations it is used in flea, lice, and tick products for pets and as an insect repellent for people. EHAP concludes that limonene poses ***no apparent public health hazard*** to children riding school buses.

Undecane is another natural VOC that has a mint scent and is considered non-toxic by the Environmental Protection Agency. Undecane was not detected on any bus, therefore EHAP concludes that undecane poses ***no apparent public health hazard*** to children riding school buses.

Sulfur Dioxide

Anyone (child or adult) who has asthma might experience worsened symptoms if they breathe sulfur dioxide in concentrations as low as 250 ppb, which is only 2.5 times higher than the detection limit of 100 ppb for sulfur dioxide on these buses [5]. Very sensitive individuals, like adults or children with asthma, could experience adverse health symptoms if the actual sulfur dioxide levels are very near the 100 ppb detection limit[5].

Adverse health symptoms include increased frequency of asthma attacks and worsened asthma symptoms, respiratory irritation, coughing, and wheezing[5]. The instruments used could not measure sulfur dioxide at concentrations that EHAP would consider safe. Therefore, EHAP concludes that sulfur dioxide poses an *indeterminate public health hazard* to children riding the school buses.

Phosgene

Phosgene was not detected on any buses. However, the lowest concentration that instruments were able to measure was 50 ppb. Subtle changes in the lungs that can mark the beginning stages of health effects in animals appear at 18 ppb[6]. This is lower than the levels of phosgene that could be detected on these school buses with the equipment used. It is unknown whether phosgene on the school buses could cause adverse health effects in children or drivers because the instruments used to collect the data were unable to detect levels as low as 18 ppb. Again, this does not mean that the actual levels of phosgene are higher than the comparison values, but it is a possibility since we do not know the actual levels. Therefore, EHAP concludes that phosgene in the school buses that were tested poses an *indeterminate public health hazard* to the children riding the school buses.

Diesel Exhaust

Diesel exhaust contains a mixture of gases and particles. Diesel particulate (elemental carbon) is the component of diesel exhaust that is actually measured in the air and used to report levels of diesel exhaust. The EPA has established a health-based reference concentration (RfC) for diesel particulate of $5 \mu\text{g}/\text{m}^3$ (5 micrograms per cubic meter of air). This RfC is based on a study that found subtle changes in the lungs of animals exposed to diesel exhaust at a human-equivalent dose of $883 \mu\text{g}/\text{m}^3$ [3]. This is 30 times higher than the highest concentration measured on or around any bus ($30 \mu\text{g}/\text{m}^3$), which was measure outside school bus #11. Therefore, non-cancer health effects due to diesel exhaust exposure are not expected for children riding the school buses.

There is, however, increasing evidence that links diesel exhaust to asthma and allergies at potentially lower concentrations [7-17]. Although there is no consensus on the diesel concentration that might lead to asthma and allergies, it would be prudent to reduce the children's level of exposure as much as possible. SKSD does have a "no-idling" policy of which some drivers seemed unaware during the site visit. Encouraging greater compliance with this existing policy would reduce children's exposure to diesel exhaust and save on resources.

There is also growing evidence that diesel exhaust can cause cancer. However, there is not enough existing scientific data to calculate increased cancer risks from specific concentrations of diesel exhaust. Most human studies have found an increased risk of lung cancer for adults who are exposed to diesel as part of their jobs (8 hours/day) over the course of several years. Children in SKSD spend less than 2 hours a day (maximum) riding the buses for only 177 days/year. In addition, the highest concentrations of diesel exhaust were found in the air outside the buses rather than inside. Therefore, EHAP

concludes that exposure to diesel exhaust at the levels measured, and under the conditions tested, poses ***no apparent public health hazard*** to children riding the buses.

Carbon Monoxide

Carbon monoxide is a clear, odorless gas that is a common component of diesel and automobile exhaust. The maximum level of carbon monoxide measured at any time occurred in the outdoor air at the Gaffin Rd. bus lot (10 ppm). This level exceeds the CV for carbon monoxide (9 ppm) by only 1 ppm. Carbon monoxide levels inside buses were lower than in outside air. This suggests that carbon monoxide that was measured inside the school buses came from the outside air and not from inside the buses themselves. Because this high reading occurred at only one time, in one location, measured in the outdoor air, and because the reading only slightly exceeded the CV, EHAP does not expect any adverse health effects due to carbon monoxide exposure from the school buses. Therefore, EHAP concludes that carbon monoxide poses ***no apparent public health hazard*** to children riding the buses.

Particulate Matter

EHAP used EPA's CV of 150 micrograms of particulate matter per cubic meter of air, for particles less than 10 microns in diameter. The outdoor air at the Gaffin Road lot reached 150 micrograms/cubic meter at one time during the monitoring. The highest level of particulate matter (PM) recorded on a bus was 146 micrograms/cubic meter, which was inside bus #124. Particulate concentrations measured inside the school buses were never higher than the concentrations in the outside air. This suggests that particulates inside the buses probably came from the outside air, and not from inside the buses themselves. Therefore, people experiencing problematic health effects at the levels of PM measured inside the school buses would also experience problems outdoors. EHAP does not expect any health effects based on particulate matter inside the school buses, and concludes that particulate matter poses ***no apparent public health hazard*** to children riding on the buses that were tested.

Phenol

Cleaners containing phenols have been used to clean school buses in the Salem-Keizer School District. Therefore, phenols could be found in the air or on the seats of school buses. The air and seat of one bus (#41) were sampled for phenol.

Phenol was not detected in the air. Even though the detection limit for phenol was 49 ppb, which is greater than the CV of 20 ppb, the levels of phenol in air that cause health effects in animals or humans are around 26,000 ppb [2]. This is at least 530 times higher than the limit of detection. Since no phenol was found in air, EHAP does not expect any health effects in children due to inhalation of phenol.

Phenol was also measured on some of the seat surfaces on bus #41. Because there are no CVs for amounts of phenol per surface area, EHAP used some assumptions to calculate an estimated dose of absorbed phenol either through swallowing small amounts left on children's hands while eating or absorbing it through the skin. Based on the calculations and exposure assumptions listed in appendix B, a child riding bus #41 at the time the

sample was collected could have a daily dose of phenols as high as 0.35 mg/kg/day. This is slightly more than EPA's oral reference dose of 0.3 mg/kg/day. However, the assumptions used to calculate this dose are very protective, and it is unlikely that any child is absorbing phenols at the level calculated (See appendix B for assumptions). Furthermore, the reference dose of 0.3 mg/kg/day includes a safety factor of 300, meaning that no adverse effects were observed in animal studies even at 93 mg/kg/day[2]. Therefore, no adverse health effects would be expected for children who accidentally swallow phenol from the surfaces of the school bus seats or absorb it from seats through their skin. EHAP concludes that exposure to phenols presents ***no apparent public health hazard*** at the levels found on bus #41.

Potential Pathways

Isocyanates and other Fire-Related Residues

Seat cushions and paint coatings on school buses are made up of flexible and hard polyurethane (PU) foams. When PU burns, isocyanate gas is formed[1, 18]. No samples were collected from the SKSD buses to measure isocyanates in the air or on interior surfaces of the bus, so it is unknown whether isocyanates were present on buses when children started riding again. However, isocyanates are reactive chemicals that do not last long in the air[19]. At least 10 days passed between the time of the fire and the time that students re-entered the buses. Therefore, it is unlikely that isocyanates would have still been present in the air on the buses by that time, so children were probably not exposed to isocyanate gas on SKSD buses.

As PU burns, microscopic liquid PU droplets, called aerosols, are also formed. As aerosols cool, they solidify and become a major part of the soot left after a PU fire. These aerosols are made up of short chains of isocyanates (oligomers), and are longer lasting in the environment than isocyanate gas [1, 18, 20]. Other components of burning PU include acid gases such as hydrochloric acid and hydrogen bromide, nitric oxides, amines and ammonia[1, 18, 20]. While these gases, like isocyanates, would probably have dissipated from the air on buses before children re-entered them, some of these chemicals could have combined with each other to condense into fine particulates that could become another part of the residual soot. Acid gases can also absorb onto the surface of aerosols and other components of soot during cooling[1, 18, 20]. Once incorporated into soot particles, these chemicals could have persisted, with the rest of the soot, and been present when children re-entered the buses after returning from winter break.

During and soon after the fire, aerosols and soot from burning PU could have settled onto surfaces in neighboring buses and been deposited within porous matrices like seat foam (drivers' seats are cloth-covered) and ceiling insulation. A routine cleaning would probably not remove this aerosol/soot from foam seat cushions or ceiling insulation. Therefore, it is possible that this soot could have persisted in these locations. It is unknown whether or how much of this fire residue material could be released over time from seat foam and/or ceiling insulation into areas of the bus where children could come in contact with it. It isn't known whether residues settled on neighboring buses, or were later released, at high enough levels to be a problem.

If these residues did get released from seats and/or the ceiling insulation, the acid gases and amines carried on soot-derived particulate matter could be very irritating to the lungs and airways if inhaled [21, 22]. The isocyanates around the outside surfaces of PU aerosol soot particles could also have health effects. Isocyanates are known to be potent chemical sensitizers [19, 23-41]. Sensitization happens when a person's immune system responds to a chemical by mounting a defense against it. Once sensitized, a person will experience health effects, often respiratory symptoms that resemble asthma, when re-exposed to concentrations of that chemical that are far lower than those that would cause effects in a non-sensitized person. Isocyanates have been shown to cause asthma-like symptoms following exposure to the skin, even without dermal (skin) symptoms like rashes [19, 24, 28]. This means that soot particles in seat cushions or ceiling insulation, even if not inhaled, could induce chemical sensitization through contact with the skin.

Children spend less time on buses than drivers, so their potential exposure to fire residues is proportionately less than the drivers. However, given the many uncertainties about this exposure pathway, EHAP concludes that isocyanates and other fire-related residues represent an *indeterminate public health hazard* to children riding the buses.

Child Health Considerations

EHAP and ATSDR recognize that infants and children may be more vulnerable to exposures than adults in communities faced with contamination of their air, water, soil, or food. This vulnerability is a result of the following factors:

- Children are more likely to play outdoors and bring food into contaminated areas.
- Children are shorter, resulting in a greater likelihood to breathe dust, soil, and heavy vapors close to the ground.
- Children are smaller, resulting in higher doses of chemical exposure per body weight.
- The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages.

Because children depend on adults for risk identification and management decisions, ATSDR is committed to evaluating their special interests on the fire-affected school buses in the Salem-Keizer school district. It is important to note that the health-based screening values used by EHAP were derived from comparison values that incorporate a high level of protectiveness for children and other sensitive individuals.

The likelihood of experiencing health effects from exposure to environmental contaminants depends on the amount of chemical one is exposed to and to the length of time a person is exposed to it. Because children spend much less time on buses than the drivers, their exposure to contaminants on the bus is also much less. Therefore, it is possible that drivers may experience health effects due to exposure to contaminants on the buses while children may not.

Conclusions

Isocyanates and other fire-related residues pose an “**indeterminate health hazard**” because it is unknown how long and in what quantities and locations they would or could persist in the buses. It is also unknown whether fire residues persisted in areas where children could come into contact with them. Therefore, EHAP is unable to determine whether or not isocyanates or other fire-generated residues pose a health hazard to the children riding the school buses.

The items that burned in the fire included foam padding and other materials that typically release isocyanates, aerosols, acid gases, and amines when burned[1]. Exposure to these contaminants can cause chemical sensitization and other respiratory symptoms that have been described by bus drivers. However, EHAP believes any risk of potential health effects that may be due to these exposures is lower for children than for drivers because they spend far less time in the buses.

Phosgene and sulfur dioxide in the school buses that were tested pose an “**indeterminate health hazard**” to the children riding the school buses. Due to the limits of detection for these chemicals, EHAP was unable to determine whether these chemicals exceed safe levels.

Carbon monoxide, benzene, limonene, undecane, diesel exhaust, particulate matter and phenol pose “**no apparent health hazard**” for the children riding on the buses tested. This was because the measured levels were either too low to cause health effects in children, or as in the case of limonene and undecane, the contaminants have low toxicities.

Recommendations:

Based upon EHAP’s review of the school bus data and the expressed community concerns, the following recommendations are appropriate and protective of the health of children who are riding school buses in the Salem-Keizer school district:

- Reduce children’s exposure to diesel exhaust even further by increasing awareness of and encouraging compliance with the school district’s “no idling” policy. In addition, ensure the proper maintenance of internal seals on the engine housing to prevent school buses from “self-polluting”.
- The fire-affected buses are good candidates to be moved to the top of the list of buses to be replaced over time.

If it is not feasible for the fire-affected buses to be replaced with newer or cleaner buses, EHAP recommends the following actions in order to fill in critical data gaps:

- Resample buses for phosgene and sulfur dioxide and analyze samples using methods that have limits of detection below 0.07 ppb for phosgene and below 10 ppb for sulfur dioxide.
- Address the possibility that foam seats (especially cloth-covered driver's seats) and ceiling insulation could serve as potential sources of fire residue that could have health implications for children. EHAP is available to the school district as a consultative resource in addressing this possibility.

Public Health Action Plan

The public health action plan for the site contains a description of actions that have been or will be taken by EHAP and other government agencies at the site. The purpose of the public health action plan is to ensure that this public health consultation both identifies public health hazards and provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. Included is a commitment on the part of EHAP to follow up on this plan to ensure that it is implemented.

Public health actions that have been taken include:

- Post-fire school bus cleaning by SKSD
- OR-OSHA's complaint inspection reviewing post-fire cleaning procedures and products
- OR-OSHA/ SKSD collaborative attempts to determine source of drivers' health symptoms
- OR-OSHA health consultation
- OR-OSHA follow-up report for diesel particulate matter and VOCs
- EHAP site visit
- EHAP health consultation

Public health actions that will be implemented:

- EHAP will hold a public availability session for the public to discuss findings of this health consultation and to address community concerns and questions.
- EHAP's toxicologist will provide consultation services as needed for SKSD in their development of future sampling/analysis plans.
- EHAP will assist the school district as needed in any outreach campaigns to increase awareness of the "no-idling" policy. EHAP's health educator will assist with this educational campaign, to be initiated by the SKSD.
- EHAP will remain available to address any public health questions or concerns regarding this issue for parents, administrators, or other concerned individuals after this report's final release.

Public Review

This document is available for public review and comments will be accepted from September 9 to October 7, 2008. A copy of the document will be on display and available during the public comment period at:

The Salem-Keizer Association of Classified Employees Office (SKACE)
2540 Coral Ave NE
Salem, OR 97305

The Salem-Keizer School District Transportation Department
998 Hawthorne Ave NE
Salem, OR 97301

It will also be sent to representatives of OR-OSHA. The report is also available on the web at <http://www.healthoregon.org/ehap>.

Site Team

**Oregon Department of Human Services
Environmental Health Assessment Program (EHAP) Team**

Authors of the Report

Dave Farrer, PhD
Public Health Toxicologist

Karen Bishop, MPH
Public Health Educator

EHAP Team

Julie Early-Alberts, MS
Program Coordinator

Sujata Joshi, MSPH
Public Health Epidemiologist

Jae Douglas, PhD
Principal Investigator

Agency for Toxic Substances and Disease Registry (ATSDR)

Alan Crawford
Division of Health Assessment and Consultation
ATSDR

Karen L. Larson, PhD
Regional Representative
Office of Regional Operations
ATSDR

References

1. Duquesne, S., et al., *Analysis of Fire Gases Released from Polyurethane and Fire-Retarded Polyurethane Coatings*. Journal of Fire Science, 2000. **18**: p. 456-482.
2. ATSDR, *DRAFT Toxicological Profile for Phenol*, D.o.H.a.H. Services, Editor. 2006: Atlanta, GA.
3. EPA. *Diesel Engine Exhaust IRIS Summary*. 2003 [cited; Available from: <http://www.epa.gov/ncea/iris/subst/0642.htm>].
4. ATSDR, *Toxicological Profile for Benzene*, D.o.H.a.H. Services, Editor. 2007: Atlanta, GA.
5. ATSDR, *Toxicological Profile for Sulfur Dioxide*, U.D.o.H.a.H. Services, Editor. 1998: Atlanta, GA.
6. EPA, *Toxicological Review of Phosgene*, U.E.P. Agency, Editor. 2005: Washington, DC.
7. Chiaverini, L., *Asthma, particulates, and diesel exhaust*. Med Health R I, 2002. **85**(4): p. 140-2.
8. Frew, A.J. and S.S. Salvi, *Diesel exhaust particles and respiratory allergy*. Clin Exp Allergy, 1997. **27**(3): p. 237-9.
9. Islam, T., *Diesel exhaust adversely affects people with moderate asthma*. Thorax, 2008. **63**(6): p. 513.
10. Jang, A.S., et al., *Additive effect of diesel exhaust particulates and ozone on airway hyperresponsiveness and inflammation in a mouse model of asthma*. J Korean Med Sci, 2005. **20**(5): p. 759-63.
11. Knox, R.B., et al., *Major grass pollen allergen Lol p 1 binds to diesel exhaust particles: implications for asthma and air pollution*. Clin Exp Allergy, 1997. **27**(3): p. 246-51.
12. McCreanor, J., et al., *Respiratory effects of exposure to diesel traffic in persons with asthma*. N Engl J Med, 2007. **357**(23): p. 2348-58.
13. McEntee, J.C. and Y. Ogneva-Himmelberger, *Diesel particulate matter, lung cancer, and asthma incidences along major traffic corridors in MA, USA: A GIS analysis*. Health Place, 2008.
14. Pandya, R.J., et al., *Diesel exhaust and asthma: hypotheses and molecular mechanisms of action*. Environ Health Perspect, 2002. **110 Suppl 1**: p. 103-12.
15. Sagai, M., A. Furuyama, and T. Ichinose, *Biological effects of diesel exhaust particles (DEP). III. Pathogenesis of asthma like symptoms in mice*. Free Radic Biol Med, 1996. **21**(2): p. 199-209.
16. Takano, H., R. Yanagisawa, and K. Inoue, *Components of diesel exhaust particles diversely enhance a variety of respiratory diseases related to infection or allergy: extracted organic chemicals and the residual particles after extraction differently affect respiratory diseases*. J Clin Biochem Nutr, 2007. **40**(2): p. 101-7.
17. Wade, J.F., 3rd and L.S. Newman, *Diesel asthma. Reactive airways disease following overexposure to locomotive exhaust*. J Occup Med, 1993. **35**(2): p. 149-54.

18. Savolainen, H. and N. Kirchner, *Toxicological Mechanisms of Fire Smoke*. The Internet Journal of Rescue and Disaster Medicine, 1998. **1**(1).
19. ATSDR, *Toxicological Profile for Hexamethylene Diisocyanate*, U.S.D.o.H.a.H. Services, Editor. 1998: Atlanta.
20. Braun, E., et al., *Assessment of the Fire Performance of School Bus Interior Components*, NIST, Editor. 1990: Washington, D.C.
21. Littorin, M., et al., *Acute respiratory disorder, rhinoconjunctivitis and fever associated with the pyrolysis of polyurethane derived from diphenylmethane diisocyanate*. Scand J Work Environ Health, 1994. **20**(3): p. 216-22.
22. Voumard, P.A., et al., [*Neurological sequelae following exposure to thermo-oxidative degradation of polyurethane compounds*]. Schweiz Med Wochenschr, 1995. **125**(27-28): p. 1367-8.
23. ATSDR, *Toxicological Profile for Formaldehyde*, D.o.H.a.H. Services, Editor. 1999: Atlanta, GA.
24. Bello, D., et al., *Skin Exposure to Isocyanates: Reasons for Concern*. Environmental Health Perspectives, 2007. **115**(3): p. 328-335.
25. Boutin, M., et al., *Determination of airborne isocyanates generated during the thermal degradation of car paint in body repair shops*. Annals of Occupational Hygiene, 2006. **50**(4): p. 385-393.
26. Cocker, J., *Biological monitoring for isocyanates*. Occup Med (Lond), 2007. **57**(6): p. 391-3.
27. Cvitanovic, S., L. Zekan, and M. Marusic, *Occurrence and specificity of IgE antibodies to isocyanates in occupationally exposed workers*. Int Arch Occup Environ Health, 1989. **61**(7): p. 483-6.
28. Deschamps, F., et al., *Mechanisms of occupational asthma induced by isocyanates*. Ann Occup Hyg, 1998. **42**(1): p. 33-6.
29. Deschamps, F., et al., *Prevalence of respiratory symptoms and increased specific IgE levels in West-African workers exposed to isocyanates*. J Toxicol Environ Health A, 1998. **54**(5): p. 335-42.
30. Goossens, A., T. Detienne, and M. Bruze, *Occupational allergic contact dermatitis caused by isocyanates*. Contact Dermatitis, 2002. **47**(5): p. 304-8.
31. Henneken, H., M. Vogel, and U. Karst, *Determination of airborne isocyanates*. Anal Bioanal Chem, 2007. **387**(1): p. 219-36.
32. Henriks-Eckerman, M.L., et al., *Exposure to airborne isocyanates and other thermal degradation products at polyurethane-processing workplaces*. J Environ Monit, 2002. **4**(5): p. 717-21.
33. Karol, M.H. and R.Z. Jin, *Mechanisms of immunotoxicity to isocyanates*. Chem Res Toxicol, 1991. **4**(5): p. 503-9.
34. Krone, C.A., *Diisocyanates and nonoccupational disease: a review*. Arch Environ Health, 2004. **59**(6): p. 306-16.
35. Krone, C.A., et al., *Isocyanates in flexible polyurethane foams*. Bull Environ Contam Toxicol, 2003. **70**(2): p. 328-35.
36. Krone, C.A. and T.D. Klingner, *Isocyanates, polyurethane and childhood asthma*. Pediatr Allergy Immunol, 2005. **16**(5): p. 368-79.
37. Lee, H.S., et al., *Occupational asthma due to isocyanates in Singapore*. Singapore Med J, 1990. **31**(5): p. 434-8.

38. Lemiere, C., et al., *Airway inflammation and functional changes after exposure to different concentrations of isocyanates*. J Allergy Clin Immunol, 2002. **110**(4): p. 641-6.
39. Levin, J.O., et al., *Isocyanates: measurement methodology, exposure and effects*. J Environ Monit, 2000. **2**(1): p. 18N-20N.
40. Maestrelli, P., et al., *Sputum eosinophilia after asthmatic responses induced by isocyanates in sensitized subjects*. Clin Exp Allergy, 1994. **24**(1): p. 29-34.
41. Pronk, A., et al., *Inhalation exposure to isocyanates of car body repair shop workers and industrial spray painters*. Ann Occup Hyg, 2006. **50**(1): p. 1-14.

Appendix A – Comparison Values

In evaluating these data, ATSDR used comparison values (CVs) to identify contaminants for further evaluation. CVs incorporate assumptions of daily exposure to a specific contaminant, as well as a specific, standard amount of air, water, and soil that someone might inhale or ingest each day for a period of time. All concentrations shown in table 1 refer to contaminant concentrations in air. Contaminants without CVs, such as limonene and undecane, are automatically selected for further evaluation.

As health-based thresholds, CVs are set at a concentration level that is below where any known or anticipated adverse human health effects are expected to occur. Different CVs are developed for cancer and non-cancer health effects. Non-cancer levels are based on valid toxicological studies for a chemical, with appropriate safety factors included, with the assumption that small children (22 pounds) and adults are exposed every day. Cancer levels are the concentrations at which there could theoretically be a one in a million excess cancer risk for an adult eating contaminated soil or drinking contaminated water every day for 70 years. For chemicals for which both cancer and non-cancer numbers exist, the lower level is used to be protective. Exceeding a CV does not automatically mean that health effects will occur, just that more evaluation is needed.

Appendix B -Dose calculation for phenol residues on seat cushions

$$ADD = \frac{Sap \times Sae \times EF_1 \times EF_2 \times ED}{AT \times BW}$$

Where ADD = Average Daily Dose and:

Exposure factor	Exposure Factor Description	Value	Units	Source of Value
Sap	Phenol per surface area on bus seats	0.0019	mg/cm ²	Average OR-OSHA measurement from swipe tests of top, bottom, and back of seats on bus #41
Sae	Bus seat surface area contacted by children	8361	cm ² (9 sq. Ft.)	Professional Judgment
EF ₁	Exposure frequency/day	2	exposure/day	Professional Judgment
EF ₂	Exposure frequency	177	days exposed/year	School days/year in Salem-Keizer School District
ED	Exposure duration	13	years	Kindergarten-12 grade
BW	Body Weight	44.5	kg	Average body weight from 5-18 years of age (19-70 kg)
AT	Averaging Time	4745	days	365 x ED

It is assumed that 100% of the phenol contacted is absorbed into the body either through the skin or orally. This is a very conservative assumption and was used to be protective of health.

In this case:

$$0.35 \text{ mg/kg/day} = \frac{0.0019 \text{ mg/cm}^2 \times 8361 \text{ cm}^2 \times 2 \text{ exposures/day} \times 177 \text{ days/year} \times 12 \text{ years}}{4745 \text{ days} \times 44.5 \text{ kg}}$$

The EPA reference dose used as the CV for phenol is 0.3 mg/kg/day. Therefore, phenol is a contaminant of concern.

APPENDIX C – Table of Events

Dates	Event	Who/What was involved	Purpose	How EHAP used the data
December 17, 2006	Fire	School buses at Main school bus facility		Reviewed fire report
December 19-29, 2006	School bus cleaning & ozoning	SKSD contractors and affected buses	To remove smoke and soot residue and odors & repair damaged exteriors	Considered methods and cleaners used
January 5, 8, & 26, 2007	Additional bus cleanings	SKSD contractors and affected buses	To more thoroughly clean specific buses based upon driver's health symptoms	Considered methods and health symptoms
February 2007	OR-OSHA opened complaint inspection	OR-OSHA Investigator, SKSD, Bus drivers	To review cleaning procedures and service reports; To examine cleaning products; To consider exposures for bus drivers based upon health complaints; To determine if SKSD had taken appropriate measures; To identify substances that would cause the persistent health effects drivers continued to experience.	Reviewed data and conclusions
February 2007	Microscopic analysis of particles in the air intake filter on bus 22	OR-OSHA investigator, SKSD, and bus #22	To determine if the air filter from the bus located across from the fire's point of origin contained high levels of residual fire debris	Data not helpful in determining cause of health effects; not used in this report
April 2007	SKSD hired a contractor to clean one of the bus' ventilation system	SKSD, contractor, and one school bus	To clean the ventilation system by blowing air through the ducts, in an attempt to alleviate driver's symptoms	Reviewed the reasons and conclusions
June 2007	OR-OSHA inspection concluded and closed	SKSD, OR-OSHA, and bus drivers		

Dates	Event	Who/What was involved	Purpose	How EHAP used the data
November 2007	SKSD hired a consultant to analyze air particulate from inside 10 buses	SKSD, Wise Steps Inc., buses 10, 14, 16, 17, 27, 31, 41, 142, 159, 161, and outdoors at lot	To identify fire residue in the air by microscopic analysis of particles trapped on air sampling filters	Data not useful in identifying causes of health effects; not used in this report
November 2007	Opening of health consultation with OR-OSHA	SKSD, OR-OSHA, and bus drivers	To consider current occupational exposures that may be responsible for bus driver's health complaints	Reviewed data collection and analysis methods, findings and conclusions
December 2007	Real-time air monitoring	OR-OSHA, SKSD, and buses 16, 17, 31, 41, 124, 159 and outdoors in Hawthorn and Gaffin Road lots	To measure particulates, carbon dioxide, carbon monoxide, VOCs, temperature, and humidity on buses in real-time	Particulate matter measurements analyzed in report (Table A1); Carbon monoxide data analyzed in report (Table A1); carbon dioxide, temperature, humidity, and VOC data not analyzed in report
December 2007	Irritant gases sampling	OR-OSHA, SKSD, and buses 16 and 41	Because irritant gases could cause symptoms experienced by bus drivers, they were measured quantitatively. Irritant gases measured: ozone, nitrogen oxides, phosgene, and sulfur dioxides	These data were used in report (Table A1)
December 2007	VOC qualitative measurement	OR-OSHA, SKSD, and buses 16 and 41	Several VOCs were tested for qualitatively. Benzene, toluene, n-undecane ethylbenzene xylenes, n-dodecane, limonene, and 2,6-dimethyl-7-octen-2-ol were detected	Because quantitative data for the VOCs of most concern were collected later, these data were not analyzed in this report.
December 2007	Phenol	OR-OSHA, SKSD, bus 41	Phenol measured in the air and on seat surfaces because it can act as a chemical sensitizer	Wipe test data was analyzed in this report

Dates	Event	Who/What was involved	Purpose	How EHAP used the data
December 2007	Particle-bound organics analyzed	OR-OSHA, SKSD, bus 16	To identify organic compounds that may be bound to dust particles in the bus	Because these data were qualitative only, and quantitative VOC data was subsequently collected, these data were not analyzed in the report
January 2008	EHAP's services were requested by the SKSD to conduct a health consultation	SKSD, EHAP, Children's exposures	To determine if the fire-affected school buses are a health hazard for the children who ride them	Received copies of all the data samples and compared the levels of contaminants to health-based standards that are protective of children's and other sensitive population's health
February 2008	Diesel particulate sampling event	OR-OSHA, SKSD, and school buses	To determine the level of particulate matter in the air that could potentially be causing the health effects experienced by the bus drivers	Participated in determining collection method, reviewed collection and analysis methods, findings and conclusions
February 2008	Quantitative VOC sampling event	OR-OSHA, SKSD, and school buses	To determine whether VOC concentrations on school buses were high enough to cause health effects in affected drivers.	These data were used in report (Table A1)
April 2008	EHAP site visit	EHAP team members, SKSD representative, bus drivers	To gather background information, tour the fire site, ride one of the affected buses and talk with affected community members	Will be used in the health consultation report

APPENDIX D

ATSDR's Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR serves the public by using the best science to take responsive public health actions and provides trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Absorption

For a person or animal, absorption is the process through which a substance enters the body through the eyes, skin, stomach, intestines, or lungs.

Acute

Occurring over a short time [compare with **chronic**].

Acute exposure

Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with **intermediate duration exposure** and **chronic exposure**].

Adverse health effect

A change in body function or cell structure that might lead to disease or health problems.

AML

Acute Myeloid Leukemia: A grouping of specific cancers of the blood.

Background level

An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biologic uptake

The transfer of substances from the environment to plants, animals, and humans.

Cancer

Any one of a group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Cancer risk

A theoretical risk for developing cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen

A substance that causes cancer.

Chronic

Occurring over a long time (more than 1 year) [compare with **acute**].

Chronic exposure

Contact with a substance that occurs over a long time (more than 1 year) [compare with **acute exposure** and **intermediate duration exposure**].

Completed exposure pathway [see **exposure pathway**].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA, also known as **Superfund**, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances.

Concentration

The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant

A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal

Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact

Contact with (touching) the skin [see **route of exposure**].

Detection limit

The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention

Measures used to prevent a disease or reduce its severity.

Disease registry

A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD

United States Department of Defense.

Dose (for chemicals that are not radioactive)

The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An **Aexposure dose@** is how much of a substance is encountered in the environment. An **Aabsorbed dose@** is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose-response relationship

The relationship between the amount of exposure [**dose**] to a substance and the resulting changes in body function or health (response).

Environmental media

Soil, water, air, **biota** (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism

Environmental media include water, air, soil, and **biota** (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The **environmental media and transport mechanism** is the second part of an **exposure pathway**.

EPA

United States Environmental Protection Agency.

Epidemiologic surveillance

The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Epidemiology

The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure

Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].

Exposure assessment

The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction

A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation

The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway

The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a **source of contamination** (such as an abandoned business); an **environmental media and transport mechanism** (such as movement through groundwater); a **point of exposure** (such as a private well); a **route of exposure** (eating, drinking, breathing, or touching); and a **receptor population** (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a **completed exposure pathway**.

Groundwater

Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with **surface water**].

Hazard

A source of potential harm from past, current, or future exposures.

Hazardous waste

Potentially harmful substances that have been released or discarded into the environment.

Health consultation

A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with **public health assessment**].

Health education

Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation

The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to estimate the possible association between the occurrence and exposure to hazardous substances.

Health promotion

The process of enabling people to increase control over, and to improve, their health.

Indeterminate public health hazard

The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence

The number of new cases of disease in a defined population over a specific time period [contrast with **prevalence**].

Ingestion

The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see **route of exposure**].

Inhalation

The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].

Lowest-observed-adverse-effect level (LOAEL)

The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

mg/kg

Milligram per kilogram.

mg/cm²

Milligram per square centimeter (of a surface).

mg/m³

Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

µg/m³

Micrograms per cubic meter: a measure of a concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration

Moving from one location to another.

MRL

Minimum Risk Level; An estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse no-cancer health effects over a specified duration of exposure.

No apparent public health hazard

A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)

The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard

A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

Oxidation

The combination of a substance with oxygen or a reaction in which the atoms in an element lose electrons and the valence of the element is correspondingly increased.

Plume

A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure

The place where someone can come into contact with a substance present in the environment [see **exposure pathway**].

Population

A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb

Parts per billion.

ppm

Parts per million.

Prevalence

The number of existing disease cases in a defined population during a specific period [contrast with **incidence**].

Prevalence survey

The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention

Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period

An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public availability session

An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public health action

A list of steps to protect public health.

Public health advisory

A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)

An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with **health consultation**].

Public health hazard

A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or **radionuclides** that could result in harmful health effects.

Public health hazard categories

Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are **no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.**

Public health statement

The first chapter of an ATSDR **toxicological profile**. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public meeting

A public forum with community members for communication about a site.

Reference Concentration (RfC)

The concentration of a chemical in air that is very unlikely to have adverse effects if inhaled continuously over a lifetime.

Reference dose (RfD)

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

Registry

A systematic collection of information on persons exposed to a specific substance or having specific diseases [see **exposure registry** and **disease registry**].

RFA

RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfC

See **reference concentration**.

RfD

See **reference dose**.

Risk

The probability that something will cause injury or harm.

Risk reduction

Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication

The exchange of information to increase understanding of health risks.

Route of exposure

The way people come into contact with a hazardous substance. Three routes of exposure are breathing [**inhalation**], eating or drinking [**ingestion**], or contact with the skin [**dermal contact**].

Safety factor [see **uncertainty factor]****Sample**

A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see **population**]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Source of contamination

The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an **exposure pathway**.

Special populations

People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Substance

A chemical.

Superfund Amendments and Reauthorization Act (SARA)

In 1986, SARA amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water

Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].

Toxic agent

Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicology

The study of the harmful effects of substances on humans or animals.

Tumor

An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor

Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a **safety factor**].

Urgent public health hazard

A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)

Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other Glossaries and Dictionaries

Environmental Protection Agency
<http://www.epa.gov/OCEPAt/terms/>

National Center for Environmental Health (CDC)
<http://www.cdc.gov/nceh/dls/report/glossary.htm>

National Library of Medicine (NIH)
<http://www.nlm.nih.gov/medlineplus/mplusdictionary.html>