

**RISK ASSESSMENT  
FOR THE QUALITY PRINTED CIRCUITS FACILITY**



**Prepared For**

**ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY  
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**Prepared By**

**ARIZONA DEPARTMENT OF HEALTH SERVICES  
Division of Disease Prevention  
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## Executive Summary

The purpose of this human health risk assessment is to determine the extent and likelihood of adverse health effects that could occur as a result of human exposure to chemicals that may have been deposited in homes following the fire at the former Quality Printed Circuits (QPC) facility. This risk assessment is prepared by the Arizona Department of Health Services (ADHS) under the guidelines prescribed by the United States Environmental Protection Agency (USEPA) Risk Assessment Guidelines for Superfund (RAGS)<sup>1</sup> and the Supplemental Guidance, "Standard Default Exposure Factors."<sup>2</sup> These guidelines use health-conservative assumptions that produce upper-bound estimates of risk. The health evaluation procedures used in this document are unlikely to underestimate risk.

The fire at the QPC facility on August 31, 1992 has caused concern about the effect of the fire on residents living in the surrounding area. On October 22 and 28, 1992, the Arizona Department of Environmental Quality (ADEQ) collected samples from 11 houses in the neighborhood near QPC in order to determine whether any harmful chemicals were deposited in homes in the path of the smoke. The houses that were selected for sampling were recommended by the South Phoenix Residents Association. Samples were taken from soils in yards and from residue in air ducts. Samples from the air ducts found some elevated levels of copper, lead, zinc, and plasticizers. The results of the soil samples found no elevated concentrations of metals or plasticizers.

In January, 1993, the Agency for Toxic Substances and Disease Registry (ATSDR) analyzed the results of the October sampling and concluded that any breathing problems that people may have as a result of the fire were probably caused by inhalation of gases at the time of the fire.

Although the ATSDR and the ADHS concluded that the concentrations of chemicals that were found would not pose a health risk, some citizens of the area have reported having a variety of health symptoms and believe that contaminants remaining in the homes as a result of the fire are responsible. In order to specifically address this question, the ADEQ hired the Zenitech Corporation, a Tucson based environmental consulting company, to conduct environmental sampling and analysis in the homes near QPC.

Samples were collected by Zenitech from 10 study and 3 control houses from May 3-14, 1993. Samples of airborne particulates, household dust, soil, and material deposited on ductwork, vents, and evaporative cooler pads were collected in the selected homes. The air samples were analyzed for metals, semi-volatile organic compounds (SVOCs), and airborne particulates; soil samples were analyzed for metals and SVOCs; household dust samples were analyzed for metals; evaporative cooler pads were analyzed for metals, anions, and SVOCs; and ventilation ducts were analyzed for metals and anions.<sup>3</sup> After making statistical comparisons of the study and control homes, Zenitech identified the following areas of concern:<sup>3</sup>

Zinc concentrations in the air inside the study homes were higher than the concentrations outside the homes.

Fluoride, Copper and Zinc concentrations in the ductwork of study homes were higher than concentrations in the control homes.

Copper, Lead, Nickel, and Tin concentrations in the housedust of study homes were higher than housedust in the control homes.

Based upon review and analysis of the data, Zenitech concluded " ... that sufficient evidence exists that elevated levels of certain substances may be present in homes close to the former QPC II facility. The substances which are potentially elevated could have arisen from the August 31, 1992 QPC II fire or from another, as yet unidentified, source or regional phenomenon."<sup>3</sup>

This risk assessment quantitatively evaluates whether these potentially elevated substances represent a health risk to those individuals who may be exposed. The exposure routes evaluated include incidental ingestion of soil and housedust, dermal contact with housedust, and inhalation of metals suspended in air. Chapter 3 provides the formulas and dose estimates for each of the complete exposure pathways. Chapter 4 discusses the toxicological properties of the metals found in the sampled media. Chapter 5 evaluates whether or not adverse health effects are likely to occur.

The results of the quantitative risk assessment indicate that no adverse health effects would be expected to occur as a result of exposure to the concentrations of chemicals found in the environmental study conducted by Zenitech, Inc.

## 1.0 INTRODUCTION

A fire at the Quality Printed Circuits (QPC) facility on August 31, 1992 has caused concern about the effect of the fire on residents living in the surrounding area. The purpose of this human health risk assessment is to determine the extent and likelihood of adverse health effects that could occur as a result of human exposure to chemicals that may have been deposited in homes following the fire. Since no quantitative air monitoring data are available from the day of the fire, this risk assessment cannot address the health effects that resulted from acute exposure to the smoke. The Arizona Department of Health Services (ADHS) is attempting to address this issue by providing, under contract, medical examination, testing, and diagnostic services to residents who suffered adverse health effects from acute exposure to the smoke.

This risk assessment is prepared by the ADHS under the guidelines prescribed by the United States Environmental Protection Agency (USEPA) Risk Assessment Guidelines for Superfund (RAGS)<sup>1</sup> and the Supplemental Guidance, "Standard Default Exposure Factors."<sup>2</sup>

### Overview

The Quality Printed Circuits (QPC) factory was a manufacturing plant which produced circuit boards used in computers and other electronic equipment. In the manufacturing process, metal foil and other materials are put through an imaging process and treated with chemicals for reinforcement. The chemicals used in large quantities in this process were copper, sulfuric acid, and nitric acid.

On the morning on August 31, 1992, a fire started somewhere in the production area of the facility. The fire was fought by the City of Phoenix Fire Department for several hours with assistance from Arizona Department of Environmental Quality (ADEQ) Emergency Response personnel.

Based upon available meteorological data, ADEQ Air Quality scientists and engineers have developed a map of the area that may have been affected by smoke from the fire. The map shows that the area directly east and north of the fire were likely the most heavily impacted, however, it may never be possible to precisely define how big the affected area may have been.

On October 22 and 28, 1992, the ADEQ collected samples from 11 houses in the

neighborhood near QPC in order to determine whether any harmful chemicals were deposited in homes in the path of the smoke. The houses that were selected for sampling were recommended by the South Phoenix Residents Association. Samples were taken from soils in the yards and from residue in air ducts. The results of the soil samples found no elevated concentrations substances. Samples from the air ducts found some elevated levels of copper, lead, zinc, and plasticizers. Plasticizers are organic substances added to plastics to make them soft or pliable.

In January, 1993, the Agency for Toxic Substances and Disease Registry (ATSDR) analyzed the results of the October sampling and concluded that any breathing problems that people may have as a result of the fire were probably caused by inhalation of gases at the time of the fire.

Although the ATSDR and ADHS concluded that the concentrations of chemicals that were found would not pose a health risk, some citizens of the area have reported having a variety of health symptoms and believe that contaminants remaining in the homes as a result of the fire are responsible. In order to specifically address this question, the ADEQ hired the Zenitech Corporation to conduct environmental sampling and analysis in study and control homes near QPC. The objective of the sampling was to determine whether fire-related chemicals are in greater concentrations in houses close to the fire than houses further away.

After making statistical comparisons of the study and control homes, Zenitech identified the following areas of concern:<sup>3</sup>

Zinc concentrations in the air inside the study homes were higher than the concentrations outside the homes.

Fluoride, Copper and Zinc concentrations in the ductwork of study homes were higher than concentrations in the control homes.

Copper, Lead, Nickel, and Tin concentrations in the housedust of study homes were higher than housedust in the control homes.

Based upon an analysis of the data, Zenitech concluded " ... that sufficient evidence exists that elevated levels of certain substances may be present in homes close to the former

QPC II facility. The substances which are potentially elevated could have arisen from the August 31, 1992 QPC II fire or from another, as yet unidentified, source or regional phenomenon."<sup>3</sup>

The purpose of this human health risk assessment is to determine the extent and likelihood of adverse health effects as a result of exposure to metals found during this most recent investigation.

## **2.0 CHEMICALS OF POTENTIAL CONCERN**

This section identifies the chemicals of potential concern in the study homes. The chemicals that were selected based upon data from the Zenitech summary report dated June 21, 1993, and information about the chemicals that were used at the plant.

### **2.1 Source of Contamination**

The conclusion that concentrations of certain chemicals are elevated in homes close to the facility indicates that the source of the chemicals may have been the fire at the QPC facility. However, it is possible that concentrations were found to be higher due to an unidentified source or regional phenomenon.<sup>3</sup>

### **2.2 Data Collection and Evaluation**

Samples were collected by Zenitech from the 10 study and 3 control houses from May 3rd thru 14th, 1993. In order to be selected as a study or control home, the home had to be at least 15 years old, have an evaporative cooler, and could contain no residents who smoke. The details of the procedures used for selection are available in the Sampling and Analysis Plan prepared by Zenitech.<sup>4</sup> The sampling plan was approved by the ADEQ.

Samples collected were: airborne particulates, household dust, soil, and material deposited on ductwork and evaporative cooler pads. The air samples were analyzed for metals, semi-volatile organic compounds (SVOCs), and airborne particulates; soil samples were analyzed for metals and SVOCs; household dust samples were analyzed for metals; evaporative cooler pads were tested for metals, anions, and SVOCs; and ventilation ducts were sampled for metals and anions.<sup>3</sup>

The following is a list of the chemicals for which analyses were conducted in the soil samples:

**BASE NEUTRAL ANALYTE**

N-Nitrosodimethylamine  
Aniline  
Bis(2-chloroethyl) Ether  
1,2-Dichlorobenzene  
1,3-Dichlorobenzene  
1,4-Dichlorobenzene  
Bis(2-chloroisopropyl) Ether  
N-Nitroso-di-n-propylamine  
Hexachloroethane  
Nitrobenzene  
Isophorone  
Bis(2-chloroethoxy)methane  
1,2,4-Trichlorobenzene  
Naphthalene  
4-Chloroaniline  
Hexachlorobutadiene  
2-Methylnaphthalene  
Hexachlorocyclopentadiene

2-Chloronaphthalene  
2-Nitroaniline  
Dimethyl Phthalate  
Acenaphthylene  
3-Nitroaniline  
Acenaphthene  
Dibenzofuran  
Acenaphthene  
2,4-Dinitrotoluene  
2-6 Dinitrotoluene  
Diethyl Phthalate  
4-Chlorophenyl Phenyl Ether  
Fluorene  
4-Nitroaniline  
N-Nitrosodiphenylamine  
4-Bromophenyl Phenyl Ether  
Hexachlorobenzene  
Phenanthrene

Anthracene  
Di-n-butyl Phthalate  
Fluoranthene  
Pyrene  
Butylbenzyl Phthalate  
3,3'-Dichlorobenzidine  
Benz(a)anthracene  
Bis(2-ethylhexyl) Phthalate  
Chrysene  
Di-n-octyl Phthalate  
Benzo(b)fluoranthene  
Benzo(k)fluoranthene  
Benzo(a)pyrene  
Indeno(1,2,3-c,d)pyrene  
Dibenz(a,h)anthracene  
Benzo(g,h,i)perylene

**ACID ANALYTE**

Phenol  
2-Chlorophenol  
Benzyl Alcohol  
2-Methylphenol  
3-and 4-Methylphenol  
2-Nitrophenol

2,4-Dimethylphenol  
Benzoic Acid  
2,4-Dichlorophenol  
4-Chloro-3-methylphenol  
2,4,6-Trichlorophenol

2,4,5-Trichlorophenol  
2,4-Dinitrophenol  
4-Nitrophenol  
2-Methyl-4,6-dinitrophenol  
Pentachlorophenol

**ANALYTE**

Boron  
Copper  
Lead

Nickel  
Tin  
Zinc

Fluoride  
Nitrate  
Sulfate

The following is a list of the chemicals for which analyses were conducted in the household dust samples:

**ANALYTE**

Boron  
Copper  
Lead  
Nickel  
Tin  
Zinc

The following is a list of the chemicals for which analyses were conducted in the air samples:

**SEMI-VOLATILE ORGANICS IN AIR BY T013**

Phenol	4-Chloroaniline	4-Nitroaniline
bis(2-Chloroethyl)ether	Hexachlorobutadiene	2-Methyl-4, 6-dinitrophenol
2-Chlorophenol	4-Chloro-3-methylphenol	N-nitrosodiphenylamine
1,3-Dichlorobenzene	2-Methylnaphthalene	4-Bromophenyl phenyl ether
1,4-Dichlorobenzene	Hexachlorocyclopentadiene	Hexachlorobenzene
Benzyl alcohol	2,4,6-Trichlorophenol	Pentachlorophenol
1,2 Dichlorobenzene	2,4,5-Trichlorophenol	Phenanthrene
2-Methylphenol	2-Chloronaphthalene	Anthracene
bis(2-Chloroisopropyl)ether	2-Nitroaniline	Di-n-butyl phthalate
3-Methylphenol & 4-Methylphenol	Dimethyl phthalate	Fluoranthene
n-Nitrosodi-n-propylamine	Acenaphthylene	Pyrene
Hexachloroethane	3-Nitroaniline	Butyl benzyl phthalate
Nitrobenzene	Acenaphthene	3,3-Dichlorobenzidine
Isophorone	2,4-Dinitrophenol	Benzo(a)anthracene
2-Nitrophenol	4-Nitrophenol	bis(2-Ethylhexyl)phthalate
2,4-Dimethylphenol	Dibenzofuran	Chrysene
Benzoic acid	2,4-Dinitrotoluene	Di-n-octyl phthalate
bis(2-Chloroethoxy)methane	2,6-Dinitrotoluene	Benzo(b)fluoranthene
2,4-Dichlorophenol	Diethyl phthalate	Benzo(k)fluoranthene
1,2,4-Trichlorobenzene	4-Chlorophenyl phenyl ether	Benzo(a)pyrene
Naphthalene	Fluorene	Ideno(1,2,3-c,d)pyrene



## 2.3 Analytical Results

### Air

No lead, nickel or tin were detected in the air samples. As a result, these chemicals were eliminated as chemicals of concern in air. Copper and zinc were detected in some indoor air samples and are included as chemicals of concern.

With the exception of one detection of bis(2-ethylhexyl)phthalate at 0.073 mg/m<sup>3</sup> in one air sample, no SVOCs were detected in any of the analyses. Bis(2-ethylhexyl)phthalate is present in numerous household plastic products and food, and is a common laboratory contaminant. The major concern with bis(2-ethylhexyl)phthalate is its potential ability to cause cancer following long-term exposure. Because this chemical was detected in only one air sample and was not found deposited in air ducts, it was concluded that long term exposure is not likely. Accordingly, bis(2-ethylhexyl)phthalate is not evaluated in this risk assessment.

The mean, standard deviation and upper 95 % confidence limit of the concentrations of metals found in air are:

<b>Study Homes</b>			
	<u>Mean</u>	<u>Standard Deviation</u> (n=10)	<u>95% UCL</u>
Zinc	0.0007 mg/m <sup>3</sup>	0.00053	0.001 mg/m <sup>3</sup>
Copper	0.0001 mg/m <sup>3</sup>	0.00003	0.0001 mg/m <sup>3</sup>

  

<b>Control Homes</b>			
	<u>Mean</u>	<u>Standard Deviation</u> (n=3)	<u>95% UCL</u>
Zinc	0.0017 mg/m <sup>3</sup>	0.0014	0.005 mg/m <sup>3</sup>
Copper	0.0001 mg/m <sup>3</sup>	0.0	0.0001 mg/m <sup>3</sup>

## Soil

No SVOCs were detected in any of the soil samples collected. As a result, all SVOCs were eliminated as chemicals of concern for soils in the risk assessment. Boron, Copper, Lead, Nickel, and Zinc were detected in soils and are therefore selected as chemicals of concern in soils. The mean, standard deviation, and upper 95 % confidence limit of the concentrations of chemicals found in soil are:

### Study Homes

	<u>Mean</u>	<u>Standard Deviation</u> (n=20)	<u>95 % UCL</u>
Boron	4 mg/kg	3	5 mg/kg
Copper	22 mg/kg	3	23 mg/kg
Lead	26 mg/kg	8	30 mg/kg
Nickel	17 mg/kg	3	18 mg/kg
Zinc	80 mg/kg	27	93 mg/kg

### Control Homes

	<u>Mean</u>	<u>Standard Deviation</u> (n=6)	<u>95 % UCL</u>
Boron	9 mg/kg	2	11 mg/kg
Copper	24 mg/kg	7	31 mg/kg
Lead	33 mg/kg	12	45 mg/kg
Nickel	17 mg/kg	2	19 mg/kg
Zinc	88 mg/kg	36	130 mg/kg

## Housedust

Boron, Copper, Lead, Nickel, Tin and Zinc were detected in housedust and are therefore chemicals of concern in housedust. Samples that were collected behind, under, and on top of refrigerators and freezers, on top of shelving and cabinets, and along kitchen and living room baseboards were used to determine the concentrations of these metals in housedust. The mean, standard deviation, and upper 95 % confidence limit of the concentrations found in housedust are:

### Study Homes

	<u>Mean</u>	<u>Standard Deviation</u> (n=13)	<u>95% UCL</u>
Boron	74 mg/kg	130	150 mg/kg
Copper	200 mg/kg	210	330 mg/kg
Lead	99 mg/kg	64	140 mg/kg
Nickel	150 mg/kg	240	290 mg/kg
Tin	31 mg/kg	35	52 mg/kg
Zinc	4500 mg/kg	7000	8900 mg/kg

### Control Homes

	<u>Mean</u>	<u>Standard Deviation</u> (n=3)	<u>95% UCL</u>
Boron	600 mg/kg	1000	3100 mg/kg
Copper	8 mg/kg	6	24 mg/kg
Lead	5 mg/kg	0	5 mg/kg
Nickel	15 mg/kg	18	60 mg/kg
Tin	2.5 mg/kg	0	2.5 mg/kg
Zinc	400 mg/kg	500	1800 mg/kg

### Duct Surface and Vent Samples

Copper and Zinc were detected in greater concentrations in the ductwork in the study houses than the single control house sample, and are therefore considered chemicals of concern in ductwork and vents in study homes. The swipe sample collected at the control house was below detection limits for all the metals. The mean, standard deviation, and upper 95% confidence limit of the concentrations found in swipe samples of ductwork in study homes are:

### Study Homes

	<u>Mean</u>	<u>Standard Deviation</u> (n=3)	<u>95 % UCL</u>
Copper	0.0008 mg/100cm <sup>2</sup>	0.00015	0.0012 mg/100cm <sup>2</sup>
Zinc	0.07 mg/100cm <sup>2</sup>	0.075	0.26 mg/100cm <sup>2</sup>

The mean, standard deviation, and upper 95 % confidence limit of the concentrations of metals found on the interior surfaces of heater/cooler vents are:

### Study Homes

	<u>Mean</u>	<u>Standard Deviation</u> (n=7)	<u>95 % UCL</u>
Copper	1022 mg/kg	1846	2729
Zinc	40973 mg/kg	42481	80274

### Control Homes

	<u>Mean</u>	<u>Standard Deviation</u> (n=3)	<u>95 % UCL</u>
Copper	44 mg/kg	17	87
Zinc	15600 mg/kg	9002	37963

## 2.4 Data Uncertainties

Efforts were made in the sampling plan to select study and control homes that were of similar ages, however, homes were not selected based upon the presence or absence of lead based paint. Since lead based paint can be a significant source of lead in housedust, failure to use this criteria as a basis for selection introduces uncertainty into the lead concentration results.

The sampling procedures used were designed to determine if a difference exists between concentrations of chemicals in study homes versus control homes. As a result, conclusions about concentrations in single homes may not be drawn.<sup>3</sup>

Uncertainty in the results exists due to the small study sizes, particularly within the control population. When limited data are available, accurate and reliable estimates of contaminant concentrations are difficult to obtain. In order to compensate for this uncertainty, 95% upper confidence limit (UCL) estimates were used in the risk characterization.

### **3.0 EXPOSURE ASSESSMENT**

The exposure assessment evaluates possible exposure pathways to determine ways in which humans can come into contact with the chemicals of concern. An exposure pathway is considered complete when a chemical of concern comes into contact with a receptor. The four steps comprising an exposure assessment are: 1) identification of the exposure setting; 2) description of the exposed population and exposure pathways; 3) estimation of exposure concentrations of chemicals; and 4) calculation of intake doses for each pathway.

#### **3.1 Exposure Pathway Identification**

A potentially complete exposure pathway describes the route a chemical may take from the source to a receptor. A complete exposure pathway includes the following components.<sup>1</sup>

- 1) A source and mechanism of release to the environment,
- 2) A medium for the transport of the released chemical to the environment,
- 3) A point of potential human contact with the contaminated media,
- 4) An exposure route at the exposure point, (ingestion, inhalation, dermal contact).

#### **3.2 Exposure Points and Routes**

##### **Air Exposure**

Inhalation of chemicals that are suspended in air is considered a complete exposure pathway. Exposures are quantified using measured indoor air concentrations.

Particles less than 10 microns in size may be inhaled and deposited in various portions of the respiratory tract. Particles which are between 5 and 10 microns in aerodynamic diameter are usually deposited in nasopharynx (above the soft palate) and r. n. , blowing the nose. Particles with an aerodynamic diameter of between 2 and 5 microns are deposited in the

tracheobronchus (air pathway), are removed by the cilia, and are ultimately ingested. Particles that are around 1 micron in aerodynamic diameter may be deposited in the alveoli (air sacs) in the lungs.<sup>15</sup>

### **Housedust Exposure**

Direct contact and incidental ingestion of chemicals in the housedust of study homes is considered a complete exposure pathway. Dermal absorption of these metals is negligible, and dermal absorption is not considered a complete exposure pathway for housedust. However, Chapter 5 evaluates dermal contact with housedust to determine whether surface contact with housedust has the potential to cause dermatitis or other skin problems.

### **Soil Exposure**

Despite the fact that none of the chemicals tested were found in greater concentrations in the soils around the study houses than the control houses, direct contact and incidental ingestion of soils are considered a complete exposure pathway. Dermal absorption of these metals is negligible, and dermal absorption is not considered a complete exposure pathway for soils. However, Chapter 5 evaluates dermal contact with soil to determine whether surface contact with soil has the potential to cause dermatitis or other skin problems.

### **Exposure to Metals in Ductwork and Vents**

While no direct contact with chemicals of concern in ductwork or vents would be expected to occur, indirect exposure through inhalation of contaminants which may erode and become suspended in air may be possible. Any metals that erode from the ductwork would be expected to contribute to the concentrations of metals in indoor air and housedust. Measured indoor air and housedust concentrations would reflect this contribution. The measured concentrations of metals in air and housedust provide the most meaningful information about any potential risk and are evaluated in this risk assessment.

In addition to evaluating risk from exposure to actual metal concentrations in housedust and indoor air, the following model was developed in order to form a theoretical concentration of metals in a model house if the total mass of copper and zinc were to erode in one month.

*Part 1- Erosion from Ducts.*

Results from swipe samples were analyzed in order to determine the 95% UCL of the metal concentration in milligrams per square meter of ductwork (mg/m<sup>2</sup>). An estimate of the average surface area of the ductwork was then made. With this information, it is possible to estimate the total mass of metals in the ducts. An assumption is made that the total mass of the metals will erode from the ductwork and become suspended in the air during the next month. By dividing the mass of metals in the ductwork by the total volume of air that will be expelled from an average evaporative cooler during the next month, a theoretical estimate of the concentration in air may be made. The following calculations derive the concentration estimate for ducts:

A 2000 ft<sup>2</sup> house was assumed to have ventilation ductwork of the following dimensions: The main duct has dimensions of 40 cm by 20 cm and is 20 meters in length. The smaller duct has dimensions of 15 cm by 30 cm and is 40 meters in length. Using these dimensions, an estimated 30 square meters of duct surface is present in the modeled house.

To determine the total mass of copper and zinc in the ductwork, the upper 95% confidence limit of the experimental results from the sampling is used as follows:

$$\text{Total mass of copper in mg} = (0.0012 \text{ mg/dm}^2)(100 \text{ dm}^2/1 \text{ m}^2)(30 \text{ m}^2) = 3.6 \text{ mg of copper in the ductwork.}$$

$$\text{Total mass of zinc in mg} = (0.26 \text{ mg/dm}^2)(100 \text{ dm}^2/1 \text{ m}^2)(30 \text{ m}^2) = 780 \text{ mg of zinc in the ductwork.}$$

Assuming that the total mass of zinc and copper will erode from the ductwork in the next month, and by dividing by the volume of air expelled in a month by a 5000 ft<sup>3</sup>/minute (141 m<sup>3</sup>/min) evaporative cooler running 20 hours per day, a theoretical estimate of the concentration of these metals in air as a result of metals in the duct can be obtained. The calculations are as follows:

$$\text{Copper concentration in air} = (3.6 \text{ mg}) / (141 \text{ m}^3/\text{min})(60 \text{ min}/\text{hour})(20 \text{ hours}/\text{day})(30 \text{ days}) = 7 \times 10^{-7} \text{ mg/m}^3$$

$$\text{Zinc concentration in air} = (780 \text{ mg}) / (141 \text{ m}^3/\text{min})(60 \text{ min}/\text{hour})(20 \text{ hours}/\text{day})(30 \text{ days}) = 1.5 \times 10^{-4} \text{ mg/m}^3$$

## *Part 2- Erosion from Vents*

The results of samples taken from heater/cooler vents were analyzed in order to determine the 95% UCL of the metal concentration on vents in milligrams per kilogram of debris (mg/kg). An estimate of the total mass of debris on the vents was then made. With this information, it is possible to estimate the total mass of metals on the heater/cooler vents. An assumption is made that the total mass of the metals will erode from the vents and become suspended in the air during the next month. By dividing the mass of metals on the vents by the total volume of air that will be expelled from an average evaporative cooler during the next month, a theoretical estimate of the concentration in air may be made. The following calculations derive the concentration estimates:

An average house is assumed to have 10 heater/cooler vents. Each vent is assumed to have 50 grams of debris deposited on the inside surface. Using these estimates, the average house would have a total of 0.5 kg (about 1 pound) of debris on the vents. To determine the total mass of copper and zinc on the vents, the upper 95% confidence limit of the results from vent samples are used as follows:

Total mass of copper in mg = (2729 mg/kg)(0.5 kg) = 1365 mg of copper on the vents.

Total mass of zinc in mg = (80274 mg/kg)(0.5 kg) = 40137 mg of zinc on the vents.

Assuming the total mass of zinc and copper will erode from the vents in the next month, and by dividing by the volume of air expelled by a 5000 ft<sup>3</sup>/minute (141 m<sup>3</sup>/min) evaporative cooler in 1 month, a theoretical estimate of the concentration of these metals in air as a result of metals on the vents can be obtained. The calculations are as follows:

Copper concentration in air = (1365 mg)/(141 m<sup>3</sup>/min)(60 min/hour)(20 hours/day)(30 days) = 2.7 x 10<sup>-4</sup> mg/m<sup>3</sup>

Zinc concentration in air = (40137 mg)/(141 m<sup>3</sup>/min)(60 min/hour)(20 hours/day)(30 days) = 7.9 x 10<sup>-3</sup> mg/m<sup>3</sup>

The concentrations in Parts 1 and 2 are then added together to obtain a theoretical upper bound estimate of the concentrations of copper and zinc in the air. These concentrations are then inserted into an exposure scenario and evaluated for potential health effects.



This model was developed for information purposes only. A more meaningful way to evaluate potential health effects from inhalation of compounds is to use actual indoor air data. Risk using indoor air data is evaluated in this risk assessment.

### 3.3 Fate and Transport of Smoke Particles

In order for a metal to escape from a fire, the temperature of the fire must reach the boiling point of that particular metal. To determine which of the metals of concern may have been vaporized by the fire, it is necessary to examine the boiling points of the elements of concern and compare these to estimated temperatures achieved by the fire. The following table displays the melting and boiling points of the chemicals of concern:

<u>Element</u>	<u>Melting Point (°C)</u>	<u>Boiling Point (°C)</u>
Boron	2300	2550
Copper	1083	2567
Lead	327	1740
Nickel	1455	2730
Tin	231	2770
Zinc	419	907

Estimating the temperature of the fire is very difficult due to the highly variable conditions that may have existed, however, temperatures in excess of 1000°C are not unusual for large structure fires.<sup>6</sup> It is therefore possible that at least some of the metals in the facility may have reached their boiling points and vaporized. Vaporization of these metals would then be expected to form particulates of varying sizes. These particles would immediately begin the inevitable process of spontaneous and continuous coagulation. The behavior of these airborne particles will vary as the particle size distribution changes.

Particulates suspended in a calm atmosphere will settle slowly as a result of gravity, and eventually will deposit on the ground or other surface. The rate at which particles fall is guided by a well known physical law known as Stoke's law. According to Stoke's Law, the tendency of a particle to deposit is highly dependant upon the size of the particle.<sup>5</sup> The rate at which a particle settles is known as the terminal velocity. For particles that are capable of depositing

in the lungs, terminal velocities are very small. The terminal velocity of spherical particles one micron in diameter is approximately 0.0035 (cm/s) centimeters per second.<sup>5</sup>

At short distances from a smoke source, large particles may deposit on the ground and other surfaces causing significant depletion of particles originating from a fire. However, particles of small size will be deposited at great distances from the source, as described by the expression  $d = (h)(u)/(v)$ , where  $d$  is the horizontal distance at which the particle is deposited,  $h$  is the height above the ground from which the particle is emitted,  $u$  is the wind speed, and  $v$  is the terminal velocity of the particle.<sup>5</sup>

Particles with a terminal velocity of 0.0035 (cm/s) in a non-turbulent atmosphere with a slow wind speed of 1 m/sec (meter per second) would be expected to travel more than 286 kilometers (171) miles before settling 1 meter. Any particles of this size that were generated by the fire would likely have been ejected to a height greater than 1 meter by the intense thermal air currents generated by the fire. The vast majority of small particles were therefore likely deposited at great distances relative to the fire.

Particles 1 micron in size that may have been injected into area homes through evaporative coolers would require more than 79 hours to settle a distance of 1 meter inside the home, assuming no air movement. At a conservative air exchange rate of 0.5 per hour, virtually no deposition of particles 1 micron in size would be expected in homes in the vicinity. Particles of this size would be expected to be vented to the outside air within a few hours. It is possible, however, that at least some deposition of larger particles occurred in area homes as a result of the fire. Particle size is an important factor, since larger particles are removed by the upper respiratory tract and ingested rather than deposited in the lungs.

### 3.4 Quantification of Exposures

Estimates of exposure concentrations and pathway specific intake doses must be made to quantify exposures. Exposures are estimated to derive the potential hazard and risk that humans may face as a result of exposure to the chemicals of concern in the study homes. Exposures are estimated for current conditions using data from the Zenitech sampling results.

Air and housedust contaminant concentrations have been calculated and summarized previously. They are estimates of concentrations that could potentially be contacted at an

exposure point. Chemical intake or dose is expressed as mass per unit body weight and time. Most toxicity values are expressed on the basis of administered dose not absorbed dose. Therefore, chemical intakes from soil ingestion are also expressed as administered dose.

Intake equations for ingestion and inhalation are summarized in the following tables. Variable values for reasonable maximum exposures (RME) for adults and children are shown. The intake formulas follow EPA guidelines.<sup>1</sup> Variable values incorporate standard assumptions adopted by the EPA for human health risk and exposure assessments. All are taken from EPA standard default exposure factors.<sup>2</sup>

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Formula Used to Calculate Chronic Daily Intake (CDI) from Ingestion of Housedust and Soil

$$CDI = \frac{(CS)(IR)(CF)(EF)(ED)}{(BW)(AT)}$$

Where:

- CDI = Chronic Daily Intake (mg/kg-day)
- CS = 95 % UCL Concentration in Housedust or Soil (mg/kg)
- IR = Ingestion Rate (mg/day)
- CF = Conversion Factor (1.0E-6 kg/mg)
- EF = Exposure Frequency (days/year)
- ED = Exposure Duration (years)
- BW = Body Weight (kg)
- AT = Averaging Time (period over which exposure is averaged-days)

Variable Values:

- CS : Concentration in the housedust
- IR : 100 mg/day for adults  
200 mg/day for children
- EF : 350 days/year
- ED : 30 years for adults, 9 years for children
- BW : 70 kg for adults, 15 kg for children
- AT : (ED)(365 days/year)

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Formula Used to Calculate Chronic Daily Intake (CDI) from Inhalation

$$CDI = \frac{(CA)(IR)(EF)(ED)}{(BW)(AT)}$$

Where:

- CDI = Chronic Daily Intake (mg/kg-day)
- CA = 95% UCL Concentration in Air (mg/m<sup>3</sup>)
- IR = Inhalation Rate (m<sup>3</sup>/day)
- EF = Exposure Frequency (days/year)
- ED = Exposure Duration (years)
- BW = Body Weight (kg)
- AT = Averaging Time (period over which exposure is averaged-days)

Variable Values:

- CA : Chemical concentration in the air
  - IR : 20m<sup>3</sup>/day
  - EF : 350 days/year
  - ED : 30 years for adults, 9 years for children
  - BW : 70 kg for adults, 15 kg for children
  - AT : (ED)(365 days/year)
- 

### 3.5 Exposure Estimates

The chronic daily intake (CDI) values displayed in the following tables estimate individual exposures using the exposure parameters described above.

Housedust Ingestion CDI in Study Homes in mg/kg-day		
Chemical	Adult	Child
Boron	2.1E-04	1.9E-03
Copper	4.5E-04	4.2E-03
Lead	1.9E-04	1.8E-03
Nickel	4.0E-04	3.8E-03
Tin	7.1E-05	6.6E-04
Zinc	1.2E-02	1.1E-01

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Soil Ingestion CDI in Study Homes in mg/kg-day		
Chemical	Adult	Child
Boron	7.0E-06	6.6E-05
Copper	3.2E-05	3.0E-04
Lead	4.1E-05	3.9E-04
Nickel	2.5E-05	2.3E-04
Zinc	1.3E-04	1.2E-03

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Inhalation CDI in Study Homes in mg/kg-day		
Chemical	Adult	Child
Copper	3.6E-05	1.7E-04
Zinc	2.9E-04	1.3E-03

Inhalation CDI From Modeled Air in Study Homes in mg/kg-day

Chemical	Adult	Child
Copper	7.4E-05	3.4E-04
Zinc	2.2E-03	1.0E-02

Housedust Ingestion CDI in Control Homes in mg/kg-day

Chemical	Adult	Child
Boron	4.2E-03	4.0E-02
Copper	3.2E-05	3.0E-04
Lead	6.8E-06	6.4E-05
Nickel	8.2E-05	7.7E-04
Tin	3.4E-06	3.2E-05
Zinc	2.4E-03	2.3E-02

Soil Ingestion CDI in Control Homes in mg/kg-day

Chemical	Adult	Child
Boron	1.5E-05	1.4E-04
Copper	4.2E-05	4.0E-04
Lead	6.1E-05	5.7E-04
Nickel	2.6E-05	2.4E-04
Zinc	1.7E-04	1.6E-03

Inhalation CDI in Control Homes in mg/kg-day

Chemical	Adult	Child
Copper	2.7E-05	1.3E-04
Zinc	1.4E-03	6.7E-03

## 4.0 TOXICITY ASSESSMENT

Adverse effects associated with chemicals of potential concern in the study and control homes are summarized in this section. The derivation of the dose-response variables used to estimate risks to human health are incorporated into risk assessment methodology by the USEPA. Each compound of concern must be examined for potential carcinogenic and noncarcinogenic effects.

### 4.1 Information About Noncarcinogenic Effects

Reference doses (RfDs) and reference concentrations (RfCs) are values that are used for noncarcinogenic effects of contaminants in quantitative risk assessments. RfD and RfC values are determined by the EPA using experimental data about a compound's noncarcinogenic toxicity. It is assumed in the development of an RfD or RfC that there is a threshold of exposure for which there are no adverse health effects. An RfD is an estimated daily intake rate for a specific chemical which will pose no appreciable risk of adverse health effects to humans, including sensitive populations. An RfC is an estimated concentration in air for a specific chemical which will pose no appreciable risk of adverse health effects to humans, including sensitive populations. The following table displays RfDs and RfCs for chemicals of concern at the study and control homes. All RfDs were taken from the Health Effects Assessment Summary Tables (HEAST)<sup>16</sup> and Integrated Risk Information System (IRIS).<sup>17</sup>



Table 4.1 Noncancer Health Effects For Chemicals of Concern

Chemical	Inhalation RFC	Ingestion RfD (mg/kg day)	Confidence	Sensitive Organs & Systems Affected	RfC/RfD Source
Boron (Bo)	—	0.09	Medium	Gastrointestinal, Testes	— / HEAST
Copper (Cu)	—	0.037*	—	Gastrointestinal	— / HEAST
Lead (Pb)	—	—	—	Neurological, Blood, Gastrointestinal	— / —
Nickel (Ni)	—	0.02	Medium	Gastrointestinal, Blood, Kidneys, Liver	— / IRIS
Tin (Sn)	—	0.6	—	Gastrointestinal, Blood, Kidneys, Liver	— / HEAST
Zinc (Zn)	—	0.3	Medium	Anemia, Gastrointestinal	— / IRIS

\* RfD Was Derived From the Drinking Water Standard

## 4.2 Toxicity Summaries

Possible health effects associated with the chemicals of concern at the disposal site are described in the following toxicity profiles. The sources, uses and health effects of the chemicals are described. When reading these toxicity profiles it is important to remember that all health effects are dose dependant. Sources include profiles from the Toxic Substances and Disease Registry, and IRIS.<sup>7,8,9,10,11,12,17</sup>

### **Boron (B)**

Boron (CAS No. 7440-42-8) is an element found naturally in sediment and sedimentary rock. The environmental discharge of boron is judged to occur mainly from the erosion of nature. In addition, air, water, or soil may be contaminated with boron following discharge from coal-burning plants, copper smelters, and pesticides. Typical boron compounds are boric acid, borax, borate, and boron oxide. Boron's main use is in the manufacture of glass with other applications in fire retardant and in leather tanning and finishing industries. High exposure levels are found with workers employed in industries utilizing boron-containing products, with persons residing near waste sites or areas with natural boron deposits, and with consumers utilizing cosmetics, medicines, or pesticides containing boron. The average daily boron intake is estimated to be between 10 and 25 mg.

The routes of exposure for boron include inhalation and ingestion. No human or animal studies were found which dealt with absorption, distribution, metabolism, or excretion of boron by the three routes of exposure.

Toxic effects following inhalation of boron at high concentrations include irritation to the upper respiratory tract (cough; dry mouth, nose, throat; sore throat) and chronic eye irritation in occupational groups exposed to boron oxide and boric acid dust. In two adults, symptoms of vomiting occurred following ingestion of boric acid-containing fungicide and insecticide. No human studies were available which dealt with the effect of dermal exposure. In rabbits, conjunctivitis and dermatitis were seen with dermal and ocular exposures. No studies were found dealing with the development of cancer in animals or humans following boron exposure by inhalation, ingestion, or dermal contact. Boron has an EPA Weight-of-Evidence Classification of D (not classifiable as to human carcinogenicity).

## Copper

Copper (CAS No. 7440-50-8) is a reddish metal which is a natural component of rock, soil, water, sediment, and air. It occurs in the elemental state and as a compound. Copper is an essential element for all living organisms including humans. The Recommended Daily Allowance of copper is between 2-3 mg per day. Most people eat or drink about 1 mg of copper every day.

The major sources of release, primarily into soil, are from mining operations, agriculture, solid waste, and sludge from public treatment plants. The waste from these sources is generally in a mineral form and is unlikely to harm biota (plant and animal life). Also, transport and transformation of copper is unlikely.

Copper in water occurs from weathering of soil and discharges from industries and sewage treatment plants. Air emissions of copper result from wind-blown dust, volcanoes, and human sources, such as copper smelters and ore processing facilities.

High exposure levels may occur in the general population from drinking water which contains copper settling out of the distribution system. However, copper may be tasted in drinking water at a level which is not toxic to the human body. Running tap water may lower the concentration of copper in drinking water. Job-related exposures may occur in mining, agriculture, and water treatment occupations.

Human exposure may occur by inhalation, ingestion, or dermal contact with soil, water, or other copper containing substances. The majority of the copper compounds found in the environment are in a fixed state (adhering to dust, dirt, or mineral particles) and are unlikely to affect human health. Copper detected at hazardous waste sites are usually found in this form.

Soluble copper compounds are the form most likely to impact on human health. However, if dissolved in water bodies such as lakes or rivers, soluble copper compounds adhere to solid particles, diminishing their ability to cause adverse health effects. Copper is also a component of food, and a mineral needed by the human body.

Gastrointestinal (vomiting, diarrhea, nausea, abdominal pain, and metallic taste in mouth), hematological (acute hemolytic anemia), hepatic (cirrhosis, necrosis of liver) and renal (necrosis of tubular cells) effects have been observed with ingestion of large quantities in humans. Copper has an EPA Weight-of-Evidence Classification of D (not classifiable).

## Lead (Pb)

Lead (CAS No. 7439-92-1) is an element found throughout the environment in the earth's crust and from processes initiated by man. Synonyms include lead metal, plumbum, and pigment metal. Lead is found in air, food, water, and dust. Its primary use is in the production of storage batteries with additional applications which include the manufacture of paint, gasoline additives, metal products (sheet lead, solder), and ammunition. The highest airborne concentrations of lead have been from vehicle emissions during the period when gasoline with lead additive was widely used. Other airborne sources include industrial emissions (smelting operations and the production of lead batteries), natural emissions (active volcano), and cigarette smoking. The primary source of lead in water is from plumbing and solder and lead-containing dust, soil, and wastewater. Food and beverages may also contain lead if crops or the food operations are contaminated with lead-filled dust. Workers are mainly exposed through inhalation in jobs involving smelting, production of steel and batteries, gasoline stations, and auto repair.

Lead interacts with a number of substances as demonstrated in human and animal studies. For example, absorption of lead in the body was lower in subjects given oral calcium and phosphorus supplements. An inverse relationship was also seen between dietary iron, vitamin D, and zinc and lead. With high lead levels in the body, the concentrations of these three substances were low. In fact, iron deficiency resulted in a two to threefold greater absorption rate of lead in study subjects when compared to those individuals who were not deficient. In animals, similar conditions were observed. For example, the administration of iron orally or by injection seemed to lessen the effect of lead on body enzyme activity in one animal study. When lead was administered to rats, mercury deposition increased in the rat kidneys. Animal studies have shown that the combined activity of cadmium and lead manifested itself in rats with weight loss and an increase in the weight of body organs (brain, liver, and adrenal glands). Rats exposed to lead and ethanol demonstrated a greater inclination toward the neurological and hepatic effects of lead. Phenylhydrazine and lead combined intensified the effect on the different phases of anemia in a rat experiment.

The routes of exposure for lead include inhalation, ingestion, or dermal contact. If deposition of lead particles occurs in the lower respiratory tract, the particle absorption is almost

total. Fifty percent of the lead which is ingested by children is absorbed by the body with an 8% and 15% rate of absorption in two separate studies examining ingestion exposure in adults. Fasting has been shown to enhance ingestion absorption to 45% in adults. In animals, the absorption of alkyl lead (tetraethyl lead) occurred more rapidly by dermal application in rabbits than by ingestion. Since man's dermal absorption rate is lower, absorption in humans by dermal contact is less than by inhalation or ingestion. Inorganic lead is not metabolized or biotransformed; however, metabolism does occur in the liver with organic (alkyl) lead. Regardless of the route of absorption, lead is distributed in the blood, soft tissue, and bone with the majority of the total body burden in the bone. For the lead which is not absorbed, excretion in humans occurs through the urine and feces. Transplacental transfer has also been observed in humans.

A variety of toxic effects have been documented in humans from inhalation and ingestion exposures to lead. Severity of symptoms is dose dependent with higher doses of lead producing more severe symptoms. Impairment to the heme (iron) synthesis with resultant anemia has been seen. Neurobehavioral toxicity has been documented in occupational groups mainly from inhalation but also from ingestion. Lead encephalopathy is the most serious neurobehavioral effect with symptoms of dullness, irritability, poor attention span, headache, muscular tremor, memory loss, and hallucinations. If the exposure concentration is high enough, the condition becomes quite severe with coma and death resulting. Acute encephalopathy and death have been documented in children with mainly ingestion and secondarily inhalation exposure. At lower lead concentration levels, children have manifested neurological impairment (hyperactivity, peripheral neuropathy) and cognitive deficits (lower IQ). With inhalation and ingestion, some of the other consequences of lead exposure include cardiovascular toxicity (abnormal EKGs, high blood pressure), nephropathy, interference with Vitamin D metabolism, gastrointestinal symptoms (colic), developmental toxicity (low birthweight), compromise of the immune system, and reproductive toxicity (miscarriage). Studies in these areas for dermal exposures were not found. With ingestion exposures to lead, growth retardation has also been observed in children.

Data in epidemiologic studies were not adequate to establish an association between lead exposure and the development of cancer. Failure to document the specific lead compound, its dose, and the compound's exposure routes were all weaknesses of these studies. An examination

of lead production and battery workers who had inhaled lead in the workplace has demonstrated higher rates of malignancies and mortality than would otherwise have been expected. An increased number of renal cancers were also observed in lead smelter workers. Lead has an EPA Weight-of-Evidence Classification of B2 (probable human carcinogen).

### **Nickel (Ni)**

Nickel (CAS# 7440-02-0) is a hard metal found in a number of ores, often combined with sulfur, antimony and arsenic and is often used in metal alloys such as stainless steel. Nickel is also used in a number of industrial processes like electroplating, anodizing and casting.

Humans are exposed to nickel by inhaling nickel dust or fumes (usually in an occupational setting), by ingesting nickel in food and water, and from skin contact. For most people, ingestion of food containing nickel is the main source of exposure. The average person takes in 0.3 mg of nickel per day from food. Typical drinking water contains about 0.005 mg/l nickel. About 10% of the nickel ingested is absorbed by the intestinal tract. When nickel fumes or dust are inhaled, a larger percentage of the nickel is absorbed. The percentage absorbed depends upon the size and type of particle inhaled.

The primary health effect from ingestion of excess nickel is gastrointestinal distress including diarrhea, vomiting, abdominal cramps and nausea. When skin contact with nickel is made, a skin allergy may develop resulting in itching, redness and a rash.

### **Tin**

Tin (CAS No. 7440-31-5) is an element present in nature in the form of organic and inorganic compounds. The major sources of release are from the burning of fossil fuels and from the production and use of tin and its compounds. In addition, tin may occur naturally in the ambient air.

Environmental levels of tin in the air are usually low, except at sites of pollution. Wind may cause tin in soil to become airborne. Agricultural activities (use of organotins as biocides), smelting and refining processes and burning of fossil fuels are other sources of release to the ambient air. Emissions to water may also result from industrial activities (smelting and refining) and agricultural uses. Soil releases occur from the use of organotin pesticides.

Exposure to the general public results principally from ingestion of foods which contain natural levels of tin (fresh meats, vegetables, and cereals) and from foods contained in tin cans. The average daily intake of tin is about 4 mg per day, mostly from food. Occupational exposures may be significant. Inhalation or dermal exposures may result in workers during the manufacture and application of tin-containing fungicides and insecticides.

Human exposure may occur by inhalation, ingestion, or dermal contact. The effects to human health from tin exposure have been reported in incidents involving workers. With inhalation exposure, a worker at a chemical plant died following the use of an organotin for cleaning a caldron.

Gastrointestinal (gastroenteritis) and neurological (headache, photophobia, and convulsions) effects have been reported with human ingestion of tin compounds.

Tin has an EPA Weight-of-Evidence Classification of D (not classifiable as to human carcinogenicity).

### **Zinc (Zn)**

Zinc (CAS# 7740-66-6) and compounds containing zinc are found naturally in the air, water, soil and foods. Zinc has many industrial uses and is a component in several metal alloys including brass. Zinc is also an important food element needed by the body in low doses, but can be harmful if too much is taken in. The average daily intake of zinc is between 7 and 16 mg per day. The Recommended Daily Allowance of zinc is 15 mg per day for men and 12 mg per day for women.

The primary exposure routes for zinc are ingestion and inhalation. About 20-30% of ingested zinc is absorbed by the body when ingested. Most zinc is unabsorbed and passes in the feces. The greater the quantity of zinc present in the blood and tissues, the less it will be absorbed. There is some evidence to indicate that high calcium intake may also decrease the amount of zinc absorbed by the body. Zinc may also be absorbed through inhalation of zinc containing fumes, usually in an industrial setting. Very little zinc is absorbed through the skin.

Zinc toxicity from excessive ingestion is unusual, but gastrointestinal distress has been reported following large oral exposure to zinc. The major health effects of drinking water with too much zinc are digestive problems. These problems include intestinal cramps and diarrhea.

Higher doses of zinc that may occur from taking too many dietary supplements may result in more acute symptoms including nausea, vomiting, and intestinal bleeding.

There is no evidence that zinc causes cancer or birth defects in humans. Zinc has a USEPA WoE classification of D (not classifiable as to human carcinogenicity).

## **5.0 RISK CHARACTERIZATION**

Risks are characterized in this chapter utilizing exposure and toxicology information previously discussed. Risk characterization is presented in a quantitative format. When data are available, quantitative risk characterizations are performed and evaluated quantitatively. If data are unavailable, risks are discussed in a qualitative manner. The specifics of the risk characterization are reported in the following sections:

### **5.1 Risk Estimation Methods and Calculations**

Risk estimation methods were based on USEPA guidelines.<sup>1</sup> Risk calculations proceed from estimation for a single compound for a single exposure route, to a summation of risk for all chemicals of concern for a given route, to a summation of risk across exposure routes.

If the same population is exposed via more than one pathway, results from individual pathways may be summed to estimate the possible health effects. Care must be taken to assure that appropriate pathways are summed for a population.

Noncarcinogenic health effects include neurotoxic, hepatotoxic, nephrotoxic, teratogenic, reproductive reactions, and any other noncancer related systemic toxic responses. The potential for an individual suffering a noncarcinogenic effect is not expressed as a probability, but as a ratio or quotient by comparison of the CDI to the chemical specific RfD which is not expected to produce toxic effects. The RfDs for the chemicals of concern are displayed in Table 4.1. Since all exposures in this risk assessment are considered long-term, or chronic exposures, chronic RfDs are used for all comparisons. The Hazard Quotient (HQ) is the ratio of an exposure level over a specified period (CDI) to the experimentally determined toxicity of the chemical. The HQ is calculated as follows:



$$HQ = CDI/RfD$$

Where:

CDI = Daily Intake (dose) in mg/kg-day;

RfD = Reference Dose in mg/kg-day.

Hazard quotients for chemicals with similar health effects are assumed to be additive. If appropriate, the HQs for individual chemicals are summed to obtain an Hazard Index (HI).

The HI is not a probability. If the HI exceeds 1, the most sensitive members of the exposed population may experience adverse health effects. The higher the HI, the greater the concern. In this risk assessment Hazard Indices are evaluated for exposure to housedust, soil, and air.

The calculated HQs and HIs from ingestion of soil and housedust and from inhalation of air at the study and control houses are displayed in the following tables.

Hazard Quotients and Index from Ingestion of Housedust in Study Homes

Chemical	Adult	Child
Boron	0.00	0.0
Copper	0.01	0.1
Lead		
Nickel	0.02	0.2
Tin	0.00	0.0
Zinc	0.04	0.4
Hazard Index	0.08	0.7

Hazard Quotients and Index from Ingestion of Soil in Study Homes

Chemical	Adult	Child
Boron	0.00	0.00
Copper	0.00	0.01
Lead		
Nickel	0.00	0.01
Zinc	0.00	0.00
Hazard Index	0.00	0.02

Hazard Quotients and Index from Inhalation in Study Homes

Chemical	Adult	Child
Copper	1E-03	5E-03
Zinc	1E-03	4E-03
Hazard Index	2E-03	9E-03

Hazard Quotients and Index From Modeled Air in Study Homes

Chemical	Adult	Child
Copper	2E-03	9E-03
Zinc	7E-03	3E-02
Hazard Index	9E-03	4E-02

Hazard Quotients and Index from Ingestion of Housedust in Control Homes

Chemical	Adult	Child
Boron	0.05	0.4
Copper	0.00	0.0
Lead		
Nickel	0.00	0.0
Tin	0.00	0.0
Zinc	0.01	0.1
Hazard Index	0.06	0.6

Hazard Quotients and Index from Ingestion of Soil in Control Homes

Chemical	Adult	Child
Boron	0.00	0.00
Copper	0.00	0.01
Lead		
Nickel	0.00	0.01
Zinc	0.00	0.01
Hazard Index	0.00	0.03

Hazard Quotients and Index from Inhalation in Control Homes

Chemical	Adult	Child
Copper	7E-04	3E-03
Zinc	5E-03	2E-02
Hazard Index	0.01	0.03

## 5.2 Discussion of Results

The Hazard Index from all exposure routes in the study homes was 0.08 for adults and 0.7 for children, indicating that no adverse health effects would be expected to occur to the most sensitive individuals as a result of exposure to the concentrations of chemicals found in the Zenitech study. The majority of the calculated Hazard Index in study homes is contributed by incidental ingestion of housedust containing zinc and copper. Both zinc and copper are essential elements for humans, and have established Recommended Daily Allowances (RDAs). The expected zinc and copper intakes from incidental ingestion of housedust in the study homes would be substantially less than the RDAs.

If the concentrations of metals that were found were substantially higher, and if a sufficient quantity of housedust was available, the expected health effects would be gastrointestinal. The following sections discuss the quantitative risk analysis results by exposure route:

### Air Exposure

Particles less than 10 microns in size may be inhaled and deposited in various portions of the respiratory tract. Particles which are between 5 and 10 microns in aerodynamic diameter are usually deposited in nasopharynx (above the soft palate) and removed by blowing of the nose. Particles with an aerodynamic diameter of between 2 and 5 microns are deposited in the tracheobronchus (air pathway), are removed by the cilia, and are ultimately ingested. Only particles that are around 1 micron in diameter may be deposited in the alveoli (air sacs) and absorbed.<sup>15</sup>

For the purposes of this risk assessment, all chemicals of concern in air will be assumed to be less than 10 microns in size. As discussed in Section 3.3, it is highly unlikely that any particles of zinc that remain in houses are of the respirable fraction (less than 1 micron). However, even if it is assumed that all the zinc found in the air samples is zinc oxide ( $ZnO_2$ ) particles between 0.2 and 1 micron in size, the concentrations found would be substantially less than the concentrations required to produce symptoms of metal fume fever. Exposure to fumes over  $52 \text{ mg/m}^3$  are required to cause metal fume fever.<sup>14</sup> The symptoms go away in 24 to 48

hours and leave no long lasting effect.<sup>14</sup> The No Observed Affect Effect Level (NOAEL) for any respiratory effects from ZnO<sub>2</sub> in humans is between 2 and 0.034 mg/m<sup>3</sup>.<sup>12</sup> The upper 95 % confidence interval of the concentrations of zinc found was 0.001 mg/m<sup>3</sup> in the study houses and was 0.005 mg/m<sup>3</sup> in control houses. The concentrations of zinc found in the Zenitech study are thousands of times smaller than would be necessary to produce symptoms of metal fume fever.

The Hazard Indices from inhalation of zinc and copper in indoor air using standard exposure scenarios for both adults and children are less than 0.02 in the study and control homes, indicating that no health effects would be expected as a result of exposure to the concentrations of chemicals found in the Zenitech study.

Modeled air concentrations using conservative assumptions that would overestimate risk indicated that the concentrations of metals found in the ductwork are substantially less than would be required to produce health effects.

#### **Housedust**

The Hazard Indices in the control homes were virtually the same as the study homes. The Hazard Indices from ingestion of housedust in the study homes were 0.08 for adults and 0.7 for children. The HIs in the control homes were 0.06 for adults and 0.6 for children. Hazard Indices in this range indicate that no health effects would be expected to occur to the most sensitive adults or children as a result of incidental ingestion of housedust in either the study or control homes.

Since EPA has not established an RfD for lead, it could not be included in the quantitative evaluation. The EPA has, however, issued interim guidance recommending a residential soil cleanup level of from 500-1000 mg/kg. This cleanup level is based on a Center for Disease Control (CDC) statement that "... lead in soil and dust appears to be responsible for blood levels in children increasing above background levels when the concentration in soil or dust exceeds 500-1000 mg/kg."<sup>13</sup> The mean and 95 % UCL of lead in housedust were 99 and 140 mg/kg respectively. Concentrations of lead in this range would not be expected to increase blood lead levels in children or cause any other health effects.

## **Soil**

The Hazard Indices from ingestion of soil in the study and control homes are much less than 1, indicating that no health effects would be expected to occur to the most sensitive adults or children as a result of incidental ingestion of soil.

## **Dermal Contact**

Of the metals detected in the Zenitech study, nickel is known to cause contact dermatitis and other skin problems. Nickel dermatitis may occur in individuals exposed to nickel who are sensitized to nickel, however, nearly all nickel dermatitis is as a result of workplace exposure. An estimated 5% of the general population is sensitized to nickel. The threshold for response in sensitized persons is not well known, but it may be as low as 0.007 mg/kg-day, which is comparable to dietary intake levels.<sup>10</sup> It may therefore be possible that environmental exposures to nickel may elicit nickel dermatitis in sensitized persons.<sup>10</sup> It is not known whether the concentrations or types of nickel found in the Zenitech study are capable of eliciting dermatitis in sensitized persons.

### **5.3 Uncertainties in the Risk Characterization Process**

All risk estimates are based on a number of assumptions regarding contaminant concentrations, environmental fate of contaminants, exposures, doses and toxicity information. Uncertainty exists at all stages in this process. Care is taken at each step to insure that assumptions and estimates are upper bounds in order to be protective of public health.

Since limited data are available, accurate and reliable estimates of contaminant concentrations are difficult to obtain. The quantity of data is therefore of concern when interpreting the results of this risk assessment. In order to compensate for this uncertainty, 95% UCL estimates were used for risk characterizations.

### **5.4 Conclusion**

The results of this quantitative risk assessment indicate that no adverse health effects would be expected to occur as a result of exposure to the concentrations of chemicals found in the environmental study conducted by Zenitech, Inc.

## References

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