Centra Gas
35 Sutherland Avenue
Winnipeg Manitoba

HEALTH RISKS
AT THE SUTHERLAND AVENUE SITE

OHG CONSULTING INC.
Occupational Hygiene Group

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Project 00-J-082

DATE: 20 December 2000

D.C. Windsor
Manitoba Hydro
820 Taylor Avenue
P.O.Box 815
Winnipeg MB R3C 2P4

Dear Mr. Windsor

Re: HEALTH RISKS
AT THE SUTHERLAND AVENUE SITE

OHG Consulting Inc. is pleased to submit our Health Risk Assessment from materials from a former manufactured gas plant at the Sutherland Avenue site. Should you have any questions or require additional assistance please contact Mr. John Elias.

Yours truly,

OHG Consulting Inc.

John Elias, MPH, CIH, ROH, CRSP
Occupational Hygienist

HEALTH RISKS AT THE SUTHERLAND AVENUE SITE

Centra Gas
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OHG Project Number 00-J-082

Date of Report: 20 December 2000

Assessment Performed by:

John Elias, MPH, CIH, ROH, CRSP
OHG Consulting Inc.
121 Keedian Drive
East St. Paul MB
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BACKGROUND

OHG Consulting Inc. has been asked to address concerns raised by Centra Gas employees regarding perceived health effects arising from materials from a former manufactured gas plant at the Sutherland Avenue site.

This study is a review of past studies with the intention of assessing the methods used, combining the findings from these reports and drawing conclusions from the total body of work with respect to worker risk at the site.

CH2M Hill started a major environmental study in 1993. This study ended in 1995 with the *Final Report - Environmental Health and Safety Assessment of the Sutherland Avenue Operations Facility in Winnipeg Manitoba*. Other studies included the 1997 *Indoor Air Quality Investigation, 35 Sutherland Avenue Winnipeg Manitoba*, by Wardrop Engineering Inc. and the 1999 *Air Quality Monitoring, Centra Gas Operations Building 35 Sutherland Avenue* by Agra Earth and Environmental.

TOXICITY/EXPOSURE LIMITS

Coal gasification plants produce a wide variety of chemicals. Many are not easily released from the soils, while others are quite volatile and would have evaporated soon after the plant was decommissioned. As a result, from the list of possible chemicals, a shorter list of likely chemicals was adopted. This short list of chemicals used in all the reviewed reports is a group of representative chemicals that are commonly used and is reasonable. If these materials are not a problem, it is unlikely that there will be a problem with any other material that may be present in the original tar and oil.

Occupational exposure limits do not exist for most of the chemicals. Exposure limits were developed from data and methods developed by the United States Environmental Protection Agency (EPA). They are designed to protect the most susceptible people in the community, those who may be older or younger, who have illnesses or are sensitized. Sensitization occurs when workers react to a chemical at much lower exposure levels than expected even when individual differences are taken into consideration. These workers may have become sensitized to the presence of the chemical through previous exposures and can react to sensitizing materials at much lower levels than will the "normal" worker. Sensitization occurs when a material capable of producing an antigen – antibody complex gets past the body's defense by injection or absorption and produces an allergic – type reaction. Allergens are usually large molecules such as proteins of plant, bacterial, or animal origin. However, allergens can also be small reactive molecules such as toluene diisocyanate or simpler substances that, after absorption, can attach themselves to the proteins in the host's body and thus form new proteins foreign to the host.

The EPA exposure limits have safety factors of 3,000 applied to the lowest measured effect. The safety factor is a combination of several, generally 10-fold factors, used in operationally deriving the Reference Dose (RfD) from experimental data. Safety factors (or uncertainty factors) are intended to account for (1) the variation in sensitivity among the members of the human population; (2) the uncertainty in extrapolating animal data to the case of humans; (3) the uncertainty in extrapolating from data obtained in a study that is of less-than-lifetime exposure; and (4) the uncertainty in using data based on the lowest reported effect rather than no reported effect data. This process produces an exposure level that is well below usually accepted occupational exposure levels. For example, the exposure level for naphthalene based on EPA criteria and methods is 0.023 mg/m^3, while the TLV for workplaces is 52 mg/m^3.

An extra level of protection was produced by adding non-carcinogenic health effects. Where two or more chemicals affect the same organ or system, and there is no evidence to the contrary, the effects are added. The CH2M Hill report added the health effects, and this should have been done in the other reports.

All of the chemicals of concern have some non-carcinogenic effects at high concentrations such as dermatitis - skin reddening, itching and irritation salivation, vomiting, headache, loss of pupillary reflex, hypothermia, cyanosis, mild convulsions, a smoky appearance in urine and contact with the eyes will cause burning reddening of the eyes; loss of vision may occur from excessive contact. Low long-term exposure to some of the materials may lead to cancer. To have these effects, the chemicals must get to a susceptible person in a high enough concentration for a long enough time.

EXPOSURE LEVELS

Worker's exposure levels at the site were estimated by different means. These methods of exposure estimation are reviewed in the order that they contribute to our knowledge of actual exposures. These are:

1. Mathematical modeling of exposure levels.
   A model was used to predict worker exposure to soil chemicals. The model used the highest soil concentration on the site, and a soil type that allowed high vapour movement in the soil. Therefore the model overestimated exposures. If these estimated exposures are acceptable, the real ones would also be acceptable. The model predicted that no one would be overexposed.

2. Measurements of concentrations under the elevator pit.
   Construction of the elevator pit included an under-floor ventilation system that were used to sample vapours under the building. The only material actually found in the air under the elevator was naphthalene. The naphthalene level

used here is a peak value, not an average indoor level. This will provide an additional safety factor. The model predicted that this was the most likely material to be found in the air. The other materials that were not measured were not ignored in this report. The actual levels can be assumed to be between the lowest level of detection and zero. Rather than use zero, half the level of detection limit was used. This was not done in all reports, and could result in an overestimation of exposure if not done.

The levels found under the floor (including those assumed at half the level of detection) were below the accepted exposure limit, and would not present a problem to workers. This agrees with the results of the model.

3. Measurements of PAH concentrations inside the workplace.
Vapours from under the floor can diffuse into the building through cracks and opening in the foundation and floor. There is a significant dilution of exposure levels when a vapour must diffuse through the cracks in a floor into a basement. Such indoor levels can be as much as one 1000th of outside exposure levels as discussed in the US Environmental Protection Agency (EPA) document titled *Appendix H - Evaluation of the Effect on the Draft SSLs of the Johnson and Ettinger Model (EQ, 1994a).* This effect was also noted in the CH2M Hill December 1995 report *Environmental, Health and Safety Assessment of the Sutherland Avenue Operations Facility in Winnipeg, Manitoba, Phase IIB: Offsite Soil Gas Survey.* The JAWMA, March 92, page 277 carried an article titled *Soil-Gas Contamination and Entry of Volatile Organic Compounds into a House Near a Landfill*, that reported measured soil-gas levels at 100 to 1000 times higher than inside the house.

   Samples were collected in the basement mechanical rooms where levels were expected to be highest. Again, the only material measured was naphthalene, and again, the naphthalene level used here is a peak measured value, not an average indoor level. Because of the levels of detection, the values used in this risk analysis are similar to those found under the floor, not the expected lower values that one would expect as the result of vapours diffusing through the basement floor. This added an extra level of protection. These samples also showed no problem for workers.

Predicted exposure levels for non-carcinogenic effects (shown in Table 1) are less than the EPA exposure limits and are acceptable for all chemicals, as are the additive effects.

Risks of carcinogenic effects are less than the EPA criteria of one excess cancer in 100,000 workers over a lifetime exposure. The highest risk (Benzo[a]pyrene, Benzo[b]fluoranthene, Dibenz[a,h]anthracene) is 3 in a million, and the lowest risk (Chrysene) is 3 in a billion. Under worst case conditions, the risk of cancer is one-third the acceptable level. As shown in the Table 2.

The health risks for both the carcinogens and non-carcinogens as determined by this review were found to be similar to those of the previous studies. All exposures are within the acceptable ranges, and no worker has an unacceptable exposure due to working in the building.

TABLE 1: The most reasonable predicted exposure levels are compared to the acceptable EPA exposure levels. All predicted exposure levels are less than the acceptable exposure level. Additive effects are shown, and are 0.07 of the acceptable level.

PAH	**Acceptable Exposure level (mg/m3)**	**Most Reasonable Predicted Exposure Level (mg/m^3)**	**Additive Effects (C_n/T_n)**
Naphthalene	0.023	0.0014	0.06
Acenaphthene	0.35	0.000003	0.000008
Acenaphthylene	0.35	0.000003	0.000008
Fluorene	0.23	0.000003	0.00001
Phenanthrene	0.003	0.000003	0.001
Anthracene	1.75	0.000003	0.000002
Fluoranthene	0.23	0.000003	0.00001
Pyrene	0.175	0.000003	0.00002
Benz[a]anthracene	0.003	0.000003	0.001
Chrysene	0.003	0.000003	0.001
Benzo[b]fluoranthene	0.003	0.000003	0.001
Benzo[k]fluoranthene	0.003	0.000003	0.001
Benzo[a]pyrene	0.003	0.000003	0.001
Indeno[1,2,3-cd]pyrene	0.003	0.000003	0.001
Dibenz[a,h]anthracene	0.003	0.000003	0.001
Benzo[g,h,i]perylene	0.003	0.000003	0.001
Benzene	1.6	0.0003	0.0002
Toluene	188	0.0003	0.000002
Ethylbenzene	434	0.0003	0.0000007
Xylene	434	0.0003	0.0000007
Sum of Additive Effects =			**0.07**

TABLE 2: The most reasonable predicted exposure level for carcinogens is shown to be better than one excess cancer in 100,000 cases.

CHEMICAL	Most Reasonable Predicted Exposure Level (mg/m^3)	Oral Slope Factor* $(mg/kg\text{-}day)^{-1}$	Risk Level (acceptable risk is better than I in 100,000)
Benz[a]anthracene	0.000003	0.73	3,000,000
Benzo[a]pyrene	0.000003	7.3	300,000
Benzo[b]fluoranthene	0.000003	7.3	300,000
Benzo[k]fluoranthene	0.000003	0.073	30,000,000
Chrysene	0.000003	0.0073	300,000,000
Dibenz[a,h]anthracene	0.000003	7.3	300,000
Indeno[1,2,3-cd]pyrene	0.000003	0.73	3,000,000

*The EPA defines the Slope Factor as a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.

CONCLUSIONS

1. We feel that the conclusion in the original reports of no unacceptable risk of carcinogenic and non-carcinogenic effects is a safe and correct conclusion. Exposures were estimated by more than one method (modeling, under floor measurements and indoor measurements), and the methods did not have major differences. The assumptions in each method had safety factors, which would overestimate exposures, and the exposure criteria were designed to protect the most sensitive people in the community.

2. The methods used in the original reports for the data analysis were correct, and the conclusions drawn were also correct. The methods we used applied more safety factors, and every opportunity to give the benefit of the doubt to the workers was taken, and the basic conclusion of the original reports, that exposures were acceptable, was not contradicted.

3. Levels below the levels of detection were not properly addressed in the original reports. Levels below the level of detection cannot be assumed to not exist. If this is in fact the case, that conclusion must be explained. In this case it did not make a difference in the conclusions, but it may have raised doubts about the conclusions.

4. The varying levels of detection for the different samples could give the appearance of varying exposure. What looks like rising and falling exposures is

actually the result of different sampling times and laboratory methods. Any variation in levels of detection in repeated measurements must be explained.

5. The sampling/analytical procedures must be appropriate for the intended use. The methods must be able to detect exposures, at least, at the acceptable exposure level. The sampling method should detect levels below the acceptable exposure level. Some samples had a level of detection over 10 times higher than the level of interest. Without an explanation, this could be interpreted as a significant exposure.

ADDITIONAL ISSUES

Staff at the site have raised the following concerns/questions about their safety at the site.

1. What is their risk of developing cancer over a lifetime exposure at the site?

   The worst case prediction was that the most susceptible person had a risk of 3 in 1,000,000 of developing cancer from exposures at the site. This is within the acceptable criteria used here.

2. If the site is "contaminated" and cannot be sold, why is it safe for workers?

   The site can be used for its original industrial purpose without risk to workers. However, it cannot be rezoned for residential use, or other use that could result in persons coming into direct contact with impacted soil.

3. The site is not being remediated, or does not have to be remediated, yet soil samples from the site are handled through strict procedures.

   The samples were being handled according to prescribed methods for soil sampling. When samples are collected, care must be taken so that there is no cross contamination between samples. This means the engineer collecting the sample must wear fresh gloves for each sample, and that tools must be carefully washed between samples. This gives the appearance that the engineer is taking steps to protect himself whereas he is protecting the sample.

4. Can the site be safely developed in the future?

   The site can be developed, as is, for other industrial usage. However, it cannot be rezoned for residential use, or other use that could result in persons coming into direct contact with impacted soil without being cleaned to the standards for that use.

5. What is the toxicity of soils under the elevators?

   For the chemicals that we are concerned about to have an adverse effect they must get to a susceptible person in a high enough concentration for a long enough period of time to affect that person. High short-term exposures can cause eye irritation or dermatitis that stop when exposures stop. Low long-term exposure to some of the materials can lead to cancer.

   All exposure levels are well below the acceptable exposure level for non-carcinogenic effects. The highest exposure is from naphthalene that is less than one-tenth the acceptable exposure level. Other materials are up to one millionth of their acceptable exposure level. If we assume that the health effects are additive for all materials, the sum of the effects is 0.07, much less than the criteria of 1, therefore the exposures are acceptable.

The worst case prediction was that the most susceptible person had a risk of 3 in 1,000,000 of developing cancer from exposures at the site. This is within the acceptable criteria used here.

6. What concentrations or doses are workers exposed to?

   Air samples were collected in the basement mechanical rooms, where levels were expected to be highest. The only material detected was naphthalene. The naphthalene level used here is a peak measured value, not an average indoor level. Six indoor samples taken since 1993 had no measurable PAH levels, and only 4 had measurable levels. The peak level measured was 0.0014 mg/m^3 for naphthalene. The exposure level for naphthalene is 0.023 mg/m^3 for community exposures and 52 mg/m^3 for normal healthy workers.

7. What are the effects of the chemicals?

   For the chemicals that we are concerned about to have an adverse effect, they must get to a susceptible person in a high enough concentration for a long enough period of time to affect that person. High short-term exposures can cause eye irritation or dermatitis that stop when exposures stop. Low long-term exposure to some of the materials can lead to cancer.

8. Where were samples taken?

   Soil samples were collected from the Sutherland Avenue site. Exact locations are found in the original reports. Chemical concentrations were lower near Sutherland Avenue, and became higher towards the river. Some of the highest samples were collected in the parking lot at the north end of the site. The shallow soil samples had very low levels of the more volatile chemicals such as benzene, toluene, ethyl benzene, and xylene.

   Air samples were collected from under the building as well as from the basement and second floor.

9. What is the exposure history of workers at this site?

   The earliest estimates of worker exposure were from 1993, and showed no excessive exposure levels. They were below the level of detection at that time. It would be safe to assume that they were higher in the past, but at unknown levels. The highest onsite exposures were when the gas plant was operational.

10. What air monitoring has taken place at this site?

Air samples were taken inside the building to estimate worker exposures in 1993 by CH2M Hill and in March, June, August 1996, and April, and August 1999, by AGRA. Samples were taken in the basement level where few workers are present full time, on the second floor, and from under the elevator floor. Most samples were below the levels of detection.

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SUPPLEMENTAL INFORMATION

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Dear Mr. Windsor

**Re: HEALTH RISKS
AT THE SUTHERLAND AVENUE SITE
SUPPLEMENTAL INFORMATION**

OHG Consulting Inc. is pleased to submit our this supplemental report for the Health Risk Assessment from materials from a former manufactured gas plant at the Sutherland Avenue site. It contains additional information, and a more detailed rationalisation for the conclusions, should they be needed. Should you have any questions or require additional assistance please contact Mr. John Elias.

Yours truly,

OHG Consulting Inc.

John Elias, MPH, CIH, ROH, CRSP
Occupational Hygienist

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SUPPLEMENTAL INFORMATION

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OHG Project Number 00-J-082

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GLOSSARY

BTEX	A short hand form for benzene, toluene, ethyl benzene, xylene.
Blood-to-air partition coefficient	Ratio of concentrations for a given chemical achieved between blood and air at equilibrium.
Carcinogen	An agent capable of inducing a cancer response.
Chemicals of Concern	Chemicals that are site-related and whose data are of sufficient quality for use in the assessment.
Chronic Daily Intake (CDI)	Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time (7 years or more).
Detection Limit	The lowest amount that can be distinguished from the normal "noise" of an analytical instrument or method.
EPA	Environmental Protection Agency - the US Agency responsible for the environmental protection.
Excess lifetime risk	The additional or extra risk incurred over the lifetime of an individual by exposure to a toxic substance.
LOD	Level of detection. This is the lowest measurable amount of material that the method can detect.
mg/m3	Milligrams per cubic meter, a measure of concentration.
molecular weight	The sum of the atomic weights of all the atoms in the molecule.
PAHs	Polycyclic aromatic hydrocarbons (PAHs) are a group of organic chemicals that have a fused ring structure of two or more benzene rings.(Also called polynuclear aromatic hydrocarbons (PNAs)).
ppm	Parts per million, a measure of concentration.
RfD	An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime.
Risk	The probability of injury, disease, or death under specific circumstances. In quantitative terms, risk is expressed in values ranging from zero (representing the certainty that

	harm will not occur) to one (representing the certainty that harm will occur). The following are examples showing the manner in which risk is expressed in IRIS: E-4 = a risk of 1/10,000; E-5 = a risk of 1/100,000; E-6 = a risk of 1/1,000,000. Similarly, 1.3E-3 = a risk of 1.3/1000 = 1/770; 8E-3 = a risk of 1/125; and 1.2E-5 = a risk of 1/83,000.
SF	See Slope Factor.
Slope Factor	A plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.
TEF	Toxicity Equivalency Factor, a method of estimating the cancer potency of carcinogenic PAHs by comparing them to the potency of benzo(a)pyrene.
Threshold Limit Values (TLVs)	Recommended guidelines for occupational exposure to airborne contaminants published by the American Conference of Governmental Industrial Hygienists (ACGIH). The TLVs represent the average concentration (in mg/cu.m) for an 8-hour workday and a 40-hour work week to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

HEALTH RISKS AT THE SUTHERLAND AVENUE SITE

1.0 INTRODUCTION

OHG Consulting Inc. has been asked to address concerns raised by Centra Gas employees regarding perceived health effects arising from materials from a former manufactured gas plant at the Sutherland Avenue site.

The project consists of a review of past occupational and environmental studies at the site to determine if they address the concerns of staff. The project has two goals, first a review of the studies to ensure that they are complete, and present a fair picture of risks, and second, the presentation of the findings with a minimum of jargon. However, for precision, some jargon must be used.

To aid the reader, there will be a brief summary of the key points at the end of each section. This summary will be in italics and indented to make them easier to locate.

Workers at the site have raised the following concerns/questions about their safety at the site. The bracket following each concern directs the reader to the answer.

1. What is their risk of developing cancer over a lifetime exposure at the site? (6.2 CARCINOGENIC RISK LEVELS)

2. If the site is "contaminated" and cannot be sold, why is it safe for workers? (10.0 RESIDUAL ISSUES)

3. The site is not being remediated, or does not have to be remediated, yet soil samples from the site are handled through strict procedures. (10.0 RESIDUAL ISSUES)

4. Can the site be safely developed in the future? (10.0 RESIDUAL ISSUES)

5. What is the toxicity of soils under the elevators? (4.2 TOXICITY), (6.1 NONCARCINOGENIC RISK LEVELS), (6.2 CARCINOGENIC RISK LEVELS)

6. What concentrations or doses are workers exposed to? (5.3 LEVELS INSIDE THE BUILDING)

7. What are the effects of the chemicals? (4.2 TOXICITY)

8. Where were samples taken? (2.1 SOIL POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

9. What is the exposure history of workers at this site? (10.0 RESIDUAL ISSUES)

10. What air monitoring has taken place at this site? (2.2 AIRBORNE POLYCYCLIC AROMATIC HYDROCARBONS (PAHs))

2.0 BACKGROUND STUDIES

CH2M Hill started a major environmental study in 1993. This study ended in 1995 with the *Final Report - Environmental Health and Safety Assessment of the Sutherland Avenue Operations Facility in Winnipeg Manitoba.* Other studies included the 1997 *Indoor Air Quality Investigation, 35 Sutherland Avenue Winnipeg Manitoba,* by Wardrop Engineering Inc. and the 1999 *Air Quality Monitoring, Centra Gas Operations Building 35 Sutherland Avenue* by Agra Earth and Environmental.

This study is a review of these works with the intention of assessing the methods used, combining the findings from these reports and drawing conclusions from the total body of work with respect to worker risk at the site.

It is not the intention of this section to reproduce all the data and findings of the above mentioned reports. The following is a brief summary of the pertinent findings in the context of the concerns and questions of the workers at the site.

2.1 SOIL POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

CH2M Hill carried out an assessment of chemicals in the ground. Figure 1 shows the site with the sampling locations identified. Figure 2 is an example of the PAHs found in the soil. This data page was selected because of the samples collected close to the surface. These samples are of primary significance in this analysis.

The concentration of chemicals were reported as being lower near Sutherland Avenue, and higher near the river. Some of the highest samples were collected in the parking lot at the north end of the site. The sample used for estimating worker exposure came from a parking lot sample with a higher than average concentration of chemicals.

The shallow soil samples shown in the first 3 data columns in Figure 2 show very low levels of the more volatile benzene, toluene, ethyl benzene, and xylene (BTEX). The significance of this is discussed later. These samples were collected in the north parking lot.

This information is used to determine what chemicals are of concern, and the concentrations are used to estimate worker exposures.

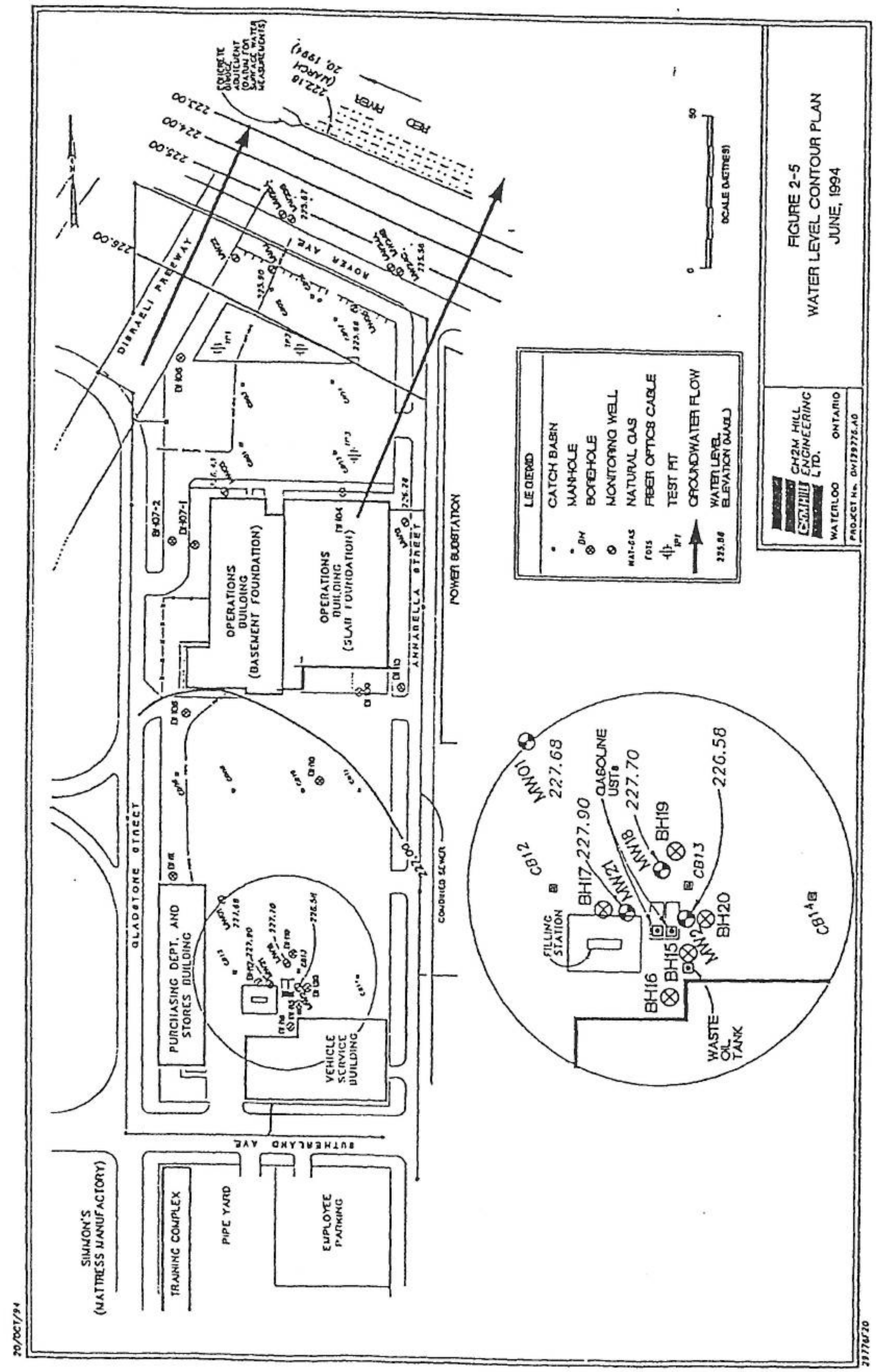

FIGURE 1: Site plan showing sampling locations

Table 7.4 (cont'd)

Comparison of Chemical Analysis of Soil Samples to Available Criteria (Organics)

Sample Location	TP1	TP2	TP3	MW2	MW16	MW18 (Dup)	MW18	MW21	MDL	CRITERIA: CCEM "ABC" FOR COAL GASIFICATION SITES A	B	C	CCME INTERIM REMEDIATION Residential/ Parkland	Commercial/ Industrial	MANITOBA UST Level II	Level III	MHCPS
				Located near underground storage tanks													
Sample Depth (m)	1.52	1.83	0.30–0.91	4.57–5.18	3.05–3.81	3.05–3.81	1.52–3.05	1.83–2.13									
FIELD CLASSIFICATION	TC	VC to TC	VC	C(noVC)	TC	TC	C(noVC)	VC									
SOIL DEPOSIT	•	•	•	▲	▲	▲	▸◂	▸◂									
Sample Date	05–Oct–93	05–Oct–93	05–Oct–93	20–Sep–93	29–Sep–93	29–Sep–93	29–Sep–93	30–Sep–93									
Laboratory No.	10225–08	10225–10	10225–09	10227–06	10227–02	10227–04	10227–03	10227–05									
PAH's (µg/kg)																	
Naphthalene	6.65	364[b]	87300[b]	7.74	8.29	NA	411	843	0.88	100	5,000	50,000	5,000	50,000	--	--	--
Acenaphthylene	17.6	12800[b]	90500[b]	<	<	NA	9.3	46.7	0.9	--	--	--	--	--	--	--	--
Acenaphthene	<	<112[b]	6370[b]	<	<	NA	3.14	63	1.12	--	--	--	--	--	--	--	--
Fluorene	<	753[b]	15900[b]	<	<	NA	6.69	735	2.4	--	--	--	--	--	--	--	--
Phenanthrene	8.74	1660[b]	73200[b]	<	<	NA	16.9	2430	3.6	100	5,000	50,000	5,000	50,000	--	--	--
Anthracene	5.53	1580[b]	54200[b]	<	<	NA	5.47	183	1.6	--	--	--	--	--	--	--	--
Fluoranthene	17.1	19800[b]	762000[b]	1.85	<	NA	9.60	532	1.18	--	--	--	--	--	--	--	--
Pyrene	20.1	40400[b]	629000[b]	<	<	NA	7.76	363	1.98	100	10,000	100,000	10,000	100,000	--	--	--
Benzo (a) anthracene	11.2	17900[b]	381000[b]	1.66	<	NA	4.45	80	0.88	100	1,000	10,000	1,000	10,000	--	--	--
Chrysene	16.5	42000[b]	292000[b]	1.47	<	NA	3.2	64.6	1	--	--	--	--	--	--	--	--
Benzo (b) fluoranthene	37.8[COM]	34600[b]	390000[b]	<	<	NA	5.9[COM]	70.4[COM]	1.94	100	1,000	10,000	1,000	10,000	--	--	--
Benzo (k) fluoranthene	COM	35700[b]	283000[b]	<	<	NA	COM	COM	2.2	100	1,000	10,000	1,000	10,000	--	--	--
Benzo (a) pyrene	15.9	22800[b]	479000[b]	2.09	<	NA	3.13	33	1.42	100	1,000	10,000	1,000	10,000	--	--	--
Indeno (1,2,3–cd) pyrene	25.5	70000[b]	342000[b]	<	<	NA	<	18.2	1.42	100	1,000	10,000	1,000	10,000	--	--	--
Dibenzo (a,h) anthracene	4.55	<186[b]	53400[b]	<	<	NA	<	2.05	1.86	100	1,000	10,000	1,000	10,000	--	--	--
Benzo (ghi) perylene	26.7	69100[b]	257000[b]	<	<	NA	<	13.1	1.74	--	--	--	--	--	--	--	--
BTEX (µg/kg)																	
Benzene	<	<	<	<11[a]	<	NA	<11[c]	<	0.56	--	--	--	500	5,000	500	5,000	100,000
Toluene	<	<	<	121[a]	<	NA	104[c]	<	0.8	--	--	--	3,000	30,000	3,000	30,000	100,000
m & p Xylene	<	<	3.18	61.6[a]	1.3	NA	166[a]	21.8	0.59	--	--	--	5,000	50,000	5,000	50,000	100,000
Ethyl Benzene	<	<	0.81	13.1[c]	<	NA	16.4[c]	11.1	0.39	--	--	--	5,000	50,000	5,000	50,000	100,000
o–Xylene	<	<	2.11	156[a]	1.25	NA	102[a]	<	0.42	--	--	--	5,000	50,000	5,000	50,000	100,000
Phenolics (µg/kg)	<	5740	14700	NA	NA	NA	NA	NA	100	--	--	--	--	--	--	--	--
TPH (mg/kg)																	
Total Volatile Hydrocarbon	NA	NA	NA	1.95	<	<	12.9	NA	1	--	--	--	--	--	150	800	--
Total Semi–Volatile Hydrocarbon	NA	NA	NA	72.9	15.7	18.2	108	NA	1	--	--	--	--	--	2000	2000	--
Total Petroleum Hydrocarbon	NA	NA	NA	74.9	15.7	18.2	121	NA	1	--	--	--	--	--	--	--	--

Notes:

COM – Combined result
Dup – Duplicate sample
MDL – Method Detection Limit
NA – Not applicable
< – Less than MDL
UST – Underground Storage Tank
MHCPS – Manitoba Hazardous Classification for Petroleum Soils
– Samples reported on dry weight basis

a – Due to dilution, MDL's are 5000 x those stated
b – Due to dilution, MDL's are 100 x those stated
c – Due to dilution, MDL's are 20 x those stated

CCME – Canadian Environmental Quality Criteria for Contaminated Sites
-- – Guideline not available
[shaded box] EXCEEDS AT LEAST ONE CRITERIA

– MANITOBA CRITERIA ONLY APPLIES TO LOCATIONS IN THE VICINITY OF THE UNDERGROUND STORAGE TANKS

Analyzed by CANVIRO Analytical Laboratories Ltd. (CALL)

FIELD CONTAMINATION CLASSIFICATION
NC – No contamination
TC – Trace contamination
VC – Visual contamination
C(noVC) – Contaminated but no visual evidence

SOIL DEPOSIT
♦ STRATIFIED GLACIOLACUSTRINE/GLACIOFLUVIAL DEPOSIT
• FILL WITH INDUSTRIAL DEBRIS
▸◂ FILL WITHOUT INDUSTRIAL DEBRIS
▲ WEATHERED GLACIOLACUSTRINE SILTY CLAY/CLAYEY SILT DEPOSIT

FIGURE 2: An example of the sampling data emphasizing samples collected close to the surface.

Chemical concentrations were lower near Sutherland Avenue, and became higher towards the river. Some of the highest samples were collected in the parking lot at the north end of the site. The shallow soil samples had very low levels of the more volatile chemicals such as benzene, toluene, ethyl benzene, and xylene.

2.2 AIRBORNE POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

The concentration of chemicals in the workplace was assessed by two different methods.

CH2M Hill estimated the exposure inside the building using a mathematical model. They also carried out air sampling in 1993 to measure actual exposures. In April, July, September 1996, and May, September 1999, AGRA carried out air sampling inside the building to estimate worker exposures. Samples were taken in the basement level where few workers are present full time, on the second floor, and from under the elevator floor. Tables 1 to 4 summarize the significant information.

A third study by Wardrop Engineering focused on indoor air quality (IAQ), and is not pertinent to a risk analysis of exposures to PAHs.

TABLE 1: Air samples in the South Mechanical Room. All Values in mg/m^3.

Date	Sept 93	March 96	Aug 96	April 99	Aug 99
Sampler	CH2M Hill	AGRA	AGRA	AGRA	AGRA
Naphthalene	<0.000005	<0.002	0.0014	0.0005	
Acenaphthene	<0.000005	<0.002	<0.0004	<0.00009	
Acenaphthylene	<0.000005	<0.002	<0.0005	<0.00018	
Fluorene	<0.000005	<0.002	<0.0004	<0.00009	
Phenanthrene	<0.000005	<0.002	<0.0004	<0.00004	
Anthracene	<0.000005	<0.002	<0.0004	<0.00009	
Fluoranthene	<0.000005	<0.002	<0.0004	<0.00009	
Pyrene	<0.000005	<0.002	<0.0005	<0.00028	
Benz[a]anthracene	<0.000005	<0.002	<0.0004	<0.00009	
Chrysene	<0.000005	<0.002	<0.0004	<0.00009	
Benzo[b]fluoranthene	<0.000005	<0.01	<0.0007	<0.00037	
Benzo[k]fluoranthene	<0.000005	<0.01	<0.0007	<0.00037	
Benzo[a]pyrene	<0.000005	<0.01	<0.0004	<0.00028	
Indeno[1,2,3-cd]pyrene	<0.000005	<0.01	<0.0007	<0.00028	
Dibenz[a,h]anthracene	<0.000005	<0.01	<0.0007	<0.00037	
Benzo[g,h,i]perylene	<0.000005	<0.01	<0.0004	<0.00018	
Benzene	<0.0005	<0.142		<0.05	<0.005
Toluene	<0.0005	<0.142		<0.05	<0.005
Ethylbenzene	<0.0005	<0.142		<0.05	<0.005
Xylene	<0.0005	<0.142		<0.2	<0.02

TABLE 2: Air samples in the North Mechanical Room. All Values in mg/m^3.

Date	Sept 93	March 96	Aug 96	April 99	Aug 99
Sampler	CH2M Hill	AGRA	AGRA*	AGRA*	AGRA
Naphthalene	<0.000005	<0.002	0.0014	0.0008	<0.00008
Acenaphthene	<0.000005	<0.002	<0.0002	<0.00009	<0.00004
Acenaphthylene	<0.000005	<0.002	<0.0004	<0.00018	<0.00008
Fluorene	<0.000005	<0.002	<0.0002	<0.00009	<0.00004
Phenanthrene	<0.000005	<0.002	<0.0002	<0.00009	<0.00004
Anthracene	<0.000005	<0.002	<0.0002	<0.00009	<0.00004
Fluoranthene	<0.000005	<0.002	<0.0002	<0.00009	<0.00004
Pyrene	<0.000005	<0.002	<0.0004	<0.00028	<0.00012
Benz[a]anthracene	<0.000005	<0.002	<0.0002	<0.00009	<0.00004
Chrysene	<0.000005	<0.002	<0.0002	<0.00009	<0.00004
Benzo[b]fluoranthene	<0.000005	<0.01	<0.0005	<0.00037	<0.00016
Benzo[k]fluoranthene	<0.000005	<0.01	<0.0005	<0.00037	<0.00016
Benzo[a]pyrene	<0.000005	<0.01	<0.0002	<0.00028	<0.00012
Indeno[1,2,3-cd]pyrene	<0.000005	<0.01	<0.0005	<0.00028	<0.00012
Dibenz[a,h]anthracene	<0.000005	<0.01	<0.0005	<0.00037	<0.00016
Benzo[g,h,i]perylene	<0.000005	<0.01	<0.0002	<0.00018	<0.00008
Benzene	<0.0005	<0.142		<0.05	<0.005
Toluene	<0.0005	<0.142		<0.05	<0.005
Ethylbenzene	<0.0005	<0.142		<0.05	<0.005
Xylene	<0.0005	<0.142		<0.2	<0.02

* Outside elevator, near North Mechanical Room

TABLE 3: Air samples in the Second Floor Office Area. All Values in mg/m^3.

Date	Sept 93	March 96
Sampler	CH2M Hill	AGRA
Naphthalene	<0.000005	<0.002
Acenaphthene	<0.000005	<0.002
Acenaphthylene	<0.000005	<0.002
Fluorene	<0.000005	<0.002
Phenanthrene	<0.000005	<0.002
Anthracene	<0.000005	<0.002
Fluoranthene	<0.000005	<0.002
Pyrene	<0.000005	<0.002
Benz[a]anthracene	<0.000005	<0.002
Chrysene	<0.000005	<0.002
Benzo[b]fluoranthene	<0.000005	<0.01
Benzo[k]fluoranthene	<0.000005	<0.01
Benzo[a]pyrene	<0.000005	<0.01
Indeno[1,2,3-cd]pyrene	<0.000005	<0.01
Dibenz[a,h]anthracene	<0.000005	<0.01
Benzo[g,h,i]perylene	<0.000005	<0.01
Benzene	<0.0005	<0.142
Toluene	<0.0005	<0.142
Ethylbenzene	<0.0005	<0.142
Xylene	<0.0005	<0.142

TABLE 4: Air samples in the space under the elevator. All Values in mg/m³.

Date	**June 96**	**Aug 96**	**April 99**	**Aug 99**
Sampler	**AGRA**	**AGRA**	**AGRA**	**AGRA**
Naphthalene	<0.002	0.0016	0.0008	<0.00018
Acenaphthene	<0.002	<0.0003	<0.00007	<0.00009
Acenaphthylene	<0.002	<0.0004	<0.00014	<0.00018
Fluorene	<0.002	<0.0003	<0.00007	<0.00009
Phenanthrene	<0.002	<0.0003	<0.00007	<0.00009
Anthracene	<0.002	<0.0003	<0.00007	<0.00009
Fluoranthene	<0.002	<0.0003	<0.00007	<0.00009
Pyrene	<0.002	<0.0004	<0.00021	<0.00028
Benz[a]anthracene	<0.002	<0.0003	<0.00007	<0.00009
Chrysene	<0.002	<0.0003	<0.00007	<0.00009
Benzo[b]fluoranthene	<0.01	<0.0005	<0.00028	<0.00037
Benzo[k]fluoranthene	<0.01	<0.0005	<0.00028	<0.00037
Benzo[a]pyrene	<0.01	<0.0003	<0.00021	<0.00028
Indeno[1,2,3-cd]pyrene	<0.01	<0.0005	<0.00021	<0.00028
Dibenz[a,h]anthracene	<0.01	<0.0005	<0.00028	<0.00037
Benzo[g,h,i]perylene	<0.01	<0.0003	<0.00014	<0.00018
Benzene			<0.05	<0.005
Toluene			<0.05	<0.005
Ethylbenzene			<0.05	<0.005
Xylene			<0.2	<0.02

It should be noted that the values appear to change with each survey. These variations are not due to changes in the chemicals in the air as most samples were below the levels of detection, shown by the symbol "<". They are due to the differences in sampling time and laboratory techniques. These variations tend to confuse the issues, and should have been avoided.

Given the low expected concentrations, sampling and analytical methods should have been selected for low levels of detection. Differences between the levels of detection range up to a factor of 100. Differences this large should not happen without an explanation.

Table 4 shows the air concentrations under the elevator floor. When the elevator was installed, a slotted pipe was placed in the gravel fill under and around the elevator pit to lead the vapours away from the elevator pit. The vapour venting system is shown in Figure 3.

The samples only show what was present on the day they were taken. However, they were consistently low over the period sampled. There was a question about how these levels could have changed over time. This is unknown, but one could assume that they were likely higher in the past, particularly when the building was new, but most likely still undetectable.

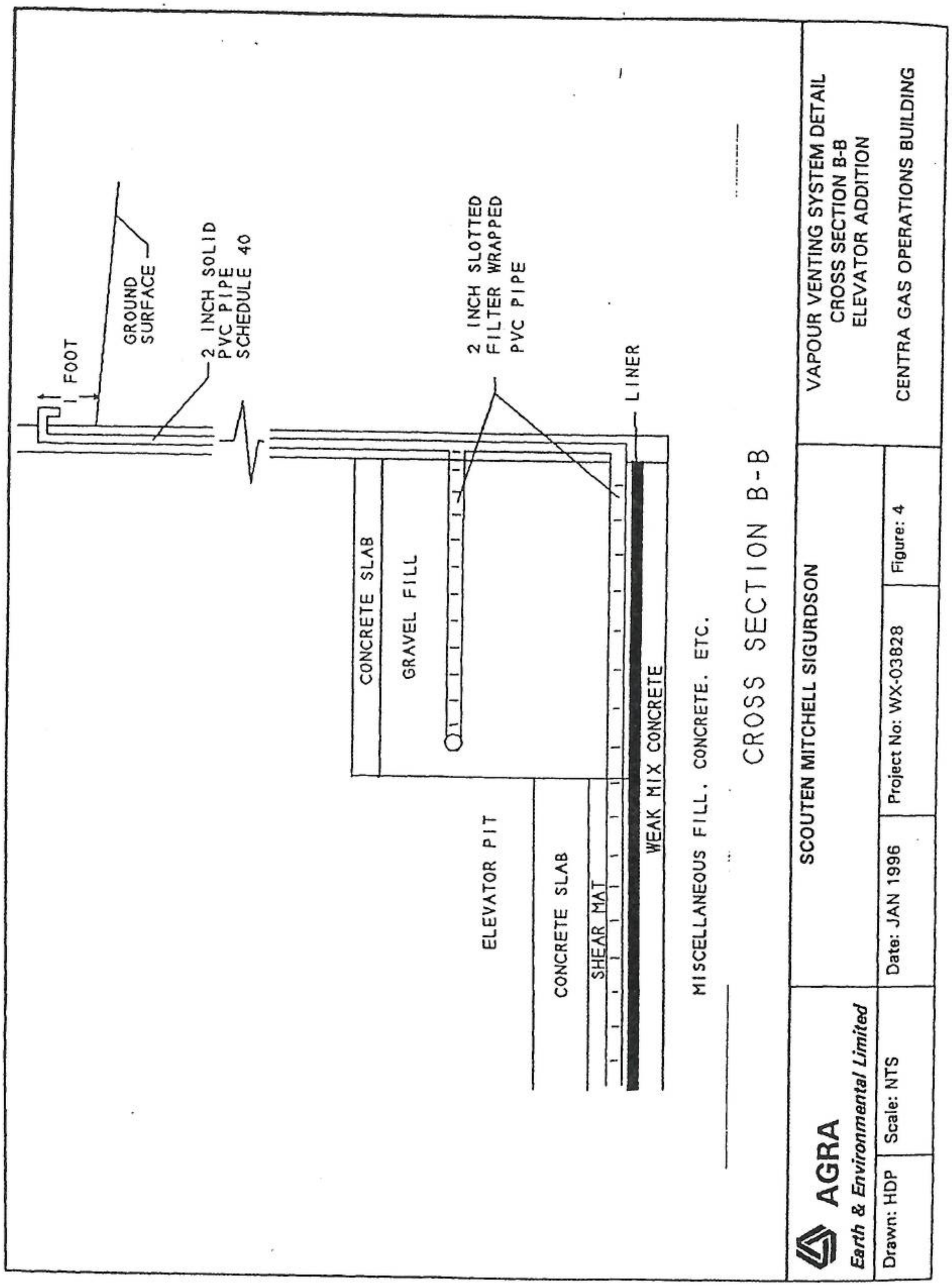

FIGURE 3: Vapour collection system around the elevator pit.

Air samples were taken inside the building to estimate worker exposures. There appeared to be significant variations in these samples. The variations between the samples were not due to changes in the chemicals in the air, they are due to the differences in sampling time and laboratory techniques. These variations tend to confuse the issues, and should have been avoided. Most samples were below the levels of detection.

3.0 STUDY METHOD

As stated in the introduction, this project is a review or summary of past studies of soil chemicals and their impact on the health of workers at the Centra Gas Sutherland Avenue site.

The studies will be reviewed relative to accepted methods, such as the EPA *Risk Assessment Guidance For Superfund, Volume I, Human Health Evaluation Manual (Part A).*

The assumptions made in the interpretation of the data will then be reviewed to determine if they are reasonable. It should be noted that in any risk analysis such as this, certain assumptions must be made. When this is done, the significance of these assumptions should be discussed along with their impact on the precision of the final conclusions. Usually these assumptions favour the person at risk (i.e. they are conservative) and overestimates risk.

Once the methods and assumptions have been accepted, the process will be reviewed and summarized in the following steps.

1. The chemicals under study will be reviewed, and the exposure criteria developed and discussed.

2. Theoretical exposure levels will be presented and the significance of the findings discussed. These are exposure levels that CH2M Hill estimated with the AERIS mathematical model.

3. The levels of vapours found under the building (around elevator) will be presented and their significance discussed.

4. The levels of vapours found inside the building will be presented and their significance discussed.

5. A risk analysis will be presented and explained with conclusions and recommendations if necessary The levels of vapours found under the building (around elevator) will be presented and their significance discussed.

4.0 CHEMICALS OF CONCERN

This section discusses the chemicals found in soils under a coal gasification plant, and the hazards they present. Not all chemicals are of equal concern. Those of concern are identified in the following sections.

Their health effects are discussed, with emphasis on carcinogenic and non-carcinogenic effects. The need to add similar effects is also discussed.

Since most of the chemicals of concern do not have established threshold limit values (TLVs), Acceptable Exposure Levels were developed for this project using generally accepted data and method provided by the US Environmental Protection Agency (EPA).

4.1 COAL GASSIFICATION

Coal gasification is a process for converting coal partially or completely to combustible gases. After purification, these gases - carbon monoxide, carbon dioxide, hydrogen, methane, and nitrogen - can be used as fuels or as raw materials for chemical or fertilizer manufacture. From the early 19th century until the 1940s almost all fuel gas distributed for residential or commercial use in the United States was produced by the gasification of coal or coke. In the 1940s the growing availability of low-cost natural gas led to its substitution for gases derived from coal.

Byproducts of the process likely included:

- Tar sludge
- Clinkers, ash, and coke
- Fixed cyanide, ammonia, and sulphur
- Oil sludge and gas condensates
- Tar liquors

It is the liquid residues that are of concern here. These residues are a mixture of many chemicals. This group of chemicals are called polycyclic aromatic hydrocarbons or PAHs. The major ones are:

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benz[a]anthracene
- Benzene
- Benzo[a]pyrene
- Benzo[b]fluoranthene
- Benzo[g,h,i]perylene
- Benzo[k]fluoranthene
- Chrysene
- Dibenz[a,h]anthracene
- Ethyl benzene

- Fluoranthene
- Fluorene
- Indeno[1,2,3-cd]pyrene
- Naphthalene
- Phenanthrene
- Pyrene
- Toluene
- Xylene

These are the more abundant and the more volatile chemicals found in the mixture. These materials were also found in the soil samples and thus have a potential to be found in air samples. These chemicals are the ones that are commonly used as indicator chemicals. If these are at an acceptable level, it is assumed that other less abundant and less mobile materials will not be a significant concern.

Whether or not a chemical is likely to become airborne depends on two factors:

1. How readily the chemical will volatilize from surface soils. The U.S. Environmental Protection Agency (U.S. EPA) evaluates chemicals that are likely to volatilize to ambient air as those with Henry's Law Constants greater than 10^{-5} atm-m^3/mol. Henry's Law Constant is a measure of how readily a material will evaporate.

2. How readily a chemical will adhere to soil. The U.S. Environmental Protection Agency (U.S. EPA) evaluates chemicals that are likely to volatilize to ambient air as those with a relatively low organic carbon partition coefficients or K_{oc}s less than 4 (U.S. EPA 1996). The organic carbon partition coefficients or K_{oc}s is a measure how strongly the chemical adheres to soil.

Chemicals with a high Henry's Law Constant (more than 10^{-5} atm-m^3/mol) and a K_{oc}s more than 5 are likely to be retained in the soil, and not likely to become airborne. Table 5 shows the ranking of soil chemicals relative to the likelihood that they will become airborne, and thus put workers at risk.

The BTEX group (benzene, toluene, ethylbenzene, xylene) are not shown in Table 5. The data to include them was not readily available in the body of work under review. However, these materials are considered volatile. In fact, they are volatile enough to have been lost from the upper soil layers through evaporation over the years. BTEX concentrations in the soils sampled nearest to the surface ranged from not detectable to 0.5 mg/kg (ppm) for o-xylene, well below occupational exposure levels if all of the material was airborne.

Peak soil water samples found well below the surface, showed that concentrations of BTEX (except for benzene) in water were also less than occupational exposure levels. Benzene levels in soil water well below the surface were above the occupational exposure levels. It is felt that by the time these materials evaporate from the ground water into the air in the soil, and migrate to the surface, their impact will be minimal.

TABLE 5 : Chemicals in the soil ranked by their ability to become airborne using their Henry's Law Constant and their organic carbon partition coefficients or K_{oc}s.

CHEMICAL	Molecular Weight	Henry's Law	log K_{OC}	
Anthracene	178	1.02E.03	4.41	Likely to become airborne
cenaphthylene	152	1.48E-03	3.4	
Naphthalene	128	4.80E-04	3.1	
Phenanthrene	178	1.59E-04	4.15	
Acenaphthene	154	9.20E-05	3.66	
Fluorene	116	6.42E-05	3.86	
Benzo[k]fluoranthene	252	3.94E-05	5.74	Not likely to become airborne
Benzo[b]fluoranthene	252	1.19E-05	5.74	
Fluoranthene	202	6.46E-06	4.58	
Pyrene	202	5.04E-06	4.92	
Benzo[a]pyrene	252	1.55E-06	6.74	
Benz[a]anthracene	228	1.16E-06	6.14	
Chrysene	228	1.05E-06	5.3	
Dibenz[a,h]anthracene	278	7.33E-08	6.52	
Indeno[1,2,3-cd]pyrene	276	6.86E-08	6.2	
Benzo[g,h,i]perylene	276	5.34E-08	6.2	

NOTE: The BTEX group is not shown in this table, but is assumed to be volatile.

(Coal gasification plants produce a wide variety of chemicals. Many are not easily released from the soils, while others are quite volatile and would have evaporated soon after the plant was decommissioned. As a result, a list of chemicals of concern is listed above, the core chemicals of concern are Anthracene, Acenaphthylene, Naphthalene, Phenanthrene, Acenaphthene, and Fluorene.)

4.2 TOXICITY

Information on the toxic properties of chemical substances is obtained from animal studies, from controlled epidemiological investigations of exposed human populations and from clinical studies or case reports of exposed humans. When information from these varied sources is combined, relationships between exposure to an agent and various forms of toxicity can be established.

In general, as the dose of a toxic chemical increases, the potential for a toxic effect also increases. Severe, high-dose exposures to toxic chemicals can result in permanent injury. However, environmental exposures to chemicals typically result in much lower doses that are more likely to result in reversible effects that disappear following cessation of exposure (e.g., eye irritation or dermatitis). Some effects, such as cancer, are related to lifetime dose. For these effects the total amount of material that a person is exposed to is important, not just the short-term exposures. For this reason, estimates must be made of the total exposure over a lifetime as well as short-term exposures related to the reverslble effects mentioned earlier. As a result, the toxic effects of higher dose exposures described in the following sections are not expected to occur.

The presence of toxic or hazardous chemicals in soil does not automatically result in unusual risk for those at or near the site, or working above the soils. These materials must get to a susceptible person in high enough concentration to have an adverse effect

> *(For the chemicals that we are concerned about to have an adverse effect they must get to a susceptible person in a high enough concentration for a long enough period of time to affect that person. High short-term exposures can cause eye irritation or dermatitis that stop when exposures stop. Low long-term exposure to some of the materials can lead to cancer.)*

4.2.1 EFFECTS

The chemicals in question can be absorbed through the lungs, digestive tract and skin. Acute effects from skin contact with a pure mixture of the chemicals are limited primarily to phototoxicity that is caused by exposure to a toxic substance followed by exposure to sunlight. The primary phototoxic effects are dermatitis - skin reddening, itching and irritation. Dermatitis has been observed in workers exposed to coal tar and roofing tar which also contain high concentrations of PAH's. These dermatoses usually disappear when contact is eliminated. Symptoms of systemic illness from acute exposure to high doses of PAH also include salivation, vomiting, headache, loss of pupillary reflex, hypothermia, cyanosis, mild convulsions and a smoky appearance in urine. Contact with the eyes will cause burning reddening of the eyes; loss of vision may occur from excessive contact. In some cases, short-term exposure to very large amounts of the chemicals (typically suicide attempts or accidental ingestion of pure solution) can cause cardiovascular collapse and intense irritation of the digestive tract.

Toxicity from long-term or chronic exposure to the PAH's in coal tar chemicals is often separated into two categories, the carcinogenic and noncarcinogenic effects. The lower molecular weight-PAH's, predominantly with two and three carbon rings (e.g., acenaphthene, anthracene, fluorene, fluoranthene, naphthalene, phenanthrene and pyrene) are noncarcinogenic and relatively less toxic than the PAH's with four to seven carbon rings. These higher molecular weight PAH's (e.g., benzo(a)anthracene, benzo(b+k)fluoranthenes, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene) can elicit both carcinogenic and noncarcinogenic health effects. The noncarcinogenic effects of chronic exposure to PAH's involves cellular depletion in rapidly proliferating tissues throughout the body, including the skin, intestinal epithelium, bone marrow, lymphoid organs and gonads.

However, carcinogenicity is the toxic effect of greatest public health concern following chronic exposure to mixtures of PAH's. Occupational studies of workers who were exposed to mixtures containing PAH's in industries such as coke production, roofing, oil refining or coal gasification provides evidence to indicate that certain PAH's are carcinogenic in humans and animals. The site of tumor induction is generally related to the route of exposure; stomach tumors are observed following ingestion, lung tumors following inhalation and skin tumors following dermal exposure although tumors can form at other locations (e.g., lung tumors after dermal exposure).

As discussed above, the higher the molecular weight, the more toxic the material. Table 6 is a comparison to the toxicity of the chemicals of concern relative to their molecular weight. The chemicals are grouped into two groups, those with a molecular weight less than 200, and those greater than 200. As seen in Table 6, this also divides the chemicals into those that are likely to become airborne, and those that are unlikely to become airborne.

Column 5 compares the relative toxicity of the chemicals based on carcinogenicity. The relative cancer potencies were determined by comparing to benzo(*a*)pyrene. Benzo(*a*)pyrene is scored as one, and chemicals with a lower value are less potent carcinogens, and those with a higher value are more potent.

Column 6 classifies the chemicals by their US Environmental Protection Agency (US EPA) evaluation for carcinogenicity. A Class D chemical is not classifiable as a human carcinogen, and a Class B2 chemical is a probable human carcinogen.

It can be seen that the chemicals that are non-carcinogenic are likely to become airborne, and thus are of primary concern in this study. The more toxic chemicals, and those that are probable human carcinogens are less likely to become airborne. These last chemicals are still of concern, and are included in this evaluation, as they have been in the previous evaluations. However, those materials that workers are most likely to come into contact with are of greatest concern.

TABLE 6: A comparison of toxicity relative to molecular weights.

CHEMICAL	Molecular Weight	Henry's Law	log K_{OC}	TEF*	Class	
Anthracene	178	1.02E.03	4.41	0.01	D	Likely to become airborne
cenaphthylene	152	1.48E-03	3.4	0.001	D	
Naphthalene	128	4.80E-04	3.1			
Phenanthrene	178	1.59E-04	4.15	0.001	D	
Acenaphthene	154	9.20E-05	3.66	0.001		
Fluorene	116	6.42E-05	3.86	0.001	D	
Benzo[k]fluoranthene	252	3.94E-05	5.74	0.1	B2	Not likely to become airborne
Benzo[b]fluoranthene	252	1.19E-05	5.74	0.1	B2	
Fluoranthene	202	6.46E-06	4.58	0.001	D	
Pyrene	202	5.04E-06	4.92	0.001	D	
Benzo[a]pyrene	252	1.55E-06	6.74	1	B2	
Benz[a]anthracene	228	1.16E-06	6.14	0	B2	
Chrysene	228	1.05E-06	5.3	0.01	B2	
Dibenz[a,h]anthracene	278	7.33E-08	6.52	5	B2	
Indeno[1,2,3-cd]pyrene	276	6.86E-08	6.2	0.1	B2	
Benzo[g,h,i]perylene	276	5.34E-08	6.2	0.01	D	

NOTE: The BTEX group is not included in this table but is assumed to be volatile and in the case of benzene, a carcinogen.

TEF = Toxicity Equivalency Factor

(All of the chemicals of concern have some non-carcinogenic effects at high concentrations such as dermatitis - skin reddening, itching and irritation salivation, vomiting, headache, loss of pupillary reflex, hypothermia, cyanosis, mild convulsions, a smoky appearance in urine and contact with the eyes will cause burning reddening of the eyes; loss of vision may occur from excessive contact. The heavier, less volatile materials can cause cancer of the stomach, lung or skin depending on how the person came into contact with the material. We are concerned about lung cancers.)

4.2.2 ADDITIVE EFFECTS

Many materials have more than one effect, often a combination of odour, chronic or acute effects. Where two or more materials affect the same organs or systems, and there is no evidence to the contrary, the effects should be considered additive.

Addition is done by dividing the exposure criteria into the actual exposure level for each material. This gives the ratio of the exposure to the standard. All ratios are then added for each effect. If the sum of the ratios is greater than one, an overexposure is assumed. The formula for this is:

$$\underline{C1} + \underline{C2} + \ldots\ldots \quad \underline{Cn} = <1$$

T1 T2 Tn

Where C1 = the exposure level for ingredient 1
T1 = the exposure criteria for ingredient 1

It should be noted that not all effects have the same importance. Each effect will occur at different exposure levels. For example, the exposure standard for acetone, based on odour, is 48 mg/m^3. Other effects such as respiratory effects and asphyxia will occur at higher levels. Workplace exposures to acetone are based on health effects and not odour. A normal healthy worker can be exposed to over 1000 mg/m^3 for eight hours a day, 5 days a week, for 30 years without adverse effect. A worst case situation is adopted when it is assumed that a one-exposure criteria applies to all effects.

The health effects for most of the materials of concern are not well defined, and may not be all-inclusive. For the purpose of this analysis it will be assumed that the effects of all chemicals are additive.

The additive effects were calculated according to the process outlined for "the case when data is available only for mixture components". This is the process that can be used to assess the effect of several ingredients on the same organ or system. This method is described in Notices, Environmental Protection Agency (FRL-2984-2) Guidelines for the Health Risk Assessment of Chemical Mixtures, Wednesday, September 24, 1986. This method follows the lead taken by the American Conference of Governmental Industrial Documentation for Threshold Limit Values for Chemical Substances and Physical Agents by the American Conference of Governmental Industrial Hygienist (ACGIH), 1999. the Occupational Safety and Health Administration (OSHA), and the World Health Organization (WHO).

Carcinogenic effects are not additive. Both EPA and the ACGIH believe that the exposure levels for carcinogens is so low that no effects are expected and therefore they are not additive.

(Where two or more chemicals affect the same organ or system, and there is no evidence to the contrary, the effects are additive for non-carcinogenic effects. For this study, all non-carcinogenic effects are considered to be additive. This provides an extra level of protection.)

4.2.3 EXPOSURE CRITERIA

Most of the chemicals of concern do not have established occupational exposure levels. Where an occupational exposure standard such as the Threshold Limit Values (TLVs) does not exist, they will be developed for this project. This will be done by starting with EPA toxicological assessments, and using that information to derive workplace exposures.

These EPA reference doses (RfD) and slope factors are quite conservative. They are designed to protect the most susceptible people in the community, those who may be older or younger, who have illnesses or are sensitized. Many of the RfDs and slope factors have safety factors of 3,000 added to the lowest measured effect.

These factors produce exposure levels for the community that are well below occupational exposure levels. For example, the exposure level for naphthalene based on EPA criteria and methods is 0.023 mg/m^3, while the TLV for workplaces is 52 mg/m^3.

It is felt that if exposures are less than the TLV or as in the case of most materials less than EPA derived exposure criteria, there should be no significant adverse health effect.

> *(There are few TLVs established for the chemicals of concern. Exposure levels will be developed from EPA data using EPA methods. This will result in very conservative exposure criteria designed to protect the most susceptible members of the community.)*

4.2.3.1 NON-CARCINOGENIC EFFECTS

The toxic effects are based on a reference dose or RfD. A chronic RfD is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound. Chronic RfDs can be used to evaluate exposure for non-carcinogenic effects associated with exposure periods between 7 years and a lifetime.

Toxic effects are considered for both non-carcinogenic and carcinogenic chemicals.

Chronic RfDs are expressed as the amount of material a person can be exposed to per day (mg/kg-day), where:

mg = the amount of material that a person can be exposed to in a day
kg = the weight of the exposed person in killograms, usually 70kg for adult male

Acceptable exposure levels can be calculated by dividing the RfD by the average body weight of a male (70kg), and dividing by the volume of air breathed in a day (12m^3). It should be noted that the usual value for the volume of air breathed is 10m^3 per day. This is for resting conditions and it was felt that 12 m^3 per day was more accurate and safer for workers.

TABLE 7: Chronic RfDs for non-carcinogenic effects for the chemicals of concern and the acceptable exposure levels calculated from them. Where an acceptable RfD was not available (marked with *), the lowest acceptable exposure level was used found in the list was used. TLVs were used where available.

CHEMICAL	RfD mg/kg/day	Acceptable Exposure level (mg/m3)
Acenaphthene	0.06	0.35
Acenaphthylene	0.06	0.35
Anthracene	0.3	1.75
Benz[a]anthracene	0.00057	0.003
Benzene (TLV used)		1.6
Benzo[a]pyrene	0.00057	0.003
Benzo[b]fluoranthene	0.00057	0.003
Benzo[g,h,i]perylene		0.003*
Benzo[k]fluoranthene	0.00057	0.003
Chrysene	0.00057	0.003
Dibenz[a,h]anthracene	0.00057	0.003
Ethyl benzene (TLV used)		434
Fluoranthene	0.04	0.23
Fluorene	0.04	0.23
Indeno[1,2,3-cd]pyrene	0.00057	0.003
Naphthalene	0.004	0.023
Phenanthrene		0.003*
Pyrene	0.03	0.175
Toluene (TLV used)		188
Xylene (TLV used)		434

If actual exposures are lower than the Acceptable Exposure Level, then it can be assumed that there will be no adverse health effects.

(Acceptable Exposure Levels were developed for non-carcinogenic chemicals without a TLV. This was done using EPA approved methods.)

4.2.3.2 CARCINOGENIC EFFECTS

Carcinogenic effects, unlike non-carcinogenic health effects, are generally thought to be a phenomenon for which risk evaluation based on presumption of a threshold is inappropriate. For carcinogens, EPA assumes that a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and eventually to a clinical state of disease. That is, no dose is risk-free. For carcinogenic effects, EPA uses a two-part evaluation in which the substance first is assigned a weight-of-evidence classification, and then a slope factor is calculated.

In the first step of the evaluation, EPA evaluated the data to determine the likelihood that the agent is a human carcinogen. The EPA weight-of-evidence classification system is shown below.

Group	Description
A	Human carcinogen
B1	Probable human carcinogen, there are limited human data available
B2	Probable human carcinogen, there is sufficient evidence in animals and inadequate or no evidence in humans
C	Possible human carcinogens
D	Not classifiable as to human carcinogenicity
E	Evidence of non-carcinogenicity for humans

The chemicals of concern in this study are either group B2 or group D.

In the second step in the evaluation, slope factors are calculated for groups A, B1, and B2. The slope factor is a plausible high estimate of the probability of a response per unit intake of a chemical over a lifetime. It is used to estimate a worst case probability that an individual will develop cancer as a result of exposure to a particular level of a carcinogen.

Slope factor = risk per unit dose
= risk per mg/kg-day

where: mg = amount of material that a person is exposed to
kg = the body weight of the person who is exposed (usually 70 kg for an adult male)

The slope factors for the carcinogenic effects of the chemicals of concern are shown below.

CHEMICAL	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$
Benz[a]anthracene	0.73
Benzo[a]pyrene	7.3
Benzo[b]fluoranthene	7.3
Benzo[k]fluoranthene	0.073
Chrysene	0.0073
Dibenz[a,h]anthracene	7.3
Indeno[1,2,3-cd]pyrene	0.73

The risk for individual substances is calculated by multiplying the Chronic Daily Intake (CDI) averaged over 70 years (mg/kg-day) by the Slope Factor, expressed in $(mg/kg\text{-}day)^{-1}$.

$$Risk = CDI * SF$$

If the risk is less than 1 in 10^{-5}, the levels considered acceptable by the Department of Conservation, it will be considered acceptable here.

The Chronic Daily Intake is calculated from the following assumptions:

Assumptions	**For 8hr/day, 5 days/week**	**Units**
Inhalation rate (IR) =	1.5	m3/hr
Exposure time (ET) =	8	hrs
Exposure frequency (EF) =	250	days/year
Exposure duration (ED) =	35	years
Body weight (BW) =	70	kg
Averaging time (AT) =	12775	days

Where CDI = ((IR*ET*EF*ED)/(BW*AT))*(Concentration in Air)

(An acceptable exposure level for carcinogens is defined as the level which results in a risk of cancer less than one chance in a hundred thousand exposed workers. This is calculated using EPA methods and data, for a person working 8 hours in a day, 5 days a week, 50 weeks a year for 35 years.)

5.0 EXPOSURE LEVELS

Worker's exposure levels have been estimated by different groups and by different means. These methods of exposure estimation will be reviewed in the order that they contribute to our knowledge of actual exposures. These are:

1. Mathematical modeling of PAH levels in the workplace based on worst case scenarios to estimate worker exposures.

2. Measurements of PAH concentrations under the elevator pit as an indicator of what could be in the building.

3. Measurements of PAH concentrations inside the workplace as an estimate of worker exposures.

This stepwise approach is necessary since many of the PAH airborne concentrations are less than the level of detection. These levels cannot be treated as zero, but a best estimate of what that concentration is must made. By looking at the data in the order suggested, such an estimate can be made.

5.1 EXPOSURE MODELING

In January 1995, CH2M Hill released their *Volume I, Final Report, Environmental Health and Safety Assessment of the Sutherland Avenue Operations Facility In Winnipeg Manitoba, Phase II: Detailed Site Characterization.* This report included an estimate of worker exposures that were determined with the AERIS model.

The AERIS model is a soil toxicity model developed to meet the soil testing requirements for the Decommissioning Steering Committee in Canada. It provides estimates of concentration of chemicals in contaminated soil that are used to help establish cleanup guidelines or to indicate when remedial actions are required. Model inputs include site-specific data, physical and chemical properties, transportation calculation methods, and exposure parameters. Model assumptions are shown in Table 8. The model estimates human exposures resulting from contaminated soil.

Models are a tool used to estimate exposures, and can never have all the factors that influence exposures. Therefore, they are usually conservative. That is, they overestimate exposures as a safety precaution. The CH2M Hill report does not describe the model and its limitations in any detail, and does not present its biases or weaknesses. There is little information available about AERIS, as it is an older program developed in the late 1980s. Even, the developers of the model do not support it today.

The choice of loose mixed grain sand as a description of the unsaturated soil would overestimate worker exposure in the building, as would the choice of chemical concentrations for the model taken from test holes made in the parking lot at the north end of the site. This is where the highest concentrations were found. Therefore if estimates based on this site are acceptable, actual exposures, which would be lower, will be acceptable also. Exposures are proportional to soil concentration.

Given the conservative nature of models, and the favourable bias of the two data choices mentioned above, it appears reasonable to take the predicted exposures as calculated in the CH2M Hill report at face value.

The program is given information about the chemicals in the soil such as how well it is bound to the soil, and how easily it vapourizes. It then estimates the concentration of vapours in the soil. Given the size of the air spaces in the soil it then estimates how quickly the vapours move through the soil. It then estimates how freely the vapours will enter the building basement, and what the exposures are of the people inside.

TABLE 8: Assumptions used in modeling exposures inside the buildings. Except where noted as site-specific values, the parameters are standard default values.

Exposed workers	Office personhel, maintenance/operational crew members
Number of exposed people in building	70
Maximum time spent on site	• 8 hours/day inside, 1 hour outside summer and winter • 2 hours/day outdoors and 4 hours/day indoors on weekends in summer • 1 hour/day outdoors 4 hours/day indoors on weekends in winter • remainder of time away from site
Carcinogen exposure time	70 years
Noncarcinogen exposure time	Actual exposure time
Inhalation rate	1.0 m^3/hr
Building Volume	21,600 m^3
Basement dimensions	69 x 57 x 3 m
Air exchanges	• 2 events/hour in summer • 1 event/hour in winter
Exposure levels	Based on maximum soil concentrations measured in at north end of site in parking lot

Table 9 shows the worst case exposure level as calculated by AERIS and reported in the CH2M Hill report, *Volume I, Final Report, Environmental Health and Safety Assessment of the Sutherland Avenue Operations Facility In Winnipeg Manitoba, Phase II: Detailed Site Characterization.* The value is a maximum level based on the single highest concentrations found on the site, not an average level.

It should be noted that the chemicals of greatest concern, carcinogens, also have a low predicted exposure level. This is to be expected. As seen in Tables 5 and 6, these are the chemicals that adhere strongest to soils, and do not easily become mobile as vapours.

The model predicts that the chemical most likely to become airborne and enter the workplace is naphthalene. Naphthalene has a workplace exposure level of 52 mg/m^3.

TABLE 9: Calculated exposure levels as calculated by the AERIS Model, using the highest concentration of chemicals found in the ground.

PAH	Exposures Based on Max Concentration (mg/m^3)
Naphthalene	0.021
Acenaphthene	0.000031
Acenaphthylene	
Fluorene	0.00098
Phenanthrene	
Anthracene	0.00098
Fluoranthene	0.0000063
Pyrene	0.0000055
Benz[a]anthracene*	0.000000022
Chrysene*	0.000001
Benzo[b]fluoranthene*	0.00000064
Benzo[k]fluoranthene*	0.0000015
Benzo[a]pyrene*	0.000000039
Indeno[1,2,3-cd]pyrene*	
Dibenz[a,h]anthracene*	0.000000000075
Benzo[g,h,i]perylene	0.00000000097
Benzene	
Toluene	
Ethylbenzene	
Xylene	

* Carcinogen

The AERIS model was used to predict worker exposure to soil chemicals. The model used the highest soil concentration on the site, and a soil type that allowed high vapour movement in the soil. Therefore the model would overestimate exposures. If these estimated exposures are acceptable, the real ones would also be acceptable.

5.2 LEVELS UNDER THE ELEVATOR FLOOR

In 1996 an elevator was installed. Its construction included an excavation below the basement floor. During construction coal tar odours were noted, raising concerns about staff safety in the building.

Construction included an under-floor ventilation system (shown in Figure 3). Vapour concentrations were collected from below the floor by inserting the sampling hose into the ventilation pipe.

Table 4 shows the concentrations of materials found for each of the four samples. Most of the samples were below the level of detection (LOD) as shown by the symbol "<". LOD does not mean that there is no material present. It only means that the concentration is too low to measure. It could be zero, or it could be just below the LOD. To properly account for this value, a most reasonable level of half the LOD was chosen to estimate exposures. This value is shown in Table 10, Column 3.

The measured value used in Table 10 was the highest measured concentration where such a value was found. The other values are reported levels of detection as determined in the most sensitive test.

TABLE 10: Air samples in the space under the elevator. All values in mg/m^3. The measured value is the most sensitive measurement. The most reasonable level is half of the level of detection

PAH	Measured Value	Most Reasonable Level
Naphthalene	0.0016	0.0016
Acenaphthene	<0.00007	0.00004
Acenaphthylene	<0.00014	0.00007
Fluorene	<0.00007	0.00004
Phenanthrene	<0.00007	0.00004
Anthracene	<0.00007	0.00004
Fluoranthene	<0.00007	0.00004
Pyrene	<0.00021	0.0001
Benz[a]anthracene	<0.00007	0.00004
Chrysene	<0.00007	0.00004
Benzo[b]fluoranthene	<0.00028	0.0001
Benzo[k]fluoranthene	<0.00028	0.0001
Benzo[a]pyrene	<0.00021	0.0001
Indeno[1,2,3-cd]pyrene	<0.00021	0.0001
Dibenz[a,h]anthracene	<0.00028	0.0001
Benzo[g,h,i]perylene	<0.00014	0.00007
Benzene	<0.005	0.003
Toluene	<0.005	0.003
Ethylbenzene	<0.005	0.003
Xylene	<0.02	0.01

< = less than, in this case less than the level of detection

The only material actually found in the air under the elevator was naphthalene. The model predicted that this was the most likely material to be found in the air.

It should be noted that the naphthalene value is not an average level. It is a peak value. Twice, no naphthalene was found, and once 0.0008 mg/m^3 was found.

There is a significant dilution of exposure levels when a vapour must diffuse through the cracks in a floor into a basement. Such indoor levels can be as much as one 1000th of outside exposure levels as discussed in the US Environmental

Protection Agency (EPA) document titled *Appendix H - Evaluation of the Effect on the Draft SSLs of the Johnson and Ettinger Model (EQ, 1994a).* This effect was also noted in the CH2M Hill December 1995 report *Environmental, Health and Safety Assessment of the Sutherland Avenue Operations' Facility in Winnipeg, Manitoba, Phase IIB: Offsite Soil Gas Survey.* The JAWMA, March 92, page 277 carried an article titled *Soil-Gas Contamination and Entry of Volatile Organic Compounds into a House Near a Landfill,* that reported measured soil-gas levels at 100 to 1000 times higher than inside the house.

When such a dilution factor is applied to the measured vapour levels under the floor, the indoor vapour levels predicted by the model in Section 5.1 appear to overestimate exposures inside the building.

> *Construction of the elevator pit included an under-floor ventilation system that could be used to sample vapours under the building. The only material actually found in the air under the elevator was naphthalene. The model predicted that this was the most likely material to be found in the air. This under-floor level must be further diluted by about 1000 to represent indoor exposure levels. The diluted levels are similar to those the model predicted.*

5.3 LEVELS INSIDE THE BUILDING

Samples were collected in the basement, in the mechanical rooms where levels were expected to be highest. Samples were also collected on the second floor.

Tables 1, 2 and 3 show the concentrations of materials found for three locations and the samples collected since 1993. Most of the samples were below the level of detection (LOD) as shown by the symbol "<". LOD does not mean that there is no material present. It only means that the concentration is too low to measure. It could be zero, or it could be just below the LOD. To properly account for this value, a most reasonable level of half the LOD was chosen to estimate exposures. This value is shown in Table 11, Column 3.

Using half the detection level should overestimate exposure levels from the materials of greatest concern, the carcinogenic materials. The model predicts that, due to adherence of these materials to soils and their high vapour pressure, they will be at least one 1000^{th} of the value assumed to be inside the building. Similarly, the indoor levels predicted from the vapour concentration found under the elevator are up to one 1000^{th} the values assumed to be inside the building. As can be seen, using half the detection level is a conservative method of estimating worker exposures, that is it has a good safety factor built into it.

The measured value used in Table 11 was the highest measured indoor concentration where such a value was found. The other values are reported levels of detection as determined in the most sensitive test. The only material measured was naphthalene, the material that the model predicted as having the highest indoor air concentration. The naphthalene level used here is a peak measured value, not an average indoor level. Seven indoor samples taken since 1993 had no measurable PAH levels, and only 4 had measurable levels.

The levels found inside, as represented by the Most Reasonable Levels, are compatible with the outside levels found below the floor, or the inside levels estimated by modeling or from diluted outside measured exposure levels.

TABLE 11: Air samples inside the building. All values in mg/m^3. The measured value is the most sensitive measurement. The most reasonable level is half of the level of detection

PAH	Measured Value	Most Reasonable Level
Naphthalene	0.0014	0.0014
Acenaphthene	<0.000005	0.000003
Acenaphthylene	<0.000005	0.000003
Fluorene	<0.000005	0.000003
Phenanthrene	<0.000005	0.000003
Anthracene	<0.000005	0.000003
Fluoranthene	<0.000005	0.000003
Pyrene	<0.000005	0.000003
Benz[a]anthracene	<0.000005	0.000003
Chrysene	<0.000005	0.000003
Benzo[b]fluoranthene	<0.000005	0.000003
Benzo[k]fluoranthene	<0.000005	0.000003
Benzo[a]pyrene	<0.000005	0.000003
Indeno[1,2,3-cd]pyrene	<0.000005	0.000003
Dibenz[a,h]anthracene	<0.000005	0.000003
Benzo[g,h,i]perylene	<0.000005	0.000003
Benzene	<0.0005	0.0003
Toluene	<0.0005	0.0003
Ethylbenzene	<0.0005	0.0003
Xylene	<0.0005	0.0003

< = less than, in this case less than the level of detection

Samples were collected in the basement, in the mechanical rooms where levels were expected to be highest. The only material measured was naphthalene. The naphthalene level used here is a peak measured value, not an average indoor level. Seven indoor samples taken since 1993 had no measurable PAH levels, and only 4 had measurable levels.

6.0 RISK ANALYSIS

In Section 4, the chemicals of concern were defined, and their acceptable exposure levels developed. In Section 5 the potential exposure levels were developed. In this Section, the acceptable exposure levels and the predicted exposure levels are brought together to determine if there is an unacceptable risk to workers at the Sutherland Avenue location.

6.1 NONCARCINOGENIC RISK LEVELS

In Section 5.3 potential exposure levels for workers inside the building were developed (Table 11). In Section 4.2.3.1 the acceptable exposure levels for exposure to noncarcinogenic effects were developed (Table 7). In this section the information from these two tables are combined in Table 12.

TABLE 12: Exposure levels to indoor PAHs compared to the acceptable exposure levels for noncarcinogenic effects.

PAH	Acceptable Exposure level (mg/m3)	Most Reasonable Predicted Exposure Level (mg/m^3)	Additive Effects (C_n/T_n)
Naphthalene	0.023	0.0014	0.06
Acenaphthene	0.35	0.000003	0.000008
Acenaphthylene	0.35	0.000003	0.000008
Fluorene	0.23	0.000003	0.00001
Phenanthrene	0.003	0.000003	0.001
Anthracene	1.75	0.000003	0.000002
Fluoranthene	0.23	0.000003	0.00001
Pyrene	0.175	0.000003	0.00002
Benz[a]anthracene	0.003	0.000003	0.001
Chrysene	0.003	0.000003	0.001
Benzo[b]fluoranthene	0.003	0.000003	0.001
Benzo[k]fluoranthene	0.003	0.000003	0.001
Benzo[a]pyrene	0.003	0.000003	0.001
Indeno[1,2,3-cd]pyrene	0.003	0.000003	0.001
Dibenz[a,h]anthracene	0.003	0.000003	0.001
Benzo[g,h,i]perylene	0.003	0.000003	0.001
Benzene	1.6	0.0003	0.0002
Toluene	188	0.0003	0.000002
Ethylbenzene	434	0.0003	0.0000007
Xylene	434	0.0003	0.0000007
Sum of Additive Effects =			**0.07**

Column 2 reproduces the acceptable exposure levels for noncarcinogenic effects as shown in Section 4.2.3.1. Column 3 contains the exposure levels for workers at Sutherland Avenue. As can be seen, all exposure levels are well below the acceptable exposure level. The highest exposure is from naphthalene that is less than one tenth the acceptable exposure level. Other materials are up to one millionth of their acceptable exposure level.

To ensure that there are no additive effects, the exposure levels were added using the method described in Section 4.2.2. Column 4 is the exposure criteria divided into the actual exposure level for each material. This gives the ratio of the exposure to the standard. All ratios are then added for each effect. If the sum of the ratios is greater than one, an overexposure is assumed. At the bottom of Column 4, in bold is the sum of the effects, 0.07. This is well below the criteria of 1, indicating that there is no problem with additive effects.

> *All exposure levels are well below the acceptable exposure level. The highest exposure is from naphthalene that is less than one-tenth the acceptable exposure level. Other materials are up to one millionth of their acceptable exposure level. If we assume that the health effects are additive for all materials, the sum of the effects is 0.07, much less than the criteria of 1, therefore the exposures are acceptable.*

6.2 CARCINOGENIC RISK LEVELS

In Section 5.3 potential exposure levels for workers inside the building were developed (Table 11). These are the same levels developed for non-carcinogenic effects. In Section 4.2.3.2 the criteria (slope factor) for determining risk as a result of exposure to carcinogens were developed. In this section the information from these two tables are combined in Table 13.

As explained in Section 4.2.3.2 the risk is calculated from the exposure level and the slope factor using the factors described below.

Assumptions	**For 8hr/day, 5 days/week**	**Units**
Inhalation rate (IR) =	1.5	m3/hr
Exposure time (ET) =	8	hrs
Exposure frequency (EF) =	250	days/year
Exposure duration (ED) =	35	years
Body weight (BW) =	70	kg
Averaging time (AT) =	12775	days

The resulting risk is shown in column 4 of Table 14.

TABLE 13: Exposure levels to indoor PAHs and the risk those exposures present.

CHEMICAL	Most Reasonable Predicted Exposure Level (mg/m^3)	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Risk Level (acceptable risk is 0.00001 or better)
Benz[a]anthracene	0.000003	0.73	0.0000003
Benzo[a]pyrene	0.000003	7.3	0.000003
Benzo[b]fluoranthene	0.000003	7.3	0.000003
Benzo[k]fluoranthene	0.000003	0.073	0.00000003
Chrysene	0.000003	0.0073	0.000000003
Dibenz[a,h]anthracene	0.000003	7.3	0.000003
Indeno[1,2,3-cd]pyrene	0.000003	0.73	0.0000003

All risks are less than the criteria of one excess cancer in 100,000 workers over a lifetime exposure. The highest risk (Benzo[a]pyrene, Benzo[b]fluoranthene, Dibenz[a,h]anthracene) is 3 in a million, and the lowest risk (Chrysene) is 3 in a billion. Under worst case conditions, the risk of cancer is one-tenth the acceptable level.

> *The worst case prediction was that the most susceptible person had a risk of 3 in 1,000,000 of developing cancer from exposures at the site. This is within the acceptable criteria used here.*

7.0 CONFIDENCE IN FINDINGS

The risk analysis for noncarcinogens and carcinogens showed that the exposure levels were at least one tenth the acceptable exposure levels. The next question is "how much can we trust that number"?

7.1 EXPOSURE LEVELS

The biggest problem that we have in estimating risk is how to deal with the large number of measurements that were below the level of detection (LOD). The task would be quite simple if we could just measure the levels that workers are exposed to and compare them to a standard. As discussed earlier LOD does not mean that there is no material present. It only means that the concentration is too low to measure. It could be zero, or it could be just below the LOD. To properly account for this value, a most reasonable level of half the LOD was chosen to estimate exposures. There are three factors that can be used to determine how well we can trust a number half the LOD.

1. The model is less reliable than actual measurements. Models tend to overestimate exposures as a safety factor to makeup for their lack of precision. But, they do give a reasonable estimate of the magnitude of the exposure. For more volatile materials (noncarcinogens), the modeled exposures were higher than the measured values as seen in Table 14. This comparison is valid only where the expected values are high enough to be measured. This suggests that the model will overestimate exposure to the carcinogenic materials also.

This comparison suggests that although the measurements are a reasonable estimator of exposure to the more volatile noncarcinogens, the measurements based on half the level of detection overestimate exposure to the less volatile carcinogens. Sometimes this overestimation is by a factor of 1000. This increases our confidence in the exposure levels.

2. The area with the highest concentrations should be the area under the floor of the elevator pit. Air samples collected from under the floor were less than the level of detection for the measured exposure levels. The method used for under the floor levels was the same as for inside the building. Experience with models and measurements shows that under-floor levels are 100 to 1000 times lower than inside measurements. The risk to workers was based on the same levels as were found under the floor. No adjustment was made for diluting the under-floor levels. Therefore the actual indoor levels are likely much lower than the values used in the risk analysis. This increases our confidence in the exposure levels.

3. All calculations were based on the peak level or the level of detection of the most sensitive measurement. The values used were not the average measured exposure level. Since most measurements failed to find anything above the detection level, this overestimated the exposures used in the risk analysis. This increases our confidence in the exposure levels.

From the above, we can feel confident in the numbers used in estimating worker risk inside the building. If there is a bias in the use of half the LOD it is in favour of the workers, and may overestimate risk by a factor of up to 1000.

TABLE 14: Comparison of modeled and measured exposure levels. Shaded values are predicted levels that were higher than measured values.

PAH	Most Reasonable Predicted Exposure Level (mg/m^3) (Measured)	Exposures Based on Max Concentration (mg/m^3) (Modeled)	
Naphthalene	0.0014	0.021	Likely to become airborne
Acenaphthene	0.000003	0.000031	
Acenaphthylene	0.000003		
Fluorene	0.000003	0.00098	
Phenanthrene	0.000003		
Anthracene	0.000003	0.00098	
Fluoranthene	0.000003	0.0000063	
Pyrene	0.000003	0.0000055	Not likely to become airborne
Benz[a]anthracene*	0.000003	0.000000022	
Chrysene*	0.000003	0.000001	
Benzo[b]fluoranthene*	0.000003	0.00000064	
Benzo[k]fluoranthene*	0.000003	0.0000015	
Benzo[a]pyrene*	0.000003	0.000000039	
Indeno[1,2,3-cd]pyrene*	0.000003		
Dibenz[a,h]anthracene*	0.000003	0.000000000075	
Benzo[g,h,i]perylene	0.000003	0.00000000097	
Benzene	0.0003		
Toluene	0.0003		
Ethylbenzene	0.0003		
Xylene	0.0003		

The large number of samples that were less that the level of detection introduces uncertainty into the data. However, the data is supported by the model as well as estimates based on underfloor measurements. Use of peak exposures rather than average exposures provide an added margin of safety. If there is a bias in the use of half the LOD it is in favour of the workers, and may overestimate risk by a factor of up to 1000.

7.2 EXPOSURE CRITERIA

The next area of uncertainty is the exposure criteria that were used. Does it provide an effective level of protection? There are two factors that must be considered.

1. The acceptable exposure criteria used in this review (as in the original studies) is the EPA Integrated Risk Information System (IRIS), where data was available. The RfD can be used to estimate a level of environmental exposure at or below which no adverse effect is expected to occur. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be

without appreciable risk of deleterious effects during a lifetime. RfDs are based on an assumption of lifetime exposure and may not be appropriately applied to less-than-lifetime exposure situations. RfDs are also derived for the noncarcinogenic effects of chemicals that are carcinogenic.

Since the exposure criteria presented in the IRIS database is designed to protect sensitive subgroups for a lifetime exposure, workers should be adequately protected by these criteria. For example, the criteria for worker exposure based on the needs of a sensitive group exposed to naphthalene is 0.023 mg/m^3 based on IRIS, while the TLV for normal healthy workers is 52 mg/m^3.

It is felt that by using exposure criteria based on a lifetime dose for sensitive populations will provide an adequate margin of safety for workers at this site.

2. IRIS did not have reference concentrations for inhaled materials, and oral doses were used. The doses were used as presented by IRIS. No adjustments were made for the vapours exhaled and not retained in the body. This would exaggerate the effects by 20-25%. This would provide an additional margin of safety for workers at the site.

From the above, we can feel confident in the exposure criteria used in estimating worker risk inside the building. If there is a bias in the use of the IRIS criteria, it is in favour of the workers, and may overestimate risk.

> *Since the IRIS database is designed to protect sensitive subgroups for a lifetime exposure, workers should be adequately protected by these criteria. No adjustments were made for the vapours exhaled and not retained in the body. This would exaggerate the effects by 20-25%. We can feel confident in the exposure criteria used in estimating worker risk inside the building. If there is a bias in the use of the IRIS criteria, it is in favour of the workers, and may overestimate risk.*

8.0 SIGNIFICANCE OF EXPOSURES TO CARCINOGENS

The estimated exposure levels of PAHs inside the building were based on peak measured levels, or half the level of detection for the most sensitive method used. These levels are similar to the 1996 peak levels as measured for by Environment Manitoba in Winnipeg as shown in Table 15. In other words the exposures present inside the building are not significantly different from those outside.

TABLE 15: Comparison of estimated exposures inside the based on peak levels at Sutherland Ave building and peak levels measured in Winnipeg in 1996.

CHEMICAL	Most Reasonable Predicted Exposure Level (mg/m^3)	Peak Manitoba Environmental Exposure Level (mg/m^3)
Naphthalene	0.0014	0.001
Benz[a]anthracene	0.000003	0.000001
Benzo[a]pyrene	0.000003	0.0000004
Benzo[b]fluoranthene	0.000003	0.0000015
Benzo[k]fluoranthene	0.000003	0.0000015
Chrysene	0.000003	0.000001
Dibenz[a,h]anthracene	0.000003	0.0000001
Indeno[1,2,3-cd]pyrene	0.000003	0.0000008

Table 16 is a risk comparison of different types of accidents that can be found on the job. The risk of one excess death due to exposure to carcinogens found at the Sutherland Avenue site are relatively low, lower even than eating 10 charcoal-broiled steaks every year for 35 years, and about the same as living a lifetime in Winnipeg. The Winnipeg risk was based on peak Benzo[b]fluoranthene levels measured in 1995-96. A peak community level was used so that a comparison could be made with peak workplace levels.

TABLE 16: Comparison of individual lifetime risk of death due to various accidents that could be found on the job.

ACCIDENT TYPE	INDIVIDUAL LIFETIME RISK
Motor vehicle	1 in 115
Work accidents	1 in 200
Falls	1 in 300
Fires and hot substances	1 in 725
Drowning	1 in 850
Falling objects	1 in 4,600
Electrocution	1 in 4,600
Expense account eating 10 charcoal-broiled steaks/year	1 in 29,000
Lightning	1 in 57,000
Living in Winnipeg (based on peak Benzo[b]fluoranthene)	1 in 300,000
Workplace exposure to PAH at Sutherland Ave	1 in 350,000

9.0 CONCLUSIONS

1. The exposure estimates carried out by various groups since 1993 followed acceptable methods, and present a fair estimate of worker risk. However, to increase the reader's confidence in the data and their interpretation, the following should be considered:

    - Variations in detection levels between different samples should be controlled so as to reduce doubt about the methods used. This variation in detection levels could make the exposures appear to be 10-100 times higher than they are.

- Sampling time and laboratory limits should be optimized so as to reduce detection levels as much as possible, and then that method followed in future work so as to eliminate an apparent fluctuation in exposure levels. Work carried out over an extended time frame should be consistent, or carry an explanation for any variation in method, and its impact on the findings.

- Levels below the detection levels should be addressed in all reports. <LODs should not be ignored with the implication that if none was measured none was there.

2. Exposure to carcinogens at the Sutherland Avenue facility do not present an unacceptable risk of death due to cancer. The exposure level that this is based on is a worst case peak estimate. Exposure levels for most materials were too low to measure (only naphthalene was measured). The acceptable exposure level was set to protect the most sensitive members of the population.

   Using the same criteria, the excess risk due to working at Sutherland Avenue was less than the excess risk of living in Winnipeg.

3. Non-carcinogenic effects were low enough that when all effects were added, exposures were less than one-tenth the level required to protect the most sensitive members of the population.

10.0 RESIDUAL ISSUES

The following are issues raised by staff that were not addressed directly in the report.

1. If the site is "contaminated" and cannot be sold, why is it safe for workers?

   The site can be used for its original industrial purpose without risk to workers. However, it cannot be rezoned for residential use, or other use that could result in persons coming into direct contact with impacted soil.

2. The site is not being remediated, or does not have to be remediated, yet soil samples from the site are handled through strict procedures.

   The samples were being handled according to prescribed methods for soil sampling. When samples are collected, care must be taken so that there is no cross contamination between samples. This means the engineer collecting the sample must wear fresh gloves for each sample, and that tools must be carefully washed between samples. This gives the appearance that the engineer is taking steps to protect himself whereas he is protecting the sample.

3. Can the site be safely developed in the future?

   The site can be developed, as is, for other industrial usage. However, it cannot be rezoned for residential use, or other use that could result in persons coming into direct contact with impacted soil without being cleaned to the standards for that use.

4. What is the exposure history of workers at this site?

   The earliest estimates of worker exposure were from 1993, and showed no excessive exposure levels. They were below the level of detection at that time. It would be safe to assume that they were higher in the past, but at unknown levels. The highest onsite exposure were when the gas plant was in operational.