Health Risk Analysis for Human Exposure to Contaminated Soils, at Arcadia Cleaners, Sandy's Magic Touch and Kachina Cleaners

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1.0 INTRODUCTION

The purpose of this risk analysis is to evaluate the health risks that may be presented by exposure to volatile organic compounds (VOCs) in soil gas at Arcadia Cleaners, Sandy's Magic Touch Cleaners, and Kachina Cleaners.

1.1 Authority

Pursuant to Arizona Revised Statutes §§ 49-282, this risk analysis is written in accordance with the requirements of Contract Number 2217-000000-3-3-AB-2001 for the Arizona Department of Environmental Quality (ADEQ). This document was prepared using guidelines prescribed by the U.S. Environmental Protection Agency (USEPA) Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual: Part A[1] and RAGS Human Health Supplement.[2]

1.2 Overview

Subsurface soil at these facilities has been contaminated with solvents as a result of historical uncontrolled releases at the sites. The Earth Technology Corporation has performed shallow soil gas investigations at the sites.

1.3 Goals and Objectives

The goal of this risk analysis is to provide risk information necessary to assist decision-making within the risk management process. The objective of this risk analysis is to provide an evaluation of health risks that may result from exposure to solvents in subsurface soil at the facilities. The potential for groundwater contamination *is not* addressed in this analysis.

2.0 CHEMICALS OF CONCERN

Tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1,1 trichloroethane (TCA), and 1,1 dichloroethylene are the chemicals of concern in subsurface soils.

2.1 Data Collection and Evaluation

Soil Gas

This risk analysis uses soil gas data collected and analyzed by the Earth Technology Corporation in May of 1996. All soil gas samples were analyzed using EPA method 8010 for TCE, PCE, 1,1,1 TCA, and 1,1 DCE. Forty soil gas samples were taken at 11 locations at Arcadia Cleaners, 35 soil gas samples were collected at 10 locations at Sandy's Magic Touch Cleaners, and 24 soil gas samples were collected from 9 locations at Kachina Cleaners. All facilities are located in East Phoenix. Tables 1 through 3 summarize the results of the investigations.

2.2 Data Quality

Quality Assurance/Quality Control (QA/QC) for soil gas samples are unknown. Data used in the analysis are preliminary and subject to change. The data appears to be of adequate quality for use in this screening level risk analysis.

3.0 EXPOSURE ASSESSMENT

This exposure assessment focuses on potential future human exposure to chemicals of concern in soil gas at the facilities. It quantitatively estimates the inhalation exposure pathway associated with chemical contamination in soil at the site.

3.1 Exposed Populations

The populations potentially exposed to contaminants in soil in the study area include:

Current Exposure:

- Individuals working at the facility that may be exposed to vapors as a result of inhalation of solvents diffusing through soil and vapor barriers. Areas of potential exposure include those working indoors and outdoors at the facilities.

Potential Future Exposure:

- Individuals that may live at the areas of contaminated soil under future land uses.

3.2 Exposure Pathway Identification

A potentially complete human exposure pathway describes the route a chemical may take from the source to a receptor. A complete exposure pathway includes the following components:

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

3.3 Exposure Points and Routes

The potentially complete exposure route to the contaminants in soil is inhalation of vapors that diffuse through soils. Exposure routes are discussed in more detail in this section.

Air Exposure

Exposure to PCE may be possible as a result of inhalation of vapors diffusing through soil and vapor barriers. Soil gas data will be used to quantitatively estimate exposure to vapors from these releases.

Groundwater Exposure

The objective of this risk analysis does not include an evaluation of the potential for groundwater impact.

3.4 Summary of Exposure Points to be Quantified

Exposure pathways selected for quantified risk analysis are summarized in Table 3.1.

Table 3.1 -- Exposure Pathway Summary

Potential Exposed Population	Exposure Point	Exposure Route	Path Evaluated	Path Selected	Exposure Type	Rationale
Current Land Use						
Occupational	Direct contact with contaminated surface soil	Ingestion Dermal	Yes Yes	No No	*None*	No documentation of exposed surface soil (0-2 ft.) contamination
Occupational	Inhalation of vapors originating in soil/soil gas	Inhalation	Yes	Yes	*Actual*	Indoor and outdoor inhalation of vapors possible
Potential Future Land Use						
Residential	Direct soil contact on-site	Ingestion Dermal	Yes Yes	Yes	None	Exposure and risk depend upon future uses and risk management
Residential	Inhalation of vapors.	Inhalation	Yes	Yes	Potential	Exposure and risk depend upon future uses and risk management

3.5 Quantification of Exposures

Estimates of exposure concentrations and pathway specific intake doses must be made to quantify exposures. Repeated, prolonged (chronic) exposures are assumed, due to the relatively low levels of exposure via environmental media. Exposures from inhalation of solvent vapors indoors and outdoors will be estimated.

The upper 95% confidence limit (UCL) of the concentrations found in ambient air were used to estimate exposure concentrations. The formula for calculating the UCL is as follows:

$$UCL = \text{mean} + t_{(n-1)} * (\sigma/\sqrt{n})$$

3.5.1 Soil Gas Estimation Methods

The health risks presented from inhalation of vapors that may infiltrate into the facilities and outdoor air near the facility were modeled using a conservative methodology. Exposure estimates were made using soil gas concentrations. Soil sample analytical results were reported in ug/L of solvents in soil gas. Samples reporting below the detection limit were eliminated from the data set.

3.5.2 Flux Estimation Methods

Flux from the solvent in soil gas was calculated using the Karimi et al.[3] model as described in the EPA Superfund Exposure Assessment Manual (SEAM)[4] and the Air/Superfund National Technical Guidance Study Series Document: Assessing Potential Indoor Air Impacts for Superfund Sites.[5] The Karimi model assumes zero concentration of volatilizing material at the soil surface and a non-diminishing and continuous source of contaminants in a system in equilibrium.

Each of the measured soil gas concentrations of were used in the Karimi model to calculate flux as represented by the following equation:

$$J_i = (D_i)(C_g)(P_a^{3.33}/P_t^2)/L$$

where:

J_i	=	Flux Rate of Component i ($mg/m^2 \bullet sec$)
D_i	=	Diffusion Coefficient in Air of Component i [4] (m^2/sec)
C_g	=	Concentration in Soil Gas of Component i (mg/m^3)
P_a	=	Air Filled Porosity of the Soil [6] (0.25 dimensionless)
P_t	=	Total Soil Porosity[7] (0.45 dimensionless)
L	=	Depth to Contamination (m)

The upper 95% confidence limit (UCL) of the flux values was used to estimate flux for the entire facility. The formula for calculating the UCL is as follows:

$$UCL = \text{mean} + t_{(n-1)}*(\sigma/\sqrt{n})$$

3.5.3 Indoor Air Estimation Methods

A conservative indoor air model was used to predict concentrations of contaminants in indoor air for receptors working inside the facilities. The concentration in indoor air was calculated using default dimensions using the following model:

$$IAC=(J_i)(a)(F)/(ACH/3600)(v)$$

where:

IAC	=	Indoor Air Concentration (mg/m^3)
J_i	=	Flux Rate of Component i ($mg/m^2 \bullet sec$)
a	=	Area of Building Floor (m^2)
F	=	Fraction of Floor Through Which Soil Gas May Enter (unitless)
ACH	=	Building Air Changes Per Hour (air changes/hr)
v	=	Volume of Building (m^3)

The indoor air concentration (IAC) is dependent on the fraction of floor (F) through which soil gas may enter, the volume of the building (v) and the number of air changes per hour (ACH). The value for F was assumed to be 0.001.[5] The value for ACH was conservatively assumed to be 0.8. The volume of the Kachina Cleaners building (580 m^3) was determined using site specific data. The 95%UCL of flux estimates was used as a measure of flux for the building.

3.4.4 Outdoor Air Concentration Estimation Methods

A "box model" was used to predict conservative ambient concentrations of contaminants in outdoor air for receptors outside the building. The model predicts conservative ambient concentrations of contaminants for receptors located at the downwind edge of the exposure area, and assumes that vapors within the box are well mixed. The concentration of the component in outdoor air was calculated using the following "box model"[4]:

$$OAC=(J_i)(a)(F)/(w)(h)(u)$$

where:

OAC	=	Outdoor Air Concentration (mg/m^3)
J_i	=	Flux Rate of Component i ($mg/m^2 \bullet sec$)
a	=	Area of Emission (m^2)
F	=	Fraction of Surface Available for Diffusion (dimensionless)
w	=	Square Root of Box Area (m)
h	=	Height of Box (m)
u	=	Wind Velocity (m/sec)

The model to estimate outdoor air concentrations above the parking lot assume vapors in soil gas diffuse into an imaginary "box", with dimensions of 10m x 10m x 3m. The average annual wind speed for Phoenix of 2.6 m/sec was used in the equation. The estimate assumes that the outdoor area is unpaved and assumes an F value of 1 (100%).

Predicted outdoor air concentrations were then used in the exposure scenario outlined in Table 3.2 to quantify potential health risks.

3.5 Exposure Estimates

Predicted indoor and outdoor air concentrations are used in the exposure scenario outlined in Table 3.2 to quantify potential health risks.

Table 3.2 - Calculation of inhalation intakes for vapor exposure.

CHRONIC DAILY INTAKE: $CDI = \frac{(AC)(IR)(ET)(CF)(EF)(ED)}{(BW)(AT)}$

where:

AC = Chemical Concentration in Air (mg/m^3)
IR = Inhalation Rate (m^3/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kilograms)
AT = Averaging Time (days)

Residential Variable Values:

		Central Est.	RME
IR:		15 (m^3/day)	20 (m^3/day)
EF:		350 (days/year)	350 (days/year)
ED:		9 (years)	30 (years)
BW:		70 (kg)	70 (kg)
AT:	For noncarcinogenic effects	ED x 365 (days)	ED x 365 (days)
AT:	For carcinogenic effects	70 x 365 (days)	70x365 (days)

Occupational Variable Values:

		Central Est.	RME
IR:		15 (m^3/day)	20 (m^3/day)
EF:		250 (days/year)	250 (days/year)
ED:		4.2 (years)	25 (years)
BW:		70 (kg)	70 (kg)
AT:	For noncarcinogenic effects	ED x 365 (days)	ED x 365 (days)
AT:	For carcinogenic effects	70 x 365 (days)	70x365 (days)

The worksheets for calculating soil gas exposure is displayed in the Appendix.

3.6 Uncertainties in the Exposure Assessment

All exposure parameters were chosen to produce conservative estimates of total risk from exposure to contaminants.

Exposures calculated from soil gas and soil concentrations of solvents were not measured, but were modeled using conservative methodologies. The major modeling efforts in this assessment are related to the releases of VOCs to the atmosphere from soil. It should be recognized that when a model is used the uncertainty of the estimated quantities is greater than if an accurate measurement were taken. Modeling creates uncertainties in the exposure analysis, however, due to the conservative models used, actual exposure is likely to be less than that estimated here.

All exposure parameters were chosen to produce conservative estimates of total risk from exposures to contaminants. Exposure concentrations used in the calculation of reasonable maximum intakes are 95% upper-bounds estimates.

Exposure doses (CDI) used in the calculation of carcinogenic risks and noncarcinogenic hazard quotients are also included in the risk calculation worksheets in the Appendix. These doses are based on the assumptions and calculations shown in previous sections. They may be considered upper-bound estimates. The estimated doses are used in conjunction with slope factors (carcinogenic risk calculations) and reference doses (noncarcinogenic calculations) to produce probability estimates of carcinogenic risk, and hazard quotients for noncarcinogenic adverse health effects.

4.0 TOXICITY ASSESSMENT

The toxicological information on the chemicals of concern for this study is summarized in this chapter. Emphasis is placed upon the non-carcinogenic and carcinogenic effects with discussions on the dose-response variables (reference dose, slope factor) utilized in the statement of risk. Each chemical is summarized with regard to use, interactions with other chemicals, exposure routes, toxicokinetics, toxic (health) effects, and carcinogenicity.

4.1 Dose-Response Variable for Non-Carcinogenic Effects

The reference dose (RfD) is used as a dose-response variable for assessing the non-carcinogenic effects of exposure to chemicals. The chronic RfD is utilized in calculating the risk of long-term exposure to specific chemicals. USEPA defines the chronic reference dose as "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. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound".[1] The USEPA derives the RfDs from animal and, when available, human studies by taking the highest dose at which no adverse effect is seen (NOAEL or no-observed-adverse-effect level) and dividing it by the product of the uncertainty factor (UF) and modifying factor (MF) as shown in the formula below (1). The UF is usually 10 or factors of 10 and estimates the uncertainty in the data from which the NOAEL is derived, especially if it is obtained from animal studies. The MF usually ranges from 0 to 10 and indicates further uncertainty as judged by the professional.

$$RfD = NOAEL/UF \times MF$$

The RfD is measured in mg/kg-day and assumes a threshold or level of exposure at which no adverse health effect will be seen. Although the subchronic RfD is available for short-term exposures, the chronic RfD is utilized in this study to measure the long-term, non-carcinogenic effect from exposure to the chemicals of concern. The noncarcinogenic hazard quotient (HQ) is computed by dividing the exposure level for the chemical of concern by the specific RfD for that chemical. The noncarcinogenic hazard index (HI) is computed by summing the HQ for individual chemicals for an exposure pathway and represents an estimate of the total hazard for that pathway. Adverse health effects may occur when the HQ or HI exceeds one. RfDs for non-carcinogenic toxicity were obtained from the USEPA on-line Integrated Risk Information System (IRIS)[7] database, and the USEPA Health Effects Assessment Summary Tables (HEAST)[8], FY-1994. Table 4-1 displays RfDs for the COCs.

Table 4.1: Reference Dose (RfD) for Ingestion and Inhalation

Chemical	Inhalation RfD (mg/kg-d)	Ingestion RfD (mg/kg-d)	Confidence In Data (Oral)	Sensitive Organs and Systems Affected	RfC/RfD Source	UF/MF
1,1 Dichloroethylene	0.009				IRIS/-----	1,000/1
Tetrachloroethylene (PCE)	0.01	0.01	Medium	CNS, Kidney, Liver	—— / IRIS	1,000/1
1,1,1 Trichloroethane	0.29	0.09	N/A	CNS, GI, Reproductive Systems, Heart, Kidney, Liver, Lung	HEAST/HEAST	1,000/1
Trichloroethylene	0.006	Withdrawn	N/A	CNS, Eye,GI, Heart Kidney, Liver, Lung	N/A	N/A

4.2 Dose-Response Variable for Carcinogenic Effects

The slope factor (SF) is utilized as the dose-response variable for assessing the carcinogenic effects of exposure to chemicals. USEPA 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".[1] The SF is an estimate of the quantitative relationship between dose and carcinogenic response.

The SF is measured in units of $(mg/kg\text{-}day)^{-1}$ and is usually determined using the upper 95 percent confidence limit of the slope of the linearized multi-stage model. The model assumes that there is no threshold for the initiation of cancer (i.e. any exposure poses a risk of cancer). Since data on carcinogenicity is often derived from high-dose experiments on animals, extrapolations are made from these high doses to lower doses. When available, human data are utilized to determine the slope factor. Excess cancer risk is expressed as a function of exposure and is calculated by multiplying an estimated dose of a chemical by the slope factor (SF). The application of the nonthreshold assumption and the utilization of the upper 95 percent confidence limit for estimating the slope factor provides a conservative estimate of potential carcinogenic risk.

From human and animal experimental data, the USEPA's Carcinogen Advisory Group has grouped chemicals by weight-of-evidence (WoE) into classes from A to E which designate their potential as a cancer-causing agent. The WoE represents the carcinogenicity evidence from human and animal studies and indicates the strength of the data. An A classification signifies that the chemical is a proven human carcinogen. Probable human carcinogens are designated either B1, showing that studies in humans are strongly suggestive but not conclusive, or B2 if the chemical has been found to be conclusively carcinogenic in repeated animal studies but not conclusive in human studies. A chemical may be classified C, a possible human carcinogen, if a single high-quality animal study or several low-quality animal studies indicate carcinogenicity. If there is insufficient human and animal evidence to determine the carcinogenicity of the chemical, it is classified as D. A chemical conclusively demonstrated to be non-carcinogenic to humans is in group E. This designation is rare due to the difficulty in producing the necessary negative data.

RfDs for non-carcinogenic toxicity and slope factors for carcinogenic toxicity were obtained from the USEPA on-line Integrated Risk Information System (IRIS)[7] database, and the USEPA Health Effects Assessment Summary Tables (HEAST)[8], FY-1995.

Table 4.2: Slope Factor (SF) for Carcinogenic Chemicals of Concern

Chemical	WoE[1]	Slope Factor/Unit Risk[1]		Type of Cancer	Study Source of SF	Reference for SF
		Inhalation $(mg/kg\text{-}day)^{-1}$	Ingestion $(ug/L)^{-1}$ $[(mg/kg\text{-}day)^{-1}]$	Inhalation/Ingestion		
	C	1.2				IRIS (1996)
Tetrachloroethene (PCE)	B2	2E-3	1.5E-6 [5.1E-2]	Bladder, Cervix, Kidney, Lung and Skin Cancers / Liver Cancer	Rat, Mouse / Mouse	HEAST (1991)
Trichloroethene (TCE)	N/A	6E-3	[1.1E-2]	Testicular, Lymphoma, Liver, Kidney	Mouse/Mouse	HEAST (1991)

5.0 RISK CHARACTERIZATION

Inhalation risks from sub-surface soil contamination are evaluated in this chapter using exposure and toxicology information previously discussed. The risk characterization is presented in a quantitative and qualitative format.

5.1 Risk Estimation Methods

Risk estimation methods used in this report were based on USEPA guidelines.

5.1.1 Calculation of Carcinogenic Risk

Carcinogenic risk is calculated as the incremental probability of an individual developing cancer over a lifetime (70 years), due to exposure to a carcinogenic compound. This is also referred to as incremental or excess lifetime cancer risk (ELCR) and represents the increased risk of developing cancer above the background rate, estimated at about 3E-1 (30%).

Estimates of ELCR were based on calculations developed in the following order. Information on exposure pathways, exposure concentrations, and toxicology was assembled or calculated. Chronic daily intakes (CDI) were then calculated using assumptions from the exposure and toxicity reviews presented in Chapters 3 and 4. Chemical specific carcinogenic slope factors (SF), were used to convert estimated CDI, averaged over a lifetime, to ELCR.

The dose-response relationship is considered to be linear under the low dose conditions usually encountered in environmental exposures. Under this assumption, the SF is a constant, and risk is directly related to intake. Therefore, the linear low-dose cancer risk equation is:

1,1
Dichloroethylene

$$\text{Risk} = \text{CDI} \times \text{SF}$$

where:

Risk=a unitless probability of an individual developing cancer;
CDI = Chronic daily intake (dose) averaged over 70 years (mg/kg-day);
SF = Slope Factor, expressed in $(\text{mg/kg-day})^{-1}$.

The SF usually represents an upper 95^{th} percentile confidence limit of the probability of response, based on experimental animal data. Therefore, the risk estimate will also be an upper-bound estimate and *true risk* is likely to be less than predicted by this model.

For known or suspected carcinogens, the USEPA considers exposure levels that present an excess lifetime cancer risk to an individual of between 1E-4 to 1E-6 to be acceptable.

5.1.2 Noncarcinogenic Effects

Noncarcinogenic effects include neurotoxic, hepatotoxic, nephrotoxic, teratogenic, reproductive reactions, and any other noncancer related systemic toxic responses. The potential for an individual suffering a noncarcinogenic effect is not expressed as a probability, but as a ratio or quotient. The hazard quotient (HQ) is the ratio of an exposure level over a specified period (CDI) to the chemical specific reference dose (RfD) which is not expected to produce toxic effects over the period of concern. The HQ is calculated as follows:

Noncancer Hazard Quotient = CDI/RfD

CDI = Daily intake (dose) in mg/kg-day;
RfD = reference dose in mg/kg-day.

The HQ is not expressed as a probability. If the HQ exceeds 1 there is concern that the exposed individual may experience adverse health effects. The higher the HQ, the greater the concern. Effects can be evaluated over three time periods; short term, usually less than 2 weeks (acute), 2 weeks to 7 years (subchronic), and more than 7 years (chronic). In this assessment only chronic exposures were evaluated.

5.2 Occupational Risk Analysis Under Current Conditions

Excess Lifetime Cancer Risk Estimates

ELCR and HQ estimates were made in order to evaluate the potential health risks that may be presented by inhalation of vapors diffusing through soil and vapor barriers. A model was used that estimates air concentrations of solvents as they diffuse through soil and mix with outdoor air. The model uses the 95% UCL of the flux estimates to calculate exposure concentrations.

The reasonable maximum ELCR estimate for outdoor occupational exposure at Arcadia Cleaners was 3E-7 (three-in-ten-million). The reasonable maximum ELCR estimate for indoor occupational exposure at Arcadia Cleaners was 7E-7 (seven-in-ten-million).

The reasonable maximum ELCR estimate for outdoor occupational exposure at Sandy's Magic Touch Cleaners was 6E-7 (six-in-ten-million). The reasonable maximum ELCR estimate for indoor occupational exposure was 1E-6 (one-in-one-million).

The reasonable maximum ELCR estimate for outdoor occupational exposure at Kachina Cleaners was 5E-8 (five-in-one-hundred-million). The reasonable maximum ELCR estimate for indoor occupational exposure was 1E-7 (one-in-ten-million).

Noncancer Hazard Analysis

The reasonable maximum HI was substantially less than 1 at all facilities for occupational exposure, indicating that non-cancer health effects would not be expected from exposure to solvents diffusing from the soil near the facilities.

5.3 Residential Risk Analysis Under Potential Future Conditions

Excess Lifetime Cancer Risk Estimates

The reasonable maximum ELCR estimate for outdoor residential exposure at Arcadia Cleaners was 5E-7 (five-in-ten-million). The reasonable maximum ELCR estimate for indoor residential exposure at Arcadia Cleaners was 1E-6 (one-in-one-million).

The reasonable maximum ELCR estimate for outdoor residential exposure at Sandy's Magic Touch Cleaners was 1E-6 (one-in-one-million). The reasonable maximum ELCR estimate for indoor residential exposure at Sandy's Cleaners was 2E-6 (two-in-one-million).

The reasonable maximum ELCR estimate for outdoor residential exposure at Kachina Cleaners was 8E-8 (eight-in-one-hunderd-million). The reasonable maximum ELCR estimate for indoor residential exposure at Kachina Cleaners was 2E-7 (two-in-ten-million).

Noncancer Hazard Analysis

The reasonable maximum HI was substantially less than 1 at all facilities for potential future residential exposure, indicating that non-cancer health effects would not be expected from exposure to solvents diffusing from the soil near the facilities.

5.3 Uncertainties in the Risk Characterization

All risk estimates are based on a number of assumptions regarding contaminant concentrations, exposures, and toxicity information. Uncertainty is present at all stages in this process. Care is taken at each step in the process to insure that the assumptions made are upper-bound estimates.

Risk and hazard estimates are based on dose-response relationships observed, primarily, in experimental animals. This introduces several sources of uncertainty into the final estimates that are used to characterize risk. There may be differences between animals and humans in metabolic response to a chemical. The test animals may have genetic predispositions that are not considered. High doses are administered to small populations and then low dose response is estimated by extrapolation. Experimental animals have naturally short life spans, whereas humans do not. The toxicity values used were developed singly and responses may differ when complex mixtures are present.

5.4 Summary

The objective of this risk analysis is to provide an evaluation of health risks that may result from exposure to solvents present in sub-surface soil and soil gas at Arcadia Cleaners, Kachina Cleaners and Sandy's Magic Touch Cleaners. The results indicate that, under current conditions, excess lifetime cancer risk estimates from inhalation of vapors diffusing through soil at the facilities are negligible. Non-cancer health effect analyses indicated that, under current conditions, adverse acute health effects are unlikely to occur as a result of inhalation of vapors diffusing through soil at the facilities.

Ingestion of contaminated soil was not quantitatively evaluated since contaminated soil at the site is not accessible. The potential for groundwater degradation, and the resulting potential health risks, are not addressed in this risk analysis.

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3. Karimi A., Farmer W., Cliath M.(1987) Vapor Phase Diffusion of Benzene in Soil. **Journal of Environmental Quality**. Vol 16:1. p.38-43.

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7. U.S. Environmental Protection Agency. 1996. **Integrated Risk Information System (IRIS) Online.** Office of Health and Environment. Cincinnati, OH. May, 1993. Washington, DC. May, 1996.

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9. U.S. Department of Health and Human Services. 1989-1993. **Toxicological Profiles.** Agency for Toxic Substances and Disease Registry. Atlanta, Georgia.

Appendix

Table 1. -- Concentrations of Contaminants Detected in Soil Gas, Arcadia Cleaners

Chemical	Freq/det	Max	Mean	Std dev	95% UCL
1,1,1 - Trichlorethane	0/40				
Trichlorethene	0/40				
Tetrachloroethene	39/40	16000	5327.64	3938.42	6602.19
1,1-Dichloroethene	10/40	44	11.71	14.79	22.13

(All units in mg/m3)

Table 2. -- Concentrations of Contaminants Detected in Soil Gas, Sandy's Magic Touch Cleaners

Chemical	Freq/det	Max	Mean	Std dev	95% UCL
111 Trichlorethane	3/35	39	15.53	20.51	53.22
Trichlorethene	4/35	11	5.73	3.90	11.13
Tetrachloroethene	31/35	5600	1776.26	1488.61	2322.21
1,1-Dichloroethene	11/35	86	34.27	32.74	56.00

(All units in mg/m3)

Table 3. -- Concentrations of Contaminants Detected in Soil Gas, Kachina Cleaners

Chemical	**Freq/det**	**Max**	**Mean**	**Std dev**	**95% UCL**
111 Trichlorethane	0/24				
Trichlorethene	0/24				
Tetrachloroethene	24/24	460	112.82	140.85	112.82
1,1-Dichloroethene	15/24	7.3	4.15	1.62	4.15

(All units in mg/m3)

Table SG4. -- CALCULATION OF EXPOSURE CONCENRATIONS AND OCCUPATIONAL RISK DUE TO POTENTIAL SOIL GAS RELEASES, ARCADIA CLEANERS.

LOCATION	L DEPTH (m)	Cg SOIL GAS CONCEN. (g/m3)	Do DIFFUSION COEFICIENT (m2/sec)	Ds(1) EFFECTIVE DIFFUSION COEFFICIENT (m2/sec)	J(1) FLUX RATE (g/m2-day)	E EMISSIONS (g/day)	OAC(2) OUTSIDE AIR CONCEN. (mg/m3)	IAC(3) INSIDE AIR CONCEN. (mg/m3)	INHALATION SLOPE FACTOR 1/(mg/kg-day)	INHALATION REFERENCE DOSE (mg/kg-day)	AVG OUTSIDE AIR ELCR	RME OUTSIDE AIR ELCR	AVG INDOOR AIR ELCR	RME INDOOR AIR ELCR	AVG OUTSIDE AIR HQ	RME OUTSIDE AIR HQ	AVG INDOOR AIR HQ	RME INDOOR AIR HQ
1,1-DCE	2	2.2E-02	1.0E-05	4.9E-07	6.3E-04	6.26E-02	2.79E-06	6.52E-06	1.2	0.009	2.94E-08	2.34E-07	6.89E-08	5.47E-07	4.54E-05	6.06E-05	1.06E-04	1.42E-04
PCE	2	6.6E+00	7.4E-06	3.6E-07	1.4E-01	1.37E+01	6.09E-04	1.42E-03	0.002	0.01	1.07E-08	8.51E-08	2.51E-08	1.99E-07	8.94E-03	1.19E-02	2.09E-02	2.79E-02
										TOTALS	4E-08	3E-07	9E-08	7E-07	9E-03	1E-02	2E-02	3E-02

Table SG5. -- CALCULATION OF EXPOSURE CONCENRATIONS AND OCCUPATIONAL RISK DUE TO POTENTIAL SOIL GAS RELEASES, SANDY'S CLEANERS.

LOCATION	L DEPTH (m)	Cg SOIL GAS CONCEN. (g/m3)	Do DIFFUSION COEFICIENT (m2/sec)	Ds(1) EFFECTIVE DIFFUSION COEFFICIENT (m2/sec)	J(1) FLUX RATE (g/m2-day)	E EMISSIONS (g/day)	OAC(2) OUTSIDE AIR CONCEN. (mg/m3)	IAC(3) INSIDE AIR CONCEN. (mg/m3)	INHALATION SLOPE FACTOR 1/(mg/kg-day)	INHALATION REFERENCE DOSE (mg/kg-day)	AVG OUTSIDE AIR ELCR	RME OUTSIDE AIR ELCR	AVG INDOOR AIR ELCR	RME INDOOR AIR ELCR	AVG OUTSIDE AIR HQ	RME OUTSIDE AIR HQ	AVG INDOOR AIR HQ	RME INDOOR AIR HQ
1,1-DCE	2	5.6E-02	1.0E-05	4.9E-07	1.6E-03	1.58E-01	7.05E-06	1.65E-05	1.2	0.009	7.45E-08	5.91E-07	1.74E-07	1.38E-06	1.15E-04	1.53E-04	2.69E-04	3.59E-04
PCE	2	2.3E+00	7.4E-06	3.6E-07	4.6E-02	4.81E+00	2.14E-04	5.01E-04	0.002	0.01	3.77E-09	2.99E-08	8.83E-09	7.00E-08	3.14E-03	4.19E-03	7.36E-03	9.81E-03
TCE	2	1.1E-02	8.0E-06	3.9E-07	2.5E-04	2.45E-02	1.09E-06	2.56E-06	0.006	0.006	5.77E-11	4.58E-10	1.35E-10	1.07E-09	2.67E-05	3.56E-05	6.25E-05	8.34E-05
1,1,1-TCA	2	0.053	8.4E-06	4.1E-07	1.2E-03	1.25E-01	5.55E-06	1.30E-05		0.29					2.81E-06	3.74E-06	6.57E-06	8.76E-06
										TOTALS	8E-08	6E-07	2E-07	1E-06	3E-03	4E-03	8E-03	1E-02

Table SG6. -- CALCULATION OF EXPOSURE CONCENRATIONS AND OCCUPATIONAL RISK DUE TO POTENTIAL SOIL GAS RELEASES, KACHINA CLEANERS.

LOCATION	L DEPTH (m)	Cg SOIL GAS CONCEN. (g/m3)	Do DIFFUSION COEFICIENT (m2/sec)	Ds(1) EFFECTIVE DIFFUSION COEFFICIENT (m2/sec)	J(1) FLUX RATE (g/m2-day)	E EMISSIONS (g/day)	OAC(2) OUTSIDE AIR CONCEN. (mg/m3)	IAC(3) INSIDE AIR CONCEN. (mg/m3)	INHALATION SLOPE FACTOR 1/(mg/kg-day)	INHALATION REFERENCE DOSE (mg/kg-day)	AVG OUTSIDE AIR ELCR	RME OUTSIDE AIR ELCR	AVG INDOOR AIR ELCR	RME INDOOR AIR ELCR	AVG OUTSIDE AIR HQ	RME OUTSIDE AIR HQ	AVG INDOOR AIR HQ	RME INDOOR AIR HQ
1,1-DCE	2	4.2E-03	1.0E-05	4.9E-07	1.2E-04	1.17E-02	5.22E-07	1.22E-06	1.2	0.009	5.52E-09	4.38E-08	1.29E-08	1.03E-07	8.52E-06	1.14E-05	1.99E-05	2.66E-05
PCE	2	1.1E-01	7.4E-06	3.6E-07	2.3E-03	2.32E-01	1.03E-05	2.42E-05	0.002	0.01	1.82E-10	1.44E-09	4.26E-10	3.38E-09	1.52E-04	2.02E-04	3.55E-04	4.73E-04
										TOTALS	6E-09	5E-08	1E-08	1E-07	2E-04	2E-04	4E-04	5E-04

Table SG1. -- CALCULATION OF EXPOSURE CONCENRATIONS AND RESIDENTIAL RISK DUE TO POTENTIAL SOIL GAS RELEASES, ARCADIA CLEANERS.

LOCATION	L DEPTH (m)	Cg SOIL GAS CONCEN. (g/m3)	Do DIFFUSION COEFICIENT (m2/sec)	Ds(1) EFFECTIVE DIFFUSION COEFFICIENT (m2/sec)	J(1) FLUX RATE (g/m2-day)	E EMISSIONS (g/day)	OAC(2) OUTSIDE AIR CONCEN. (mg/m3)	IAC(3) INSIDE AIR CONCEN. (mg/m3)	INHALATION SLOPE FACTOR 1/(mg/kg-day)	INHALATION REFERENCE DOSE (mg/kg-day)	AVG OUTSIDE AIR ELCR	RME OUTSIDE AIR ELCR	AVG INDOOR AIR ELCR	RME INDOOR AIR ELCR	AVG OUTSIDE AIR HQ	RME OUTSIDE AIR HQ	AVG INDOOR AIR HQ	RME INDOOR AIR HQ
1,1-DCE	2	2.2E-02	1.0E-05	4.9E-07	6.3E-04	6.26E-02	2.79E-06	6.52E-06	1.2	0.009	8.83E-08	3.93E-07	2.07E-07	9.16E-07	6.36E-05	8.48E-05	1.49E-04	1.98E-04
PCE	2	6.6E+00	7.4E-06	3.6E-07	1.4E-01	1.37E+01	6.09E-04	1.42E-03	0.002	0.01	3.22E-08	1.43E-07	7.53E-08	3.35E-07	1.25E-02	1.67E-02	2.93E-02	3.90E-02
										TOTALS	1E-07	5E-07	3E-07	1E-06	1E-02	2E-02	3E-02	4E-02

Table SG2. -- CALCULATION OF EXPOSURE CONCENRATIONS AND RESIDENTIAL RISK DUE TO POTENTIAL SOIL GAS RELEASES, SANDY'S CLEANERS.

LOCATION	L DEPTH (m)	Cg SOIL GAS CONCEN. (g/m3)	Do DIFFUSION COEFICIENT (m2/sec)	Ds(1) EFFECTIVE DIFFUSION COEFFICIENT (m2/sec)	J(1) FLUX RATE (g/m2-day)	E EMISSIONS (g/day)	OAC(2) OUTSIDE AIR CONCEN. (mg/m3)	IAC(3) INSIDE AIR CONCEN. (mg/m3)	INHALATION SLOPE FACTOR 1/(mg/kg-day)	INHALATION REFERENCE DOSE (mg/kg-day)	AVG OUTSIDE AIR ELCR	RME OUTSIDE AIR ELCR	AVG INDOOR AIR ELCR	RME INDOOR AIR ELCR	AVG OUTSIDE AIR HQ	RME OUTSIDE AIR HQ	AVG INDOOR AIR HQ	RME INDOOR AIR HQ
1,1-DCE	2	5.6E-02	1.0E-05	4.9E-07	1.6E-03	1.58E-01	7.05E-06	1.65E-05	1.2	0.009	2.23E-07	9.93E-07	5.23E-07	2.32E-06	1.61E-04	2.15E-04	3.77E-04	5.02E-04
PCE	2	2.3E+00	7.4E-06	3.6E-07	4.8E-02	4.81E+00	2.14E-04	5.01E-04	0.002	0.01	1.13E-08	5.03E-08	2.65E-08	1.18E-07	4.40E-03	5.87E-03	1.03E-02	1.37E-02
TCE	2	1.1E-02	8.0E-06	3.9E-07	2.5E-04	2.45E-02	1.09E-06	2.56E-06	0.006	0.006	1.73E-10	7.70E-10	4.05E-10	1.80E-09	3.74E-05	4.99E-05	8.76E-05	1.17E-04
1,1,1-TCA	2	0.053	8.4E-06	4.1E-07	1.2E-03	1.25E-01	5.55E-06	1.30E-05		0.29					3.93E-06	5.24E-06	9.20E-06	1.23E-05
										TOTALS	2E-07	1E-06	5E-07	2E-06	5E-03	6E-03	1E-02	1E-02

Table SG3. -- CALCULATION OF EXPOSURE CONCENRATIONS AND RESIDENTIAL RISK DUE TO POTENTIAL SOIL GAS RELEASES, KACHINA CLEANERS.

LOCATION	L DEPTH (m)	Cg SOIL GAS CONCEN. (g/m3)	Do DIFFUSION COEFICIENT (m2/sec)	Ds(1) EFFECTIVE DIFFUSION COEFFICIENT (m2/sec)	J(1) FLUX RATE (g/m2-day)	E EMISSIONS (g/day)	OAC(2) OUTSIDE AIR CONCEN. (mg/m3)	IAC(3) INSIDE AIR CONCEN. (mg/m3)	INHALATION SLOPE FACTOR 1/(mg/kg-day)	INHALATION REFERENCE DOSE (mg/kg-day)	AVG OUTSIDE AIR ELCR	RME OUTSIDE AIR ELCR	AVG INDOOR AIR ELCR	RME INDOOR AIR ELCR	AVG OUTSIDE AIR HQ	RME OUTSIDE AIR HQ	AVG INDOOR AIR HQ	RME INDOOR AIR HQ
1,1-DCE	2	4.2E-03	1.0E-05	4.9E-07	1.2E-04	1.17E-02	5.22E-07	1.22E-06	1.2	0.009	1.66E-08	7.36E-08	3.86E-08	1.72E-07	1.19E-05	1.59E-05	2.79E-05	3.72E-05
PCE	2	1.1E-01	7.4E-06	3.6E-07	2.3E-03	2.32E-01	1.03E-05	2.42E-05	0.002	0.01	5.46E-10	2.43E-09	1.28E-09	5.68E-09	2.12E-04	2.83E-04	4.97E-04	6.62E-04
										TOTALS	2E-08	8E-08	4E-08	2E-07	2E-04	3E-04	5E-04	7E-04