Risk Analysis
for Various PCE Concentrations in Soils
Sandy's Magic Touch Cleaners Facility
Phoenix, Arizona

Arizona Department of Health Services

Prepared By
The Office of Environmental Health
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1.0 Introduction

Sandy's Magic Touch Cleaners is located at 4730 East Indian School Road in Phoenix, Arizona. The facility is in a retail shopping center and is adjoined by other businesses. The facility is primarily surrounded by residential and commercial property. Asphalt parking areas are to the east and west of the facility. The retail center housing Sandy's Cleaners business was constructed in 1966 and the facility has contained a dry-cleaning business since then.

Earth Technology, Inc. and Western Technologies, Inc. have performed shallow soil, soil gas, and groundwater investigations at the site. The investigations revealed that subsurface soil and groundwater beneath Sandy's Cleaners have been contaminated with tetrachloroethylene (PCE) and other chlorinated hydrocarbons. The Arizona Department of Health Services, Office of Environmental Health prepared a Baseline Human Health Risk Assessment for the facility in March of 1997. The results of the risk assessment suggested that, under current conditions, the subsurface soil contamination from the facility presents a negligible risk to shoppers and residents located directly to the west of the facility (ADHS 1997). However, insufficient data were available to estimate risks to employees from potential exposure to PCE vapors inside Sandy's Cleaners and the adjoining businesses.

The primary objective of this report is to evaluate the potential for health risks from exposure to PCE, TCE, and 1,1 DCE vapors that may be migrating from the contaminated subsurface soils into the facility. Since soil or soil gas samples have not been collected from beneath the foundation of the building, this analysis uses a range of possible contaminant concentrations in soil and a screening level model to estimate risk. The analysis assumes that contaminants are uniformly present at concentrations ranging from soil saturation limits to 0.1 mg/kg.

The secondary objective is to evaluate the potential for health risks from exposure to solvent vapors under various potential future land uses. Since soil or soil gas samples have not been collected from beneath the foundation of the building, this analysis uses a range of possible contaminant concentrations in soil and a screening level model to estimate risk. The analysis assumes that PCE, TCE and 1,1 DCE would be uniformly present at concentrations ranging from 640 mg/kg to 0.1 mg/kg.

The risk levels presented in the Appendix may be compared with the acceptable range of risk established by the USEPA. 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 (one-in-ten-thousand to one-in-one-million) to be within the acceptable range of risk. Risk estimates less than 1E-6 (one-in-one-million) are considered negligible.

2.0 Exposure Assessment

Health risks were evaluated using a risk assessment approach. Exposures were estimated using upper-bounds exposure assumptions. The toxicity assessment uses USEPA Reference Doses (RfDs) and Cancer Slope factors (SF). Risks were characterized by combining exposure and toxicity to develop excess lifetime cancer risk estimates for carcinogenicity and a Hazard Quotient for systemic toxicity.

2.1 Estimating Flux

The concentration of PCE that may be present in indoor air at Sandy's Cleaners or any other potential future facilities that may be located at the site is dependent on many factors including the concentration of PCE in sub-surface soils, the depth of the contamination, the fraction of floor through which vapor may enter, the volume of the building, the number of air changes per hour, soil, and other chemical properties.

The screening level model used in this analysis was taken from the 1995 USEPA document entitled *"Air/Superfund National Technical Guidance Study Series,* Guideline for Predictive Baseline Emissions

Estimation for Superfund Sites, Interim Final." The model operates under the assumption that the contamination is in equilibrium and that the source extends from the ground surface to groundwater. Since there is no data suggesting whether a clean soil layer exists beneath the foundation, the model assumes that no clean soil layer is present (ie. the contamination extends from immediately underneath the facility).

The concentration of PCE beneath the facility was assumed to be uniformly present at concentrations ranging from the soil saturation limit of 640 mg/kg to 0.1 mg/kg. Soil saturation corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles and the solubility limits of the available soil moisture have been reached. When contaminants reach the soil saturation limit, emissions flux from soil to air reaches a plateau. Volatile emissions do not increase above this level no matter how much more chemical is added to the soil.

Equation 1 was used to estimate emission flux at the soil saturation limit (USEPA 1995). The approach assumes steady-state conditions and an infinite source over the averaging period. The quantitative results are displayed in the Appendix in the column identified as "Average Maximum Flux":

$$\overline{F_i} = \beta\, C_{o,i} \left(\frac{4\, D_{A,i}}{\pi\, \tau} \right)^{1/2} 0.116 \qquad (1)$$

where:

F_i	=	Average maximum emission flux from surface soils over exposure averaging period τ, g/m^2-s
β	=	Average soil dry bulk density, g/m^3-soil
$C_{o,i}$	=	Initial soil concentration of i, g/g-soil
$D_{A,i}$	=	Apparent diffusivity coefficient, cm^2/d
τ	=	Exposure averaging period, days (for residential land-use τ= 10,950 days)
π	=	Pi, 3.1416
0.116	=	Factor to convert g/cm^2-d to g/m^2-s

where:

$$D_A = \frac{[(\Theta_a^{10/3} D_i H' + \Theta_w^{10/3} D_w)/n^2]}{\rho_B K_d + \Theta_w + \Theta_a H'}$$

where:

D_A	Apparent diffusivity (cm^2/d)	--
ρ_b	Dry soil bulk density (g/cm^3)	1.5
Θ_a	Air filled soil porosity (L_{air}/L_{soil})	0.28 or n-Θ_w
n	Total soil porosity (L_{pore}/L_{soil})	0.43 or 1 - (ρ_b/ρ_s)
Θ_w	Water-filled soil porosity (L_{water}/L_{soil})	0.15
Di	Diffusivity in air (cm^2/d)	Chemical-specific
H'	Dimensionless Henry's Law constant	Calculated from H by multiplying by 41
D_W	Diffusivity in water (cm^2/d)	Chemical-specific
K_d	Soil-water partition coefficient (cm^3/g) = $K_{oc}f_{oc}$	Chemical-specific
K_{oc}	Soil organic carbon-water partition coefficient (cm^3/g)	Chemical-specific
f_{oc}	Fraction organic carbon in soil (g/g)	0.006 (0.6%)

2.2 Indoor Air Concentrations

Vapors diffusing through subsurface soils may enter the facility through cracks and seams in the foundation. Calculations to estimate vapor intrusion into enclosed space may be controlled by diffusive and convective transport.

The indoor air concentration is dependent on the fraction of the floor through which soil gas may enter, the volume of the building, the number of air changes per hour and the flux. For buildings with slab floors, the fraction of floor space through which soil gas may enter can be assumed to be 0.001 or 0.1% (USEPA 1992). The indoor air exchange rate with outdoor air was conservatively assumed to be 1 change per hour. The actual dimensions of the structure were used in the model. Equation 2 displays the formula and assumptions used to estimate indoor air concentrations.

$$IAC = [(J_i)(a)(F)]/[(ACH)(v)] \qquad (2)$$

IAC	=	Indoor air concentration (mg/m^3)
J_i	=	Flux rate of component i (mg/m^2·sec)
a	=	Area of building floor (m^2)
F	=	Fraction of floor through which vapors may enter (Dimension less)
ACH	=	Building air changes per hour (air changes/hour)
v	=	Volume of building (m^3)

2.3 Inhalation Exposure Assumptions

This exposure assessment focuses on the current occupational population at the facility, potential future residents, and a potential future day care facility. It estimates the magnitudes of exposures to PCE that would be associated with the site if PCE were present directly beneath the building at various concentrations. The calculations using Equation 3 apply standard default exposure factors for occupational and potential future residential land uses (USEPA 1991). In addition, a scenario that evaluates risk to children under a day care facility was evaluated.

$$CDI = \frac{(AC)(IR)(EF)(ED)}{(BW)(AT)} \qquad (3)$$

where:

AC	=	Chemical concentration in air (indoor or outdoor) (mg/m^3)
IR	=	Inhalation rate (m^3/day or workday)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kilograms)
AT	=	Averaging time (days)

Reasonable Maximum Exposure (RME) Assumptions:

	Occupational	Residential	Day Care
AC:	(mg/m^3)	(mg/m^3)	(mg/m^3)
IR:	20 (m^3/workday)	20 (m^3/day)	8.7 (m^3/day)
EF:	250 (days/year)	350 (days/year)	250 (days/year)
ED:	25 (years)	30 (years)	6 (years)
BW:	70 (kg)	70 (kg)	15 (kg)
AT: (carc.)	25,550 (days)	25,550 (days)	25,550 (days)
AT: (non-carc.)	9,125 (days)	10,950 (days)	2,190 (days)

2.4 Ingestion Exposure Assumptions

The calculations using Equation 4 apply standard default exposure factors for occupational and potential future residential land uses (USEPA 1991). In addition, a scenario that evaluates risk to children under a day care facility was evaluated.

$$CDI = \frac{(AC)(IR)(EF)(ED)}{(BW)(AT)} \qquad (4)$$

where:

CS	=	Chemical concentration in soil (mg/kg)
IR	=	Ingestion rate (mg/day)
CF	=	Conversion factor (10^{-6}kg/mg)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kilograms)
AT	=	Averaging time (days)

Reasonable Maximum Exposure (RME) Assumptions:

	Occupational	Residential	Day Care
AC:	(mg/kg)	(mg/kg)	(mg/kg)
IR:	50 (mg/workday)	100 (mg/day)	200 (mg/day)
EF:	250 (days/year)	350 (days/year)	250 (days/year)
ED:	25 (years)	30 (years)	6 (years)
BW:	70 (kg)	70 (kg)	15 (kg)
AT: (carc.)	25,550 (days)	25,550 (days)	25,550 (days)
AT: (non-carc.)	9,125 (days)	10,950 (days)	2,190 (days)

3.0 Toxicity Assessment

Toxicity has been assessed using USEPA Reference Doses (RfDs) and Cancer Slope Factors (SF) for use in developing excess lifetime cancer risk estimates for carcinogenicity and a Hazard Quotient for systemic toxicity.

Carcinogenicity

The slope factor (SF) is used 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"(USEPA 1989). 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 95th percentile 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. 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 non-threshold assumption and the use of the upper 95th percentile confidence limit for estimating the slope factor provides a conservative estimate of potential carcinogenic risk.

Systemic Toxicity

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 used 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" (USEPA 1989). 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 suggests 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 used in this study to measure the long-term, non-carcinogenic effect from exposure to the chemical 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. When the HQ is less than 1, adverse health effects are not expected.

The Slope Factor and Reference Doses for PCE are as follows:

Slope Factor = 2.0E-03 $(mg/kg\text{-}day)^{-1}$

Reference Dose = 1.0E-02 (mg/kg-day)

4.0 Risk Characterization

This risk characterization focuses on risks from exposure to PCE from possible sub-surface soil contamination beneath Sandy's Cleaners. Since soil or soil gas samples have not been collected from beneath the foundation of the building, this analysis uses a range of possible PCE concentrations in soil and a screening level model to estimate risk. The analysis includes future residential and day-care land uses.

A similar analysis has been conducted for 1,1 DCE and TCE, which may be present beneath the facility as a result of biological degradation of PCE over time. These results have been included in the Appendix.

Carcinogenicity

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 called incremental or excess lifetime cancer risk (ELCR) and represents the increased risk of developing cancer above the background rate, estimated to be about 3E-1 (30%).

Estimates of ELCR were based on the results of the exposure and toxicity assessments. Chemical specific carcinogenic slope factors (SF), were used to convert estimated CDI, averaged over a lifetime, to ELCR.

The dose-response relationship is considered 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:

$$ELCR = CDI \times SF$$

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 $(mg/kg\text{-}day)^{-1}$.

The SF usually represents an upper 95th 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 within the acceptable range of risk. Risk estimates less than 1E-6 (one-in-one-million) are considered negligible.

Systemic Toxicity

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. A HQ in excess of 1 does not necessarily indicate the presence of a health risk, rather, it suggests that adverse health effects in exposed individuals cannot be ruled out. A HQ in excess of 1 does not necessarily suggest that there is a noncancer health concern, but that additional in-depth toxicological analysis may be warranted in order to draw conclusions regarding noncancer health effects.

4.1 Current Potential Occupational Risk

The results of this analysis suggest that PCE at the soil saturation limit underneath the facility would result in an ELCR of 2E-6 (two-in-one-million). Risk under this scenario is from inhalation of subsurface vapors diffusing into the facility. PCE soil concentrations less than 400 mg/kg would result in a negligible cancer risk (ie. less than one-in-one-million). Non-cancer hazard quotients were less than 1 at soil saturation, indicating that non-cancer health effects would not be expected even if PCE were uniformly present at the soil saturation limit beneath the facility.

4.2 Potential Future Residential Risk

The results of this analysis suggest that PCE at the soil saturation limit underneath a potential future house would result in an ELCR of 3E-6 (three-in-one-million) from inhalation of PCE vapors. Risks from ingestion of soil at the saturation limit would result in an ELCR of 2E-5 (two-in-one-hundred-thousand), however, exposure to PCE by this exposure route is unlikely due to the volatile nature of PCE. Combined risks would result in an ELCR of 2E-5. Concentrations of PCE less than 50 mg/kg (12,000 ug/L in soil gas) would result in a negligible cancer risk (ie. less than one-in-one-million).

Non-cancer hazard quotients were all less than 1, indicating that non-cancer health effects would not be expected even if PCE were uniformly present at the soil saturation limit beneath a potential future home.

4.3 Potential Future Risk at a Day-care Facility

The results of this analysis suggest that PCE at the soil saturation limit underneath a potential future day-care facility would result in an ELCR of 8E-7 (eight-in-ten-million) from inhalation of PCE vapors. Risks from ingestion of soil at the saturation limit would result in an ELCR of 3E-5 (three-in-one-hundred-thousand), however, exposure to PCE by this exposure route is unlikely due to the volatile nature of PCE. Combined risks would result in an ELCR of 3E-5. Concentrations of PCE less than 50 mg/kg would result in a negligible cancer risk (ie. less than one-in-one-million).

Non-cancer hazard quotients were all less than 1, indicating that non-cancer health effects would not be expected even if PCE were uniformly present at the soil saturation limit beneath a potential future home.

5.0 Summary

The primary objective of this report is to evaluate the potential for health risks from exposure to PCE vapors that may be migrating from the contaminated subsurface soils into the facility. Since soil gas samples have not been collected from beneath the foundation of the building, this analysis uses a range of possible PCE concentrations in soil and a screening level model to estimate risk. The analysis assumes that PCE is uniformly present at concentrations ranging from the soil saturation limit of 640 mg/kg to 0.1 mg/kg.

The secondary objective is to evaluate the potential for health risks from exposure to PCE vapors under various potential future land uses. Since soil gas samples have not been collected from beneath the foundation of the building, this analysis uses a range of possible PCE concentrations in soil and a screening level model to estimate risk. The analysis assumes that PCE would be uniformly present at concentrations ranging from the soil saturation limit of 640 mg/kg to 0.1 mg/kg.

The spreadsheets in the Appendix present the quantitative results of the analysis for the inhalation and ingestion exposure pathways. The spreadsheets display the following information:

- Theoretical contaminant concentrations in mg/kg;
- Approximate soil gas concentrations that correspond to the soil concentrations;
- Apparent diffusivity values calculated using D_A from Equation 1;
- Average maximum flux estimates using Equation 1;
- Indoor air calculations using Equation 2; and
- ELCR and HQ values from equations described in Section 4.0.

The results of this analysis suggest that PCE at the soil saturation limit underneath the facility would result in an ELCR of 2E-6 (two-in-one-million). This value is within the acceptable range of risk established by the USEPA, however, it is greater than the risk level that is considered negligible (1E-6). Risk under the occupational scenario is from inhalation of subsurface vapors diffusing into the facility. PCE soil concentrations less than 400 mg/kg would result in a negligible cancer risk (ie. less than one-in-one-million). *Therefore, PCE concentrations less than 400 mg/kg uniformly present beneath the facility would present a negligible excess lifetime cancer risk to employees.* Non-cancer hazard quotients were less than 1 at soil saturation, indicating that non-cancer health effects would not be expected even if PCE were uniformly present at the soil saturation limit beneath the facility.

PCE at the soil saturation limit underneath a potential future house would result in an ELCR of 3E-6 (three-in-one-million) from inhalation of PCE vapors. Risks from ingestion of soil at the saturation limit would result in an ELCR of 2E-5 (two-in-one-hundred-thousand), however, exposure to PCE by this exposure route is unlikely due to the volatile nature of PCE. *Concentrations of PCE less than 50 mg/kg (12,000 ug/L in soil gas) would result in a negligible cancer risk (ie. less than one-in-one-million) under a residential exposure scenario.*

PCE at the soil saturation limit underneath a potential future day-care facility would result in an ELCR of 8E-7 (eight-in-ten-million) from inhalation of PCE vapors. Risks from ingestion of soil at the saturation limit would result in an ELCR of 3E-5 (three-in-one-hundred-thousand), however, exposure to PCE by this exposure route is unlikely due to the volatile nature of PCE. *Concentrations of PCE less than 50 mg/kg would result in a negligible cancer risk (ie. less than one-in-one-million) under a day care facility exposure scenario.*

6.0 Conclusions

- *PCE concentrations less than 400 mg/kg (95,000 ug/L in soil gas) uniformly present beneath the facility would present a negligible excess lifetime cancer risk (ie. less than one-in-one-million) to employees under a current exposure scenario which includes only inhalation exposure.*
- *Concentrations of PCE less than 50 mg/kg (12,000 ug/L in soil gas) uniformly present beneath the current facility would result in a negligible cancer risk under a potential future residential exposure scenario that includes the inhalation and ingestion exposure pathways.*
- *Concentrations of PCE less than 50 mg/kg (12,000 ug/L in soil gas) uniformly present beneath the current facility would result in a negligible cancer risk under a day care facility exposure scenario that includes the inhalation and ingestion exposure pathways.*

7.0 Uncertainties

A number of uncertainties exist in any risk assessment including the degree of confidence that all chemicals of concern have been identified, the uncertainty in exposure concentrations and other exposure assumptions, and the toxicity assessment.

This analysis evaluates the potential for risks from PCE under various alternative land uses. The equations used to estimate exposure concentrations are conservative, and will tend to overestimate exposure and risk. The exposure scenarios used are based upon USEPA standard default exposure factors, and are upper bound estimates. The toxicity assessment relies on USEPA cancer slope factors and reference doses, which are inherently conservative and likely overestimate toxicity and carcinogenicity. A more accurate characterization of current and potential future risks at the site would require actual soil or soil gas monitoring data.

8.0 Recommendations

The ADEQ should review former facility operations and previous soil and soil gas data collected by Earth Technology, Inc. and Western Technologies, Inc. to determine whether the concentration of PCE beneath the facility may reasonably be expected to exceed 50 mg/kg in soil or 12,000 ug/L in soil gas. If the ADEQ believes that the available information indicates that concentrations are likely less than this level, then the ADEQ may conclude that a negligible health risk would exist under potential future residential land use. If the ADEQ believes that PCE concentrations may exceed 50 mg/kg beneath the facility, then additional soil or soil gas sampling may be required in order to conclude that health risks would be negligible (ie. less than a one-in-a-million excess lifetime cancer risk) under potential future residential land uses.

References

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Calculation of Potential Excess Lifetime Cancer Risk and Noncancer Hazard for 1,1 DCE, Sandys Cleaners Risk/Sensitivity Analysis

INHALATION EXPOSURE

1,1 DCE SOIL CONCENTRATION	1,1 DCE SOIL GAS CONCENTRATION	1,1 DCE SOIL GAS CONCENTRATION	APPARENT DIFFUSIVITY	AVERAGE MAXIMUM FLUX	AVERAGE MAXIMUM FLUX	INDOOR AIR CONCENTRATION	OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg	mg/L	ug/L	cm2/day	g/m2s	mg/m2s	mg/m3	unitless	unitless				
			DA	Fi	Fi	IAC	*ELCR*	*HQ*	*ELCR*	*HQ*	*ELCR*	*HQ*
640	10338	1.0E+07	1.4E+03	4.5E-05	4.5E-02	5.4E-02	7E-04	1E+00	1E-03	2E+00	3E-04	5E-01
500	8077	8.1E+06	1.4E+03	3.5E-05	3.5E-02	4.2E-02	5E-04	9E-01	8E-04	1E+00	3E-04	4E-01
400	6462	6.5E+06	1.4E+03	2.8E-05	2.8E-02	3.3E-02	4E-04	7E-01	7E-04	1E+00	2E-04	3E-01
300	4846	4.8E+06	1.4E+03	2.1E-05	2.1E-02	2.5E-02	3E-04	5E-01	5E-04	8E-01	2E-04	2E-01
200	3231	3.2E+06	1.4E+03	1.4E-05	1.4E-02	1.7E-02	2E-04	4E-01	4E-04	5E-01	1E-04	1E-01
100	1615	1.6E+06	1.4E+03	7.0E-06	7.0E-03	8.4E-03	1E-04	2E-01	2E-04	3E-01	5E-05	7E-02
50	808	8.1E+05	1.4E+03	3.5E-06	3.5E-03	4.2E-03	5E-05	9E-02	8E-05	1E-01	3E-05	4E-02
10	162	1.6E+05	1.4E+03	7.0E-07	7.0E-04	8.4E-04	1E-05	2E-02	2E-05	3E-02	5E-06	7E-03
1	16.2	1.6E+04	1.4E+03	7.0E-08	7.0E-05	8.4E-05	1E-06	2E-03	2E-06	3E-03	5E-07	7E-04
0.1	1.6	1.6E+03	1.4E+03	7.0E-09	7.0E-06	8.4E-06	1E-07	2E-04	2E-07	3E-04	5E-08	7E-05

INGESTION EXPOSURE

1,1 DCE SOIL CONCENTRATION			OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg								
640			7E-05	3E-02	2E-04	1E-01	3E-04	6E-01
500			5E-05	3E-02	2E-04	8E-02	2E-04	5E-01
400			4E-05	2E-02	1E-04	6E-02	2E-04	4E-01
300			3E-05	2E-02	1E-04	5E-02	1E-04	3E-01
200			2E-05	1E-02	7E-05	3E-02	8E-05	2E-01
100			1E-05	5E-03	4E-05	2E-02	5E-05	1E-01
50			5E-06	3E-03	2E-05	8E-03	2E-05	6E-02
10			1E-06	5E-04	4E-06	2E-03	5E-06	1E-02
1			1E-07	5E-05	4E-07	2E-04	5E-07	1E-03
0.1			1E-08	5E-06	4E-08	2E-05	5E-08	1E-04

COMBINED EXPOSURES

1,1 DCE SOIL CONCENTRATION			OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg								
640			7E-04	1E+00	1E-03	2E+00	6E-04	1E+00
500			6E-04	9E-01	1E-03	1E+00	5E-04	9E-01
400			5E-04	7E-01	8E-04	1E+00	4E-04	7E-01
300			3E-04	6E-01	6E-04	8E-01	3E-04	5E-01
200			2E-04	4E-01	4E-04	5E-01	2E-04	4E-01
100			1E-04	2E-01	2E-04	3E-01	1E-04	2E-01
50			6E-05	9E-02	1E-04	1E-01	5E-05	9E-02
10			1E-05	2E-02	2E-05	3E-02	1E-05	2E-02
1			1E-06	2E-03	2E-06	3E-03	1E-06	2E-03
0.1			1E-07	2E-04	2E-07	3E-04	1E-07	2E-04

2

Calculation of Potential Excess Lifetime Cancer Risk and Noncancer Hazard for TCE, Sandys Cleaners Risk/Sensitivity Analysis

INHALATION EXPOSURE

TCE SOIL CONCENTRATION	TCE SOIL GAS CONCENTRATION	TCE SOIL GAS CONCENTRATION	APPARENT DIFFUSIVITY	AVERAGE MAXIMUM FLUX	AVERAGE MAXIMUM FLUX	INDOOR AIR CONCENTRATION	OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg	mg/L	ug/L	cm2/day	g/m2s	mg/m2s	mg/m3	unitless	unitless				
			DA	Fi	Fi	IAC	ELCR	HQ	ELCR	HQ	ELCR	HQ
640	304	3.0E+05	1.5E+02	1.5E-05	1.5E-02	1.7E-02	7E-06	6E-01	1E-05	6E-01	4E-06	2E-01
500	237	2.4E+05	1.5E+02	1.1E-05	1.1E-02	1.4E-02	6E-06	4E-01	1E-05	6E-01	3E-06	2E-01
400	190	1.9E+05	1.5E+02	9.1E-06	9.1E-03	1.1E-02	5E-06	4E-01	8E-06	5E-01	2E-06	1E-01
300	142	1.4E+05	1.5E+02	6.8E-06	6.8E-03	8.2E-03	3E-06	3E-01	6E-06	4E-01	2E-06	1E-01
200	95	9.5E+04	1.5E+02	4.5E-06	4.5E-03	5.5E-03	2E-06	2E-01	4E-06	2E-01	1E-06	7E-02
100	47	4.7E+04	1.5E+02	2.3E-06	2.3E-03	2.7E-03	1E-06	9E-02	2E-06	1E-01	6E-07	4E-02
50	24	2.4E+04	1.5E+02	1.1E-06	1.1E-03	1.4E-03	6E-07	4E-02	1E-06	6E-02	3E-07	2E-02
10	5	4.7E+03	1.5E+02	2.3E-07	2.3E-04	2.7E-04	1E-07	9E-03	2E-07	1E-02	6E-08	4E-03
1	0.5	4.7E+02	1.5E+02	2.3E-08	2.3E-05	2.7E-05	1E-08	9E-04	2E-08	1E-03	6E-09	4E-04
0.1	4.7E-02	4.7E+01	1.5E+02	2.3E-09	2.3E-06	2.7E-06	1E-09	9E-05	2E-08	1E-04	6E-10	4E-05

INGESTION EXPOSURE

TCE SOIL CONCENTRATION			OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg								
640			1E-06	5E-02	4E-06	1E-01	8E-06	1E+00
500			1E-06	4E-02	3E-06	1E-01	4E-06	8E-01
400			8E-07	3E-02	3E-06	9E-02	3E-06	6E-01
300			6E-07	2E-02	2E-06	7E-02	3E-06	5E-01
200			4E-07	2E-02	1E-06	5E-02	2E-06	3E-01
100			2E-07	8E-03	6E-07	2E-02	9E-07	2E-01
50			1E-07	4E-03	3E-07	1E-02	4E-07	8E-02
10			2E-08	8E-04	6E-08	2E-03	9E-08	2E-02
1			2E-09	8E-05	6E-09	2E-04	9E-09	2E-03
0.1			2E-10	8E-06	6E-10	2E-05	9E-10	2E-04

COMBINED EXPOSURES

TCE SOIL CONCENTRATION			OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg								
640			9E-06	6E-01	2E-05	9E-01	9E-06	1E+00
500			7E-06	5E-01	1E-05	7E-01	7E-06	9E-01
400			5E-06	4E-01	1E-05	6E-01	6E-06	8E-01
300			4E-06	3E-01	8E-06	4E-01	4E-06	6E-01
200			3E-06	2E-01	5E-06	3E-01	3E-06	4E-01
100			1E-06	1E-01	3E-06	1E-01	1E-06	2E-01
50			7E-07	6E-02	1E-06	7E-02	7E-07	9E-02
10			1E-07	1E-02	3E-07	1E-02	1E-07	2E-02
1			1E-08	1E-03	3E-08	1E-03	1E-08	2E-03
0.1			1E-09	1E-04	3E-09	1E-04	1E-09	2E-04

Oa=.28
Dl=6620cm2/d
H'=.94
Ow=.15
Pb=1.5g/cm3
Dw=0.71cm2/d
n=.43
foc=.006
koc=880

B=1.5g/cm3
Co=.00064
Cv,eq=.000167g/cm3
DA=71.64cm2/d
t=10950d/30y

1000mg/g

Fi=.005314mg/m2s
a=227m2
f=.001
ACS=1/3600
v=681m3

AC=.00637mg/m3
IR=20m3/day
EF=250d/y
ED=25y
BW=70kg
AT=25550d
SF=.002

3

Calculation of Potential Excess Lifetime Cancer Risk and Noncancer Hazard for PCE, Sandys Cleaners Risk/Sensitivity Analysis

INHALATION EXPOSURE

PCE SOIL CONCENTRATION	PCE SOIL GAS CONCENTRATION	PCE SOIL GAS CONCENTRATION	APPARENT DIFFUSIVITY	AVERAGE MAXIMUM FLUX	AVERAGE MAXIMUM FLUX	INDOOR AIR CONCENTRATION	OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg	mg/L	ug/L	cm2/day	g/m2s	mg/m2s	mg/m3	unitless	unitless				
			DA	Fi	Fi	iAC	*ELCR*	*HQ*	*ELCR*	*HQ*	*ELCR*	*HQ*
640	152	1.5E+05	7.2E+01	1.0E-05	1.0E-02	1.2E-02	2E-08	2E-01	3E-08	3E-01	8E-07	1E-01
500	119	1.2E+05	7.2E+01	7.9E-06	7.9E-03	9.5E-03	1E-08	2E-01	2E-08	3E-01	7E-07	8E-02
400	95	9.5E+04	7.2E+01	6.4E-06	6.4E-03	7.6E-03	1E-08	1E-01	2E-08	2E-01	5E-07	6E-02
300	71	7.1E+04	7.2E+01	4.8E-06	4.8E-03	5.7E-03	8E-07	1E-01	1E-08	2E-01	4E-07	5E-02
200	47	4.7E+04	7.2E+01	3.2E-06	3.2E-03	3.8E-03	5E-07	7E-02	9E-07	1E-01	3E-07	3E-02
100	24	2.4E+04	7.2E+01	1.6E-06	1.6E-03	1.9E-03	3E-07	4E-02	5E-07	5E-02	1E-07	2E-02
50	12	1.2E+04	7.2E+01	7.9E-07	7.9E-04	9.5E-04	1E-07	2E-02	2E-07	3E-02	7E-08	8E-03
10	2	2.4E+03	7.2E+01	1.6E-07	1.6E-04	1.9E-04	3E-08	4E-03	5E-08	5E-03	1E-08	2E-03
1	0.2	2.4E+02	7.2E+01	1.6E-08	1.6E-05	1.9E-05	3E-09	4E-04	5E-09	5E-04	1E-09	2E-04
0.1	0.02	2.4E+01	7.2E+01	1.6E-09	1.6E-06	1.9E-06	3E-10	4E-05	5E-10	5E-05	1E-10	2E-05

INGESTION EXPOSURE

PCE SOIL CONCENTRATION	OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg						
640	8E-06	3E-02	2E-05	9E-02	3E-05	6E-01
500	5E-06	2E-02	2E-05	7E-02	2E-05	5E-01
400	4E-06	2E-02	1E-05	5E-02	2E-05	4E-01
300	3E-06	1E-02	9E-06	4E-02	1E-05	3E-01
200	2E-06	1E-02	6E-06	3E-02	9E-06	2E-01
100	9E-07	5E-03	3E-06	1E-02	4E-06	9E-02
50	5E-07	2E-03	2E-06	7E-03	2E-06	5E-02
10	9E-08	5E-04	3E-07	1E-03	4E-07	9E-03
1	9E-09	5E-05	3E-08	1E-04	4E-09	9E-04
0.1	9E-10	5E-06	3E-09	1E-05	4E-09	9E-05

COMBINED EXPOSURES

PCE SOIL CONCENTRATION	OCCUPATIONAL ELCR	OCCUPATIONAL HQ	RESIDENTIAL ELCR	RESIDENTIAL HQ	DAYCARE ELCR	DAYCARE HQ
mg/kg						
640	8E-06	3E-01	2E-05	4E-01	3E-05	7E-01
500	6E-06	2E-01	2E-05	3E-01	2E-05	5E-01
400	5E-06	2E-01	1E-05	3E-01	2E-05	4E-01
300	4E-06	1E-01	1E-05	2E-01	1E-05	3E-01
200	2E-06	8E-02	7E-06	1E-01	8E-06	2E-01
100	1E-06	4E-02	4E-06	7E-02	4E-06	1E-01
50	6E-07	2E-02	2E-06	3E-02	2E-06	5E-02
10	1E-07	4E-03	4E-07	7E-03	4E-07	1E-02
1	1E-08	4E-04	4E-08	7E-04	4E-08	1E-03
0.1	1E-09	4E-05	4E-09	7E-05	4E-09	1E-04

AC=.00637mg/m3
IR=20m3/day
EF=250d/y
ED=25y
BW=70kg
AT=9125d
RfD=.01