APPENDIX K

HEALTH AND ENVIRONMENTAL ASSESSMENT CALCULATIONS

K.1 Health and Environmental Assessment Spreadsheet Calculations

K.2 Sample Calculations

K.1 HEALTH AND ENVIRONMENTAL ASSESSMENT SPREADSHEET CALCULATIONS

RISK ASSESSMENT SPREADSHEET - INHALATION OF CHEMICAL VAPORS

SITE NAME: AlliedSignal Frankford Plant
LOCATION: Philadelphia, PA
DATE: 01/12/93

HAZARD INDICES AND INCREMENTAL CANCER RISKS ARE CALCULATED BY THIS SPREADSHEET.
EXPOSURES THROUGH INHALATION OF CHEMICALS VAPORS ONLY ARE CONSIDERED.
ASSUMPTIONS ARE OUTLINED BELOW.

EXPOSURE SCENARIO-INHALATION OF CHEMICAL VAPORS BY RECREATIONAL CHILDREN AND ADULT SEWAGE TREATMENT PLANT EMPLOYEES

REFERENCE: EPA, DECEMBER 1989

RELEVANT EQUATION: IEX = (C x IR x Fi x EF x ED)/(BW x AT x 1E6)

WHERE:
C = MODELED AIR CONTACT CONCENTRATION (MG/M3
IR = AIR NHALATION RATE (M3/HR)
ET = EXPOSURE TIME (HOURS/DAY)
EF = EXPOSURE FREQUENCY (EVENTS/YEAR)
ED = EXPOSURE DURATION (YEARS)
BW = BODY WEIGHT (KG)
AT = AVERAGING TIME (DAYS)

ENTER INPUT PARAMETERS:

ADULT:		YOUTH:	
IR:	2.5	IR:	2.5
ET:	2	ET:	2
EF:	250	EF:	100
ED:	30	ED:	6
BW:	70	BW:	15
AT(CAR):	25550	AT(CAR):	25550
AT(NON):	10950	AT(NON):	2190

DETERMINE CONVERSION FACTORS:

ADULT:			YOUTH:		
CF:	4.892e-2	(NONCARC DOSE)	CF:	9.132e-2	(NONCARC DOSE)
	2.097e-2	(CARC DOSE)		7.828e-3	(CARC DOSE)

AlliedSignal Frankford Plant

EXPOSURE SCENARIO-INHALATION OF CHEMICAL VAPORS BY RECREATIONAL CHILDREN AND ADULT SEWAGE TREATMENT PLANT EMPLOYEES

CALCULATE DOSES:

CHEMICAL	C (MG/M3)	YOUTH ANNUAL DOSE (MG/KG/DAY)	ADULT ANNUAL DOSE (MG/KG/DAY)	YOUTH LIFETIME DOSE (MG/KG/DAY)	ADULT LIFETIME DOSE (MG/KG/DAY)	RFD (MG/KG/DAY)	CSF (KG-DAY/MG)
Acetone	1.97e-6	1.799e-7	9.638e-8	1.542e-8	4.131e-8	1e-1	
Benzene	3.37e-5	3.078e-6	1.649e-6	.0000003	7.066e-7	0	2.9e-2
Cumene	7.31e-8	6.676e-9	3.576e-9	5.72e-10	1.533e-9	3e-3	
Ethylbenzene	3.37e-9	3.08e-10	1.65e-10	2.64e-11	7.07e-11	2.9e-1	
Toluene	1.46e-5	1.333e-6	7.143e-7	.0000001	3.061e-7	1.1e-1	
Xylenes	5.97e-7	5.452e-8	2.921e-8	4.673e-9	1.252e-8	9e-2	
Phenol	1.14e-8	1.041e-9	5.58e-10	8.92e-11	2.39e-10	6e-1	
2-Methylphenol	2.4e-9	2.19e-10	1.17e-10	1.88e-11	5.03e-11	5e-2	
4-Methylphenol	6.41e-10	5.85e-11	3.14e-11	5.02e-12	1.34e-11	5e-3	
2,4-Dimethylphenol	5.47e-9	5.00e-10	2.68e-10	4.28e-11	1.15e-10	2e-2	
Acenaphthylene	0	0	0	0	0	0	
Anthracene	4.83e-11	4.41e-12	2.36e-12	3.78e-13	1.01e-12	3e-1	
Fluorene	1.93e-10	1.76e-11	9.44e-12	1.51e-12	4.05e-12	4e-2	
2-Methylnaphthalene	1.38e-8	1.260e-9	6.75e-10	1.08e-10	2.89e-10	2e-2	
Naphthalene	1.03e-7	9.406e-9	5.039e-9	8.06e-10	2.160e-9	4e-2	
		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	
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		0	0	0	0	0	
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		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	
		0	0	0	0	0	

AlliedSignal Frankford Plant

EXPOSURE SCENARIO-INHALATION OF CHEMICAL VAPORS BY RECREATIONAL CHILDREN AND ADULT SEWAGE TREATMENT PLANT EMPLOYEES

DETERMINE HAZARD INDICES AND CANCER RISK:

CHEMICAL	HAZARD INDEX YOUTH	HAZARD INDEX ADULT	CANCER RISK YOUTH	CANCER RISK ADULT
Acetone	1.799e-6	9.638e-7	0	0
Benzene	0	0	7.650e-9	2.049e-8
Cumene	2.225e-6	1.192e-6	0	0
Ethylbenzene	1.061e-9	5.69e-10	0	0
Toluene	1.212e-5	6.494e-6	0	0
Xylenes	6.058e-7	3.245e-7	0	0
Phenol	1.735e-9	9.30e-10	0	0
2-Methylphenol	4.384e-9	2.348e-9	0	0
4-Methylphenol	1.171e-8	6.272e-9	0	0
2,4-Dimethylphenol	2.498e-8	1.338e-8	0	0
Acenaphthylene	0	0	0	0
Anthracene	1.47e-11	7.88e-12	0	0
Fluorene	4.41e-10	2.36e-10	0	0
2-Methylnaphthalene	6.301e-8	3.376e-8	0	0
Naphthalene	2.352e-7	1.260e-7	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
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	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
TOTAL	1.709e-5	9.157e-6	7.650e-9	2.049e-8

AlliedSignal Frankford Plant ----

EXPOSURE SCENARIO-INHALATION OF CHEMICAL VAPORS BY RECREATIONAL CHILDREN AND ADULT SEWAGE TREATMENT PLANT EMPLOYEES

CALCULATE ACTION LEVELS
CARCINOGENIC RISK 1e-4

CHEMICAL	NUMBER OF CARCINOGENS	TARGET RISK	ACTION LEVEL (UG/KG)
Acetone	0	0	0
Benzene	1	1e-4	1.645e-1
Cumene	0	0	0
Ethylbenzene	0	0	0
Toluene	0	0	0
Xylenes	0	0	0
Phenol	0	0	0
2-Methylphenol	0	0	0
4-Methylphenol	0	0	0
2,4-Dimethylphenol	0	0	0
Acenaphthylene	0	0	0
Anthracene	0	0	0
Fluorene	0	0	0
2-Methylnaphthalene	0	0	0
Naphthalene	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
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	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
	0	0	0
TOTAL	1	1e-4	

K.2 SAMPLE CALCULATIONS

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT: Allied Signal Frankford Plant	JOB NUMBER: 0091
SUBJECT: Calculation of Groundwater discharge DILUTION FACTORS.	
BASED ON	DRAWING NUMBER
BY: Norman Straub NS	CHECKED BY: KMS / APPROVED BY / DATE

① GROUNDWATER DISCHARGE TO SANITARY SEWER.

DAILY GW INFILRATION RATE : 19,794 gal/day
" Sanitary Sewer flow : 25.35 ft^3/s

$$(25.35\ ft^3/sec)(7.48\ gal/ft^3)(60\ sec/min)(60\ min/hr)(24\ hr/day) = 1.64\times10^7\ gpd$$

$$DF = \frac{19794\ gpd}{(1.64\times10^7 + 19{,}794)\ gpd} = \boxed{1.21\times10^{-3}}$$

② Groundwater discharge to Frankford inlet.

DAILY GW DISCHARGE rate: 10,180 gpd

DIMENSIONS of INLET L = 750'
W = 100'

Based on observation, tidal fluctuation of 6 feet is noted.
Also, inlet is without water during low tide.
Assume 5 foot depth at high tide.

Vol of water in inlet @ HIGH TIDE = (750ft)(100ft)(5ft)

$$Vol = 375{,}000\ ft^3\ (7.48\ gal/ft^3) = 2.81\times10^6\ gal$$

During 24 hrs, two tidal cycles occur, therefore

$$DF = \frac{10{,}180\ gpd}{2(2.81\times10^6\ gpd) + 10{,}180\ gpd} = \boxed{1.81\times10^{-3}}$$

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT Allied Signal Frankford Plant		JOB NUMBER 0091	
SUBJECT Groundwater Chemical Vapor Emission.			
BASED ON Henry's Law / Ideal Gas Law		DRAWING NUMBER	
BY Norman Straub NHS	CHECKED BY	APPROVED BY KMJ8	DATE

PURPOSE: Calculate chemical vapor concentration for various chemicals based on infiltrating groundwater concentration, dilution in sewer & volatilization to extent governed by Henry's Law.

- Dilution chemical concentration

$$C_{DIL} = C_{GW} \times DF$$

WHERE C_{DIL} = Diluted chem. concentration (mg/L)
C_{GW} = chemical conc in groundwater (mg/L)
DF = Dilution factor

- Vapor partial pressure

$$p^* = \frac{C_{DIL} \times H \times CF_1}{MW \times CF_2}$$

where: p^* = chemical pressure in air (atm)
H = chemical-specific Henry's Law Constant ($\frac{m^3 \cdot atm}{mol}$)
CF_1 = Conversion factor ($\frac{1000\ L}{m^3}$)
MW = chemical molecular weight (gm/mol)
CF_2 = Conversion factor ($\frac{1000\ mg}{gm}$)

- Vapor conc (Based on Ideal Gas Law) — $PV = nRT$

$$Conc = \frac{n}{V} = \frac{P}{RT} \quad \text{or} \quad = \frac{p^*}{RT}$$

$$Conc = \frac{n}{V} = \frac{p^*}{RT} \ [=] \ mol/m^3$$

where R = Ideal gas law const. ($82.05 \frac{m^3\ atm}{mol\ K}$)
T = ambient vapor temp (K)

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT AlliedSignal Frankford Plant	JOB NUMBER 0091
SUBJECT Groundwater chemical vapor concentration	
BASED ON	DRAWING NUMBER
BY ZAB / CHECKED BY KMS	APPROVED BY / DATE

Sample Calculation

For Acetone – $C_{GW} = 900\ mg/L$ (max)
$H_{Acetone} = 4.28 \times 10^{-5}\ \frac{m^3 \cdot atm}{mol}$ (LITERATURE value)
$DF = 1.21 \times 10^{-3}$ (calculated from site data)
$MW_{acetone} = 58.08\ gm/mol$
$TEMP = 60°F\ (288.75\ K)$

- DILUTION CONCENTRATION

$$C_{DIL} = (900\ mg/L)(1.21 \times 10^{-3}) = \underline{1.09}\ mg/L$$

- chemical vapor partial pressure

$$p^* = \frac{(1.09\ mg/L)(4.28 \times 10^{-5}\ \frac{m^3 atm}{mol})(\frac{1000\ L}{m^3})}{(58.08\ gm/mol)(\frac{1000\ mg}{gm})} = 8.03 \times 10^{-7}\ atm$$

- vapor conc

$$C_{air} = \frac{p^*}{RT} = \frac{8.03 \times 10^{-7}\ atm}{(82.05\ \frac{m^3 atm}{mol\ K})(288.75\ K)} \times (58.08\ gm/mol) \times (\frac{1000\ mg}{gm})$$

$$\boxed{C_{air} = 1.97 \times 10^{-6}\ mg/m^3}$$

GROUNDWATER CHEMICAL VAPOR EMISSION MODEL

This spreadsheet model calculates equilibrium chemical vapor concentration for dissolved volatile chemicals in water. The model uses the principles defined by Henry's Law and the Ideal Gas Law to quantify vapor concentrations.

TO USE SPREADSHEET
1) Input chemical names and aqueous concentrations.
2) Input chemical-specific molecular weights and Henry's Law Constants.
3) Specify a dilution factor value and temperature.
4) Print spreadsheet using "ALT-P" macro.

Chemical	Groundwater Concentration (mg/L)	Dilution Factor	Temp (Farenheit)	Adjusted Concentration (mg/L)	Molecular Weight (g/mol)	Adjusted Concentration (mol/L)	Henry's Law Constant (m3-atm/mol)	Vapor Concentration (mg/m3)
Acetone	900	0.00121	60	1.089	58.08	0.00001875	4.28E-05	1.97E-06
Benzene	120	0.00121	60	0.1452	78.12	1.8587E-06	5.50E-03	3.37E-05
Cumene	0.098	0.00121	60	0.00011858	120.19	9.8660E-10	1.46E-02	7.31E-08
Ethylbenzene	0.01	0.00121	60	0.0000121	106.17	1.1397E-10	6.60E-03	3.37E-09
Toluene	43	0.00121	60	0.05203	92.1	5.6493E-07	6.66E-03	1.46E-05
Xylenes	2.7	0.00121	60	0.003267	106.17	3.0771E-08	4.33E-03	5.97E-07
Phenol	490	0.00121	60	0.5929	94.11	6.3001E-06	4.54E-07	1.14E-08
2-Methylphenol	12	0.00121	60	0.01452	108.1	1.3432E-07	3.92E-06	2.40E-09
4-Methylphenol	32	0.00121	60	0.03872	108.1	3.5819E-07	3.92E-07	6.41E-10
2,4-Dimethylphenol	6.3	0.00121	60	0.007623	122.16	6.2402E-08	1.70E-05	5.47E-09
Anthracene	0.011	0.00121	60	0.00001331	178.23	7.4679E-11	8.60E-05	4.83E-11
Fluorene	0.059	0.00121	60	0.00007139	166	4.3006E-10	6.40E-05	1.93E-10
2-Methylnaphthalene	0.54	0.00121	60	0.0006534	142.19	4.5953E-09	4.99E-04	1.38E-08
Naphthalene	4.4	0.00121	60	0.005324	128.16	4.1542E-08	4.60E-04	1.03E-07

CLIENT Allied Signal Frankford Plant		JOB NUMBER 0091	
SUBJECT Exposure Dose Estimates / Risk Characterization			
BASED ON USEPA, RAGS PARTA		DRAWING NUMBER	
BY Paul Pesing III from Norman Straub	CHECKED BY JT	APPROVED BY	DATE

Purpose: Calculate exposure dose estimates based on medium-specific chemical concentrations and established exposure rate values. Also, determine noncarcinogenic / carcinogenic risks associated with respective dose estimates.

Relevant Equations:

① Inhalation of Chemical Vapors

$$Dose\ (mg/Kg/day) = \frac{C_{air} \times InhR \times ET \times EF \times ED}{BW \times AT \times 365}$$

Where:

C_{air}	=	Chemical concentration in air (mg/m^3)
InhR	=	Receptor inhalation rate (m^3/hr)
ET	=	Exposure time (hr/day)
EF	=	Exposure frequency (day/yr)
ED	=	Exposure duration (yr)
BW	=	Receptor body weight (Kg)
AT	=	Averaging time (ED for noncarcinogens, LT for carcinogens, yr)
365	=	Conversion factor (days/yr)

Risks are characterized for individual receptors for all applicable exposure routes by summation of chemical-specific hazard quotients (HQs) and incremental cancer risks (ICRs)

② Hazard Quotient

$$HQ = \frac{Dose}{RfD}$$

Where:

HQ	=	Chemical- and exposure route-specific hazard quotient (unitless)
Dose	=	Calculated noncarcinogenic exposure dose (mg/Kg/day)
RfD	=	Chemical- and exposure route-specific reference dose (mg/Kg/day)

CLIENT Allied Signal Frankford	JOB NUMBER 0091
SUBJECT Exposure/Risk Calculation	
BASED ON USEPA RAGS PART A	DRAWING NUMBER
BY AP / CHECKED BY JT	APPROVED BY / DATE

Relevant Equations (Con't)

③ Incremental Cancer Risk

$$ICR = Dose \times CSF$$

Where: ICR = Exposure route-specific incremental cancer risk
Dose = Calculated chronic exposure dosage (mg/Kg/day)
CSF = Chemical- and exposure route-specific cancer slope factor $(mg/Kg/day)^{-1}$

If the calculated value of the incremental cancer risk exceeds a value of 0.1, an exponential expression is used:

$$ICR = 1 - \exp(Dose \times CSF)$$

Sample Calculation

For Toluene and Benzene, the following toxicological data are available

Chemical	RfDi (mg/Kg day)	CSFi (Kg day/mg)
Toluene	1.1×10^{-1}	NA
Benzene	NA	2.9×10^{-2}

NA = Not Available

CLIENT Allied Signal Frankford	JOB NUMBER 0091
SUBJECT Exposure / Risk Calculation	
BASED ON USEPA RAGS PART A	DRAWING NUMBER
BY AA / CHECKED BY JT	APPROVED BY / DATE

Sample Calculation (Con't)

The following exposure assessment input parameters are used:

SUMMARY OF EXPOSURE ASSESSMENT INPUT PARAMETERS

AlliedSignal Frankford Plant
Philadelphia, Pennsylvania

Parameter	Value	Units	Rationale
Chemical concentration in air (C_{air})	Modeled value	mg/m^3	Based on analytical results
Air inhalation rate (InhR)	2.5 - adults and children	m^3/hr	USEPA, March 25, 1991
Exposure time (ET)	2 - adult 2 - child	hrs/day	Conservative estimate Conservative estimate
Exposure frequency (EF)	250 - adult 100 - child		USEPA, December, 1989 Conservative estimate
Exposure duration (ED)	30 - adult 6 - child	yr	USEPA, March 25, 1991
Receptor body weight (BW)	70 - adult 15 - child	Kg	USEPA, March 25, 1991
Receptor lifetime (LT)	70	yr	USEPA, March 25, 1991

CLIENT		JOB NUMBER	
Allied Signal Frankford			
SUBJECT			
Exposure Risk Calculation			
BASED ON		DRAWING NUMBER	
U.S. EPA. RAGS Part A			
BY	CHECKED BY	APPROVED BY	DATE
AP	JT		

① Inhalation of Chemical Vapors - Adult Sewage Treatment Plant Employee

Noncarcinogenic Dose

$$Dose = \frac{C_{air} \times (2.5\ m^3/hr)(2\ hr/day)(250\ day/yr)(30\ yr)}{(70\ kg)(30\ yr)(365\ day/yr)}$$

$$= C_{air} \times (4.89 \times 10^{-2})$$

Toluene $(1.46 \times 10^{-5}\ mg/m^3)$ - $Dose = (1.46 \times 10^{-5}\ mg/m^3)(4.89 \times 10^{-2}) = 7.14 \times 10^{-7}$

$= 7.14 \times 10^{-7}\ mg/kg\text{-}day$

Carcinogenic Dose

$$Dose = \frac{C_{air} \times (2.5\ m^3/hr)(2\ hr/day)(250\ day/yr)(30\ yr)}{(70\ kg)(70\ yr)(365\ day/yr)}$$

$$= C_{air} \times 2.09 \times 10^{-2}\ m^3/kg\ day$$

Benzene $(3.37 \times 10^{-5}\ mg/m^3) \cdot Dose = (3.37 \times 10^{-5}\ mg/m^3)(2.09 \times 10^{-2}\ m^3/kg\ day)$

$$= 7.04 \times 10^{-7}\ mg/kg\ day$$

CLIENT	JOB NUMBER
Allied Signal / Frankford	0091
SUBJECT: Exposure Risk Calculation	
BASED ON: USEPA RAGS PART A	DRAWING NUMBER
BY: PI / CHECKED BY: JT	APPROVED BY / DATE

Inhalation of Volatile Chemicals

• Non carcinogenic Effects

$$HQ = \frac{7.14\times10^{-7}\ mg/kg\ day}{1.1\times10^{-1}\ mg/kg\ day} = 6.49\times10^{-6}$$

• carcinogenicity

$$ICR = (7.04\times10^{-7}\ mg/kg\ day)\times(2.9\times10^{-2}\ kg\ day/mg)$$

$$= 2.049\times10^{-8}$$

REFERENCES

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