Chevron

Research and Technology

Facsimile Message

Date 8/23/96

TO: Name MADULLAH LOGAN

Company ACHCS - EHS

City ALAMEDA

Facsimile Number 510-337-9335

FROM: Name CURT PECK

Company CRTC

Building/Room

Phone Number 510-242-7086

Number of Pages (including cover) 12

Special Instructions

Madullah - Please review this DRAFT for completeness and accuracy. I have included my "hand" equation calculations and ASTM Tables X2.5, 2.6 + 2.7 for your guidance. Please call to discuss so we can finalize this and proceed (hopefully) to closure - Thanks Curt Peck

If you do not receive all pages, please phone sender.

Our Facsimile information: **Ricoh 3100L,** **Facsimile Number (510) 242-1380**

Mailing Address: Chevron Research And Technology Company
1003 West Cutting Blvd.
P.O. Box 4054
Richmond, California 94804-0054

MEMORANDUM

Richmond, California
August 23, 1996

Health Risk Evaluation - 2nd Addendum
ASTM Vapor Volatilization Calculations
Former Chevron Station #9-5630
<u>997 Grant Avenue, San Lorenzo CA</u>

Mr. Phil Briggs:
San Ramon, California

Based on the review of my December 12, 1995 Memorandum to Mark Miller/Chevron Products regarding a Health Risk Evaluation for this site, Ms. Madullah Logan of the ACHCS has requested that the vapor volatilization factor (VFwesp) calculation be rerun for this site with all site assumptions/default values noted during the solving of the equation. The equations in ASTM RBCA document E 1739-95 Table X2.5 were solved utilizing all site-specific and default parameters given below.

Based on the results of this risk evaluation, the estimated health risk associated with the exposure to vapor volatilization from the groundwater plume at this site range between 1e-7 and 1e-8 (one in 10,000,000 to one in 100,000,000). At these risk levels the site does not pose a threat to human health or the environment and should be submitted for site closure.

<u>ASTM RBCA VFwesp Equation - Vapor Volatilization Groundwater to Enclosed-Space</u>

The volatilization factor (VFwesp) for inhalation of vapors emanating from a groundwater plume that have migrated through the soil column and into an enclosed space (residence) was calculated for this site. To solve this equation it is necessary to solve equations for effective diffusion through soils (D^{eff}_{s}), cracks (D^{eff}_{crack}), capillary (D^{eff}_{cap}) and groundwater (D^{eff}_{ws}) surfaces. These equations are listed in Table X2.5.

Using the ASTM RBCA document E 1739-95 (Table X2.5 attached) and Tables X2.6 and X2.7 parameters, the VFwesp value is calculated in step 1) below. The VFwesp value is then combined with actual site groundwater concentration values to calculate a vapor concentration (C building) in the enclosed space (step 2). The Chemical Intake value is generated for specific receptor characteristics (step 3) and a Risk value is calculated by multiplying the Cancer Slope Factor for benzene (0.029 mg/Kg-day) times the calculated Chemical Intake value (step 4).

1) Volatilization Factor wesp - (VFwesp) - groundwater to enclosed space vapors:
    A) See attached E 1739-95 Table X2.5; note that VFwesp calculation requires the solving of equations for effective diffusion between groundwater and soil and for effective diffusion between soil and foundation crack.

2) Vapor concentration in a building - C (building) = VFwesp * C (groundwater)

3) Intake Value - Intake = $\frac{\text{C (building) * Respiration rate * Days exposed * Years exposed}}{\text{Receptor Weight * Days/years * Lifetime (years)}}$

4) Risk Value - Risk = Intake * Cancer Slope Factor for Benzene (0.029 mg/Kg-day)

VFwesp Input parameters

For this site, a known depth to groundwater of 1.80 meters (6 feet) will be modeled. An estimated total porosity (qT) of 38% was input into the equation. The height of the capillary zone was estimated at 30 cm with an estimated vadose zone of 150 cm thickness. The solving of equation 2) above will be for the maximum site benzene groundwater concentration (9/91 in well C-3), for the maximum benzene concentration in the last 4 quarters of monitoring and for the current site (6/96) benzene concentration. For equation 3) above, the modeled receptor will be a resident adult with a 70 year lifetime, weighing 70 kilograms, who is exposed for 30 years, at 350 day/year at a breathing rate of 15 m^3/day.

The following ASTM RBCA Table X2.6 Residential default values for were used during the solving of this vapor volatilization equation: ER (air exchange rate) of 0.00014 s^{-1}, L_B (volume/infiltration ratio) of 200 cm, L_{crack} (wall thickness) of 15 cm and n (fraction cracks) of 0.01 cm^2-cracks/cm^2-total area were used in the solving of the equation.

ASTM RBCA default parameters for the volumetric water content and volumetric air content of the capillary zone, vadose zone and foundation from Table X2.6 were used in the solving of these equations. The default values for volumetric water content of capillary zone (q_{wcap}), vadose zone (q_{ws}) and foundation crack (q_{wcrack}) were 0.342, 0.12 and 0.12. The default values for volumetric air content for capillary zone (q_{acap}), vadose zone (qas) and foundation crack (q_{acrack}) were 0.038, 0.26 and 0.26.

Chemical specific parameters for benzene from ASTM RBCA Table X2.7 were used as follows: Diffusion coefficient in air (D^{air}) of 0.093 cm^2/sec, Diffusion coefficient in water (D^{wat}) of 1.1e-5 cm^2/sec and the Henry's Law Constant (H) of 0.22 L-H_2O/L-air were applied in these equations.

Solved Equations

The results of solving the equations for D^{eff}_{crack}, D^{eff}_{s}, D^{eff}_{cap} and D^{eff}_{ws} are as follows: D^{eff}_{crack} = 7.26e-3 cm^2/sec; D^{eff}_{s} = 7.26e-3 cm^2/sec; D^{eff}_{cap} = 2.2e-5 cm^2/sec and D^{eff}_{ws} = 1.3e-4 cm^2/sec. Substituting these values into the VFwesp equation and solving the equation resulted in a calculated VFwesp of 4.94e-3 (mg/m^3-air)/(mg/L-H_2O).

Solving the equations for estimated Risk to an adult resident at the site indicates that the current site benzene concentration of 0.84 ppb would equate to an estimated health risk of approximately 1e-8 (one in 100,000,000) and at a concentration of 7.4 ppb (12/29/95) an estimated health risk of 9.3e-7 (about one in 10,000,000) and at the site maximum of 150 ppb (9/6/91) an estimated health risk of 2e-6 (two in 1,000,000). These risk levels are at or below accepted risk levels and would indicate that the vapors associated with the groundwater plume at this site would not pose a significant health risk threat to a potential resident on this site.

Summary

Based on the known and assumed parameter values at the site, an estimated health risk to an adult resident at this site would be in the range of 1e-7 to 1e-8 range and therefore would not represent a significant threat to human health or the environment. Based on the current site conditions and this risk evaluation, it is recommended that this site be submitted to the ACHCS for site closure as soon as possible.

Please call me at 510-242-7086 with questions or comments regarding this memorandum.

Sincerely,

Curtis A. Peck, R.G. 5337

#9-5630 ASTM RBCA - Volatilization Factor for Enclosed Spaces

SOLVED EQUATIONS

1) VFwesp =

$$\frac{(0.22)\;\dfrac{[(1.3e\text{-}4\ cm^2/s)\,/\,(180\ cm)]}{[(1.4e\text{-}4\ s^{-1}) * (200\ cm)]}}{1 + \dfrac{[(1.3e\text{-}4\ cm^2/s)\,/\,(180\ cm)]}{[(1.4e\text{-}4\ s^{-1}) * (200\ cm)]} + \dfrac{[(1.3e\text{-}4\ cm^2/s\,/\,(180\ cm)]}{[(7.26e\text{-}3\ cm^2/s)\,/\,15\ cm)(0.01)]}} * [1e3\ L/m^3]$$

$$VFwesp = \frac{(0.22)\ (2.58e\text{-}5)}{1 + [(2.58e\text{-}5) + (0.149)]} * 1e3\ L/m^3$$

$$VFwesp = \frac{(5.68e\text{-}6)}{1 + 0.149} * 1e3\ L/m^3$$

$$VFwesp = (4.94e\text{-}6) * 1e3\ L/m^3$$

VFwesp = 4.94e-3 $\frac{mg/m^3\text{-air}}{mg/L\text{-water}}$

2) C building = (VFwesp) * (C water) ; where 2a) Maximum site benzene concentration C_1 = 150 ppb (0.150 mg/L in well C-3 9/6/91); where 2b) Maximum concentration in last 4 quarters C_2 = 7.4 ppb (0.0074 ppm in well C-6 12/29/95) and 2c) Current site concentration C_3 = 0.84 ppb (0.00084 ppm in well C-6 6/12/96)

$$C\ building = 4.94e\text{-}3\ \frac{[mg/m^3\text{-air}]}{[mg/L\text{-water}]} * (0.150\ mg/L)$$

2a) C building = 7.41e-4 mg/m³-air at 150 ppb benzene in C-3 (9/6/91)

2b) C Building = 3.66e-5 mg/m³-air at 7.4 ppb benzene in C-6 (12/29/96)

2c) C Building = 4.1e-6 mg/m³-air at 0.84 ppb benzene in C-6 (6/12/96)

3) Chemical Intake = $\dfrac{\textbf{(C building) * (Respiration Rate) * (Days Exposed) * (Years Exposed)}}{\textbf{(Receptor Weight) * (Days/year) * (Expected Lifetime)}}$

$$Intake = \frac{(7.41e\text{-}4\ mg/m^3) * (15\ m^3/day) * (350\ days) * (30\ years)}{(70\ Kg) * (365\ days) * (70\ years)}$$

3a) Chemical Intake = 6.53e-5 mg/Kg-day at 150 ppb benzene

3b) Chemical Intake = 3.2e-6 mg/Kg-day at 7.4 ppb benzene

3c) Chemical Intake = 3.6e-7 mg/Kg-day at 0.84 ppb benzene

4) Risk = Chemical Intake * Cancer Potency Factor (benzene); where CPF = 0.029 mg/Kg-d

Risk = (6.53e-5 mg/Kg-day) * (0.029 mg/Kg-day)

4a) Risk = 1.9e-6 at 150 ppb benzene - Maximum detected at site

4b) Risk = 9.3e-8 at 7.4 ppb benzene, the 12/29/95 situation at the site.

4c) Risk = 1e-8 at 0.84 ppb benzene, the Current site conditions

the inhalation of airborne chemicals resulting from the volatilization of chemicals from surficial soils follow guidance given in Ref (26) for inhalation of airborne chemicals.

X2.6.6 A conceptual model for the volatilization of chemicals from surficial soils to outdoor air is depicted in Fig. X2.3. For simplicity, the relationship between outdoor air and surficial soil concentrations is represented in Tables X2.2 and X2.3 by the "volatilization factor" VF_{ss} [(mg/m³-air)/(mg/kg-soil)] defined in Table X2.5. It is based on the following assumptions:

X2.6.6.1 Uniformly distributed chemical throughout the depth 0—*d* (cm) below ground surface,

X2.6.6.2 Linear equilibrium partitioning within the soil matrix between sorbed, dissolved, and vapor phases, where

TABLE X2.5 Volatilization Factors (VF_i), Leaching Factor (LF_{sw}), and Effective Diffusion Coefficients (D_i^{eff})

Symbol	Cross-Media Route (or Definition)	Equation
VF_{wesp}	Ground water → enclosed-space vapors	$VF_{wesp}\left[\frac{(mg/m^3\text{-}air)}{(mg/L\text{-}H_2O)}\right] = \frac{H\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\,L_B}\right]}{1+\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\,L_B}\right]+\left[\frac{D_{ws}^{eff}/L_{GW}}{(D_{crack}^{eff}/L_{crack})\eta}\right]} \times 10^3\,\frac{L}{m^3}$ [A]
VF_{wamb}	Ground water → ambient (outdoor) vapors	$VF_{wamb}\left[\frac{(mg/m^3\text{-}air)}{(mg/L\text{-}H_2O)}\right] = \frac{H}{1+\left[\frac{U_{air}\delta_{air}L_{GW}}{WD_{ws}^{eff}}\right]} \times 10^3\,\frac{L}{m^3}$ [B]
VF_{ss}	Surficial soils → ambient air (vapors)	$VF_{ss}\left[\frac{(mg/m^3\text{-}air)}{(mg/kg\text{-}soil)}\right] = \frac{2W\rho_s}{U_{air}\delta_{air}}\sqrt{\frac{D_s^{eff}H}{\pi(\theta_{ws}+k_s\rho_s+H\theta_{as})\tau}} \times 10^3\,\frac{cm^3\text{-}kg}{m^3\text{-}g}$ [C] or: $VF_{ss}\left[\frac{(mg/m^3\text{-}air)}{(mg/kg\text{-}soil)}\right] = \frac{W\rho_s d}{U_{air}\delta_{air}\tau} \times 10^3\,\frac{cm^3\text{-}kg}{m^3\text{-}g}$; whichever is less [D]
VF_p	Surficial soils → ambient air (particulates)	$VF_p\left[\frac{(mg/m^3\text{-}air)}{(mg/kg\text{-}soil)}\right] = \frac{P_e W}{U_{air}\delta_{air}} \times 10^3\,\frac{cm^3\text{-}kg}{m^3\text{-}g}$ [E]
VF_{samb}	Subsurface soils → ambient air	$VF_{samb}\left[\frac{(mg/m^3\text{-}air)}{(mg/kg\text{-}soil)}\right] = \frac{H\rho_s}{[\theta_{ws}+k_s\rho_s+H\theta_{as}]\left(1+\frac{U_{air}\delta_{air}L_S}{D_s^{eff}W}\right)} \times 10^3\,\frac{cm^3\text{-}kg}{m^3\text{-}g}$ [F]
VF_{sesp}	Subsurface soil → enclosed-space vapors	$VF_{sesp}\left[\frac{(mg/m^3\text{-}air)}{(mg/kg\text{-}soil)}\right] = \frac{\frac{H\rho_s}{[\theta_{ws}+k_s\rho_s+H\theta_{as}]}\left[\frac{D_s^{eff}/L_S}{ER\,L_B}\right]}{1+\left[\frac{D_s^{eff}/L_S}{ER\,L_B}\right]+\left[\frac{D_s^{eff}/L_S}{(D_{crack}^{eff}/L_{crack})\eta}\right]} \times 10^3\,\frac{cm^3\text{-}kg}{m^3\text{-}g}$ [A]
LF_{sw}	Subsurface soils → ground water	$LF_{sw}\left[\frac{(mg/L\text{-}H_2O)}{(mg/kg\text{-}soil)}\right] = \frac{\rho_s}{[\theta_{ws}+k_s\rho_s+H\theta_{as}]\left(1+\frac{U_{gw}\delta_{gw}}{IW}\right)} \times 10^0\,\frac{cm^3\text{-}kg}{L\text{-}g}$ [B]
D_s^{eff}	Effective diffusion coefficient in soil based on vapor-phase concentration	$D_s^{eff}\left[\frac{cm^2}{s}\right] = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$ [A]
D_{crack}^{eff}	Effective diffusion coefficient through foundation cracks	$D_{crack}^{eff}\left[\frac{cm^2}{s}\right] = D^{air}\frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{wcrack}^{3.33}}{\theta_T^2}$ [A]
D_{cap}^{eff}	Effective diffusion coefficient through capillary fringe	$D_{cap}^{eff}\left[\frac{cm^2}{s}\right] = D^{air}\frac{\theta_{acap}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{wcap}^{3.33}}{\theta_T^2}$ [A]
D_{ws}^{eff}	Effective diffusion coefficient between ground water and soil surface	$D_{ws}^{eff}\left[\frac{cm^2}{s}\right] = (h_{cap}+h_v)\left[\frac{h_{cap}}{D_{cap}^{eff}}+\frac{h_v}{D_s^{eff}}\right]^{-1}$ [A]
C_s^{sat}	Soil concentration at which dissolved pore-water and vapor phases become saturated	$C_s^{sat}\left[\frac{mg}{kg\text{-}soil}\right] = \frac{S}{\rho_s}\times[H\theta_{as}+\theta_{ws}+k_s\rho_s]\times 10^0\,\frac{L\text{-}g}{cm^3\text{-}kg}$ [F]

[A] See Ref (29).
[B] See Ref (30).
[C] See Ref (31).
[D] Based on mass balance.
[E] See Ref (32).
[F] See Ref (33).

TABLE X2.6 Soil, Building, Surface, and Subsurface Parameters Used in Generating Example Tier 1 RBSLs

NOTE—See X2.10 for justification of parameter selection.

Parameters	Definitions, Units	Residential	Commercial/Industrial
d	lower depth of surficial soil zone, cm	100 cm	100 cm
D^{air}	diffusion coefficient in air, cm²/s	chemical-specific	chemical-specific
D^{wat}	diffusion coefficient in water, cm²/s	chemical-specific	chemical-specific
ER	enclosed-space air exchange rate, L/s	0.00014 s^{-1}	0.00023 s^{-1}
f_{oc}	fraction of organic carbon in soil, g-C/g-soil	0.01	0.01
H	henry's law constant, (cm³-H_2O)/(cm³-air)	chemical-specific	chemical-specific
h_{cap}	thickness of capillary fringe, cm	5 cm	5 cm
h_v	thickness of vadose zone, cm	295 cm	295 cm
I	infiltration rate of water through soil, cm/years	30 cm/year	30 cm/year
k_{oc}	carbon-water sorption coefficient, cm³-H_2O/g-C	chemical-specific	chemical-specific
k_s	soil-water sorption coefficient, cm³-H_2O/g-soil	$f_{oc} \times k_{oc}$	$f_{oc} \times k_{oc}$
L_B	enclosed-space volume/infiltration area ratio, cm	200 cm	300 cm
L_{crack}	enclosed-space foundation or wall thickness, cm	15 cm	15 cm
L_{GW}	depth to ground water = $h_{cap} + h_v$, cm	300 cm	300 cm
L_S	depth to subsurface soil sources, cm	100 cm	100 cm
P_e	particulate emission rate, g/cm²-s	6.9×10^{-14}	6.9×10^{-14}
S	pure component solubility in water, mg/L-H_2O	chemical-specific	chemical-specific
U_{air}	wind speed above ground surface in ambient mixing zone, cm/s	225 cm/s	225 cm/s
U_{gw}	ground water Darcy velocity, cm/year	2500 cm/year	2500 cm/year
W	width of source area parallel to wind, or ground water flow direction, cm	1500 cm	1500 cm
δ_{air}	ambient air mixing zone height, cm	200 cm	200 cm
δ_{gw}	ground water mixing zone thickness, cm	200 cm	200 cm
η	areal fraction of cracks in foundations/walls, cm²-cracks/cm²-total area	0.01 cm²-cracks/cm²-total area	0.01 cm²-cracks/cm²-total area
θ_{acap}	volumetric air content in capillary fringe soils, cm³-air/cm³-soil	0.038 cm³-air/cm³-soil	0.38 cm³-air/cm³-soil
θ_{acrack}	volumetric air content in foundation/wall cracks, cm³-air/cm³ total volume	0.26 cm³-air/cm³ total volume	0.26 cm³-air/cm³ total volume
θ_{as}	volumetric air content in vadose zone soils, cm³-air/cm³-soil	0.26 cm³-air/cm³-soil	0.26 cm³-air/cm³-soil
θ_T	total soil porosity, cm³/cm³-soil	0.38 cm³/cm³-soil	0.38 cm³/cm³-soil
θ_{wcap}	volumetric water content in capillary fringe soils, cm³-H_2O/cm³-soil	0.342 cm³-H_2O/cm³-soil	0.342 cm³-H_2O/cm³-soil
θ_{wcrack}	volumetric water content in foundation/wall cracks, cm³-H_2O/cm³ total volume	0.12 cm³-H_2O/cm³ total volume	0.12 cm³-H_2O/cm³ total volume
θ_{ws}	volumetric water content in vadose zone soils, cm³-H_2O/cm³-soil	0.12 cm³-H_2O/cm³-soil	0.12 cm³-H_2O/cm³-soil
ρ_s	soil bulk density, g-soil/cm³-soil	1.7 g/cm³	1.7 g/cm³
τ	averaging time for vapor flux, s	7.88×10^8 s	7.88×10^8 s

the partitioning is a function of constant chemical- and soil-specific parameters,

X2.6.6.3 Diffusion through the vadose zone,

X2.6.6.4 No loss of chemical as it diffuses towards ground surface (that is, no biodegradation), and

X2.6.6.5 Steady well-mixed atmospheric dispersion of the emanating vapors within the breathing zone as modeled by a "box model" for air dispersion.

X2.6.7 In the event that the time-averaged flux exceeds that which would occur if all chemical initially present in the surficial soil zone volatilized during the exposure period, then the volatilization factor is determined from a mass balance assuming that all chemical initially present in the surficial soil zone volatilizes during the exposure period.

X2.7 *Subsurface Soils—Inhalation of Outdoor Vapors:*

X2.7.1 In this case chemical intake is a result of inhalation of outdoor vapors which originate from hydrocarbons contained in subsurface soils located some distance below ground surface. Here the goal is to determine the RBSL for subsurface soils that corresponds to the target RBSL for outdoor vapors in the breathing zone, as given in X2.2. If the selected target vapor concentration is some value other than

TABLE X2.7 Chemical-Specific Properties Used in the Derivation Example Tier 1 RBSLs

Chemical	CAS Number	M_w, g/mol	H, L-H_2O/L-air	D^{air}, cm²/s	D^{w}, cm²/s	log(K_{oc}), L/kg	log(K_{ow}), L/kg
Benzene	71-43-2	78^A	0.22^A	0.093^A	1.1×10^{-5} ^A	1.58^A	2.13^A
Toluene	108-88-3	92^A	0.26^A	0.085^A	9.4×10^{-6} ^D	2.13^A	2.65^A
Ethyl benzene	100-41-4	106^A	0.32^A	0.076^A	8.5×10^{-6} ^D	1.98^A	3.13^A
Mixed xylenes	1330-20-7	106^A	0.29^A	0.072^D	8.5×10^{-6} ^D	2.38^A	3.26^A
Naphthalene	91-20-3	128^A	0.049^A	0.072^D	9.4×10^{-6} ^A	3.11^A	3.28^A
Benzo(a)pyrene	50-32-8	252^C	5.8×10^{-8} ^B	0.050^D	5.8×10^{-6} ^D	5.59^E	5.98^B

Chemical	CAS Number	SF_o, kg-day/mg	SF_i, kg-day/mg	RfD_o, mg/kg-day	RfD_i, mg/kg-day
Benzene	71-43-2	0.029^F	0.029^F	...	...
Toluene	108-88-3	...	...	0.2^F	0.11^F
Ethyl benzene	100-41-4	...	...	0.1^F	0.29^F
Mixed xylenes	1330-20-7	...	...	2.0^F	2.0^F
Naphthalene	91-20-3	...	...	0.004^G	0.004^G
Benzo(a)pyrene	50-32-8	7.3^F	6.1^F	...	...

^A See Ref (34).
^B See Ref (35).
^C See Ref (7).
^D Diffusion coefficient calculated using the method of Fuller, Schettler, and Giddings, from Ref (11).
^E Calculated from K_{ow}/K_{oc} correlation: log(K_{oc}) = 0.937 log(K_{ow}) − 0.006, from Ref (11).
^F See Ref (2).
^G See Ref (3).