Factors of Safety

1 Unit = 60 Mil Liner (1/2)

W/ F.S. 2 under TSCA... 30 Mil

Minimum

Table of Equivalencies

2 TSCA 30 Mil = 1 Normal Liner Unit @ 60 Mil
1 Liner @ 60 Mil = 1 bentomat (2/3)
(NLU) = 3' Clay @ Spec (9/1)
= 4 Clay Natural (5)
= 3' Natural clay (6)
= Leak Detector (7)
= Keyway (8)

Line of Contam

Displacement Bias

(4.72 \div 4 = 4/\text{TLU})

Listed Barrier Items:

4 TLU's
2 Liner @ 60 Mil spp 122nd
1 bentomat
4/\text{TLU}

13 1/2 TLU's

U.S. EPA Region 5

Barrier Units...

Factor of Safety Calc.

1/16

S. Johnson 9/24/08
EC Executive Summary

Oct 2007

Mission

Sec P - Ex-1 Dug?
P - Ex2 Dug?

in Los 2005-070

Stability
Static \( P_S \geq 1.5 \)
Seismic \( S.S \geq 1.5 \)

US.EPA R-9
Barrier Analysis
Clinton, L. F., Ill.
SMI 10/18/08
Factor of Safety to Mahomet Aquifer

Worksheet for Pathways

Conservative Chem. Assume 4 TLU's
Membrane: F_s. = 100 x 4 TLU = 4 TLU
Liner/Pad: F_s. < 10 x 2 < 1 TLU

746 x 4 TLU = 2984 TLU

Wells: 15-3 3000' and WSW of Expansion
Rec. App. VII App. 6 Phil. 314-13
L =

Want this Pathway 0-8'
but have no data

Solution: Use A-A' layers
Basal - 14'
break up Pathway into 3 segments A, B, C

A: Membrane Pinhole Tech, L 1
B: Soils Mechanics
C: Vertical L, 3
D: Horizontal L, 4

POC: 45'
TD: 413'

Mahomet 10/21 10/18
29
Thickness of Compound Clay Pans

186' from base of liner
160' from lowest sump
346

173' Avg. thickness
Double clay pan composite

quoted by PDE

170' ok to use

3' difference...not significant.

170' thick stacked clay pan thickness
ok to use

Magnification by pix

\[ \frac{9x}{10'} = \frac{87}{87} \]

Assumption
reduce volume of aquifer
by neglecting
to increase impact of
chemical constituents.

Mahomet aq.

90' pix subtract

Thickness of
Mahomet Aquifer

664' from base of liner
487 CSR-1 (Conc-G4)

186' to top of Mahomet

648' el lowest sump G3
488' Top of Mahomet
160' to top of Mahomet

Draft worksheet

U.S. Env.Prot. Agency Reg 5

Mahomet Aquifer Depth Calculation

S.M. Johnson 10/1/80
<table>
<thead>
<tr>
<th>Assumption number</th>
<th>TSCA Linear Equivalent</th>
<th>Chemical of Concern (Surrogate)</th>
<th>Surrogate</th>
<th>Chemical</th>
<th>Assumption (Liberal)</th>
<th>Assumption (Conservative)</th>
<th>Frequency of Detection - Leachate FOIA's (ARD &amp; Grassy)</th>
<th>See Step 5 and Rs. Cale. for L. Red. T. Ill. Ed. A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 TLU</td>
<td>V. Conservative</td>
<td>Water</td>
<td>PCB</td>
<td>V. frequent</td>
<td>V. infrequent</td>
<td>Acidic</td>
<td>Migration: -1 ? Organic Solvents Penetrated Clay capillary ? NAPL: -1 ? Benzene May Move contrary to hydraulic gradient.. if SpGr &lt; 1 and would sink in East Artesian conditions Use 40CFR 761.19(b)(6)(X) 0.5 ppb PCB i.e 0.5 μg/L</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Substance W: @ 1 ppm</td>
<td>100x</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chemical of Concern</td>
<td>Selection of Standard for Residual Fs.</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Surrogate: Water</td>
<td>&quot;Applicable GW. Qual Std.&quot; (AGAS) = Lowest Fs. Per &gt;&gt; State PDC ?? Use Observed MDL/AGAS required</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chemical of Concern: Benzene</td>
<td>Lowest Standard (2.0 μg/L)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Substances: Acenaphthene 2.0 μg/L</td>
<td>2.69 x 10^-7 μg/L</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Substances: Phe 0.5 μg/L</td>
<td>2.69 x 10^-7 μg/L</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Substances: TCE 0.5 μg/L</td>
<td>2.69 x 10^-7 μg/L</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Substances: Xylene 0.5 μg/L</td>
<td>2.69 x 10^-7 μg/L</td>
</tr>
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<td></td>
<td></td>
<td>Substance W: @ 1 ppm</td>
<td>100x</td>
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<td>2.69 x 10^-7 μg/L</td>
</tr>
</tbody>
</table>

Note: (C = Concentration)

Model = PCB's Calc's

GIA of 96.08
Chemical Assumption Table (cont.)

Flow model notes: L. Redow

1. DLV 100/150 Zone

DTLV 100/150 Zone

2. Distance to Point of Compliance

3. Mathematical Stability

4. Assumption

5. Conservative

6. Assumption

7. Assumption

8. Assumption

9. Assumption

10. Assumption

11. Assumption

12. Assumption

13. Assumption

14. Assumption

Chemical input concentrations:

1. 10 ppm 43 ppm chemical

2. 1 ppm 1 ppm Toluene 0.26 ppm (0.26 ppm)

3. 15 ppm Naphthalene 0.43 ppm 0.43 ppm

Steps a-c-d:

1. Order of Mag. = 1 TLU

2. Order of Mag. = 2 TLUs

Use lowest value depending on...
Chemical Assumptions Table (Cont.)

Flow Model Notes: "Organic Soil"

Realistic

\[ k = 5.62 \times 10^{-3} \text{ S. eff gradient} \]

\[ k = 2.6 \times 10^{-5} \text{ cm/s (8.2 m/A)} \]

\[ V = 0.046 \text{ m/y} \]

Adsorption inorganic unit if not used... not sure if THIS should be increased.
Worksheet: Factor of Safety Calc for PCB in groundwater

A) Lower Radnor Till Sand

<table>
<thead>
<tr>
<th>Conservative</th>
<th>Typical Detection Level</th>
<th>Liberal</th>
</tr>
</thead>
<tbody>
<tr>
<td>WDI: 3 yrs data</td>
<td>7/23y detection or ~3% @ 1 ppb</td>
<td></td>
</tr>
<tr>
<td>Grayson Mt: 7 yrs data</td>
<td>2/1525 detections ~0.1% @ 1 ppb</td>
<td></td>
</tr>
<tr>
<td>Best Fit... Expected PCB's @ .5 ppb threshold</td>
<td>n 1% hits...</td>
<td></td>
</tr>
<tr>
<td>99% of time leachate is clean</td>
<td>1% of time leachate has PCB</td>
<td></td>
</tr>
</tbody>
</table>

For continuous flow modelling of PCB use:

\[ a = \frac{1}{7} \text{% of time PCB is } \leq 1 \text{ ppb} \]

\[ b = \boxed{\text{Reported } 5.6 \text{ ppb Continuous } \text{(Table 212-316-17)}} \]

What is difference? F.S. between A and B

If 1% of hits are 1 ppb and reported value is

5.6 ppb 106% of time

Then F.S. frequency is 100 y

F.S. concentration is \( 5.6x \)

\[ \varepsilon_{FS} = 560 \times \frac{2}{1000} \]

\[ \frac{917}{x} \]
Favorability of hole location:

Conclusions:
- Base area probability
  - 9/400 of a hole being "critical"

Over time, no good way to guess... Suppose it's based on liner degradation and 500 yr life under oxidizing cond.

2 liners = 1000 yrs to hole 1 ft^2 hole in each.

Time frame: Calc. Assume failure in per year

1) \( \frac{9}{400} = 0.0225 = 2.25\% \) risk / yr

2) \( \frac{2.25\%}{\frac{1}{100}} = 0.000225 = \frac{0.00225}{1000} \)

3) or 1000 yrs... 0.000225/1000 yr

Hole does not influence leakage

\( \sum 1/n + v_3 + \ldots \) Area of risk = 9

\( \frac{9}{20} \) th's of H.F. in at risk

at risk... 9 areas x 200 = 400

400 at risk... \( \frac{\frac{1}{400}}{400} \) chance of a hole per area

U.S. EPA P-5

Probability illustrations
- Liner failure creating a release...

File: Johnson 9/29/85
A) Lower Radnor fill - cont. regarding item 5) - expanding

\[ \text{Chem. } 4.5) \quad 19\% @ 1 \text{ ppb} \quad \frac{560 \times}{20 \times} \quad 100\% @ 5.6 \text{ ppb} \quad \frac{20 \times}{10 \times} \quad 100 \text{ ppb} \quad \frac{1000 \text{ ppb PCB}}{1.0 \text{ mg/L}} \quad \frac{GIA}{\text{ITL~U}} \quad \frac{\text{GI}}{\text{Input Assumptions}} \]

\[ \text{ETLU's} = 5 \]

\[ q = \frac{0.5 \text{ mg/L Ren}}{1.34 \times 10^{-2} \text{ mg/L Predicted}} \]

\[ F.S. = 3.7x \]

GIA Chemical Assumptions Combined w/ TSCA Physical Barriers

- 1 ppb PCB h.t.s 1% of time in leachate to 700 ppb Assumed continuous

Chem. - Chemistry

9 TLU's (assumed for GIA input)

Physical - Membrane

5 TLU's (assumed for GIA input)

Layer 1: 1 TLU

Layer 2: 1 TLU

Layer 3: 4.2 TLU's (Base) Geologic Unit (Traskilwy/Radnor)

Layer 4: Aquifer

\[ K_e \quad 2 \times 10^{-7} \text{ cm/s} \]

\[ 100' \text{ is } 1.57 \times 10^2 \text{ cm} \]

\[ 0.00134 \text{ mg/L} \]

Remainin, TLU's ignored Completely

Then: Reserve TLU capacity exists:

1) Chemical

2) Physical Modeling... ignored by GIA analysts.

\[ \frac{7/2}{11/17} \]

Chemical Protection: 2

Draft

Other is c

2x Selection of soils

1x Vertical velocity

1c State adjusted cancels adsorption

3c Ignoring "negative" in model runs cancels G/O localization due to use of R.

\[ \text{Effective velocity due to use of } R \]

Liner: 3b 1991/92
Modelling Notes - 1st draft
Existing Hydrochemical Dilution Model
Partial review 9/4/08

Limit of Radnor

Compliance Model (Driving force assumption?)
Worst-case?
Pathway #1
Lowest Geomembrane Clay Liners
Natural Clay Fill
L. Radnor

Isodilution contours... Fick's law, Flow... no advection
Darcy law, Flow... advection
Mixed flow... advection/diffusion
Concentrations & Area of Square
Measure square to get Concentrations Constituents $C_1, C_2$
$C_1$: Concentration drop & Volume, retardation

Advevtive - retard
diffusive - retard
T=x yrs

Drift

Laplace block
Hydraulic area
Retarded hydraulic
Very retarded
Extremely retarded constituent

12/14/08
9/4/08
Sky view
Pintole effect advection - interfacial flow
Green & Bonnardeau (1964)
In Attenuation Guide, ECN 165

"Poor" contact across
Hydraulic head

V. diffusion, advection
Three layers
Compacted clay fill
Berry clay/Radnor Till
L. Radnor Till & old organic soil

h2. Advection, dispersion dominated by regional C.W. flow. "2"

Dispersion in lower Radnor Till sheet.

Note: The diagram includes a sketch of a soil profile with labeled areas and flow paths.
Faeyer of Sech, 2006, GIA Reanalysis of Protection of Pathways:  

Compliance Pathway B-B given A-A'.

1) Protection of Pathways A-A Bau, given A-A'.
   a) Protection of Pathways & GIA Analysis model by PDC.
   b) Protection of Pathways A-A Bau, given A-A'.

2) Protective of Protection of Pathways A-A Bau, given A-A'.
   a) GIA Concentrations:  
      
      **Note:** For case in entry all conc. X/10 ppm, D/100 ppm + 1 ppm.

3) Next Extrapolate what is known from Pathways A-A Bau to Pathways B-B Bau.

4) Pathway Model 2:  
   - MFG barrier is: sand filter array 2 TLU in place +
   - Soil barriers:  
   - GIA Modelled:  
   - Pathway 1: 2 TLU Bau
   - Pathway 2: 1 TLU Bau
   - Total Soil: 1 TLU Bau

Mahomet Aquifer Protection Model:

Pathway 1: 2 TLU Bau
Pathway 2: 1 TLU Bau
Pathway Total: 1 TLU Bau

Bentonite + HORE: 8 TLU Bau (Ep. 2)
Leak detector

where 1 TLU = 1 order of magnitude change
*where 100x reduction based on PDC calc. for defects: 10/11 (Attachment 14 GIA)

---

**U.S. EPA Region 5 Final Draft...**

Mahomet Aquifer Protection Model:

Plume Model...@125 yrs.
Per PDC GIA Feb. 2008
Data from pp 335-7. Abstract 16
Migrate U.S. Stimulation & Raduno.

Sec. pp 40!
This is where I would like to consult w/ Risk folks

---

### Factor of Safety Table for CWU (PCE-Cell)

<table>
<thead>
<tr>
<th>Model</th>
<th>Power (TLU's)</th>
<th>Background Assumptions</th>
<th>F. S.</th>
<th>F. S.</th>
<th>F. S.</th>
<th>F. S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical/Statistical Model Assumed</td>
<td>9</td>
<td>Remaining Assumptions</td>
<td>(Applied to PDC by Site)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To get from leachate Risk to 30mg/L and ignored in PDC (SRU Model) &quot;Hypothetical&quot;</td>
<td>6</td>
<td>Remaining Barriers 80%</td>
<td>(assuming 30mg/ft³)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSCA Model 7/1/95</td>
<td>5</td>
<td>Barriers Systems:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Layers 80% (40% exposed)</td>
<td>2</td>
<td>Used barriers (80% reduction)</td>
<td>PDC Model 5</td>
<td>5x10^-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater Model Calc's:</td>
<td>12</td>
<td>Extrapolated from PDC-EPA Model Model by PRC.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**F. S. = Factor of Safety with respect to EPA TSCA 760.74 PCDD Rule**

- Unlikely detected at a level ≤ 0.5 μg/L

**Conclusions:**

1. TLU = TSCA / Leach Unit... 30 ml Membrane = 1
2. Corresponds to 10x reduction of leachate
3. (Checks out with PDC's)
4. groundwater Model Calc's...
5. based on work by Ground IN
6. HELP model 3 USEPA/1000/R-99/R-06

**Note:**

- PCB Concentrations in leachate to "Top of Mahomet Aquifer"
- (Not modelled to point of compliance)
- Expected reduction 1/5x10^-6 times release...
- It is 1 x 10^12th of a trillion of a trillion of "Non-detected" PCB in leachate

---

**U.S. EPA Region 5**

**Table of Safety Models**

- Clinton, IL, #3 CWU-PCBCell
- Deloit Co. ILL

**Dr. Johnson**

17/17