

Excavation Emissions Modeling

Assumptions	
Assumed Average MW of NAPL	250 (g/mol)
Assumed NAPL Temperature in Subsurface	15 (°C)
Assumed Time to Remove Pipe	4 (hr)
Assumed Pipe % Filled with NAPL	10%
Assumed Volume of Pipe Headspace	0.74 (m <sup>3</sup> )
Assumed Time to Excavate Volume of Soil	20 (hr)
Assumed NAPL Temperature in Pipe	60 (°C)

Site-Specific	
Pipe Diameter	0.5 (ft)
Pipe Length	150 (ft)
Cut Length (ft)	15 (ft)
Bottom of Excavation Surface Area	5 (ft <sup>2</sup> )
Pile Surface Area (Assume 2.5'x2.5'x4')	4 (m <sup>2</sup> )
Time to Excavate Volume of Soil	360 (s)
Emitting Surface Area (6-minute Segment)	0.11 (m <sup>2</sup> )
Excavation Depth	4 (ft)
Excavation Depth	1.2 (m)
Volume of Soil Moved	0.50 (ft <sup>3</sup> )
Volume of Soil Moved	0.0032 (m <sup>3</sup> )

Constants	
Typical Bulk Density	1.5 (g/cm <sup>3</sup> )
R	8.21E-05 (m <sup>3</sup> atm/K/mol)
R	8.31E-03 (kJ/K/mol)
R	62,361 (mm Hg*cm <sup>3</sup> /mol/K)
Soil Gas to Atmosphere Exchange Constant (Wet Soils)	0.1 (%/100)
Air-Filled Porosity (Wet or Compacted Soils)	0.35
Total Porosity	0.625 Eklund 1997 Default
Gas-Phase Mass Transfer Coefficient	0.15 cm/s Eklund 1997 Default
Time since Start of Excavation of Soil of Interest	60 s Eklund 1997 Default

Site-Specific	
TOC of Soil	0.006 (g OC/g soil)
Excavation Rate	8.85E-06 (m <sup>3</sup> /s)

Analyte	Measured Concentration in NAPL in Pipe (mg/kg)	Average Measured Concentration in Soil (ug/g)	Partial Pressure in the Pipe <sup>2</sup> (atm)	Calculated Concentration in Pipe Headspace (mg/m <sup>3</sup> )	Total Emissions from Pipe (lb)	Partial Pressure in Soil <sup>2</sup> (atm)	Equilibrium Coefficient	Effective Diffusivity in Air (cm <sup>2</sup> /s)	Total Excavation Emissions Potential (lb)	Excavation Emissions <sup>3</sup> (lb)	Total Emission (lb)	RIDEM Annual Minimum Quantity (lb)
Naphthalene	1,930	0.85	2.29E-06	11	1.75E-05	3.20E-09	4.79E-06	4.58E-03	8.90E-06	1.83E-09	1.75E-05	3
Benzene	23.7	0.13	3.49E-05	100	1.62E-04	5.79E-06	3.47E-02	7.23E-03	1.35E-06	1.77E-07	1.62E-04	10
Carbon Tetrachloride	<15.0	0.07	7.03E-06	40	6.44E-05	1.77E-06	4.05E-02	4.91E-03	6.98E-07	8.32E-08	6.44E-05	8
Ethylbenzene	6.9	0.09	9.65E-07	3.7	6.10E-06	2.88E-07	3.41E-03	5.82E-03	9.32E-07	2.97E-08	6.13E-06	9,000
Toluene	45.9	0.28	4.66E-05	157	2.56E-04	2.47E-06	8.01E-03	5.51E-03	2.96E-06	1.51E-07	2.56E-04	3,000
Styrene	39	<50	5.68E-06	22	3.52E-05	5.42E-05	2.23E-03	6.75E-03	2.63E-04	6.88E-06	4.21E-05	3,000
m&p-Xylene <sup>1</sup>	33.9	0.41	5.22E-06	20	3.30E-05	1.08E-06	2.77E-03	2.72E-03	4.30E-06	8.84E-08	3.31E-05	1,000
o-Xylene	15	0.28	1.85E-06	7.2	1.17E-05	5.89E-07	2.21E-03	6.75E-03	2.94E-06	7.64E-08	1.18E-05	

- Notes:
- All constants for m&p-xylene are the average of the individual constants for m-xylene and p-xylene.
  - The Partial Pressure in the Pipe was calculated using Raoult's Law and the Average Measured Concentration in NAPL. The Partial Pressure in Soil was calculated using Raoult's Law and the concentration in NAPL calculated by dividing the Average Measured Concentration in Soil by the TOC of Soil.
  - If the calculated Excavation Emissions exceeds the Total Excavation Emissions Potential, the Total Excavation Emissions Potential was used to calculate the Total Emission.
  - Only detected analytes with RIDEM minimum quantity values are shown. If an analyte was not detected in the soil, but was detected in the NAPL or vice versa, half the RL of the lowest RL was used to calculate the associated emissions.
  - Concentration units are in mg/kg and ug/g, both of which are equal to ppm.
  - MW = molecular weight; atm = atmosphere; kJ = kilojoules; mol = moles; NAPL = non-aqueous phase liquid; ppm = parts per million; mm Hg = millimeter mercury; cm = centimeter; m = meter; g = gram; ug = microgram; ft = feet, lb = pound; s = second; yr = year; hr = hour; < = less than the reporting limit (RL); TOC = total organic carbon.
  - Yellow Highlighting indicates model inputs.
  - Blue Highlighting indicates the calculated Excavation Emissions Rate exceeds the Total Excavation Emissions Rate Potential.
  - Red Highlighting indicates the Emissions Rate exceeds the Rhode Island Department of Environmental Management (RIDEM) Minimum Quantity.