

Estimating VOC Emissions from Vapor Management Systems for Air District Permit Exemption

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Remediation of Chlorinated and Recalcitrant Compounds:
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Background and Objective

- 55-acre site in San Francisco Bay Area formerly occupied by a manufacturing facility
 - Primary COCs: volatile organic compounds (VOCs)
 - Proposed for redevelopment as a shopping mall
- Residual VOCs in soil gas and groundwater posed a vapor intrusion concern; modeling indicated VMS was necessary
- Treadwell & Rollo provided design and construction oversight services for VMS
- Objective: To demonstrate to BAAQMD that this project's passive VMS are exempt from permitting requirements
 - Reduce post-construction regulatory compliance costs

Passive Vapor Management System (VMS)

- Purpose of VMS: Reduction of exposure and risks through preclusion of vapor intrusion to indoor air
- VMS Components:
 - Vapor barrier: Liquid Boot® spray-applied membrane, 60 mils
 - Passive collection and ventilation system: 4-in. dia. perforated PVC pipe in 12-inch gravel layer
 - Collection system directs vapors to risers, which are terminated at the roof level with wind turbines
 - Fresh air makeup is provided via a separate piping system interwoven with the vapor collection system
 - Air flow monitoring will be performed via test ports in the risers

Applicable Regulations

- BAAQMD Regulations 2 (Permits) Rule 5 (New Source Review of Toxic Air Contaminants)
 - Table 2-5-1 lists over 200 compounds
 - If emissions rate for any compound exceeds the Chronic Trigger Level (CTL) (pounds/year), a permit is required
 - 13 listed compounds have been identified at this site:
 - TCE, benzene, 1,1-DCA, 1,1-DCE, ethyl benzene, 1,1,1-TCA, naphthalene, PCE, toluene, vinyl chloride, m-xylene, o-xylene, and p-xylene
 - Needed to estimate annual emissions of each of these 13 compounds from the VMS for all new buildings at the project site

Methodology and Calculations

- Annual emissions rate is a function of constituent *concentration* and *flowrate*.

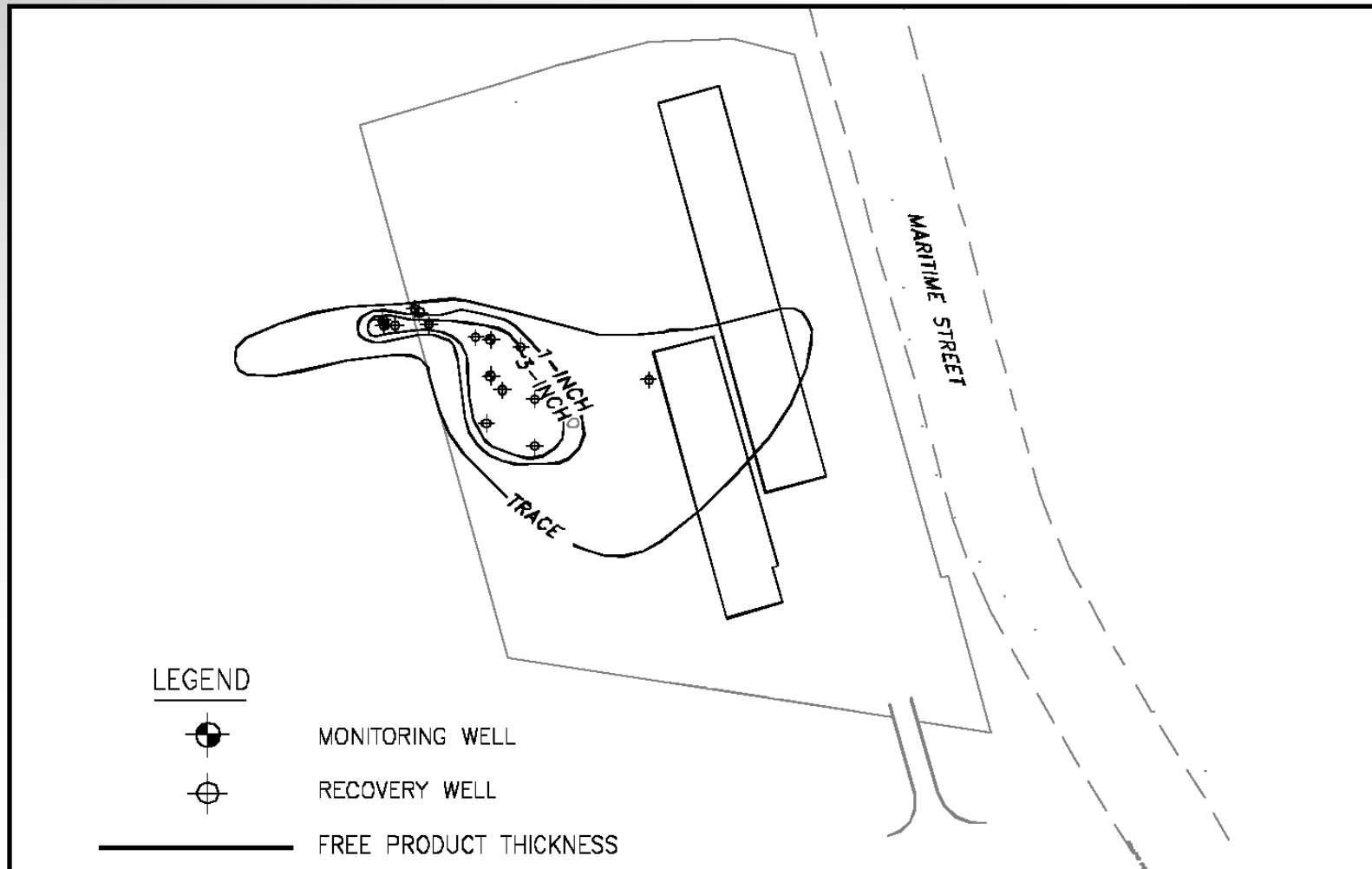
$$\left[\text{Concentration} \left(\frac{\text{mass}}{\text{volume}} \right) \right] \times \left[\text{Flowrate} \left(\frac{\text{volume}}{\text{time}} \right) \right] = \left[\text{Emissions Rate} \left(\frac{\text{mass}}{\text{time}} \right) \right]$$

- Approach to estimating *concentration* of constituents in effluent:
 - Pre-construction soil gas data
 - VMS monitoring data from existing buildings at other properties
 - Calculated the “Constituent Attenuation Factor”
- Approach to estimating *flowrate* of effluent:
 - VMS monitoring data from existing buildings at other properties
 - Calculated the number of Air Exchanges per Day in sub-slab gravel layer

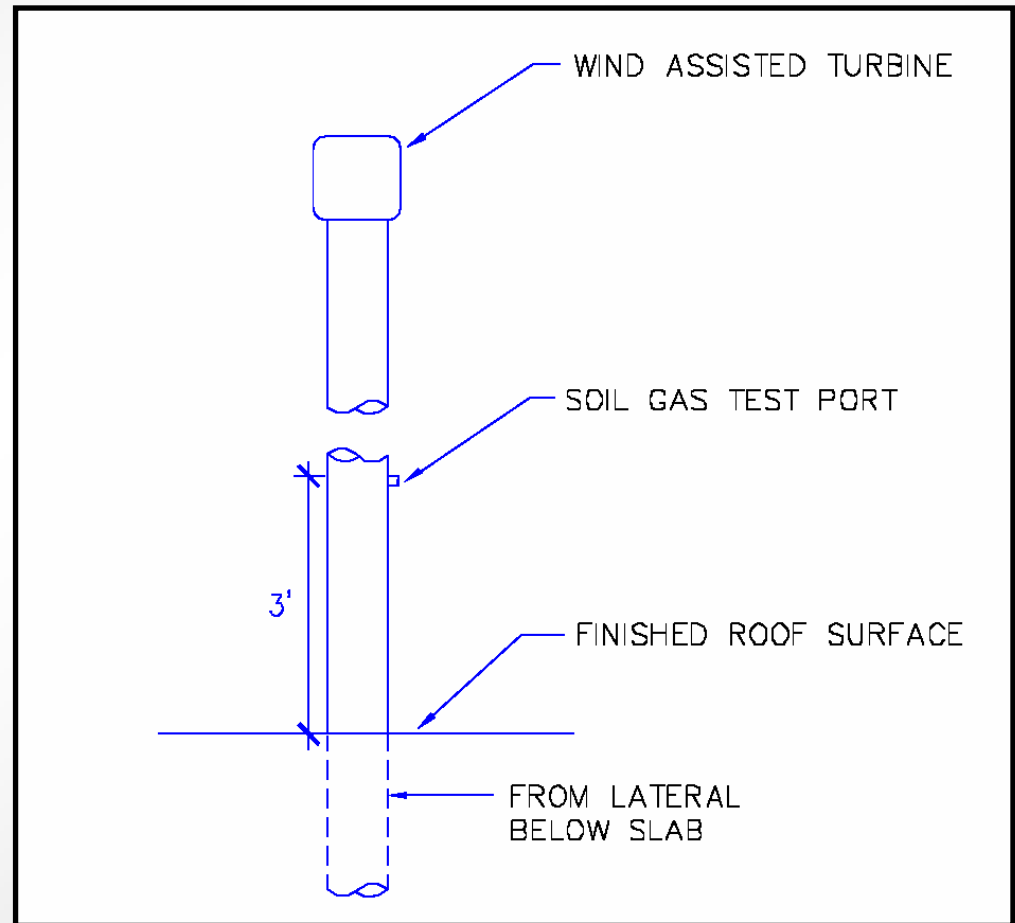
Other Properties – Descriptions

- Port of Oakland's Harbor Facilities Center
 - Two buildings, each with an independent VMS
 - Monitoring data collected via riser test ports: air velocity (ft/min), volumetric air flow (cfm), methane concentration (ppmv), oxygen concentration (% vol.), and vacuum (in. H₂O)
- Retail facility within a shopping mall in San Mateo
 - Single building, with a retrofitted VMS
 - Monitoring data collected via riser test port:
 - Whole air sample: TPHg (ug/L), oxygen (% vol.), carbon dioxide (% vol.), and methane (% vol.)
 - Hand-held instruments: VOCs (ppm), oxygen, and methane

Port of Oakland Harbor Facilities Center



Riser Pipe with Wind Turbine at Roof Level



Calculation of Estimated Effluent Concentration

- Approach: Compare pre-construction soil gas data with post-construction effluent monitoring data and calculate the Constituent Attenuation Factor
- Example: Building 1 at Port of Oakland
 - Five soil gas sampling locations within footprint of building → pre-construction methane concentrations in soil gas
 - Sampling port in effluent riser → post-construction methane concentration in riser
 - Calculate order-of-magnitude reduction in concentration → Constituent Attenuation Factor (CAF)

CAF Calculation – Building 1

Sample ID	Methane Concentration in Soil Gas (ppm)	Methane Concentration in Effluent Riser * (ppm)	Orders-of-Magnitude Reduction in Concentration (CAF)
MFC-31	380,000		
MFC-33	170,000		
MFC-35	190,000		
MFC-38	1,700		
MFC-41	2.1		
Maximum:	380,000	940	3
Average:	148,340	355	3

* From 19 monitoring events.

CAF Calculation – Summary

Building	Constituent Concentration in Soil Gas (ppm)	Constituent Concentration in Effluent Riser (ppm)	Orders-of-Magnitude Reduction in Concentration (CAF)
		<u>Methane</u>	
Port of Oakland – Building 1	Maximum: 380,000	940	3
	Average: 148,340	355	3
Port of Oakland – Building 2	Maximum: 780,000	20	4
	Average: 305,954	1	5
San Mateo – Retail Facility	Maximum: 130,000	2	5
	Average: 45,000	2	4
		<u>TPHg</u>	
San Mateo – Retail Facility	Maximum: 97,000	940	2
	Average: 51,500	355	2

Value used in emissions calculations: 3

Calculation of Estimated Effluent Flowrate

- Approach: Calculate air exchange rate for building
 - Air exchange rate is a function of effluent flowrate (cfm) through riser and volume of sub-slab gravel layer
 - Gravel layer volume (cf) = Building area (sf) x Gravel layer thickness (ft)
- Example: Building 1 at Port of Oakland
 - Volumetric flowrate (cfm) had been collected on 19 occasions
 - Building area (footprint) = 14,870 sf
 - Gravel layer thickness = 6 in = 0.5 ft
 - Calculate number of air exchanges per day

Flowrate Calculation - Summary

Building	Gravel Layer Volume (cubic feet)	Volumetric Airflow (cubic feet per minute (cfm))	Air Exchanges per Day
Port of Oakland – Building 1	29,749 sf x 0.5 ft = 14,879 cf	Maximum: 24.5 Minimum: 4.9 Average: 14.3	2.4 0.5 1.4
Port of Oakland – Building 2	23,550 sf x 0.5 ft = 11,775 cf	Maximum: 30.2 Minimum: 5.6 Average: 11.7	3.7 0.7 1.4
San Mateo, Retail Facility	4,500 sf x 0.5 ft = 2,250 cf	Maximum: 1.7 Minimum: 0.0 Average: 0.6	1.1 0.0 0.4

Value used in emissions calculations: 1.5

Calculation of Estimated VOC Emissions

- Approach:
 - Use pre-construction soil gas data with Constituent Attenuation Factor (3) to estimate post-construction effluent concentration
 - Use building areas and gravel layer thickness with Air Exchange Rate (1.5) to estimate effluent flowrate
 - Calculate emissions rate (pounds per year)

$$\left[\text{Concentration} \left(\frac{\text{mass}}{\text{volume}} \right) \right] \times \left[\text{Flowrate} \left(\frac{\text{volume}}{\text{time}} \right) \right] = \left[\text{Emissions Rate} \left(\frac{\text{mass}}{\text{time}} \right) \right]$$

Example Calculation: Estimated TCE Emissions

- Average TCE concentration in soil gas (all buildings): 12.682 ug/L
- Constituent Attenuation Factor: 3 (dimensionless)
- Total building area: 646,000 sf
- Gravel layer thickness: 1 ft
- Air Exchange Rate: 1.5 exchanges/day

$$\frac{12.682 \mu\text{g}}{\text{L}} \times (1 \times 10^{-3}) \times \frac{646,000 \text{ ft}^3}{\text{day}} \times 1.5 \times \frac{28.31 \text{ L}}{\text{ft}^3} \times \frac{365 \text{ days}}{\text{year}} \times \frac{1 \times 10^{-9} \text{ kg}}{\mu\text{g}} \times \frac{2.20 \text{ lbs}}{\text{kg}} = 0.2794 \frac{\text{lbs}}{\text{year}}$$

- Estimated emissions rate is below BAAQMD CTL of 91 lbs/year

Emissions Calculations – Summary

Constituent	Estimated Emissions Rate (pounds/year)	BAAQMD Chronic Trigger Level (CTL) (pounds/year)	Percentage of CTL (%)
TCE	0.2794	91	0.31%
Benzene	0.0008	6.4	0.01%
1,1-DCA	0.0008	110	0.00%
1,1-DCE	0.0019	2,700	0.00%
Ethyl Benzene	0.0013	77,000	0.00%
1,1,1-TCA	0.0038	39,000	0.00%
Naphthalene	0.0042	5.3	0.08%
PCE	0.0216	30	0.07%
Toluene	0.0029	12,000	0.00%
Vinyl Chloride	0.0005	2.4	0.02%
m-xylene	0.0030	27,000	0.00%
o-xylene	0.0013	27,000	0.00%
p-xylene	0.0030	27,000	0.00%

Sensitivity Analysis

Description	Average TCE Concentration (ug/L)	Air Exchanges per Day	CAF	Estimated Emissions Rate (pounds/year)
Nominal Values	12.682	1.5	3	0.2794
“Low” Air Exchange Rate	12.682	1.0	3	0.1862
“High” Air Exchange Rate	12.682	4.0	3	0.7450
“Low” CAF	12.682	1.5	5	0.0028
“High” CAF	12.682	1.5	2	2.794

In all cases, Emissions Rate is below CTL for TCE of 91 pounds/year.

Next Step: Post-Construction Monitoring Program

- Post-construction monitoring program is anticipated to begin in June 2008
 - Required by RWQCB (not by BAAQMD), per Risk Management Plan
 - 8 monitoring periods over first 12 months
- Whole-air samples will be collected from each effluent riser and analyzed for VOCs
- Parameters monitored at test ports with hand-held instruments:
 - Air velocity (ft/min)
 - Volumetric air flow (cfm)
 - Vacuum (in. H₂O)
- This data will provide the first opportunity to compare actual emissions rates with estimated rates

Conclusion

- The methodology and results were accepted by BAAQMD
- BAAQMD granted our client a permit exemption
 - Significant savings in long-term regulatory compliance costs
- This methodology will be used by T&R for future projects to pursue air permit exemptions
- Empirically-derived parameters (CAF, Air Exchange Rate) may be revised or refined in the future as performance monitoring data is collected at additional sites

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