Conceptual Site Model for Mercury Impacted Soil and Groundwater as a Tool for Effective Remediation

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Former New Jersey Chemical Manufacturing Company
Manufactured Bactericide and Fungicide (1968-1979)

Raw Materials

• Benzene, Mercuric Oxide and Acetic Acid

Bactericide/Fungicide

• Phenyl Mercuric Acetate: Organomercury compound manufactured by heating benzene and mercuric acetate
Constituents of Concern

- Benzene
- Mercury

Areas of Concern

- Benzene Underground Storage Tanks
- Industrial Wastewater Sewer System
  - Catch Basins
  - Floor Drains
- Air Vents and Ducts

Offsite Impacts
Conceptual Site Model

• Understanding of geologic, hydrogeologic, and geochemical conditions
  ➢ How these impact contaminant fate and transport
• Resulting exposure pathways
  ➢ How the selected remedial approach will minimize risk

*Key to ensuring the selected remedy provides long-term protection of human health and the environment*
Site Geology

- Discontinuous Clay Layers at 12-34 feet bgs
- *Perched Groundwater Zone at 12-15 feet bgs*
  - Depth to Groundwater = 35 feet bgs

Mercury Distribution in Soil
- Concentrations up to 1,000 mg/Kg to 17 feet bgs

Benzene Distribution in Soil
- Lower concentrations than mercury up to 100 mg/Kg at 11-20 feet bgs
- Lower concentrations extend to groundwater

Groundwater
- Significant benzene impacts naturally attenuating
- Minimal mercury impacts
Geologic Cross-Section with Benzene Impacts
Geologic Cross-Section with Mercury Impacts
Mercury Speciation – Soil

• Primarily non-extractable/non-mobile or non-extractable/semi-mobile
• Benzene concentrations intermixed with soils containing mercury did not affect the form of mercury
• Very little methyl mercury detected in soil (less than 0.3% of mercury)
• Separate sequential extraction tests: average of 82% of total mercury was extractable only with nitric acid or aqua regia = low mobility
• Elemental Mercury = vapors
Mercury Species in Soil using EPA Method 3200

Typical Compounds
- HgCl$_2$, Hg(OH)$_2$, Hg(NO$_3$)$_2$, HgSO$_4$, HgO, Hg$^{2+}$ complexes
- CH$_3$HgCl, CH$_3$CH$_2$HgCl
- Hg$_2$Cl$_2$ (major), HgS, HgSe
- Hg$^\circ$ or Hg$^\circ$-M, Hg$^{2+}$ complexes, Hg$_2$Cl$_2$ (minor)

Non-extractable Non-mobile Mercury 68.3%
Extractable Organic Mercury 3.7%
Extractable Inorganic Mercury 1.7%
Non-extractable Semi-mobile Mercury 26.4%
Mercury Speciation – Groundwater

- Most mercury associated with particulates
- Majority detected as labile mercury – low mobility
- Minimal methyl mercury detected in groundwater (0.05 – 3.8% of total Hg)
Under aerobic conditions, \textit{in situ} biological processes reverse the manufactured reaction with conversion to elemental mercury and benzene.
Exposure Pathways
• Direct Contact
• Groundwater
• Vapor Intrusion

Vapor Intrusion Assessment
• Benzene and mercury detected in sub-slab soil gas exceeded screening levels (26 µg/m³ & 66 µg/m³)
• Mercury in indoor air exceeded Rapid Action Level (2 µg/m³)
• Benzene in indoor air exceeded Indoor Air Screening Level (2 µg/m³)
• Sub-slab soil gas exceedances limited to sub-basement
Immediate Environmental Concern (IEC)
Mitigation focused on sub-basement
Interim measure - sealed floor with epoxy coating
Immediate Environmental Concern (IEC)

Engineered System
• Sub-slab depressurization system – sub-basement
• Pilot Study
• Upgraded blower recommended
• No air permit required
Vapor Intrusion Mitigation

- Sub-slab Depressurization System Continuous Operation
- Restricted Access to Sub-basement
- Exhaust Fan Operation
- Quarterly Inspections
- Annual Monitoring in Heating Season (November to March)
- Building Material Impacts
- Annual Reporting
Soil and Groundwater Remediation

Bench-Scale Treatability Studies to Evaluate Mercury Fate

- Air Sparging
- Biosparging
- Oxygen Release Compound
- Chemical Oxidation
- Chemical Stabilization
- Geotechnical Testing

Pre and Post Speciation Testing

- No change in form of mercury
- Mercury vapors detected in off-gas – must be addressed
Soil and Groundwater Remediation

Short-term Pilot Studies
- Bioventing
- Soil Vapor Extraction/Dual Phase Extraction
- Air Sparging
- Biosparging

Pre- and Post-Speciation Testing
- No change in form of mercury
Soil and Groundwater Remediation

Extended Pilot Study/Interim Remedial Action (6-12 months)

- Soil Vapor Extraction
  - Three SVE wells installed in areas of highest benzene impacts
  - VOC and mercury vapor treatment
- Biosparging
  - One biosparging well installed at center of benzene plume – increase DO to enhance aerobic biodegradation
Soil and Groundwater Remediation
Benzene Concentrations in Groundwater Over Time
Wells MW-7R and MW-17R

Benzene concentration (µg/L)

Date


MW-17R MW-7R
Mercury Concentrations in Groundwater Over Time
Well MW-9

Date

Mercury concentration (µg/L)

Jan-93 Jan-95 Jan-97 Jan-99 Jan-01 Jan-03 Jan-05 Jan-07 Jan-09 Jan-11 Jan-13 Jan-15

0 100 200 300 400 500 600 700 800 900 1,000

Mercury
Remedial Action Summary

Benzene
- VI Mitigation
- SVE – soil impacts
- Biosparging – dissolved groundwater impacts

Mercury
- VI Mitigation
- Deed Notice/Capping – direct contact and impact to groundwater
- Monitoring – limited dissolved groundwater impacts
Lessons Learned

Value of Conceptual Site Model

• Complete Understanding of Site Conditions
• Synergistic Effects of Remedial Approaches on Differing Constituents of Concern
• Identify Risks and Pathways
• Remedial Approach Targets Key Risk Pathways and Receptors that Meet Regulatory Requirements