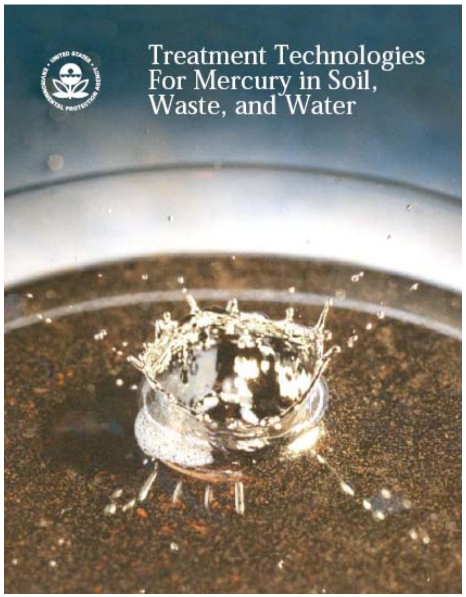
Mercury Treatment Technologies:
“2007 Baseline



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Mercury Summit, 22-23 October 2009

Nashville TN

Background

In 2007, the US Environmental Protection Agency published a topical review report on mercury treatment technologies: *Mercury Treatment Technologies in Soil, Waste and Water* (available at http://clu-in.org/542R07003)

This report:

- identified and described the state of practice for mercury treatment
- for each method, described treatment mechanisms and principles. evaluated past demonstrations/implementations, and presented historical cost experiences.
- described site-specific conditions that would impact technology selection and implementation
- introduced and provided preliminary information on emerging technologies

Mercury Summit -- Treatment Technologies

A variety of exciting and potentially useful mercury remediation technologies have been advanced over the past several years – several of these are being discussed at the DOE EM Mercury Summit

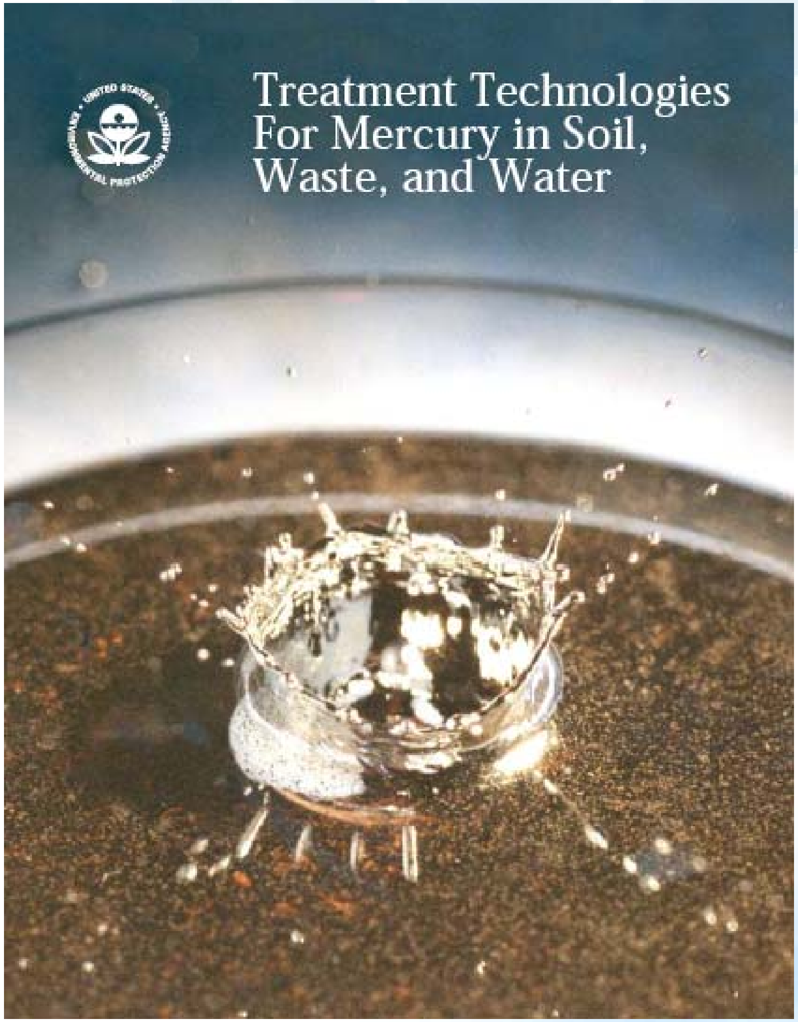
The 2007 EPA Review provides a foundation to assist in placing new treatment technology ideas into context with existing technologies

The objective of this presentation to briefly summarize the 2007 EPA report (target material(s) being treated, treatment concept and mechanism, summary information on technology status, performance, case studies, costs, etc.)

Materials being treated…

For soil and waste there were two broad treatment categories:
a) mercury stabilization, immobilization and/or detoxification
b) mercury removal

For water, all the documented treatment technologies were based on mercury removal



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Soil and Waste

Mercury stabilization, immobilization and/or detoxification

- Solidification and Stabilization (☺)
- Amalgamation (included in solidification)
- Vitrification

Mercury Removal

- Soil Washing and Acid Extraction (☺?)
- Thermal Treatment (☺)

Information outline for each technology

Summary

Technology Description (treatment mechanism(s), waste type, reagents used, maturity, etc.)

Factors Affecting Performance (limitations, strengths)

Case Studies (descriptions, summary tables that describe case study, technology performance and economics)

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Information provided in report (Solidification & Stabilization)

Summary

Solidification and stabilization (S/S) is used to treat elemental mercury and mercury-contaminated soil and sludge. This technology has been implemented at full scale and pilot scale. S/S reduces the mobility of contaminants in the media by physically binding them within a stabilized mass or inducing chemical reactions. Amalgamation, the dissolution of mercury in other metals and solidification to form a non-liquid, semi-solid alloy called an amalgam, is often used for elemental mercury.

Technology Description: S/S reduces the mobility of hazardous substances and contaminants in the environment through both physical and chemical means. It physically binds or encloses contaminants within a stabilized mass and chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms. Amalgamation is typically used to immobilize elemental mercury by dissolving the mercury in another metal to form a semisolid alloy known as an amalgam. The process is a physical immobilization and is often combined with encapsulation to prevent volatization of mercury from the amalgam.

Media Treated:

- Soil
- Sludge
- Other solids
- Liquid wastes
- Industrial waste
- Elemental (liquid) mercury

Information provided in report (2)

Technology Description (continued)

Binders and Reagents Used in S/S of Mercury:

- Cement
- Calcium polysulfide
- Chemically bonded phosphate ceramics (CBPC)
- Phosphate
- Platinum
- Polyester resins
- Polymer beads
- Polysiloxane compounds (silicon hydride and silicon hydroxide)
- pH adjustment agents
- Sodium dithiocarbamate
- Sodium metasilicate
- Sodium sulfide
- Sulfur polymer cement (SPC)

Binders and Reagents used in Amalgamation of Mercury:

- Copper
- Tin
- Nickel
- Zinc

Information provided in report (3)

Factors that Affect S/S Performance and Cost

General factors:

- **pH and redox potential:** The pH and oxidizing or reducing properties of the waste and waste disposal environment may affect the leachability of the treated material because these factors affect the solubility of mercury and its leachability (Refs. 3.2, 3.11).
- **Waste characteristics:** Certain non-mercury compounds in the waste may interact with the chemical reagents used in S/S, thus affecting the performance of the stabilization process. For example, high concentrations of chloride in the waste may render phosphate additive ineffective in stabilizing mercury (Ref. 3.10). Stabilization of dry wastes may be easier and less expensive when compared with S/S of liquid wastes (Ref. 3.13).
- **Particle size distribution:** Fine particulate matter coats the waste particles and weakens the bond between the waste and the binder (Ref. 3.18). Large aggregates in the waste could affect operation of the mixer (Ref. 3.3).
- **Mixing:** Thorough mixing is necessary to ensure that the waste particles are coated with the binder.
- **Type of binder and reagent:** The effectiveness of S/S depends in part on using the right type of binder and reagent. The use of proprietary binders or reagents may be more expensive than non-proprietary binders.
- **Moisture content:** For certain binders to be effective, the waste to be stabilized needs to have a specific moisture content. Therefore, the waste may need to be pretreated to remove the moisture (Ref. 3.2)
- **Equipment scale:** Application of S/S at large scale may reduce the unit costs when compared with a small-scale application.

Information provided in report (4)

Factors specific to S/S of mercury-contaminated media:

- **Oxidation state:** The specific mercury compound or oxidation state of mercury may affect the leachability of the treated material because these factors affect the solubility of mercury. In addition, the presence of more than one species of mercury may complicate the treatment process.
- **Amount of mercury in waste:** A higher concentration of mercury in waste may result in a higher concentration of mercury in the leachate.

Applied research opportunities are found when:

- **An alternative treatment mechanism or approach is conceived**
- **A treatment technology overcomes an identified limitation (or factor affecting treatment)**
- **A treatment technology innovation reduces cost, improves safety, treats waste in place, etc.**

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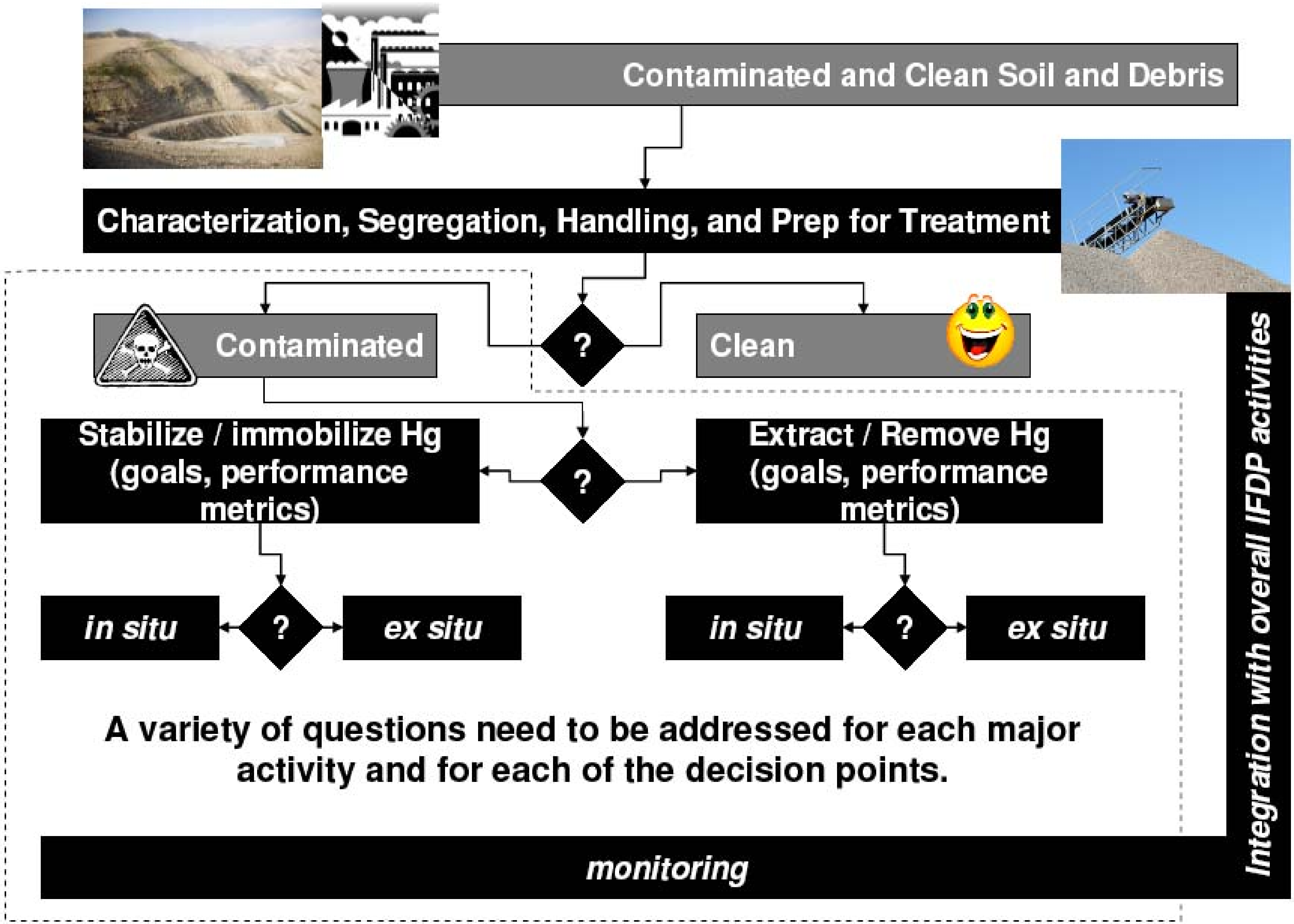
Real-world example with applied research opportunities



Thermal

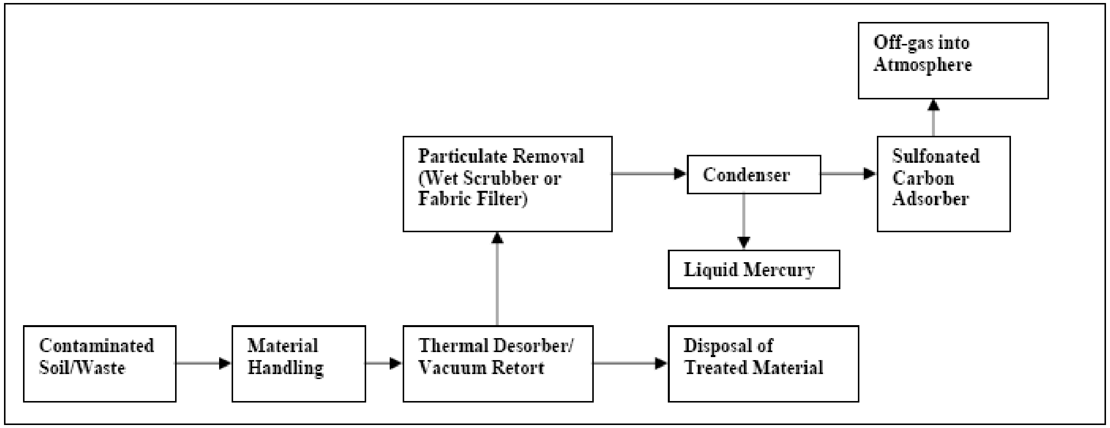
Technology Description: Thermal treatment processes are physical methods to remove mercury from the contaminated medium. Heat is supplied under reduced pressure to the contaminated soil or waste, volatilizing mercury. The off-gas is treated by condensation to generate liquid elemental mercury. The treated medium may be used as fill material or disposed.

Media Treated:

- Soil
- Sludge
- Sediment
- Other solids

Types of Thermal Treatment Systems:

- Rotary kiln – combustion
- Heated screw or auger – hot oil or steam
- Retort – conductive electrical heating or fuel-fired



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Cost summary for Soil and Waste Treatment Technologies

Cost information in the report is sketchy and often with wide range. For Soil and Waste, however, the following summarizes approximate costs:

Solidification / Stabilization --	**$100 per ton (↓)**
Thermal --	**$100 per ton (↑)**
Soil Washing --	**$400 per ton (?)**
Vitrification --	**$500 per ton (?)**

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Water

Mercury Removal

- Precipitation / Coprecipitation (☺)
- Sorption (☺)
- Membrane Filtration
- Biological

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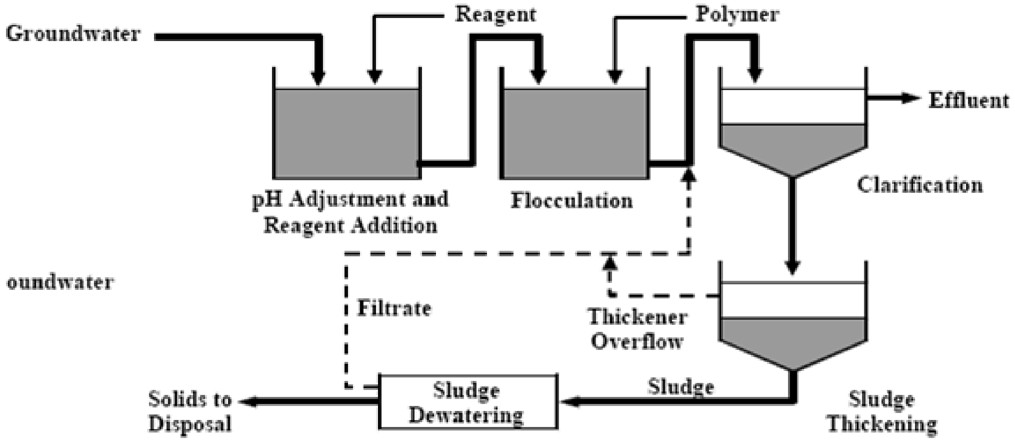
Precipitation / Coprecipitation

Summary

Precipitation/coprecipitation is a full-scale technology used to treat mercury-contaminated groundwater and wastewater. Based on the information collected to prepare this report, this technology typically can reduce mercury concentrations to less than 2 µg/L. However, some of the processes used multiple precipitation steps and additional treatment with other technologies such as activated carbon to reach this level.

Chemicals and Methods Used for Mercury Precipitation/Coprecipitation:

- Ferric salts (for example, ferric chloride), ferric sulfate, or ferric hydroxide
- Alum
- pH adjustment
- Lime softening, limestone, and calcium hydroxide
- Sulfide
- Lignin derivatives



Sorption

Technology Description: In adsorption, solutes (contaminants) concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase. The adsorbent is usually packed into a column. Contaminants are adsorbed as contaminated water is passed through the column. The column must be regenerated or disposed and replaced with new media when adsorption sites become filled.

Media Treated:

- Groundwater
- Drinking water
- Wastewater

Types of Sorbent used to Treat Mercury:

- Granular activated carbon
- Sulfur-impregnated activated carbon
- Lancy filtration

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Membrane filtration

Microfiltration

Ultrafiltration

Nanofiltration

Reverse Osmosis

Biological Treatment

Aerobic pilot scale case study

Combined aerobic – anaerobic fixed bed pilot study (originally a cyanide mine waste treatment system)

Both were for high initial concentrations and treatment to 3 to 30 ug/L (3,000 to 30,000 ng/L)

Innovative Treatments

various nano-technologies (e.g., PNNL/SAMMs)

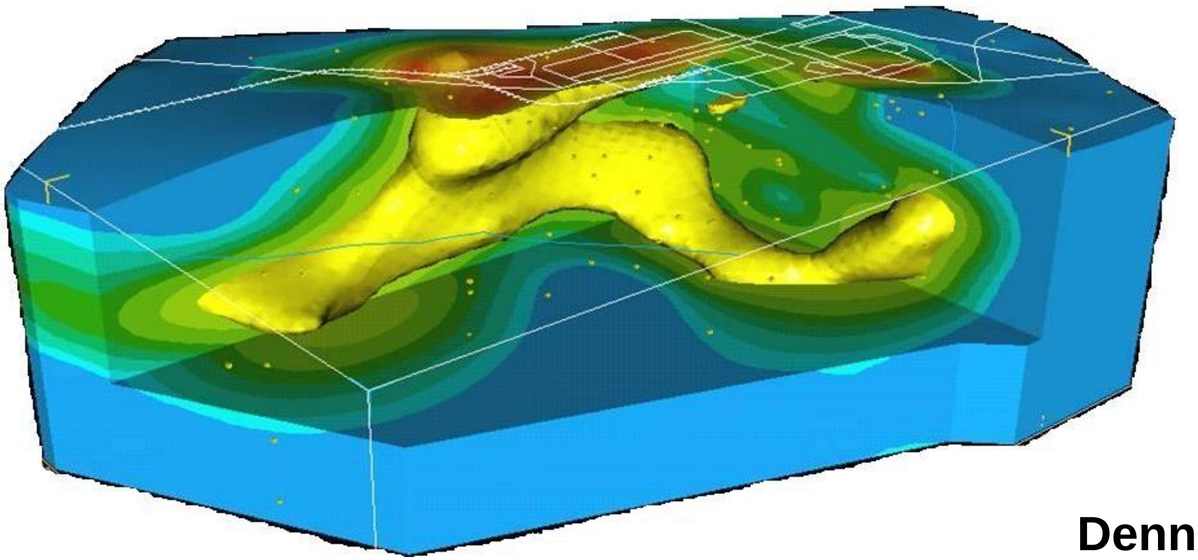
Phytoremediation (University of Georgia)

air stripping for water treatment (ORNL and SRNL)*

in situ thermal desorption (University of Texas)

* case studies for air stripping are described in the following slides and by the next speaker

Removal of Mercury in Groundwater via Chemical Reduction and Air Stripping



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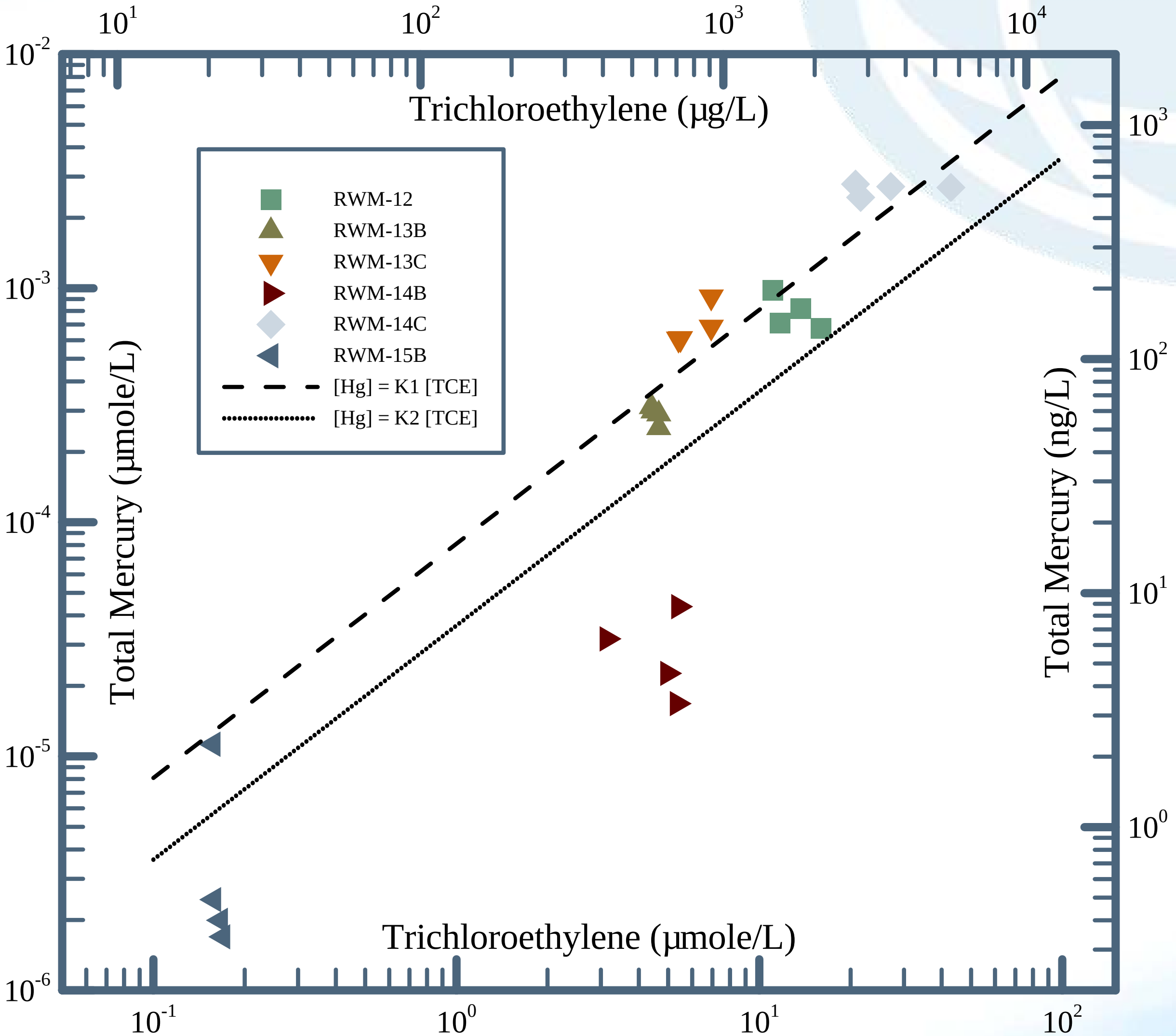
Hg Observations in Pump & Treat Wells



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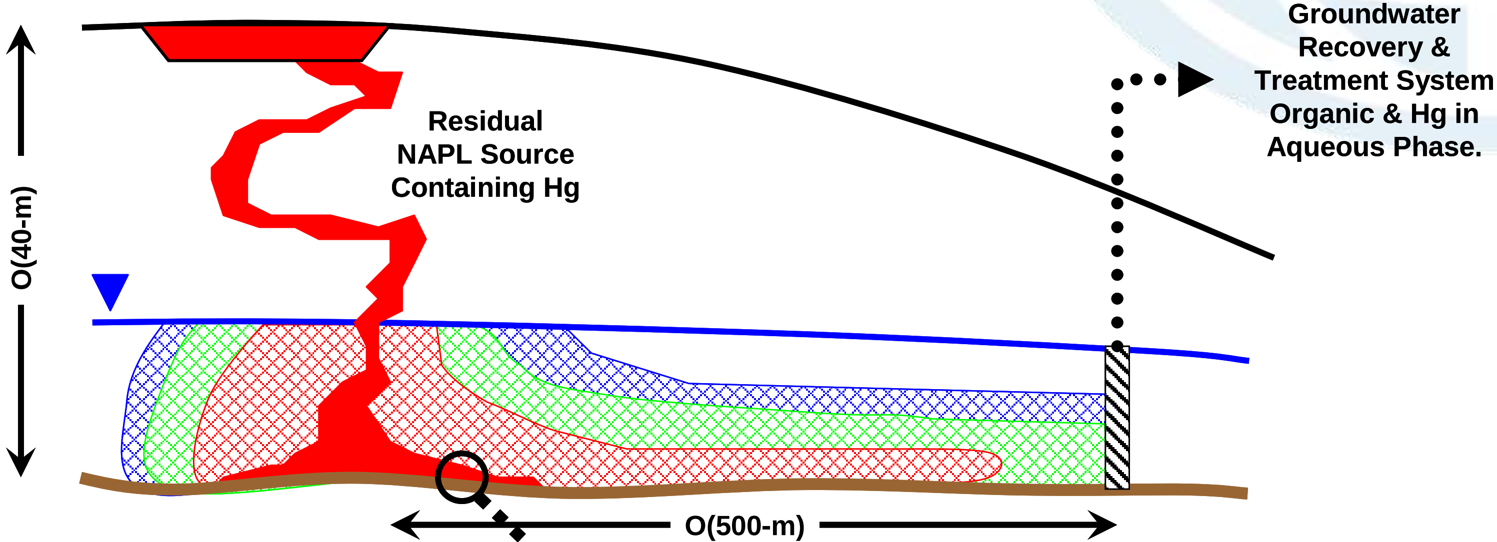
Conceptual Model of Hg Transport with DNAPL

Conceptual Model of Mercury Transport via NAPL at SRS



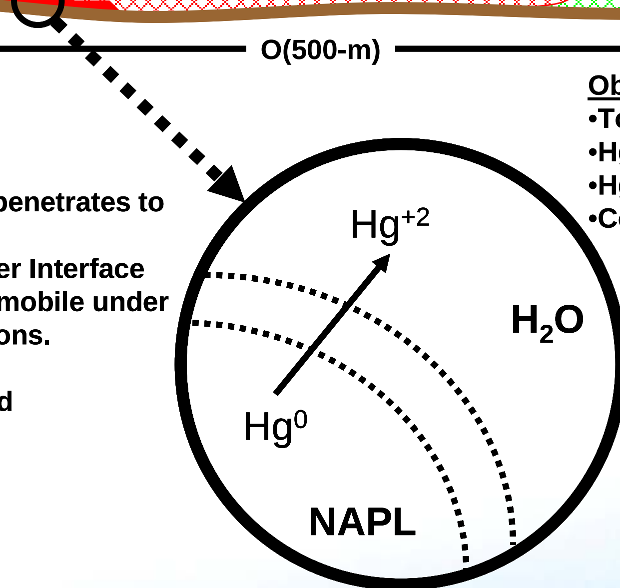
Observations from SRS System:

- Total Hg Correlates with TCE,
- Hg Not Methylated(< 0.02 ng/L),
- Hg not removed via Air Stripping
- Conclude Hg(II) in groundwater.

Hypothesis:

- Hg^0 codisposed in TCE which penetrates to subsurface depths,
- Oxidation occurs at NAPL:Water Interface
- Complexes of oxidized Hg are mobile under specific biogeochemical conditions.

- Need to understand release and transormation process.



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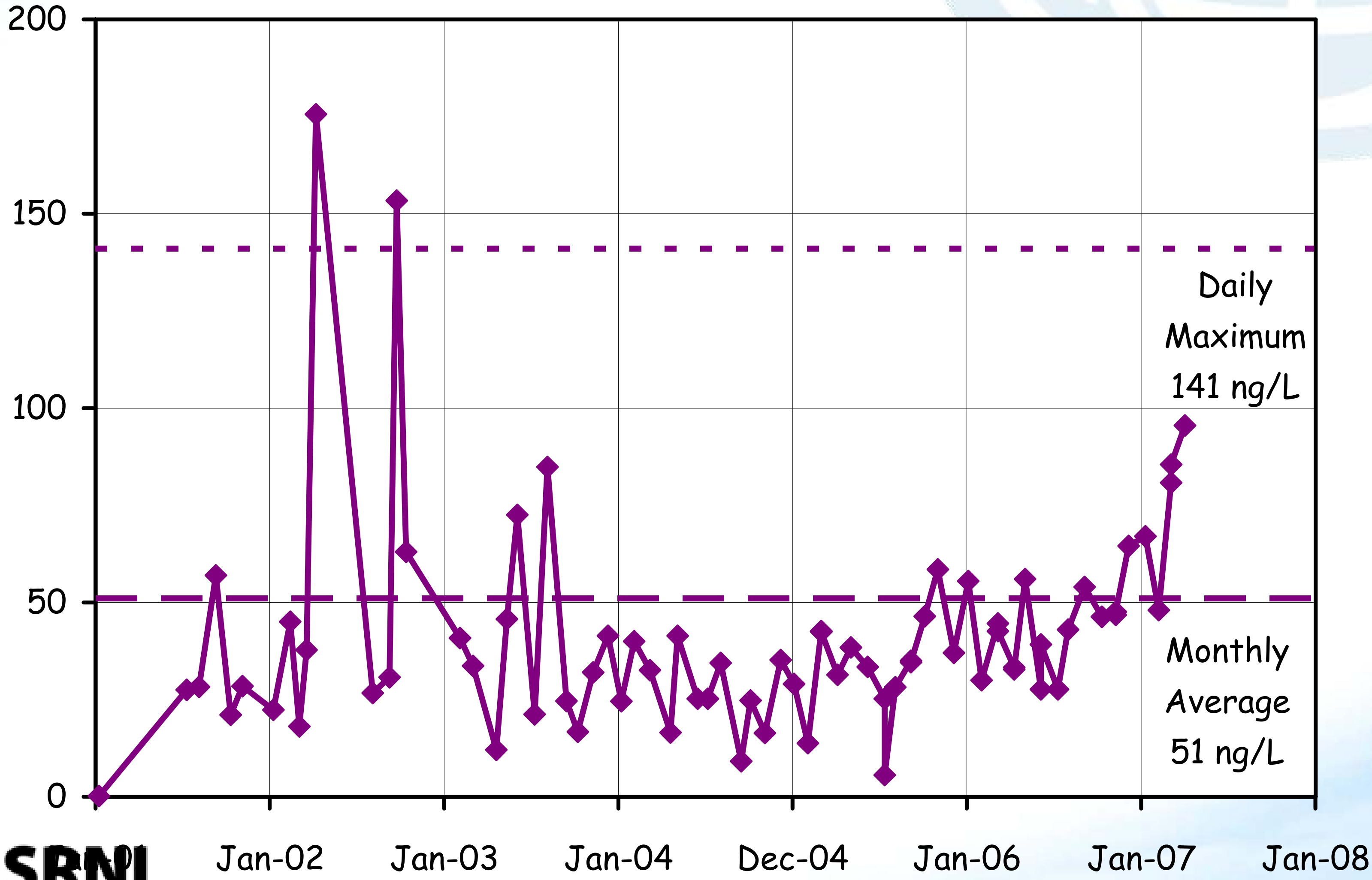
Dec-2007: NPDES Limit for Total Hg



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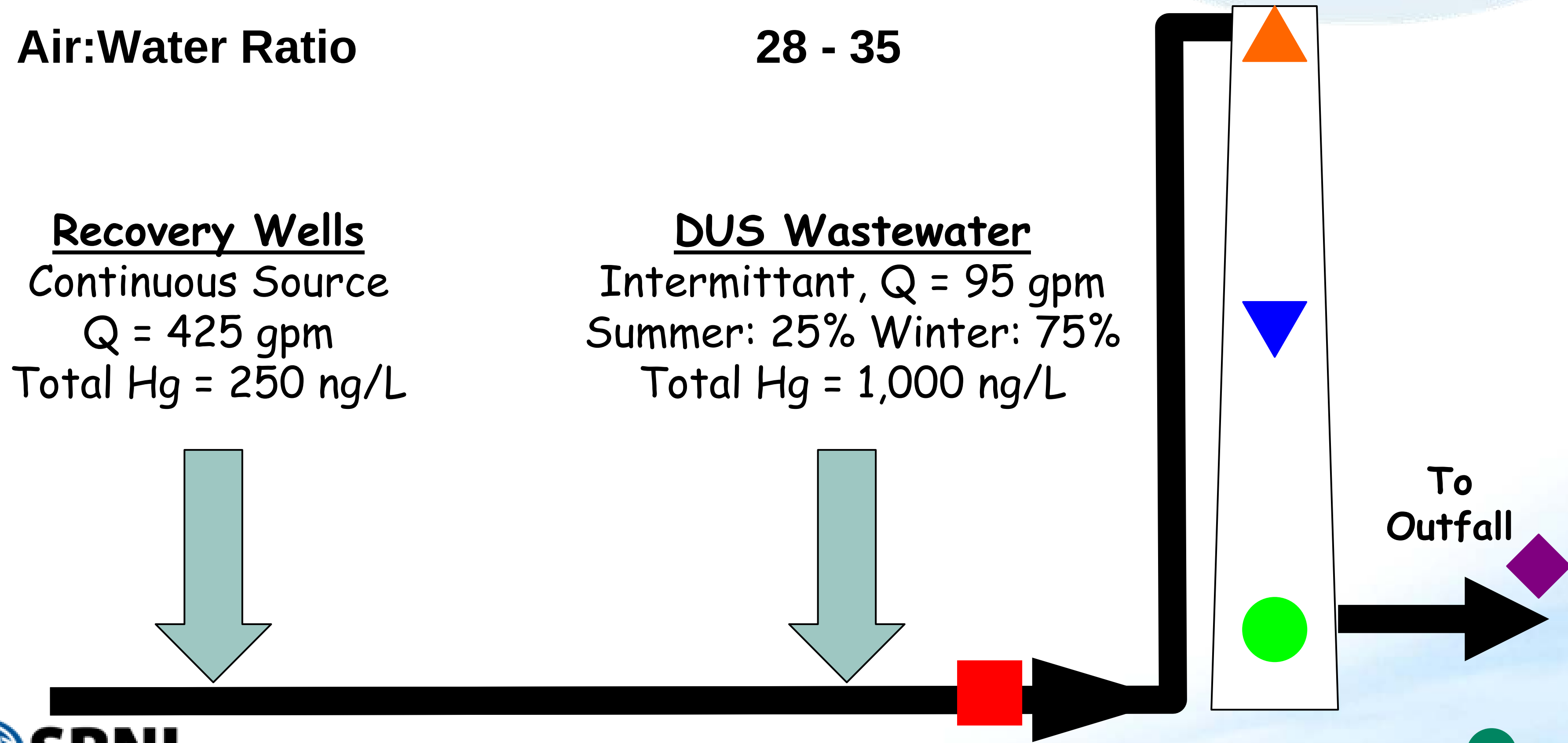
M1 Stripper Design Aspects:

Since 1985 Removed over 500,000 lbs. VOC

Air Flowrate (Q_G):	**2000 cfm**
Water Flowrate (Q_L):	**425-520 gpm**
Air:Water Ratio	**28 - 35**



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Stannous Chloride Treatment:

• EPA Analytical Methods (e.g., 1631) serve as basis:

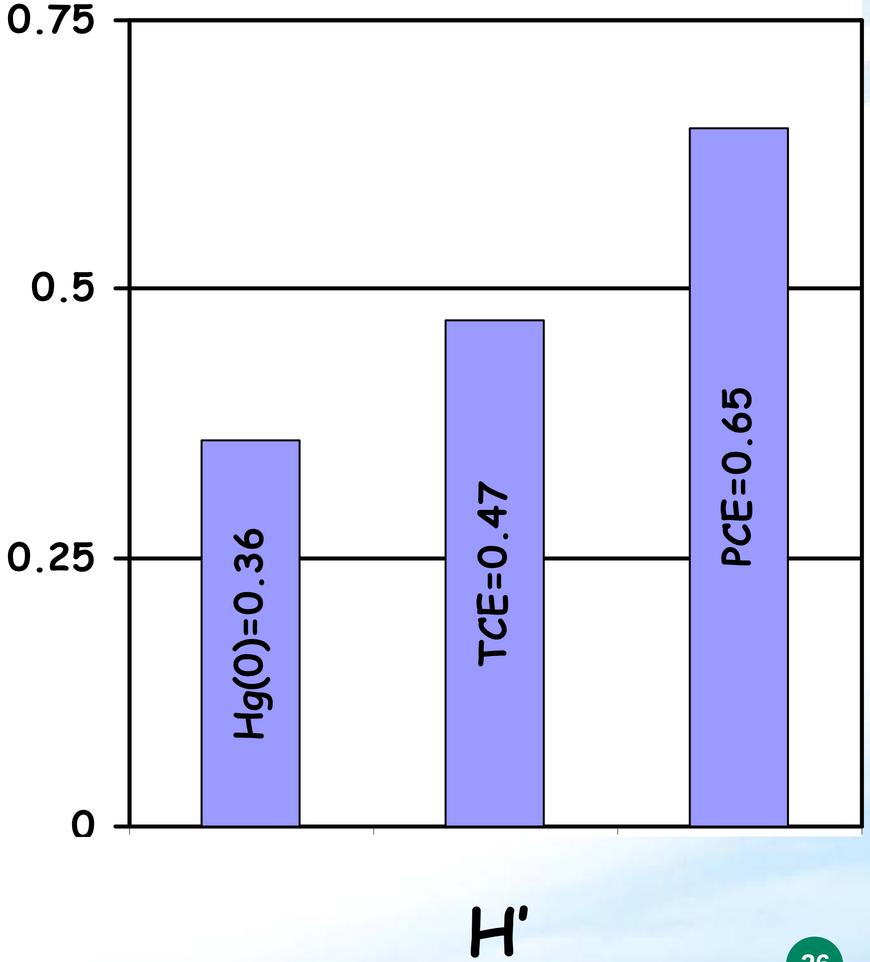
- Reduction of Hg(II) to Hg(0),
- Remove Volatile Hg(0),

• Early Tests at ORNL (Southworth, Turner et al.)

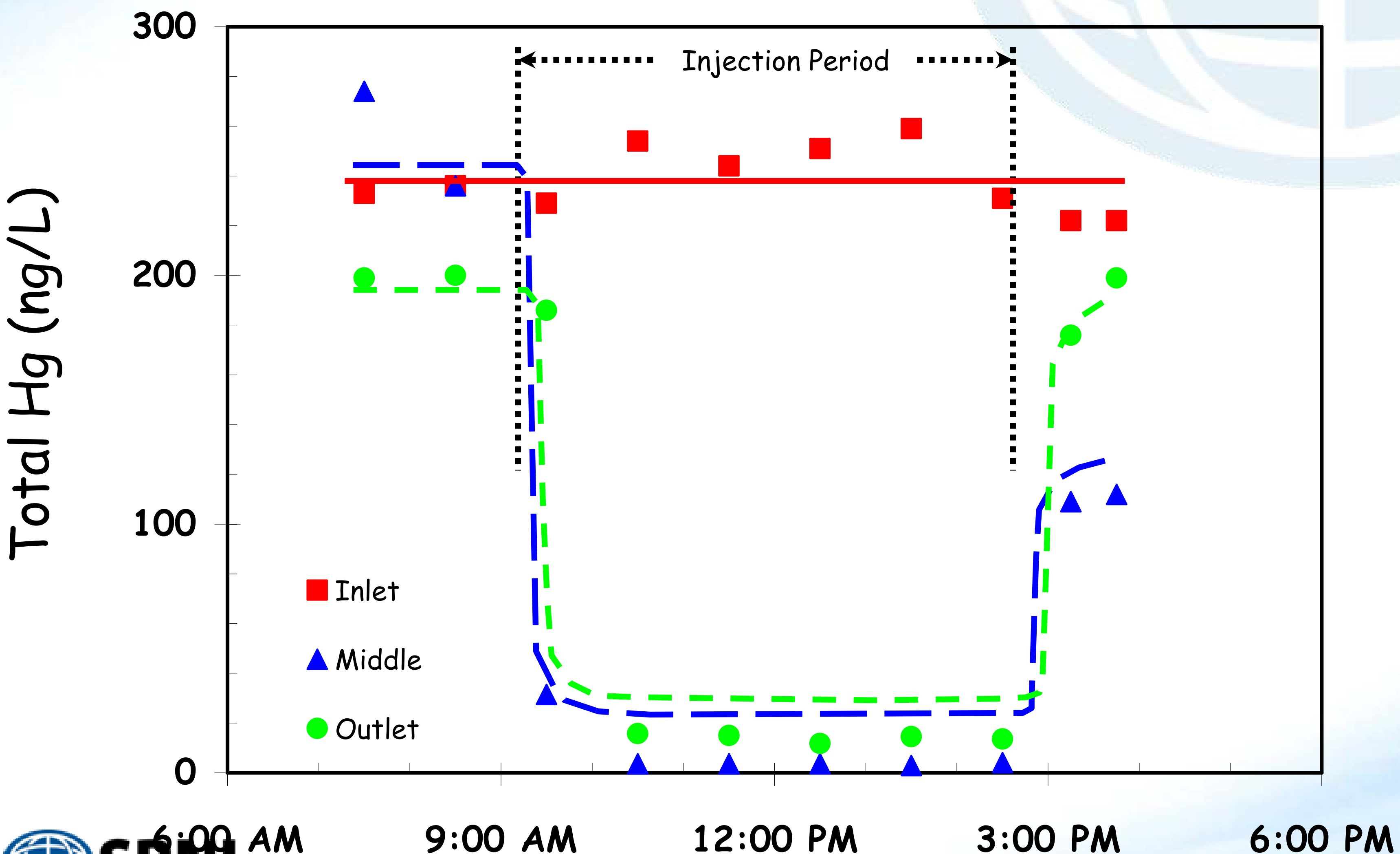
• Full scale pilot test on 150 gpm system (Looney, 2003)

• Hg(II) -> Hg(0) rapid,

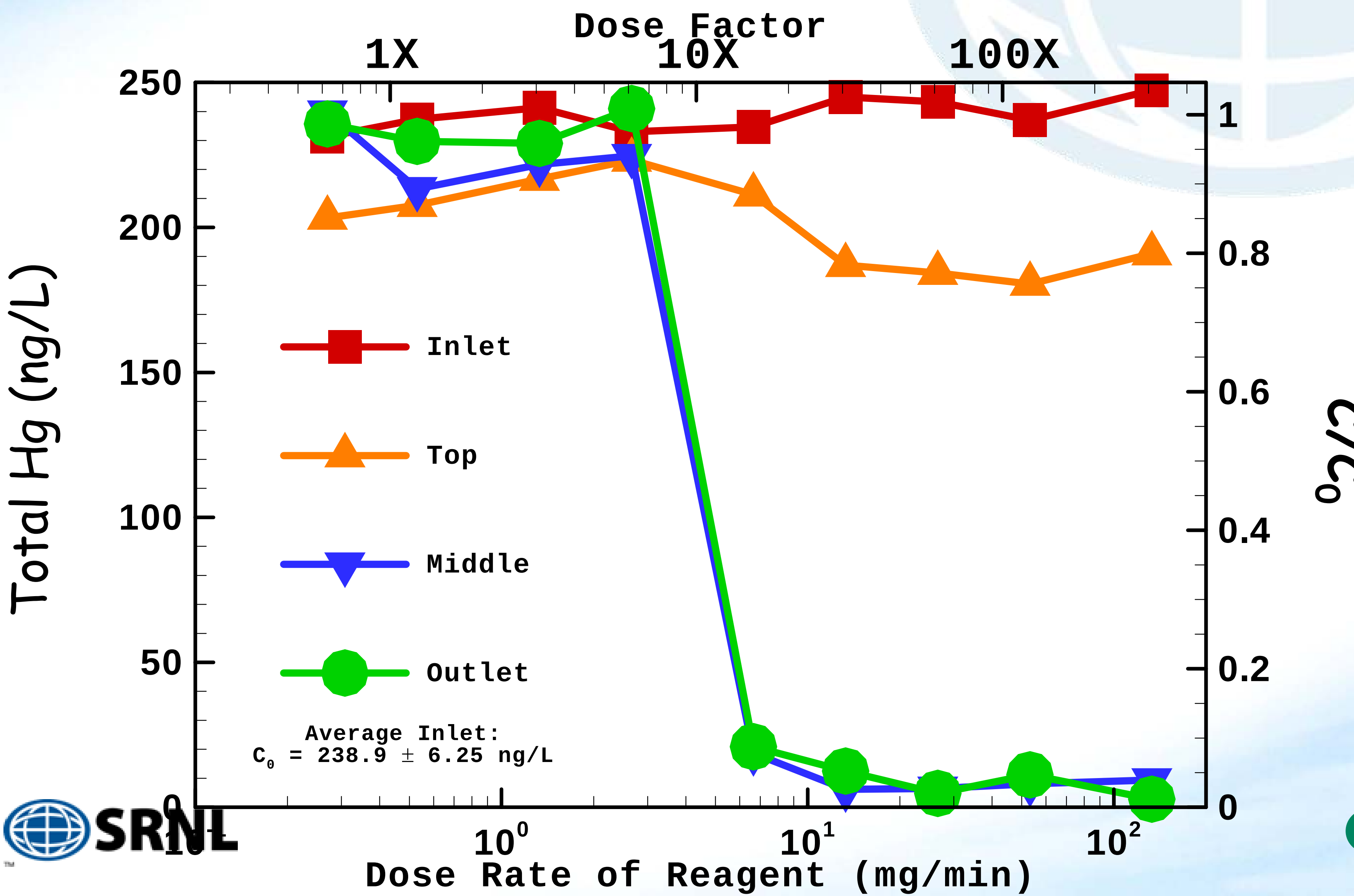
• Removal controlled by sparge, (air:water ratio)



6-Hr Proof of Concept Testing:



Dose-Response Test:



Equipment for full scale deployment:

Reagent Supply

- **10% stannous chloride solution (in 10% HCl)**

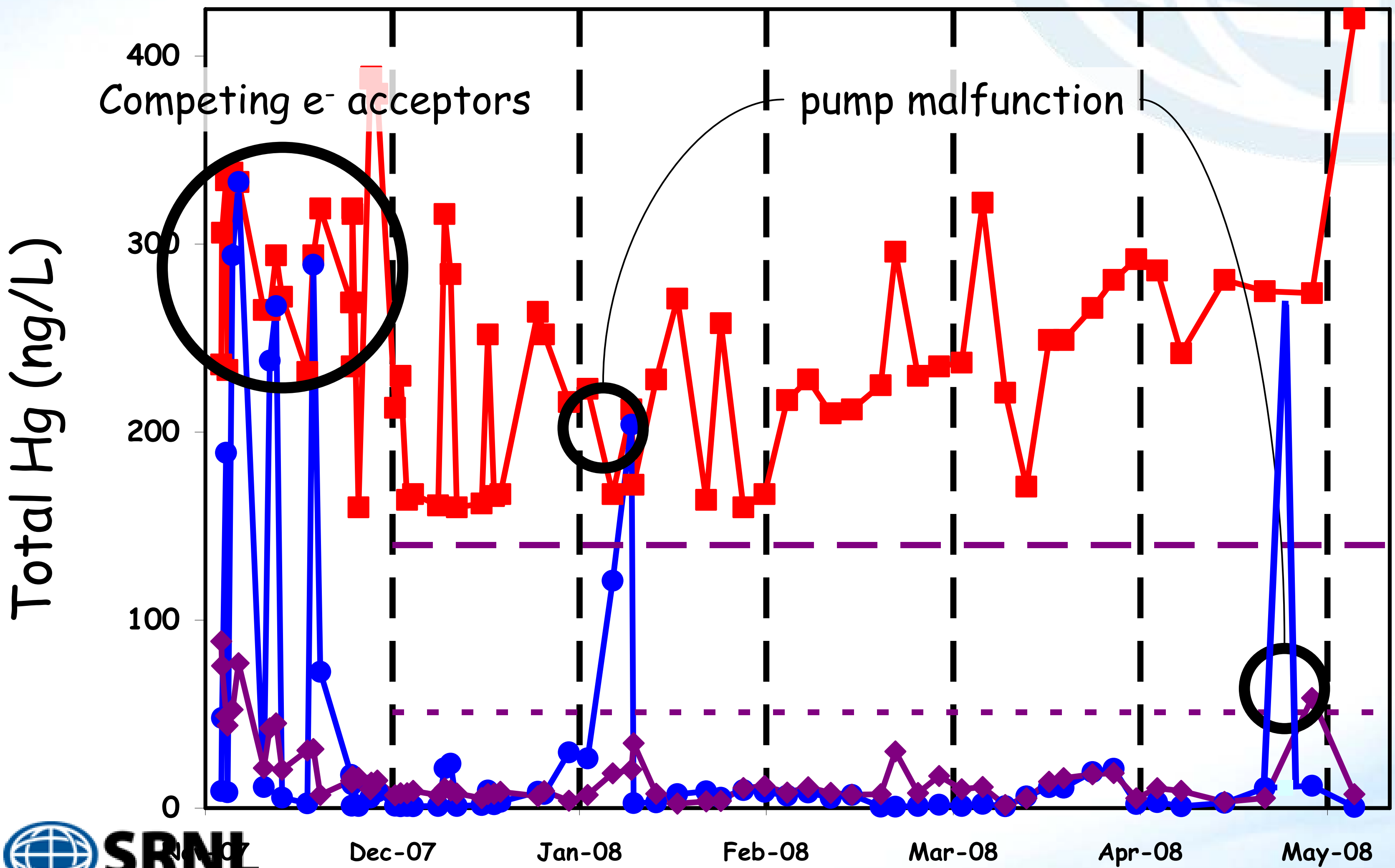
Reagent Storage Tank

Injection Pump (0.2 to 1.5 mL/min nominal)

Injection Port with Check Valve

Enclosure

Operational Performance:



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Conclusions & Summary for Air Stripping:

Technique to remove trace mercury (up to about 1000 ng/L) from wastewater on any scale,

Based upon EPA analytical method

Employs conventional air-stripping equipment,

Well suited for VOC-Hg co-contamination scenario

Additional Equipment < $5k,

Treatment process is sensitive to competing electron acceptors, does not treat organic mercury or high concentrations

Operating costs <<$0.50 per thousand gallons.

SRS system permitted, installed and has now operated for almost 2 years.


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ALT. CUSTODIAN:
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