ENPRO 356
Spring 2005
http://www.iit.edu/~ipro356s05

Problem: Mercury (Hg) Pollution

ILLINOIS INSTITUTE OF TECHNOLOGY

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Enpro 356

The Problem

Mercury is a highly toxic heavy metal that poses a major public health threat. Because mercury can interfere with developmental process, fetuses and children are most likely to be at risk.

Emission Sources

Anthropogenic Sources

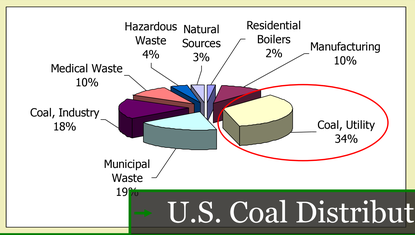
- Coal-fired power plants account for about 34% of mercury emissions in the U.S. -- by far the largest single source.
- U.S. electric utilities release approximately 48 tons of mercury every year.
- Manmade processes such as gold and ore mining
- Medical waste incineration, municipal and hazardous waste combustion
- Cement manufacturing and pulp and paper milling.

Natural Sources

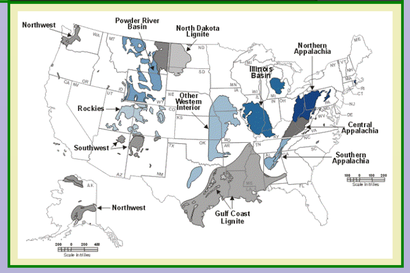
Natural activities that can release mercury into the environment include

- volcano eruptions
- weathering of rocks
- forest fires
- emissions of previously deposited mercury by biologic processes

Utility Plants Emitting the Most Hg



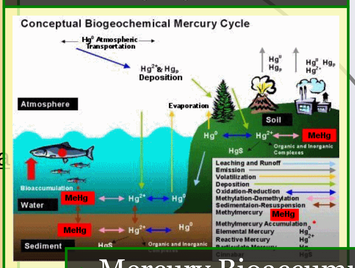
U.S. Coal Distribution



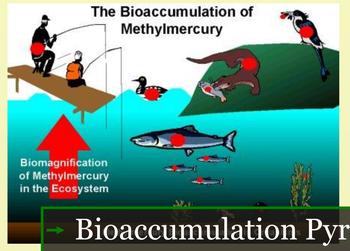
Mercury Cycle

- Mercury is released into the air from coal-fired power plant smokestacks and other sources.
- Hg falls to the ground in rain and is deposited into rivers, lakes and streams (a process known as deposition).
- As Hg settles into bodies of water, bacteria convert it to methylmercury, a highly toxic compound.
- Methylmercury builds up (or bioaccumulates) in animals that eat fish (such as pike, bass, tuna, shark and swordfish).
- Methylmercury bioaccumulates in humans.

Mercury Cycle



Mercury Bioaccumulation



Bioaccumulation Pyramid

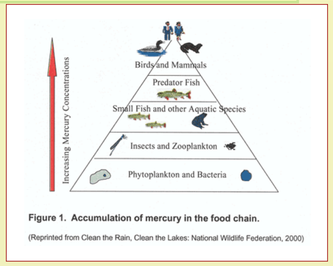


Figure 1. Accumulation of mercury in the food chain.
(Reprinted from Clean the Rain, Clean the Lakes: National Wildlife Federation, 2000)

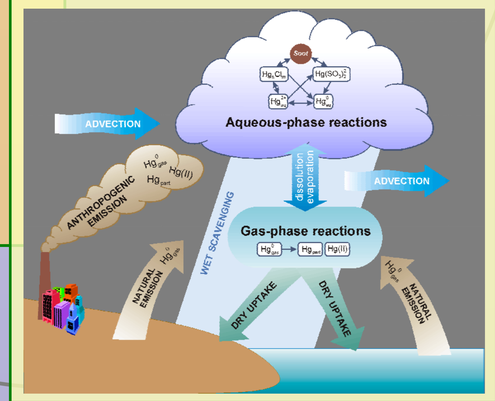
Mercury Transport

Factors

- Form of mercury emitted
- Location of the emission source
- How high above the landscape the mercury is released (e.g., the height of the stack)
- Surrounding terrain
- Weather condition

Atmospheric mercury can be transported over a range of distances before it is deposited, potentially resulting in deposition on local, regional, continental and/or global scales. Mercury that remains in the air for prolonged periods of time and travels across continents is said to be in the "global cycle."

Mercury Transport Model



Mercury Exposure

Factors

- Dosage - Concentrated consumed
- Duration of exposure - Length of time exposed
- Route of exposure - Means of entering the body
- Age and health of the person
- Chemical form of mercury - elemental (metallic), inorganic compounds, or organic compounds.

Exposure Methods & Forms

Hg Form »	Methyl-mercury	Elemental	Inorganic & Organic
Exposure	*consume food with Hg*	*breathe vapor & absorb through lung; swallow as liquid form*	*absorb through gastrointestinal tract*
Examples	*Eating fish or fish-eating animals*	*Lab spills; Hg product breakage; Dental amalgam*	*Fungicides; other outdated products*
Symptoms	*Brain and nervous system; cognitive thinking, memory*	*tremors; emotional changes; performance deficits*	*skin rashes; mood swings; memory loss;*
Characteristics	*organic form of mercury*	*liquid metal; invisible, odorless toxic vapor*	*mercury salts; white powders or crystals*

Health Effects

- Exposure to mercury can be toxic and lethal at high levels.
- Mercury = Developmental neurotoxin
- Pregnant women and children are more sensitive
- Mercury can interfere with brain development of fetuses and children
- CDC estimates one in 12 women of childbearing age in the United States have unsafe levels of mercury in their blood (more than 600,000 newborns each year)
- **Safe consumption level**: EPA's reference dose = 0.1 micrograms of mercury per kilogram of body weight per day (0.1 ug/kg/day).

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Solution: VSB (Virtual Sorbent Bed)

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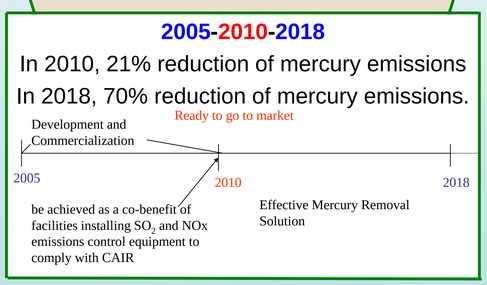
Regulations

New Regulations: The Clean Air Mercury Rule (CAMR)

- Cap-and-trade system for reducing emissions
- Limitations of emissions (per generating unit):
  - -Bittuminous coal: 21×10^{-6} lb/MW·h
  - -Subbituminous coal
    - -Wet FGD: 42×10^{-6} lb/MW·h
    - -Dry FGD: 78×10^{-6} lb/MW·h
  - -Lignite coal: 145×10^{-6} lb/MW·h
- 1st phase cap of 38 tons per year in 2010—21% decrease in emissions
- 2nd phase cap of 15 tons per year in 2018—69% decrease in emissions
- CAMR applies to all generators firing more than 73 MW or sell more than 25 MW and more than 1/3 of potential output capacity to any power distribution system
- No provisions for grandfathering

The Opportunity Ahead

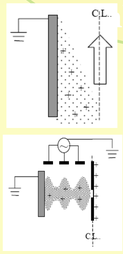
- Any technology that can meet the regulations effectively is needed
- EPA only defined emissions limits and not the technology
- The market has been left open for many technologies to compete and have an opportunity



Competition

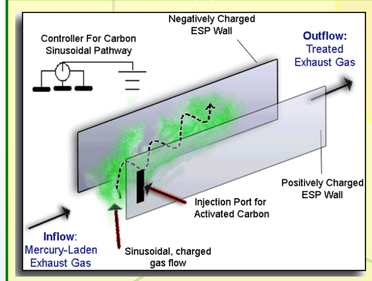
Mercury Capture Process
95% removal of gaseous mercury.
Amended Silicate™ Technology
70%-96% mercury capture
Advanced Hybrid Filter Technology
removes 50-90% of Hg
Multipollutant Technologies
Average of 85% Hg removal efficiency
Electro-Catalytic Oxidation
80 to 90% capture of the mercury

VSB vs. ESP



a. ESP only (top view)
b. ESP with VSB (top view)

VSB Prototype



Advantages

Functional advantages
-Dense sorbent loading.
-High gas-particle relative motion.
-No pressure drop.
-Eliminates jet mixing limitations.
Other advantages
-Sorbent recycling, separate fly ash collection
-Flexible, real-time responsive.
Safe and transferable

A New Star - VSB

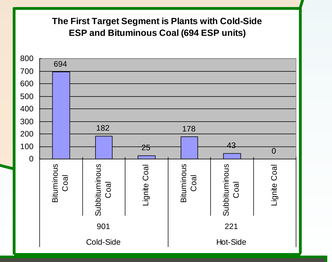
The Virtual Sorbent Beds (VSB) Technology, developed by Dr. Herek Clack, is specifically designed to increase the efficiency of mercury removal from coal combustion exhaust. VSB builds on two proven technologies, Activated Carbon Injection (ACI) and Electrostatic Precipitator (ESP).

VSB Process

1. Mercury contaminated gas enters the ESP
2. Electrically charged Activated Carbon (AC) is driven in a dense "bed" from one ESP wall to the other.
3. Pathway of AC bed is controlled sinusoidally.
4. Hg contained in the gas is adsorbed onto the AC.
5. The Hg-laden AC is collected
6. Hg-laden AC is either recovered or disposed as a hazardous waste.

Market Size

- Clean Air Mercury Rule (CAMR) created a mandatory market for mercury removal technology.
- Coal-fired Power Plants are mandated to pay for solutions.
- The VSB should, once developed, efficiently remove mercury generated by coal-fired generators, and provide an **economical solution** for coal-fired power plants.



VSB

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Decision

License Charge
-Based on how developed the technology is.
-How proven it is.
-How much more involved the team is after selling/licensing.

Strategy
•Partner up with a bigger Architectural Engineering Firm
-Due to low knowledge and resource.
-Affects how we sell it by changing who we're selling to.

Financial Data

Installation Cost
-Needs about a week to install
-Labor = $2,000 (40 total hours of work)
-No additional steel necessary
Operation Cost
-272 MW system was estimated at about $500,000.
-Power usage (average power plant)
27 million kilowatt a day
(14,000 tons of coals to operate)

Risks

•Technology still under development
•Only have prototype built
•Do not know final size
•Has not been placed in an ESP
•Has not been tested with Hg (mercury)
•Unknown efficiency
•Cost estimates inaccurate
•Have not been developed Hg disposal method
•Entering market late
•Small market
•No market name
•Patent pending