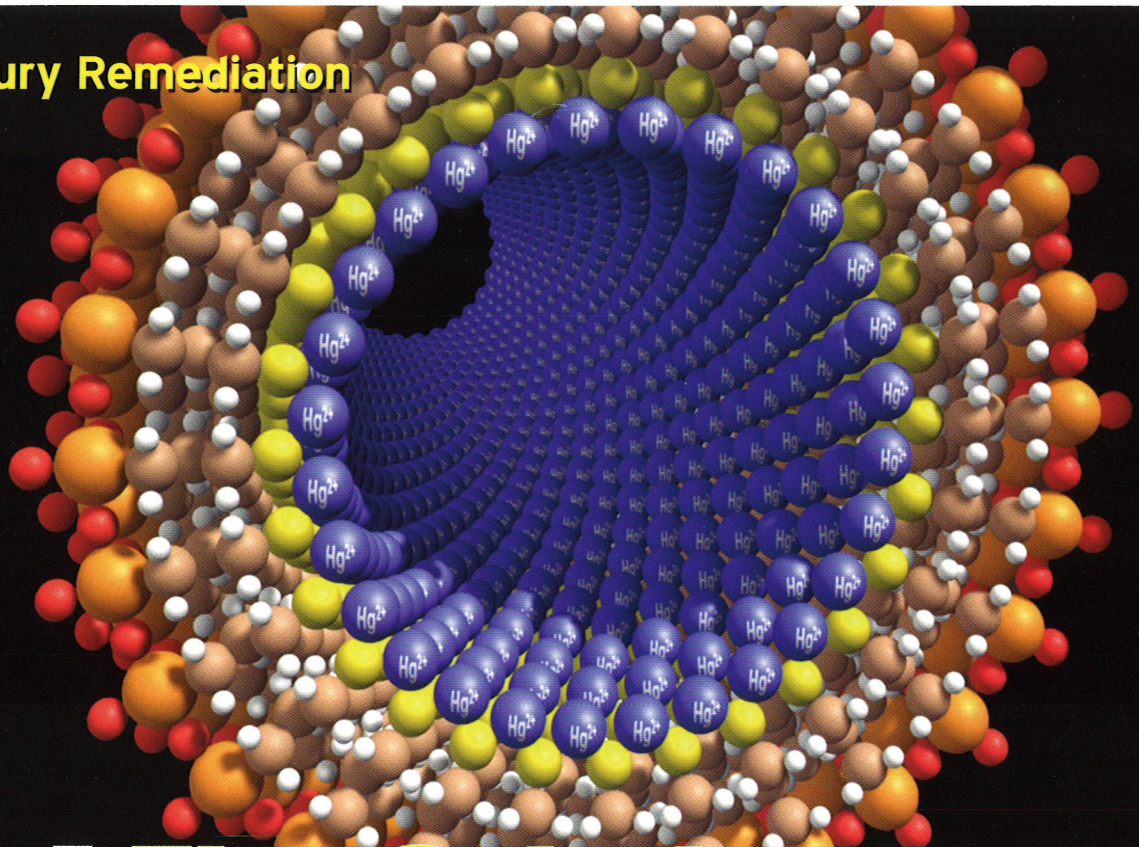
Mercury Remediation



A Tiny Solution to a Big Problem

Using nanotechnology, scientists at the Department of Energy's Pacific Northwest National Laboratory have developed a simple tool for adsorbing large quantities of mercury without creating secondary waste

A powerful, novel technology for mercury removal in waste streams provides an ounce of cure for municipalities, government, and industry. Scientists at the Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) have developed Thiol-SAMMS, or Self-Assembled Monolayers on Mesoporous Supports, as an effective and voracious tool for adsorbing mercury.

In powder form, a single tablespoon of Thiol-SAMMS possesses the same surface area as a football field and can adsorb more than half its weight in contaminants from low-level waste streams. This represents a new weapon in the battle to prevent mercury from leaching into the environment for wastewater applications currently using resins or granulated activated carbon methods in treating mercury-laced waste streams.

An Effective Tool for a Dangerous Problem

Thiol-SAMMS is an award-winning technology with broad applications in the remediation, water treatment, catalyst, sensor, and controlled-release markets. This discovery is part of a new class of hybrid nonporous materials developed at PNNL, consisting of monolayers of functional molecules with a high affinity and specificity for mercury.

It is a simple, inexpensive, easy-to-use tool that uses nanoscale technology to adsorb mercury. Commercially this technology will result in huge savings to users who are faced with costly disposal of mercury in waste streams.

It is cost-effective because it immobilizes the mercury, adsorbing large quantities without creating secondary waste, and can be safely disposed in a landfill as nonhazardous waste. Because it is not considered to be hazardous waste under the Resource Conservation Recovery Act, disposal costs are greatly reduced.

With 99 percent of the mercury adsorbed in the first five minutes, Thiol-SAMMS can help industries operate more cleanly andefficiently by providing a safe, inexpensive mercury removal and disposal method that allows it to be disposed of like ordinary waste. Currently, no commercially available mercury sorbents compare to how fast Thiol-SAMMS works to adsorb mercury.

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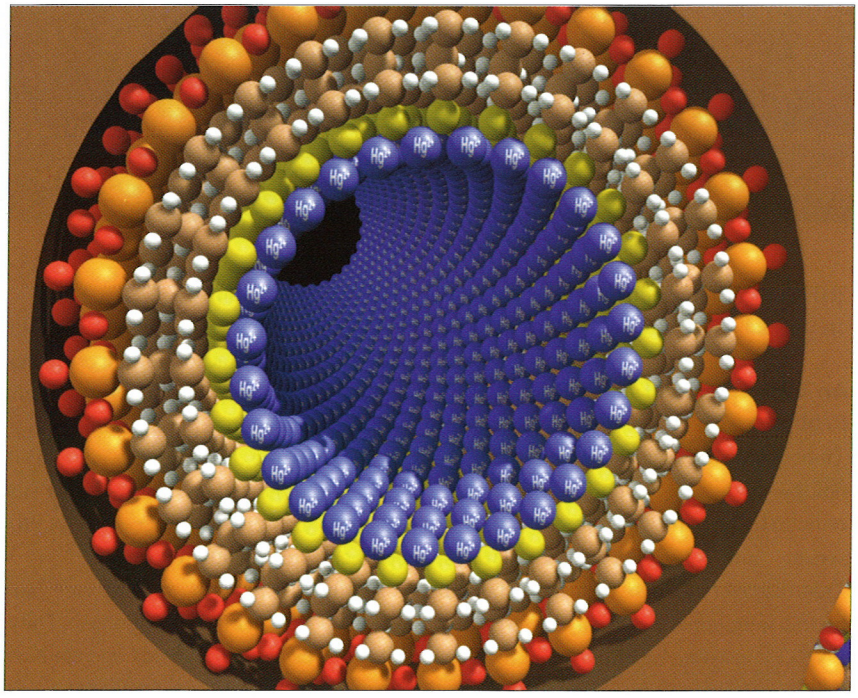
The largest source of unregulated emissions of mercury today is coal-burning power plants, accounting for approximately 48 tons per year. Aqueous effluents from coal-fired power plants include blow down water, wet scrubber effluents, and ash pond waters, typically containing high concentrations of dissolved major and dissolved toxic constituents.

Mercury, an odorless, naturally occurring element, is extremely toxic and can cause serious health effects if inhaled or ingested. Depending on the length and type of exposure, health effects can include birth defects, disease, and death. Over 10,000 tons of mercury pollution produced by humans is derived each year from various industrial sources, including fossil fuels, cement and lime production, waste and sewage sludge incineration, and mining.

Once released into the environment, mercury remains there indefinitely, contaminating the soil, sediment, and groundwater. This contamination eventually enters the food chain, exposing local populations to mercury's harmful effects.

Until now there has been no effective technology for reducing groundwater mercury to 2 parts per billion, as required by the maximum contamination limit for drinking water established by the U.S. Food and Drug Administration and the U.S. Environmental Protection Agency (EPA).

Development of innovative technologies that enable mercury removal without producing harmful byproducts or secondary waste is critically important in constantly changing industries and environment. This technology could have broad application in environmental cleanup where mercury contamination is prevalent, or for mercury removal in radiological hazardous waste.



Mercury adsorption in Thiol-SAMMS (the blue spheres represent mercury)

The Chemistry of a Well-tested Solution

SAMMS is a hybrid of two frontiers in materials science: molecular self-assembly techniques and nanoporous materials. SAMMS is created by attaching a monolayer of contaminant-specific molecules to nanoporous ceramic supports. The nanoporous materials [2 nanometers (nm) to 20 nm] with high surface areas [~600 square meters per gram (m^2/g) to 1,000 m^2/g] are functionalized with a self-assembled monolayer, resulting in an extremely high density of binding sites. The functionalized material exhibits fast kinetics, high loading, and excellent selectivity for contaminants.

Both the monolayer and the nanoporous support can be tailored for a specific application. For example, the functional group at the free end of the monolayer can be designed to selectively bind targeted molecules while the pore size, monolayer length, and density can be adjusted to give the material specific adsorptive properties. This monolayer will seek out and adsorb specific contaminants.

Bench studies to evaluate the effectiveness of this synthetic novel sorbent for removing mercury from coal-fired power plant effluents have included the evaluation of the adsorption performance at different pH values and in the presence of competing metals and ligands (molecules, ions, or atoms that are attached to the central atom of a coordination compound, a chelate, or other complex).

Thiol-SAMMS has surpassed developers' expectations in several tests. For example, when tested on 160 liters of waste solution containing about 11 parts per million of mercury, or a total of 1.76 grams, mercury concentration in the solution was reduced by about 99.5 percent. Estimates indicate that it will cost about $200, including material, analysis, and labor, to treat similar volumes of this waste solution, resulting in a savings of $3,200 over more traditional resin or carbon disposal methods.

Several types of contaminant-specific monolayered materials have been developed. While Thiol-SAMMS has been tailored to adsorb mercury, silver, lead, and cadmium,

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other SAMMS technology is being developed for removing toxic contaminants such as arsenic, chromium, and radionuclides.

A Variety of Funcionalities

Under development in several engineered forms, such as membranes, fibers, and felt, the SAMMS material can be delivered with a variety of specific functionalities.

■ *Remediation*. SAMMS can be used with a low-cost, proprietary lixiviant for remediation of mercury-contaminated soils and sediments. The lixiviant desorbs a wide range of mercury species from soils and sediments. The lixiviant can then be treated by SAMMS and reused.

■ *Waste stabilization*. By mixing the SAMMS powder with wastes such as non-liquid sludges and soils, the metal is stabilized in SAMMS whenever the wastes are leached by rainwater or other acidic groundwater, thus stabilizing these wastes to comply with regulations. In-situ stabilization with SAMMS may be cost-effective, efficient, and timely, especially for large-volume wastes in ponds and ditches. Although the metal-loaded SAMMS can control metal solubility to meet Universal Treatment Standards, it also can be easily stabilized by combining it into a cemented waste form.

■ *Water treatment*. SAMMS materials can be used in cartridges for portable water treatment systems for offices, hospitals, and homes. The performance of these membranes is equivalent to the powdered form of the materials. Filtration membranes and separation columns for large municipal and industrial water treatment and desalination facilities are possible.

■ *Metal finishing*. SAMMS can recover individual metals from sludge and reduce the amount of sludge generated. It also can be used in plating tanks to keep the ion concentration in the appropriate range for the plating process to work. Of additional benefit is its ability to remove chelated metals to reduce hazardous waste disposal volume. Applications for metal finishing include use as a final polishing step and point-of-use removal step on cleaning and bath tanks.

Recently, PNNL scientists used Thiol-SAMMS powder on 10 liters of mercury containing lab-generated waste solutions, reducing waste levels from 145.8 parts per million of mercury to 0.04 parts per million, safely below EPA and Washington State disposal limits of 0.15 parts per million. The total treatment cost using Thiol-SAMMS was $180, with a savings of $1,820 over conventional mercury-removal treatment and disposal processes.

In a separate study, PNNL scientists tested Thiol-SAMMS on 160 liters of waste solution containing about 11 parts per million of mercury. Thiol-SAMMS reduced mercury concentration in the solution to 0.06 parts per million. The cost of Thiol-SAMMS material used in this test was approximately $69.

Technology for Future Use

While there is a pressing concern regarding mercury removal and disposal, the SAMMS technology can also target specific contaminants. Additional technology has been tailored to remove radionuclides: Cesium-137, Technetium-99, Iodine-129, Americium-241, Neptunium-237, Plutonium-239, and Uranium-238.

By creating SAMMS, we hope to help industry operate more leanly and efficiently, we hope to help cleanup existing problems arising from toxic metals in the environment, and we hope to make drinking water cleaner and safe from future contamination.

PNNL is a Department of Energy (DOE) Office of Science laboratory that solves complex problems in energy, national security, the environment, and life sciences by advancing the understanding of physics, chemistry, biology, and computation. PNNL employs 3,800, has a $600 million annual budget, and has been managed by Ohio-based Battelle since the laboratory's inception in 1965.

Preliminary Lifetime Cost Comparisons for Mercury Removal Sorbents

Cost Basis	Thiol-SAMMS	Resin	Granulated Activated Carbon
Material cost/kg	$300	55	2
Mercury loading (g/kg of sorbent)	15	1	0.004
Sorbent quantity (kg)	67	1,000	250,000
Cost of sorbent for removal of 1 kg mercury	20,100	55,000	500,000
Waste disposal cost ($60/ft^3)	310	3,160	1,187,500
Total treatment cost for 10^5 L waste	20,410	58,160	1,687,500

Preliminary lifetime cost comparisons for mercury removal sorbents

Shas Mattigod, PhD, is a staff scientist V in applied geology and geochemstry at the U.S. Department of Energy's Pacific Northwest National Laboratory, operated by Battelle for the Office of Science. His professional experience relates to characterizing, developing, and managing remediation methods for liquid and solid effluents, leachates Resource Conservation & Recovery Act (RCRA) wastes, contaminated soil, and groundwater from Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites. Mattigod has authored more than 100 professional publications and papers, including four invention reports. He is leading the effort to develop novel nanoporous sorbents for environmental applications. Mattigod can be reached at

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Chart Recorder

Circular

ABB's new C1300 advanced circular chart recorder combines established chart recording technology with the latest developments in electronic data recording to provide a recording solution for a range of water and wastewater applications. With its two LCD graphical display panels, the C1300 is particularly useful for totalization applications, and its use of transflective display technology ensures that the display can be read even in direct sunlight. *ABB.*

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Controller

Differential pH

Eutech® Instruments' new ½-DIN pH 2000D controller is designed for industrial applications. Differential pH measurement reduces reference junction fouling and virtually eliminates ground loops in demanding applications. The backlit LCD indicates pH and temperature values that can be recorded via two galvanically isolated outputs. Three control modes (limit, proportional, and proportional-integral) with separately adjustable set points, delay, and hysteresis provide precise high- and low-level control. *Cole-Parmer Instrument Co.*

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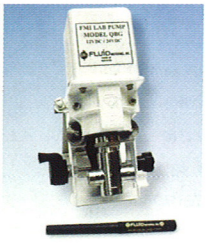

Piston Metering Pumps

Valveless

FMI's CeramPump® is a valveless piston metering pump that uses one moving part, a rotating and reciprocating ceramic piston, to accomplish both pumping and valving functions. The piston and mated liner are made of dimensionally stable, sapphire-hard ceramics for long-term, drift-free accuracy for millions of maintenance-free cycles. The inert fluid path of ceramic and fluorocarbon is ideal for injection of concentrated tracer dyes and water treatment chemicals. *Fluid Metering Inc.*

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DO Meter

Stick-style design

Designed for a wide range of applications, including wastewater and environmental monitoring, the stick-style ExStik® II dissolved oxygen meter simultaneously displays temperature and oxygen level in either saturation or concentration. Rugged enough for field applications, the DO600 can compensate for both altitude and salinity. It is waterproof to IEC 90529 IP67 standards and buoyant in water. *Extech Instruments Corp.*

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Electromagnetic Flowmeter

Rotatable display

The Badger Meter M-Series electromagnetic flowmeter uses microprocessor-based signal conversion to produce flow accuracies of ± 0.25 percent or better. A wide selection of optional liner and electrode materials ensures maximum compatibility and minimum maintenance. The electronics housing is available in meter-mount and remote-mount versions incorporating a rotatable display allowing easy viewing regardless of the meter's position. *Badger Meter Inc.*

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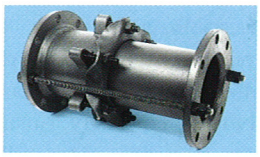

Dismantling Joi

For quick installation

The Dresser® style 131 dismantling joint provides flexibility when installing and maintaining flanged-end pipe interfaces with check valves, gate valves, ball valves, pumps, blowers, meters, engines, compressors, various fittings, and appurtenances. It allows for longitudinal adjustments in piping systems from 2 inches to 20 inches and can be used anywhere that requires quick installation or removal. Standard designs include flanges drilled to mate with AWWA Class B and Class D. *Dresser Inc.*

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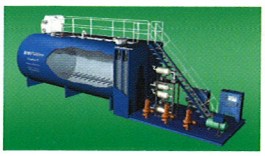
Membrane Bioreactor System

Packaged wastewater treatment plant



MemJet™ MBR (membrane bioreactor) technology is now available as a complete, pre-engineered, membrane bioreactor system in a compact skid-mounted design. Portable and easy to install, the system is for projects with time, space, and budget constraints. Units can be placed strategically to generate reclaimed water at the point of reuse, minimizing distribution networks, and can be installed incrementally to meet growing wastewater demands. *USFilter.*

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