



# New Jersey Flows

New Jersey Water Resources Research Institute

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## The Role of Bacteria in Controlling Methylmercury

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Mercury is a toxic heavy metal that has contaminated a wide variety of aquatic habitats across New Jersey through atmospheric deposition and industrial contamination. Mercury enters the environment mostly as inorganic Hg(II) where it is converted to methylmercury by bacteria in anaerobic sediments. It is this methylated form of mercury which is of particular concern since, unlike other forms of mercury, methylmercury is readily bioaccumulated and biomagnified in the aquatic food chain, posing health risks to humans who consume fish and shellfish. Because mercury toxicity is a function of its chemical speciation in the environment the reactions constituting the biogeochemical cycle of mercury (Fig. 1) are important for determining mercury toxicity. Methylmercury toxicity can lead to a variety of adverse health effects, including neurological and reproductive defects. Minimizing exposure to methylmercury in young children and women of childbearing age is especially important, since the developing brain is particularly susceptible to the toxic effects of methylmercury.

Mercury concentrations in tissues of freshwater fish are elevated throughout NJ but there is no direct relationship between the degree of mercury contamination and methylmercury production and accumulation in aquatic biota. In fact, we have observed an inverse relationship between the concentrations of total mercury and the proportion of methylmercury in the total mercury pool in samples collected in contaminated streams and lakes in the Meadowlands and Pine Barrens lakes. This inverse relationship might explain the inconsistencies of fish data. Water samples contained 100 – 6800 ng/L total mercury in the Meadowlands and only 0.4 – 6 ng/L total mercury in the Pine Barrens, while methylmercury concentrations in both systems were 0.05 – 0.8 ng/L, a range common in natural waters. (Fig. 2). This apparent paradox is not unique to NJ and it may be explained

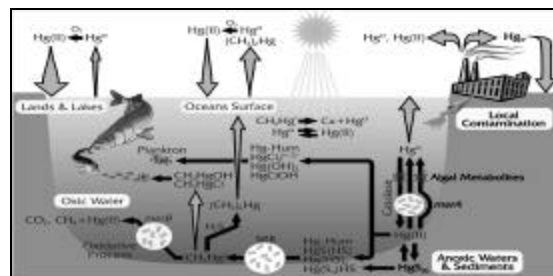


Fig. 1: The biogeochemical cycle of mercury. Mercury released by natural and anthropogenic sources is subject to various transformations (black arrows) and transport processes (gray arrows). Microbes play a critical role in some of these transformations (white circles with gray cells) and, thus, may control the formation and degradation of methylmercury, a potent neurotoxic substance.

by either decreased methylmercury production or increased methylmercury degradation in ecosystems containing high levels of total mercury.

Methylmercury degradation is mediated by bacteria in sediments, in natural waters and in soils. This activity is a part of the bacterial mercury detoxification mechanism, resulting in the degradation of methylmercury to gaseous elemental mercury, which can escape the local environment. The enzymes mediating these activities are only produced when mercury is present in the environment of the active bacteria. This is achieved by regulation of gene expression (the *mer* genes) that encode the functions required for mercury resistance. These genes are induced primarily by inorganic mercury, and thus, the enzymes responsible for methylmercury degradation are synthesized only when the level of mercury is high enough to activate their expression. Therefore, we hypothesized that methylmercury degradation by mercury resistant bacteria may explain the observed inverse relationship between total mercury and the proportion of

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### The Director's Chair

by Joan G. Ehrenfeld, Ph.D., Director, New Jersey Water Resources Research Institute  
Rutgers, The State University of New Jersey



This issue is devoted to the problem of mercury contamination in New Jersey's waters. A long history of industrial and agricultural activities plus the presence of upwind sources has resulted in significant contamination in waters throughout the state. Because the cycling of mercury in the environment is very complex, much research is now devoted to unraveling these complexities so that threats of mercury toxicity can be reduced. This issue illustrates the challenges of understanding and reducing mercury in the environment.\*

# Atmospheric Cycling of Mercury in New Jersey

By John R. Reinfelder, Ph.D.,

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Mercury (Hg) is of environmental concern primarily because of the enrichment and toxicity of the methylated form of the metal (monomethylmercury,  $\text{CH}_3\text{Hg}$ ) in wildlife, including fish, birds, and mammals, and in humans (Meili, 1991; Watras and Bloom, 1992; Burger and Gochfeld, 1997; Watras et al., 1998; Gnamus et al., 2000; Stern et al., 1996). The methylation and bioaccumulation of Hg in aquatic and terrestrial ecosystems, however, is linked to the atmosphere (Rolfus and Fitzgerald, 1995; Downs et al., 1998), which is often the main source of Hg to these environments (Mason et al., 1994; Sorensen et al., 1994). In order to understand and manage the environmental impact of Hg, we therefore need to understand the mechanisms, variability, and trends of the atmospheric deposition of Hg.

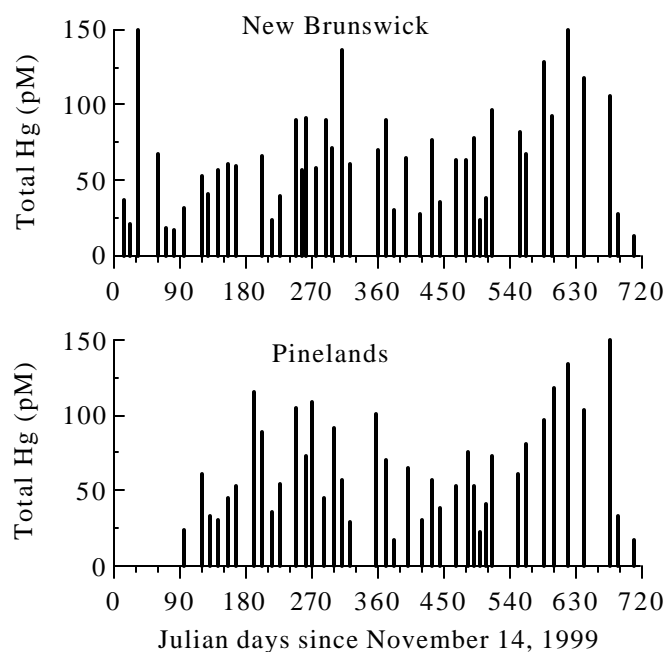
The atmospheric concentration of Hg has tripled over the past 150 years (Mason et al., 1994) as a result of the huge increase in Hg emissions associated with human activities (Pirrone et al., 1998) and Hg accumulation rates in remote water bodies over the past two decades show that global atmospheric Hg contamination is still on the rise (Lindqvist et al., 1991; Engstrom and Swain, 1997; Hermanson, 1998; Landers et al., 1998; Lorey and Driscoll, 1999). Atmospheric Hg is present mainly as gas phase, elemental  $\text{Hg}^0$ , but deposits in association with rain, snow, or aerosols in its oxidized form. Most Hg deposition studies show that the deposition associated with rain and snow dominates the atmospheric flux (Fitzgerald et al., 1991; Mason et al., 1997; Guentzel et al., 2001), but dry deposition of particle-bound Hg can be important in some urban areas (Keeler et al., 1995). In addition, gas phase forms of oxidized Hg, which are collectively referred to as reactive gaseous mercury (RGM), have been identified in the atmosphere and could account for significant Hg deposition (Lindberg and Stratton, 1998; Stratton et al., 2001; Sheu and Mason, 2001).

Results from Hg deposition studies in the eastern U.S. show annual and intra-annual variability in the concentrations of Hg in precipitation and aerosols and Hg deposition fluxes. This variability could be linked to variability in emission sources, regional transport processes, local meteorology, and atmospheric chemistry. In order to discern spatial and temporal trends of Hg deposition and to link these to Hg sources and environmental processes, long-term research and monitoring efforts are needed in geographically diverse locations (Fitzgerald, 1995). In the northeastern U.S., Hg deposition is currently being monitored in upstate New York, Pennsylvania, and Maine as part of the National Atmospheric Deposition Program's Mercury Deposition Network (<http://nadp.sws.uiuc.edu/mdn>), but no such monitoring effort has been undertaken in New Jersey. Thus there are few data on the atmospheric concentrations and deposition of Hg in New Jersey for use in risk assessments and the evaluation of deposition trends.

For the past three years, we have been measuring the concentrations and deposition fluxes of Hg in rain and fine aerosols throughout New Jersey as part of the New Jersey Atmospheric Deposition Network (NJADN) project. The results represent a baseline data set for New Jersey and are compared with Hg deposition fluxes measured elsewhere in the U.S. During this project, precipitation and fine aerosols were collected in New Brunswick, Jersey City, Camden, and New Lisbon (Pinelands),

New Jersey. While all four of these sites are subject to the North American regional sources of atmospheric Hg from the prevailing westerly winds, the two urban sites (Jersey City and Camden) receive Hg inputs from emissions of local metal recycling, power generation, and waste incineration plants and potentially from nearby oil refineries. New Brunswick's proximity to the New Jersey Turnpike and US Highway 1 make it susceptible to Hg emissions from the heavy motor vehicle traffic on these roads. The Pinelands site is located in a forested region of southern New Jersey, but is downwind of the Camden/Philadelphia area. Integrated rain samples collected every 12 d show seasonal cycles of Hg concentrations, which are generally highest in late summer (Fig. 1). These data are being used in conjunction with measurements of other contaminants to estimate the relative contributions of various emissions sources to Hg in New Jersey rain.

In addition to monitoring atmospheric deposition, we are also studying the emissions of Hg from urban point sources including land-applied, stabilized harbor sediments and historically contaminated watersheds. The goal of this work is to establish the importance of these point sources to local atmospheric Hg concentrations. We have been measuring the emissions of gaseous mercury from stabilized harbor sediments at a site in Bayonne, New Jersey and in the estuarine portion of Barry's Creek a historically contaminated stream in the New Jersey Meadowlands. Fluxes of mercury from these individual sites appear to be small relative to other sources and the background concentration, but they represent important links in the cycle of Hg as it is exchanged between the atmosphere and aquatic ecosystems. Future work will include studies of the linkage between biological and chemical processes in surface waters and air-water Hg exchange.\*



# New Jersey Fish Advisories - Update on Mercury

By Gary A. Buchanan, Ph.D., Research Scientist,  
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## INTRODUCTION

Bioaccumulation of mercury by fish has potential human health implications due to the risk of consuming contaminated fish. Consumption of mercury-contaminated fish poses potential effects on the nervous system of developing fetuses. In addition, long-term consumption by adults and older children of fish with elevated levels of mercury may result in adverse health effects, including neurological damage. Due to these concerns, the State has a responsibility to investigate contaminated biota and inform the public of any health concerns. Since 1983, New Jersey has evaluated contaminant data from fish and other biota, established fish consumption advisories, and disseminated advisory information to the public.

Mercury fish consumption advisories were first issued in 1994 for two fish species with relatively high mercury levels (largemouth bass and chain pickerel) for which there were adequate data. Several additional studies were conducted subsequent to 1994 that expanded the species and water bodies examined. Five data sets (over 1,100 tissue samples) provided an opportunity to statistically evaluate mercury tissue concentrations for several additional fish species on a broad geographical basis.

## DATA ANALYSIS

A review of the data on a statewide and regional basis shows:

- Significantly higher concentrations of mercury are consistently found in Pinelands fish as compared to the same fish species from non-Pinelands water bodies (Figure 1). Higher concentrations in Pinelands fish are related to differences in water chemistry parameters (e.g., pH, alkalinity and dissolved organic carbon) that affect rates of mercury methylation.

For temporal trends, a comparison of limited data collected during two time periods (1992-94 and 1996-97) indicated the following:

- Over this time period there was no significant difference in the average mercury concentration in chain pickerel from either Pinelands or non-Pinelands waters.
- No significant difference in the average mercury concentration in largemouth bass in non-Pinelands waters. A significant de-

crease in average concentration in largemouth bass was noted in Pinelands waters; however, data for the latter period was very limited.

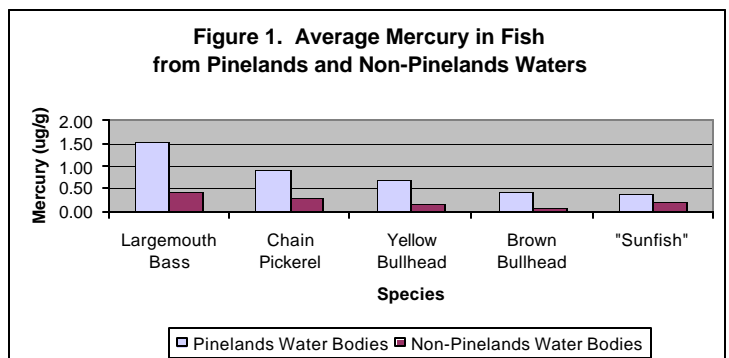
## NEW ADVISORIES

Using the risk-based mercury guidelines established in 1994, statewide and regional (i.e., Pinelands) advisories were revised, and additional specific water bodies were added to the advisory list in July 2002. These revised advisories are not limited to top trophic level predators, but cover a wide range of New Jersey's most popular and most consumed freshwater gamefish species. New and revised statewide and/or regional advisories have been developed for: largemouth bass, chain pickerel, smallmouth bass, sunfish, yellow bullhead and brown bullhead. The revised water body-specific advisories include the addition of approximately 50 lakes, ponds and rivers, and the inclusion of 19 additional species including smallmouth bass, northern pike, walleye, white perch, yellow perch, bullhead, catfish, and sunfish.

## FUTURE EFFORTS

In 2002, the NJDEP established a routine monitoring program for mercury and other contaminants in fish from New Jersey waters. This program will provide the spatial and temporal data needed to examine trends in mercury concentrations in fish, as well as provide adequate data to revise fish consumption advisories. The NJDEP is also developing or considering additional indicators of trends of mercury in environmental media.

For additional information on NJ's fish advisories go to [www.state.nj.us/dep/dsr/njmainfish.htm](http://www.state.nj.us/dep/dsr/njmainfish.htm).\*



## Spotlight on New Jersey Watersheds

# Raritan Basin Watershed Management Project

Daniel J. Van Abs, Ph.D., PP/AICP, Raritan Basin Project Mgr.

The Raritan Basin Watershed Management Plan has been nearly four years in development, with involvement from well over one hundred stakeholders from many interests and all parts of the Basin. The NJ Department of Environmental Protection and the NJ Water Supply Authority, a state-owned water supply system, jointly funded the Raritan Project. Watershed management is an integrated process that addresses the high-priority issues and makes use of many different authorities, approaches and management entities – including state-level regulation. The plan will need action from all levels of the public and private sector – no one entity is responsible for the full plan.

The Raritan River Basin includes approximately one-seventh of New Jersey's land area and one-eighth of its population. The Basin is split by NJDEP into three Watershed Management Areas,

or WMAs – North & South Branch Raritan, Lower Raritan and Millstone. The Raritan Project began in March 1999 with technical studies. In October 2000, a major public planning effort began. Over 125 people participated from a wide variety of interests were involved.

The Raritan Basin Council coordinated work among Project committees and assessed project progress, but the Watershed Management Area Committees did the bulk of plan development. Raritan Project stakeholders first worked to understand the current status and issues of the Raritan Basin. Goals – essentially long-term statements of a desired environmental quality – were then developed to respond to the key issues. The stakeholders developed measurable objectives, followed by implementation strategies that would, if implemented, achieve those objectives.

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# New Jersey Mercury Task Force

Michael Aucott, Ph.D., NJDEP Div. of Science, Research & Tech.



Stimulated, in part, by the finding of relatively high concentrations of mercury in some species of fish in New Jersey lakes, DEP Commissioner Robert C. Shinn, Jr., formed the New Jersey Mercury Task Force in 1998. The Task Force was chaired by Dr. Michael Gochfeld, of University of Medicine and Dentistry of NJ, and was composed of representatives of State agencies, recreational and commercial fishing interests, industrial and institutional stakeholders, environmental groups, and academic groups. All meetings were open to the public. The Task Force gathered available information on the behavior of mercury in the environment and its impacts, its sources and control strategies, and also developed recommendations.

In January 2002, the Task Force issued its final report. The report, in three volumes; is available at:

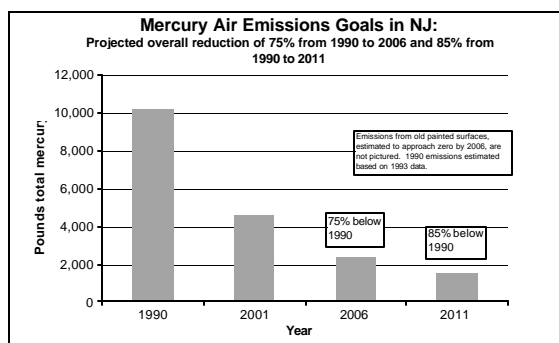
[http://www.state.nj.us/dep/dsr/mercury\\_task\\_force.htm](http://www.state.nj.us/dep/dsr/mercury_task_force.htm).

The Task Force recommended an overall goal of the virtual elimination of anthropogenic uses and releases of mercury. It emphasized that removing mercury from products is an important part of this effort, and recommended that New Jersey move on as many fronts as possible to eliminate additional mercury discharges, emissions, and associated deposition. It also emphasized that regional, national, and global actions are necessary because long-range transport of mercury results in widespread mercury pollution, and it pointed out that reduction of mercury releases will have collateral benefits, such as the reduction of other important environmental pollutants. It also noted that there is evidence that reducing air emissions can lead to reductions of mercury in fish tissue over a relatively short time period.

The Task Force recommended that the State of New Jersey adopt a two-step milestone of a 75 percent reduction in air emissions below estimated 1990 levels by 2006 and an 85 percent reduction below 1990 levels by 2011. See the figure below. The Task Force made specific recommendations regarding reductions from certain sources and for additional research. Its key recommendations are as follows:

1. Participate in and support regional, national, and global efforts to reduce mercury uses, releases, and exposures.

2. Remove mercury from products and phase out sales of mercury-containing products for which there are reasonably available alternatives.



3. Reduce emissions of mercury from the production of electricity consumed in New Jersey, including electricity generated by out-of-state sources.

4. Significantly reduce air emissions from coal combustion.
5. Significantly reduce air emissions from iron and steel and other secondary smelting industries.
6. Ensure the minimization of mercury emissions from other sources, including medical waste incinerators, sewage sludge incinerators, municipal solid waste incinerators, and discarded mercury-containing products, including fluorescent bulbs, dental amalgam waste, thermostats and switches.
7. Expand and institutionalize routine monitoring for mercury in fish from New Jersey waters through State-level programs.
8. Actively encourage the federal government to initiate and maintain comprehensive monitoring and surveillance for mercury in commercial fish and to require that information regarding the mercury content of fish be made readily available.
9. Expand and periodically evaluate the effectiveness of current outreach, advisories and education efforts to reduce exposures to mercury of sensitive populations, subsistence fishermen, and others who consume large quantities of fish.
10. Reduce exposures from cultural uses of mercury.
11. Develop comprehensive mercury budgets for New Jersey watersheds that include inputs from air deposition, in order to develop appropriate total maximum daily loads (TMDLs).
12. Maintain and enhance a long-term air deposition monitoring system that incorporates state-of-the-art detection limits and speciation to document temporal and spatial trends in mercury deposition.
13. Address critical information gaps concerning the quantities and chemical species of mercury emissions and releases, the fate and transport of mercury in the environment, and the exposure pathways.
14. Support the development of effective methods of retiring and sequestering mercury so that the chances of the eventual release of mercury to the environment are minimized.
15. Develop improved environmental indicators of the impact of mercury on New Jersey's environment.
16. Take steps within State government to provide for the implementation of the recommendations in this report.

Currently, the following actions, which build on Task Force recommendations and in some cases go beyond them, are being considered by the Department:

- **Emission rules** - Propose new air emission limits for coal combustion; iron & steel manufacturing; municipal solid waste, hospital, and hazardous waste incinerators.
- **Legislation** - Determine the best option and develop draft proposed legislation. Obtain sponsor for the legislation.
- **Advisories/fish monitoring** - Update as necessary. Establish funding for 5-year program (currently, only 7/02 - 03 is funded).
- **Research** - Investigate levels in commercial fish sold in NJ, develop indicator of recent inputs, get better data on indoor exposures, complete current projects on recycled scrap and cultural exposures.
- **Outreach & Education** - Monitor and expand new efforts as necessary.
- **Permitting** - Upgrade mercury emission requirements as feasible.
- **Enforcement** - Ensure that all facilities comply with existing air permits.\*

# Mercury in Ground Water of the Kirkwood-Cohansey Aquifer System, New Jersey Coastal Plain

By Julia L. Barringer and Zoltan Szabo,  
U.S. Geological Survey, West Trenton, New Jersey



Since 1982, more than 400 domestic wells that tap the Kirkwood-Cohansey aquifer system, the most areally extensive unconfined aquifer in the New Jersey Coastal Plain, have yielded water containing total mercury at concentrations exceeding the New Jersey drinking-water maximum contaminant level (MCL) of 2 µg/L (micrograms per liter). By 1988, the number of cases reported had alerted State and county agencies to the possibility of a widespread environmental problem. A study of the lithology of the aquifer sediments indicated that the mercury was unlikely to derive from natural sources (Dooley, 1992); the aquifer is composed primarily of quartz sand, and few minerals that might contain mercury are present or are likely to weather. A study of naturally occurring mercury concentrations in ground water indicated that background concentrations typically are less than 0.01 µg/L (Murphy and others, 1994).

In 1992, the U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection (NJDEP), began a study to evaluate the extent of mercury-contaminated ground water in the Kirkwood-Cohansey aquifer system, and to propose and evaluate hypotheses regarding the causes of the occurrences of mercury in ground water. The first phase of the study consisted of compiling available data on mercury concentrations in ground water and soils, determining mercury distributions in soils and aquifer sediments, sampling ground water, and compiling and evaluating data on possible sources of mercury (Barringer and others, 1997). In a later, regional study conducted by the USGS in cooperation with NJDEP, water samples were collected from 126 domestic and observation wells in different land uses and 28 clustered observation wells in undeveloped and agricultural land (Barringer and Szabo, 2002).

The affected domestic wells range in depth from 50 to 200 feet, and are located in at least 72 mostly residential areas that were developed primarily on former agricultural land in southern New Jersey from the 1950's through the 1970's. No evidence currently exists that conclusively links known point sources such as landfills, industrial operations, or commercial enterprises to most of the elevated concentrations of mercury in ground water in the residential areas. Possible sources of the mercury include pesticides and atmospheric deposition (Barringer and others, 1997; Barringer and

MacLeod, 2001).

Analysis of water from wells at six of the residential areas for constituents other than mercury indicates that concentrations of nitrate also commonly are elevated above background levels (less than 0.01 mg/L (milligrams per liter)), and exceed the MCL of 10 mg/L in some samples. Volatile organic compounds, including chloroform, also have been found in water from wells at many of the areas. Analytical results for water samples collected at several depths from boreholes at two of the areas indicate elevated concentrations of calcium, magnesium, barium, strontium, nitrate and chloride, which may be related to both agricultural chemical applications and septic-system effluent, as residential areas with mercury-contaminated ground water typically are unsewered housing developments (Barringer and MacLeod, 2001; Barringer and Szabo, 2002).

Results of the regional study showed that mercury concentrations in ground water typically were less than 0.01 µg/L in filtered (0.45-micrometer pore size) samples, but tended to increase with concentrations of chloride (and other constituents), indicating that mercury may be transported as a chloride complex. Concentrations of mercury greater than 0.1 µg/L did not correlate with concentrations of other constituents, however, indicating that mercury near and at the MCL may not be transported in the same chemical form as mercury at lower concentrations. Mercury concentrations greater than 1 µg/L typically are associated with residential land use; such high concentrations have not been found in water underlying undeveloped land. The distribution of these elevated mercury concentrations appears to be "spotty" at both the regional and neighborhood scales, as the presence of extensive plumes of mercury-contaminated ground water could not be demonstrated.

Soils at six of the residential areas were analyzed for mercury, as were undisturbed forest soils. Mercury was found to accumulate in the organic and clay-rich horizons of the forest soils, but was distributed relatively evenly in vertical sections through the disturbed soils at the residential areas. Moreover, concentrations of mercury were substantially lower in the disturbed soils than in the undisturbed soils. A change in the geochemical environment of the soil and aquifer brought about by land-use change probably provides mechanisms for mobilizing the mercury from soils and sediments to ground water.\*

(Article references can be obtained from [derbedrosian@aesop.rutgers.edu](mailto:derbedrosian@aesop.rutgers.edu))

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## Raritan Basin Watershed Management Project

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Only then did the Raritan Basin Council develop a vision statement to encompass the work of the WMA Committees. A shortened version is:

*We envision a Raritan River Basin where the following becomes true as quickly as possible, but within a generation: **Overcoming the Past; Managing the Future; Taking Responsibility; and Maintaining Vigilance.***

The Raritan Plan identified six major issues through the char-

acterization and assessment process:

- Surface water pollution – Excessive levels of fecal coliform bacteria and phosphorus are common around the basin. Nonpoint sources are responsible for all of the former and much of the latter. In addition, chloride levels are rising throughout the basin from road salt use.
- Loss of riparian areas – Some subwatersheds have lost as much as 80 percent of their historic riparian areas, a major stress to the streams.
- Biological impairment of streams – While few biological monitoring stations show severe impairment, a full 57 percent are

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# Mercury in Freshwater Ecosystems: A Brief Review

By John G. Hunter, Ph.D., Dept. of Biochemistry and Microbiology, Cook College, Rutgers University,

There is abundant evidence from episodes of epidemic poisoning in Japan and Iraq in the 1970's that monomethyl mercury ( $\text{CH}_3\text{Hg}^+$ , also called MeHg) is a neurotoxin and a teratogen (birth defect-causing substance). Such studies led the FDA to set a recommended limit of 1  $\mu\text{g/g}$  concentration in foodstuffs. Recently, it has been shown that this limit is exceeded in many sport fish in New Jersey (see the article "New Jersey Fish Advisories – Update on Mercury" in this issue). In order to understand how fish become contaminated with methyl mercury, it is necessary to understand how mercury behaves in the freshwater environment, and how it moves through food webs.

Anthropogenic mercury is generated when mercury-containing materials such as municipal solid waste and brown coal are burned. Volatile metallic mercury enters the atmosphere and is oxidized by exposure to sunlight to a reactive form of the element (divalent mercury,  $\text{Hg(II)}$ ); this form is then deposited on fresh waters via rain and the deposition of particles containing the divalent mercury. This is the form of inorganic mercury that is environmentally important, as other forms are not taken up by organisms. Bacteria within the sediments of the lake or reservoir can convert a portion of the divalent mercury to the toxic monomethyl mercury. The MeHg is readily absorbed by aquatic organisms, but it also may be degraded by other bacteria, by exposure to sunlight, or may be absorbed by the organic matter in the lake water and sediments. Most of the mercury that enters the food web does so through absorption into plants and plankton, which are then eaten by higher organism; little is absorbed directly by fish through their gills. Finally, the mercury may be buried in the sediments, or it may leave the water in the form of simple metallic mercury, which readily becomes a gas and enters the atmosphere.

In the mid-Atlantic region, precipitation delivers between 15-20 to as much as 2,600 micrograms of Hg per square meter per year to the ground surface. Studies using cores of sediments in which the sediment layers can be accurately dated show that in New Jersey, the flux rate (rate of transfer of mercury from the air to the ground and water) increase from 1900 to the 1940s and has decreased since that time. Similar studies in other areas, such as Lake Ontario, also show that the deposition of mercury from the air reached a maximum in the 1940's. However, not all studies have documented this trend; for example, a study in the Adirondack region of New York suggests that the deposition rate was still increasing in 1980.

The single most important step in the cycling of anthropogenic mercury is the methylation of divalent mercury to methylmercury, a process carried out by bacteria found in lake and wetland sediments. These microbes only carry out the methylation reactions under anaerobic conditions (i.e., when there is no oxygen present). The rate of methylation reflects not only the concentration of the divalent mercury but also the concentration of oxygen in the water and sediments. Because the resulting methylmercury binds strongly to particles of organic matter in the water and the sediments, the concentration of methylmercury dissolved in the water will also reflect the amount of organic matter

present in the lake.

Phytoplankton are the only organisms that actively take up methylmercury from the water. Thus, other organisms acquire their MeHg through ingestion of the plankton. The amount of MeHg that is found in higher organisms such as fish will reflect not only their feeding behavior, but also many aspects of their physiology (how much of the mercury is retained through the digestive and absorptive processes, how fast the animal grows, and how much is excreted, for example). These aspects of physiology may explain why different kinds of fish have different amounts of mercury in their tissues. Because mercury is efficiently retained in most species, the amount of mercury in the tissues increases as the animal continues to eat. More importantly, animals that eat other animals acquire their mercury loads, and so the concentrations are usually higher in predators than in prey (a process referred to as "bioaccumulation"). Several studies have found that there is approximately twice as much mercury in predators than in their prey. When food chains are long, the top predators may have mercury concentrations that are 10,000 to 1,000,000 times greater than the water concentration.

The aquatic production of methylmercury from airborne mercury is of strong concern in our area because of methylmercury's high bioaccumulation in the food chain and its demonstrated toxicity. In the past, studies involving the determination of aquatic contaminants have mainly involved the direct discharge of wastes or runoff. It is only recently that the role of air-carried contaminants has been determined to be a major source of stream and lake pollutants, and in particular, those that magnify up the food web. Mercury is one of the most important of these. (Article references can be obtained from [derbedrosian@aesop.rutgers.edu](mailto:derbedrosian@aesop.rutgers.edu))\*

## Raritan Basin Watershed Management Project

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considered moderately impaired.

- Loss of ground water recharge – Comparison of 1986 and 1995 recharge volumes indicate that many subwatersheds lost more than 10 percent of their recharge in ten years, and three subwatersheds lost perhaps 20 percent.
- Water supply limitations – The recent drought effects confirm that some rock aquifers are very poor supplies. The South River aquifer system has long since reached its capacity.
- Stormwater impacts – Streams suffer from excessive stormwater flows and the pollutants carried by them, throughout the Basin.

These, along with many other issues, comprise the focus of the Raritan Basin Watershed Management Plan. Addressing them requires clear, feasible implementation strategies; they will be the bulk of the Raritan Basin Watershed Management Plan. From incremental approaches to those that transform management practices entirely, they are the key to plan implementation.

The Raritan Basin is already a heavily used landscape, whether the use is urban, suburban or rural. Our Basin cannot be totally natural – but it can be much better, and so the Raritan Plan focuses heavily on restoration. New Jersey has little institutional capacity for restoration – most agencies focus on regulation of new development. For this reason, restoration activities will be among the biggest challenges for Plan implementation.\*

## The Role of Bacteria ...

(Continued from page 1)

methylmercury (Fig. 2) and as a consequence, a reduction in the levels of methylmercury available for its subsequent bioaccumulation in fish. According to our hypothesis, in contaminated environments, high mercury concentrations are sufficient to induce the expression of enzymes responsible for the degradation of methylmercury. As a result, methylmercury is degraded, and the proportion of methylmercury to total mercury decreases. In pristine environments, the concentrations of Hg(II) are not sufficient to effectively induce the genes responsible for demethylation, and consequently, methylmercury accumulates.

We tested this hypothesis by examining the relationship between the expression of *mer* genes in bacterial communities that inhabit mercury contaminated ecosystems in NJ and the levels of

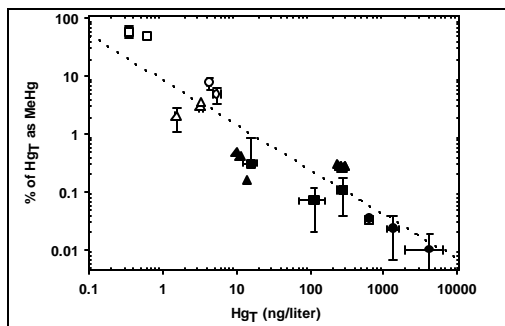


Fig. 2: An inverse relationships between total mercury and the percent of methylmercury in total mercury in water samples collected in mercury contaminated ecosystems in NJ, Berry's Creek in the Meadowlands (closed

total Hg and methylmercury in the water where these communities reside. Samples were collected in Berry's Creek, the Meadowlands, which is highly contaminated as a result of past industrial activities, and in Pine Barren lakes where atmospheric deposition of mercury has resulted in mercury contamination of aquatic biota. Berry's Creek water had very high total mercury concentrations

relative to Pine Barren lakes water (see above and Fig. 2) while water samples from the two sites contained similar concentrations of methylmercury. Our results to date suggest that bacterial methylmercury degradation is enhanced in Berry's Creek. Resistance to mercury is higher and *mer* genes and their mRNA transcripts are more abundant in the microbial communities in Berry's Creek than in Pine Barren lakes, which contain 30-800 times less mercury, indicating that the genes encoding for methylmercury degradation are activated in the more highly contaminated waters. In fact, the number of *mer* transcripts observed in these waters appeared positively correlated with increasing mercury concentrations and decreasing methylmercury to total Hg ratios (Fig. 3). In summary, microbial activities, mediated by mercury resistant bacteria that transform methylmercury to less-toxic volatile inorganic mercury, contribute to a reduction in methylmercury accumulation in Meadowlands waters but not in Pine Barren lakes where methylmercury is therefore available for accumulation in the aquatic food web. Stimulation of microbial degradation of methylmercury maybe integrated into remedial strategies aimed to reduce methylmercury production in natural waters.\*

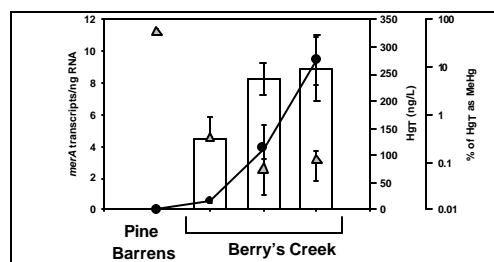
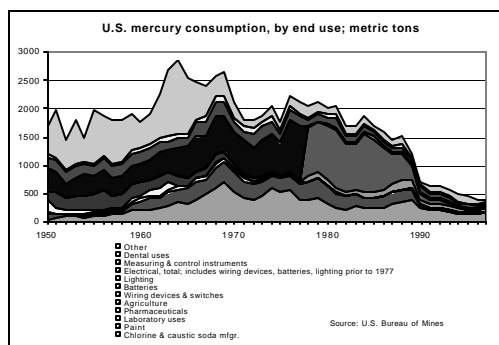


Fig. 3: A demonstration that high concentration of total mercury (circles) and low proportion of methylmercury (triangles) is related to the expression of bacterial genes encoding enzymes that degrade methylmercury to volatile elemental mercury in water samples from Berry's Creek, the Meadowlands, but not in samples from Pine Barren lakes. Expression of bacterial genes

## Historical Sources of Mercury

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Mercury has for many years been widely used in a number of products and manufacturing processes, and is a contaminant of fossil fuels, including coal. The chart below shows the intentional U.S. uses of mercury from 1950.



Mercury in fossil fuels is released as these are burned, and global emissions of mercury have risen with the rise in coal

combustion over the last several centuries. Globally, coal combustion continues to be the largest source of mercury emissions.

Some of the mercury intentionally added to products will ultimately escape to the environment. One particularly large historical source has been the combustion of solid waste, which releases mercury contained in products. Much solid waste was incinerated with essentially no emission controls until the 1970s, especially in large Eastern U.S. cities including New York and Philadelphia. As recently as the early 1990s, solid waste incineration was a large emission source. This was reduced by aggressive actions by New Jersey, including a law limiting mercury content of dry cell batteries and regulations limiting emissions from solid waste incinerators.

Up until the early 1990s, volatilization of mercury from painted surfaces was also a major source of mercury air emissions. This source was dramatically reduced by the elimination of mercury-containing fungicides in paint. Another large source, particularly in agricultural regions such as southern New Jersey, has been use of mercury as a pesticide. Other large historical sources have been manufacturing facilities using mercury, including chlor-alkali plants using mercury cells, and manufacturers of mercury-containing products.\*

# Features

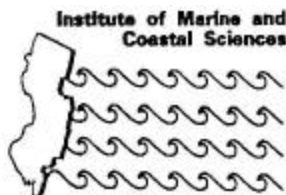
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# New Jersey Flows

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