Fish and Shellfish Program NEWSLETTER

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In This Issue

https://www.epa.gov/fish-tech

This issue of the Fish and Shellfish Program Newsletter generally focuses on mercury.

Recent Advisory News

Updates to Utah's Mercury Fish Consumption Advisory List

Three new locations were added to Utah's Mercury Fish Consumption Advisory list in January 2017. The advisories were issued after state officials found elevated levels of mercury in fish tissue in these waterways.

The new advisories include the following:

Water body	Species	Number of meals per month: Pregnant women and children under 6 years old (4-ounce meals/month)	Women of child-bearing age and children 6–16 years old (8-ounce meals/month)	Adult women past child-bearing age and men >16 years old (8-ounce meals/month)
Big Sand Wash Reservoir (Duchesne County)	Walleye	0	1	5
	Smallmouth Bass	0	1	3
	Yellow Perch	0	1	5
Millsite Reservoir (Emery County)	Splake Trout	1	2	7
Pineview Reservoir (Weber County)	Smallmouth Bass	1	2	8

For a complete list of all Utah Mercury Fish Consumption Advisories, visit www.fishadvisories.utah.gov.

An eight-ounce serving of fish is equivalent to the size of two decks of playing cards. According to an analysis completed by the Utah Department of Health, eating more than the amounts noted in the advisories over a long period of time could result in an intake of mercury that exceeds the U.S. Environmental Protection Agency (EPA) health recommendations.

Mercury is a naturally occurring element that can be transformed into methylmercury, a toxic form found in some natural waters. Those most vulnerable to the effects of mercury toxicity include women who are pregnant or may become pregnant, nursing mothers, and young children. Chronic exposure to low concentrations of methylmercury may result in neurological effects in the developing fetus and children.

Any health risks associated with eating fish from the fish advisory areas are based on long-term consumption and are not tied to eating fish occasionally. Eating fish remains an important part of a healthy diet. The American Heart Association recommends that individuals eat at least two fish or seafood meals weekly.

There is no health risk associated with mercury in the water for other uses of the waterways, such as swimming, boating, and waterskiing.

After testing hundreds of water bodies, health officials have found that fewer than 10 percent of Utah's tested waters have fish with elevated levels of mercury in their tissue.

Not all water bodies have been tested, and further testing may result in additional advisories. Utah fish consumption advisories are issued in partnership between the Utah Department of Health, the Utah Department of Environmental Quality, and the Utah Department of Natural Resources.

For more detailed information, please visit the Utah Fish Advisories website or contact Amy Dickey at ADickey@utah.gov.

Sources: https://documents.deq.utah.gov/communication-office/press-releases/2017-01-12-utah-mercury-fish-consumption-advisory-list.pdf; https://deq.utah.gov/fishadvisories/index.htm#millsite.

EPA News

EPA Approves Limits on Mercury in California Waters

On July 18, 2017, EPA announced the approval of new water quality criteria for mercury in California waters. The new rules, developed by the State Water Resources Control Board, set mercury limits in fish tissue to protect human health and aquatic-dependent wildlife. New protections also have been added for tribal cultural use and subsistence fishing.

In California, Gold Rush era mining operations released millions of pounds of naturally occurring mercury, a potent neurotoxin, into state waterways. Once there, the toxic metal builds up in fish tissue and is consumed by people and wildlife. To address that risk, the state's new criteria set maximum mercury limits in fish tissue for various species caught for sport, subsistence, and cultural practices.

"We commend the State Water Resources Control Board for working with numerous tribes and dischargers to develop and adopt water quality standards for protecting human health and wildlife throughout the state from the harmful effects of mercury," said Alexis Strauss, EPA's Acting Regional Administrator for the Pacific Southwest. "By focusing on mercury concentrations in fish tissue, these rules will have a direct and positive impact on public health and the environment."

The state's new rules set five new water quality criteria for mercury in fish tissue for tribal subsistence fishing, general subsistence fishing, prey fish, sport fish, and for fish commonly consumed by the protected California Least

Tern. The new criteria will help protect and inform the public about levels of mercury in popular sport fish like salmon, bass, sturgeon, and trout.

“Salmon, bass, sturgeon, and other popular fish like trout are sought after as a key food source by California Native American tribes, and other groups that depend on fish for sustenance, but are often contaminated by mercury. Mercury is found in many fresh water bodies in California, and is largely a legacy of the Gold Rush era, and difficult to deal with, but cannot be ignored,” said State Water Board Chair Felicia Marcus. “This approval is an important step in focusing attention on what can be done to limit exposures.”

The new mercury criteria will apply to inland surface waters, enclosed bays, and estuaries of the state, except for water bodies where approved site-specific objectives already exist, such as San Francisco Bay and Delta, Clear Lake, and portions of Walker Creek, Cache Creek, and Guadalupe River watersheds.

For more information on the health effects of exposures to mercury, please visit: https://www.epa.gov/mercury/health-effects-exposures-mercury.

To view a copy of the approval letter and standards, please visit: http://www.waterboards.ca.gov/water_issues/programs/mercury/docs/ca_hg_approval_letter_with_enclosures_signed_071417.pdf.

For more information, contact Soledad Calvino at Calvino.Maria@epa.gov.

Source: https://www.epa.gov/newsreleases/us-epa-approves-limits-mercury-california-waters.

Other News

The 13th International Conference on Mercury as a Global Pollutant

The 13th International Conference on Mercury as a Global Pollutant (ICMGP) took place July 16–21, 2017 in Providence, Rhode Island. The theme of the 2017 conference was understanding the multiple factors that accelerate and attenuate recovery of mercury contamination in response to environmental inputs on local to global scales.

Mercury science and management are the focus of attention worldwide. The Minamata Convention, a global treaty on mercury, is now being ratified and requires that countries around the world control both new and existing sources and monitor the effectiveness of those controls. In many countries, the use of mercury in artisanal gold mining is under investigation, as the magnitude of associated mercury releases and effects may have been underestimated. At the same time, uncertainty remains in the levels of exposure linked to a range of effects of mercury on wildlife and human health. Globally, many local efforts are in progress to remediate mercury contaminated sites. While these initiatives are important steps to mitigate mercury contamination, the extent and rate of potential recovery is unclear because of uncertainties in our understanding of mercury transport, cycling, and trophic transfer.

The 13th ICMGP fostered wide-ranging discussion among participants across issues spanning environmental media, biogeochemical processes, disciplines, types of mercury contamination and remediation, exposure and effects on wildlife and human health, temporal and spatial scales, societal issues, and outreach activities. The conference was a broadly based program that included the following: plenary, invited, and contributed oral presentations; poster presentations; small group meetings; workshops; opportunities for student mentoring; demonstrations by instrument vendors, industry, and research groups; and networking. The plenary sessions will result in four published papers on mercury processes and management at the global scale, mercury process and management at the local scale, mercury exposure to humans and wildlife, and mercury management through the Minamata Convention. The technical program reflected the latest advances, highlighted critical understanding, and promoted active discussion of the science of mercury and innovative strategies for its management.

Source: http://mercury2017.com/program/overview/.

Mercury Exposure from Fish Consumption in Subsistence Fishers in Rural Oklahoma

The Grand Lake watershed in northeastern Oklahoma is downwind and downstream from several major mercury pollution sources. Grand Lake is heavily fished by local recreational and subsistence anglers. Researchers from the Harvard School of Public Health and the University of Oklahoma's Health Sciences Center collaborated with Local Environmental Action Demanded, Inc. (LEAD) to quantify mercury contamination in this watershed and to address community concerns about the safety of the fish. This partnership sought to reduce exposure to mercury from contaminated fish while protecting the cultural practices of American Indian subsistence fishers.

Exposure to the neurotoxin, methylmercury, through consumption of fish is a major public health concern, especially among children and women of childbearing age. American Indians, who often rely on subsistence fishing practices, consume up to 20 times more fish than the general U.S. population. However, unique rates of fish consumption, species consumed, and food preparation techniques typical of American Indians and other ethnic populations are often not considered in risk assessment frameworks.

The partners involved in this project were interested in finding out whether people who regularly catch and consume fish from Grand Lake watershed (particularly members of the area's American Indian, Hispanic, and Micronesian populations) have higher body burdens of mercury compared to other residents of the same community who do not frequently consume local fish, as well as the general U.S. population.

The project partners:

- Found that, in contrast to the general U.S. population, freshwater species contributed the majority of fish consumption (69 percent) and dietary mercury exposure (60 percent) among study participants, despite relatively low mercury concentrations in local fish.
- Observed that hair mercury levels increased with fish consumption, age, and education, and were higher among male participants and the lowest in winter.
- Saw significant variations in fish mercury levels among locations in Grand Lake and Lake Hudson, although overall mercury levels were relatively low compared to other reservoirs in Oklahoma.

- Found that fish in local farm ponds—commonly used in the agricultural regions for raising game fish—had 2 to 17 times higher mercury levels than fish of similar length in nearby reservoirs.
- Observed that pH, water color, rainfall, and nutrients were the best predictors of fish mercury levels across systems, which partially explains the relatively low mercury levels in fish in Grand Lake and Lake Hudson.

The researchers' findings suggest that future studies involving anglers should consider seasonality in fish consumption and mercury exposure, and include household members who share their catch, particularly women and children. Efforts to evaluate benefits of reducing mercury emissions should consider dietary patterns among consumers of fish from local freshwater bodies, and keep in mind that small water bodies, such as farm ponds, may be especially enriched in mercury.

This partnership promoted safe subsistence fishing practices in a contaminated watershed by educating community members on ways to reduce the amount of mercury ingested. The partnership also empowered community members with information to work with state and regional agencies to develop consumption advisories and promote reduction of mercury emissions.

Study Citations:

Dong, Z., R.A. Lynch, and L.A. Schaider. 2016. Key contributors to variations in fish mercury within and among freshwater reservoirs in Oklahoma, USA. *Environmental Science: Processes & Impacts* 18(2):222–236. doi: 10.1039/C5EM00495K.

Dong, Z., R.C. Jim, E.L. Hatley, A.S. Backus, J.P. Shine, J.D. Spengler, and L.A. Schaider. 2015. A longitudinal study of mercury exposure associated with consumption of freshwater fish from a reservoir in rural south central USA. *Environmental Research* 136:155–162. doi: 10.1016/j.envres.2014.09.029.

For more information, contact Laurel A. Schaider at LSchaide@hsph.harvard.edu.

Source: https://www.niehs.nih.gov/research/supported/translational/peph/prog/rta/pfg/schaider/index.cfm.

Brain Benefits of Aerobic Exercise Lost to Mercury Exposure

Cognitive function improves with aerobic exercise, but not for people exposed to high levels of mercury before birth, according to research funded by the National Institute of Environmental Health Sciences (NIEHS), part of the National Institutes of Health (NIH). Adults with high prenatal exposure to methylmercury, which mainly comes from maternal consumption of fish with high mercury levels, did not experience the faster cognitive processing and better short-term memory benefits of exercise that were seen in those with low prenatal methylmercury exposures.

This is one of the first studies to examine how methylmercury exposure in the womb may affect cognitive function in adults. Mercury comes from industrial pollution in the air that falls into the water, where it turns into methylmercury and accumulates in fish. The scientists, based at the Harvard T.H. Chan School of Public Health, suspect that prenatal exposure to methylmercury, known to have toxic effects on the developing brain and nervous system, may limit the ability of nervous system tissues to grow and develop in response to increased aerobic fitness.

"We know that neurodevelopment is a delicate process that is especially sensitive to methylmercury and other environmental toxins, but we are still discovering the lifelong ripple effects of these exposures," said Gwen Collman, PhD., director of the NIEHS Division of Extramural Research and Training. "This research points to adult cognitive function as a new area of concern."

The 197 study participants are from the Faroe Islands, 200 miles north of England, where fish is a major component of the diet. Their health has been followed since they were in the womb in the late 1980s. At age 22, this subset of the original 1,022 participants took part in a follow-up exam that included estimating the participants' VO2 max, or the rate at which they can use oxygen, which increases with aerobic fitness. Also, a range of cognitive tests were performed related to short-term memory, verbal comprehension and knowledge, psychomotor speed, visual processing, long-term storage and retrieval, and cognitive processing speed.

Overall, the researchers found that higher VO2 max values were associated with better neurocognitive function, as expected based on prior research. Cognitive efficiency, which included cognitive processing speed and short term memory, benefitted the most from increased VO2 max.

But when the researchers divided the participants into two groups based on the methylmercury levels in their mothers while they were pregnant, they found that these benefits were confined to the group with the lowest exposure. Participants with prenatal methylmercury levels in the bottom 67 percent, or levels of less than 35 micrograms per liter in umbilical cord blood, still demonstrated better cognitive efficiency with higher VO2 max. However, for participants with higher methylmercury levels, cognitive function did not improve as VO2 max increased.

"We know that aerobic exercise is an important part of a healthy lifestyle, but these findings suggest that early-life exposure to pollutants may reduce the potential benefits," added Collman. "We need to pay special attention to the environment we create for pregnant moms and babies."

In addition to NIH funding, the research was supported by the Danish Council for Strategic Research, Programme Commission on Health, Food, and Welfare.

For more information, contact Virginia Guidry at Virginia.Guidry@nih.gov.

Reference: Oulhote, Y., F. Debes, S. Vestergaard, P. Weihe, and P. Grandjean. 2017. Aerobic fitness and neurocognitive function scores in young Faroese adults and potential modification by prenatal methylmercury exposure. *Environmental Health Perspectives* 125(4):677–683.

Source: https://www.niehs.nih.gov/news/newsroom/releases/2016/september16/index.cfm.

Comprehensive Study Finds Widespread Mercury Contamination Across Western North America

An international team of scientists led by the U.S. Geological Survey (USGS), recently documented widespread mercury contamination in air, soil, sediment, plants, fish, and wildlife at various levels across western North

America. They evaluated potential risk from mercury to human, fish, and wildlife health, and examined resource management activities that influence this risk.

“Mercury is widespread in the environment, and under certain conditions poses a substantial threat to environmental health and natural resource conservation,” said Collin Eagles-Smith, USGS ecologist and team lead. “We gathered decades of mercury data and research from across the West to examine patterns of mercury and methylmercury in numerous components of the western landscape. This effort takes an integrated look at where mercury occurs in western North America, how it moves through the environment, and the processes that influence its movement and transfer to aquatic food chains.”


Wetland habitats, such as the Great Salt Lake wetlands, provide critical feeding areas for many fish and wildlife species. *(Image courtesy of USGS, Collin Eagles-Smith)*

“The movement of mercury through the western landscape—traveling between the air, ground, and water to plants, animals, and ultimately humans, is extremely complex,” said Eagles-Smith. “This series of articles helps further our understanding of the processes associated with that complexity in western North America, highlights where knowledge gaps still exist, and provides information to resource managers that will help with making informed, science-based management and regulatory decisions.”

“This effort provides critical information on mercury pathways to humans and wildlife that government regulators, lawmakers, and the public can use to make decisions,” adds David Evers, Executive Director of Biodiversity Research Institute and co-organizer of the effort. “It builds upon the Northeastern and Great Lakes regional efforts that collected and analyzed environmental mercury data that were often separated by sample type.”


Vegetation patterns affect both soil moisture and the amount of sunlight that reaches the soils, two factors associated with mercury release from soils. *(Image courtesy of U.S. Fish and Wildlife Service)*

Key findings of the report include the following:

- Methylmercury contamination in fish and birds is common in many areas throughout the West, and climate and land cover are some important factors influencing mercury contamination and availability to animals.
- Fish and birds in many areas were found to have mercury concentrations above levels that have been associated with toxic effects.
- Patterns of methylmercury exposure in fish and wildlife across the West differed from patterns of inorganic mercury on the landscape.
- Some ecosystems and species are more sensitive to mercury contamination, and local environmental conditions are important factors influencing the creation and transfer of methylmercury through the food web.

- Forest soils typically contain more inorganic mercury than soils in semi-arid environments, yet the highest levels of methylmercury in fish and wildlife occurred in semi-arid areas.
- Vegetation patterns strongly influence the amount of mercury emitted to the atmosphere from soils.
- Forested areas retain mercury from the atmosphere, whereas less vegetated areas tend to release mercury to the atmosphere.
- Land disturbances, such as urban development, agriculture, and wildfires, are important factors in releasing inorganic mercury from the landscape, potentially making it available for biological uptake.
- Land and water management activities can strongly influence how methylmercury is created and transferred to fish, wildlife, and humans.

Mercury and Methylmercury

Methylmercury is created from inorganic mercury in aquatic ecosystems by bacteria. This is a complex process that only occurs under the right conditions for the bacteria to thrive. Therefore, the movement of inorganic mercury from the atmosphere or land to the water does not always result in equivalent levels of methylmercury in fish and wildlife unless the environmental condition is favorable for methylmercury production.

Sources, Storage, Transport, and Re-release

In the West, the distribution of mercury is a reflection of the diversity of sources combined with a landscape defined by extremes in climate, land cover, and habitat type. These characteristics of the western landscape influence mercury storage, chemical transformation, and buildup through the food chain.

Mercury enters the landscape from the atmosphere, natural geologic sources, historic mining activities, and re-released mercury stored in vegetation and soils. Atmospheric mercury sources are primarily direct natural emissions, such as volcanic eruptions; direct man-made emissions, such as fossil fuel emissions; and re-release from plants and soils. Mercury from the atmosphere makes its way back to earth through precipitation, dust particles, or direct uptake by plants through their leaves.

Densely forested areas, such as those found along the Pacific coastal mountain ranges, collect substantial amounts of mercury because they receive high amounts of precipitation. The deposited mercury easily binds to vegetation and rich forest soils. Soil mercury concentrations in these forests are on average 2.5 times higher than those in dry semi-arid environments. Similarly, water bodies located in these forests have among the highest concentrations of inorganic mercury in their sediments.

The western landscape is defined by extremes in climate, land cover, and habitat type. *(Image courtesy of USGS)*

Mercury Released from Soils

Soil-bound mercury can also move in the opposite direction, from land to the atmosphere. Much of the mercury emitted from the soil is re-released from previously deposited or "old" mercury. The amount of mercury released from soils varies across the region and is dependent upon vegetation patterns, which are important because these patterns affect both soil moisture and the amount of sunlight that reaches the soil—two factors associated with mercury release from soils.

In drier regions with less plant cover, the amount of mercury deposited from the atmosphere is similar to the amount released from soils, suggesting that these areas do not store mercury. In contrast, densely forested areas receive several times more mercury through atmospheric deposition than what is re-emitted to the atmosphere. As a result, western forests tend to provide long-term storage for inorganic mercury whereas much of the mercury deposited across the vast areas of sparsely vegetated semi-arid lands throughout the West either returns back into the atmosphere or becomes available for transport to aquatic ecosystems.

Mercury Released from Wildfires

Wildfire is one of the largest sources of re-released soil mercury to the atmosphere. The amount of mercury released during a wildfire depends on the size of the burned area, the amount of mercury stored in plants and soil, and the severity of burning. High severity fires, or fires that cause greater physical change in an area, release greater amounts of mercury than low severity fires because they burn more fuel and make the soil hotter. Although high severity fires release more stored mercury into the atmosphere, lower severity fires may leave behind mercury in soils in a form that can more easily be moved to aquatic ecosystems and converted to methylmercury. With the increasing rate and severity of wildfires in the West associated with a changing climate, there could be an increase in movement of mercury that has been stored for centuries.

Wildfire is one the largest sources of re-released mercury to the atmosphere and a component to the widespread movement of inorganic mercury to aquatic sediments. *(Public domain)*

Legacy Mining in the West

The West has rich geologic deposits of naturally occurring mercury, as well as gold and silver, where mercury was historically used to extract these valuable elements from rock formations. Historical mining and ore processing for these metals released extensive amounts of mercury into the environment, contaminating lake and river sediments downstream of mining operations. As a result, many of the highest levels of sediment mercury concentrations across the West are associated with legacy gold, silver, and mercury mines. However, the influence of mining on downstream mercury concentrations is most noticeable in small watersheds, because the amount of mercury from mining in larger watersheds is a fraction of what is contributed by other sources and processes such as atmospheric deposition, land disturbance, and erosion of less contaminated soils.

Land Use and Development

Agriculture and urban land development are more widespread across the West than mining, and those land uses have a large influence on the amount of mercury released from soils. As a result, lakes receiving runoff from agricultural or urbanized watersheds show higher rates of mercury accumulation in their sediments than lakes in undisturbed areas. The accumulation rate of mercury in lake sediments, calculated from sediment cores dated from to 1800–2010, showed the highest rate during the last decade (2000–2010) than at any time since the industrial revolution, and approximately five times higher than during pre-industrial times (1800–1850).

Landscape disturbances, such as wildfires, resource extraction, and land development, are major components to the widespread movement of inorganic mercury to aquatic sediment throughout water bodies of the West. However, mercury levels in fish and wildlife do not always match the levels of inorganic mercury because of the requirement for inorganic mercury to be converted to methylmercury before accumulating up the food chain.

“Methylmercury production is a complex microbial process that requires specific environmental conditions,” said Mark Marvin-DiPasquale, USGS microbiologist and co-organizer of the synthesis. “Only a small amount of the inorganic mercury is available to be made into methylmercury by bacteria, and under the right conditions even this small amount can result in methylmercury levels that pose a threat to fish, aquatic birds, and human health.”

As a result, sediment inorganic mercury concentrations alone often do not accurately indicate how much mercury makes its way into the animals living in the associated environment and ultimately, into humans who may consume those animals.

Managing Mercury Risk to Wildlife and Humans

Western North America supports many fish and wildlife communities, several of which are threatened by habitat loss or other factors, including exposure to methylmercury. Fish are indicators of methylmercury contamination because they are an important link in the food chain for both wildlife and humans. Fish and wildlife also are indicators of methylmercury availability over many months to years in the food chain. Mercury contamination of fish and birds is widespread across the West, but the patterns of exposure do not fully match patterns of inorganic mercury distribution in soils and sediments. Although the highest levels of inorganic mercury in soil are found in forested areas, the highest levels of methylmercury in fish and wildlife tend to occur in more arid regions of the West such as the Great Basin. Many existing guidelines and regulations around mercury focus on inorganic mercury in soils and sediments. The combination of inorganic mercury movement, methylmercury creation, and how long mercury stays in the food chain are some of the challenges to managing methylmercury risk to animals and humans.

Fish are indicators of methylmercury contamination because they are an important link in the food chain for both wildlife and humans. *(Image courtesy of U.S. Forest Service)*

More than half of the land, lakes, rivers, streams, and wetlands in the West are publicly owned or managed, much by the federal government. Natural resource management for both conservation and resource extraction can have a particularly strong influence on how mercury is transported over land, through water, and transferred to fish, wildlife, and humans.

Water and its management is a defining characteristic of the western landscape. It is among the continent’s most complex and widespread resource management challenges and has greatly influenced land use, development, and natural resource conservation. The need to store and transport water for shared ecological, agricultural, and human needs has resulted in complex networks of dams and man-made waterways that have transformed the western landscape and dramatically changed the physical, chemical, and biological characteristics of river systems, and in some cases influenced the movement of mercury through these systems.

Wetlands, lakes, and rivers can all promote the creation of methylmercury, and seasonal flow and flood patterns of the West result in numerous locations where methylmercury can be created. These habitats are also often important environments that are critical feeding areas for many fish and wildlife species. Management of water flows and storage throughout the West can influence methylmercury creation in these aquatic habitats and can have a strong impact on the degree of mercury exposure throughout local food webs.

Management of water flows and storage through structures such as Foster Dam in Oregon can influence methylmercury creation in aquatic habitats. *(Image courtesy of U.S. Army Corps of Engineers)*

"We found mercury contamination of birds was common in many areas throughout western North America, some at levels above what is considered toxic to birds," said Josh Ackerman, USGS wildlife biologist and lead author of one of the articles on bird mercury exposure. "Certain ecological characteristics, such as the type of habitat the birds live in, and their diet were important factors influencing bird mercury concentrations and their risk to mercury toxicity."

This body of work was conducted as part of the Western North America Mercury Synthesis Working Group and supported by the USGS John Wesley Powell Center for Analysis and Synthesis. The Working Group is comprised of partners from other United States and Canadian federal, state, and provincial agencies, as well as academic institutions and non-governmental organizations. Primary funding support was provided by the USGS, National Park Service, and EPA, with additional support from the individual authors' organizations.

More Information:

- USGS Environmental Health Science Feature
- University of Michigan News Release
- Biodiversity Research Institute News Release

Study Citation:

Eagles-Smith, C.A., J.G. Wiener, C.S. Eckley, J.J. Willacker, D.C. Evers, M. Marvin-DiPasquale, D. Obrist, J.A. Fleck, G.R. Aiken, J.M. Lepak, A.K. Jackson, J.P. Webster, A.R. Stewart, J.A. Davis, C.N. Aplers, and J.T. Ackerman. 2016. Mercury in western North America: A synthesis of environmental contamination, fluxes, bioaccumulation, and risk to fish and wildlife. *Science of The Total Environment* 568:1213–1226.
doi: 10.1016/j.scitotenv.2016.05.094.

Source: https://www.usgs.gov/news/comprehensive-study-finds-widespread-mercury-contamination-across-western-north-america?qt-news_science_products=3#qt-news_science_products.

Recently Awarded Research

The National Science Foundation Awardees

The National Science Foundation (NSF) awarded the following projects related to mercury and methylmercury.

Collaborative Research: Investigation of the Effects of Organic Matter and Sulfur in the Environmental Fate of Mercury

Professor Kathyryn Nagy of the University of Illinois at Chicago was awarded $224,698 on July 25, 2017, by the Division of Earth Sciences at the NSF.

Mercury is responsible for more than 80 percent of the fish consumption advisories in fresh waters of the United States. Most of this mercury is released by the combustion of coal and is deposited from the atmosphere near and far from the sources. Once deposited, the threat of mercury to food webs depends on the extent to which ionic mercury is converted to (1) methylmercury, the form of mercury that is accumulated from plankton to fish and ultimately to humans, and (2) elemental mercury, the form of mercury that is removed from aquatic systems by volatilization. Mercury is converted to methylmercury mainly by sulfate-reducing bacteria that thrive in aquatic environments deprived of oxygen. The ability of these bacteria to methylate mercury depends on the form of the ionic mercury—whether or not its availability to sulfate-reducing bacteria is limited by its association with organic matter or its precipitation as mercuric sulfide minerals. Mercury is converted to elemental mercury by reduction by a variety of processes for which the influence of organic matter association and precipitation as mercuric sulfide is not well known. The goal of this research is to assess the role of organic matter and sulfur in influencing the conversion of ionic mercury to methylmercury, the first step in making mercury available to aquatic organisms.

The focus of this research is to improve understanding of the interactions between mercury, sulfur, and organic matter. The research is driven by two main hypotheses that investigate the role of sulfur cycling and redox conditions on the reactivity of organic matter to mercury. The first hypothesis examines the abiotic incorporation of sulfide into organic matter as a function of organic matter composition, and the role of metals on the stability of the newly incorporated organic sulfur to oxidation. The second hypothesis addresses the effects of the composition and redox state of organic matter on the reduction of mercury from Hg(II) to Hg(0), and inhibition of the reduction of Hg(II) by complexation to reduced sulfur groups in organic matter and inorganic sulfide. The hypotheses will be tested by (1) examining sulfide incorporation into organic matter and reduction of Hg(II) to Hg(0) by organic matter using laboratory experiments and field studies at sites in the Florida Everglades and interior Alaska that represent a range of sulfur and organic matter conditions and (2) characterizing sulfur and mercury in these materials by X-ray absorption near-edge structure (XANES) spectroscopy. These efforts will be enhanced by the use of electrochemistry to study coupled metal-organic matter redox reactions and high energy-resolution XANES spectroscopy to resolve sulfur functionality.

For more information, contact Kathyryn Nagy at klnagy@uic.edu.

Source: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1628956&HistoricalAwards=false.

Hurricane-mediated Alteration of Microbial Mercury Methylation in Coastal Wetlands

Professors Tsui, Rublee, Bao, and Chow of the University of North Carolina, Greensboro, were awarded $49,826 on March 31, 2017, by the Division of Earth Sciences at the NSF.

Forested wetlands in the coastal plain of the southeastern United States are important sinks of atmospheric mercury but also represent active sites of mercury methylation and production of highly toxic methylmercury, which can contaminate regional water bodies. In October 2016, Hurricane Matthew had a final landfall that resulted in torrential rain and extensive flooding in a short period of time. This extreme weather event flooded an extensive area of the coastal plain, inundating the coastal wetland for a prolonged period that could potentially have stimulated many oxygen-deficient processes including microbial mercury methylation. This research will investigate if and how microbial mercury methylation is stimulated during the prolonged flooding period in these coastal wetlands. This study will raise the awareness of the impacts of extreme weather events on toxic mercury cycling in low-lying coastal areas in the southeastern United States.

This Grants for Rapid Response research is aimed at examining the influences of Hurricane Matthew on the dynamics of microbial mercury methylation in coastal forested wetlands near Winyah Bay, South Carolina. Specifically, this study will integrate field sampling and laboratory experiments to investigate the impacts of this extreme weather event on microbial methylation of mercury in the coastal wetland soils over the course of variation in flooding levels. To evaluate the immediate impacts of Hurricane Matthew on mercury cycling, surface water and wetland soil samples have been collected by the research team since October 10, 2016 near Winyah Bay, South Carolina, where Hurricane Matthew had a final landfall on October 8, 2016. The sampling sites represent transects along with different degrees of seawater intrusion and flood severity impacted by Hurricane Matthew. Samples will be quantified for total mercury and methylmercury, and the abundance of mercury methylation genes (hgcA) associated with the wetland surface soils over time, to examine the temporal and spatial variations of mercury methylation and abundance of mercury methylation genes. Results will be used to evaluate the formation of hot spots and hot moments of mercury methylation in these wetland soils under prolonged inundation. Moreover, controlled laboratory experiments will be employed to examine the effects of different environmental factors on microbial methylation of mercury in these wetland soils, including duration of inundation, addition of fresh litter, increase of water salinity, and a combination of these factors. The proposed work will provide a better understanding of how microbial mercury methylation, the key biogeochemical step making mercury toxic, is impacted in coastal wetlands by extreme weather events.

For more information, contact Martin Tsui at TMTsui@uncg.edu.

Source: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1711642&HistoricalAwards=false.

Examining the Role of Nanoparticles in the Formation and Degradation of Methylated Mercury in the Ocean

Professors Robert Mason and Jing Zhao of the University of Connecticut were awarded $330,000 on August 19, 2016, by the Environmental Chemistry Program in the Chemistry Division at the NSF.

In this project, Mason and Zhao will examine the role of nanoparticles in controlling the reactions between various forms of mercury in the ocean. Specifically, in contrast to freshwater environments, dimethylmercury is found in all ocean waters where measurements have been made. There is little information on its formation mechanisms. The investigators have preliminary evidence to indicate that it may be formed by reactions that involve nanoparticles and other surfaces. It is known that methylmercury, an organic form of mercury found in the ocean, is mostly formed by bacteria that react with inorganic mercury. Reactive surfaces are also be important in the degradation of methylmercury. The investigators will incorporate the research into ongoing outreach programs.

The investigators will conduct laboratory experiments with both commercially manufactured and natural nanomaterials to examine the potential importance of metal nanoparticles in forming metallic and organic forms of mercury under conditions applicable to the ocean. Techniques used in these experiments include UV-visible and fluorescence spectroscopy, electron microscopy, and mass spectrometry. Mercury analyses require instruments that are specifically designed for measurement of the different forms of mercury at low concentrations. The results of this research will enhance our understanding of the processes that form methylated mercury in the ocean which, when bioaccumulated into seafood, is an important human health concern.

For more information, contact Robert Mason at Robert.Mason@uconn.edu.

Source: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1607913&HistoricalAwards=false.

Collaborative Research: Transformations and Mercury Isotopic Fractionation of Methylmercury by Marine Phytoplankton

Professor Reinfelder of Rutgers University, New Brunswick, was awarded $229,752 on August 2, 2016, by the Division of Ocean Sciences at the NSF.

The accumulation of mercury in seafood is a public health concern. The presence of mercury in seafood depends to a large degree on the air-sea exchange of mercury, with atmospheric deposition leading to accumulation of mercury in the ocean. The pathways to seafood start with the uptake of mercury by phytoplankton from seawater where it has always been assumed to accumulate to be eaten by grazers and then passed on to larger organisms. This project challenges this assumption with preliminary data that suggest certain phytoplankton species can transform mercury to volatile forms (mercury vapor and dimethylmercury) that are lost to the atmosphere, a process that removes mercury from the ocean rather than simply concentrating it into the ecosystem and seafood. This process, which has not been studied before, could dramatically alter our view of the mercury cycle in the ocean. The researchers will look for the specific phytoplankton species that are capable of volatilizing mercury and quantify the rates at which they do so.

Biogeochemical cycling of mercury in the ocean may be more complex than previously assumed. New evidence has challenged the idea that methylmercury merely accumulates in phytoplankton and undergoes little to no transformation before being passed into the food web. This project aims to more fully elucidate the mechanisms behind the intracellular transformation of methylmercury to volatile mercury and dimethylmercury that can be lost to the atmosphere, as well as to evaluate the range of algal taxa that can perform this transformation using directed culture work. Additionally, the principal investigators will investigate evidence that thiols, organic selenium compounds, and sulfides are required to facilitate these reactions within the phytoplankton, and specific pathways will be investigated and quantified through this research. Stable mercury isotopic data has been used to track mercury sources and pathways in marine systems and its fractionation during these methylmercury transformations will also be quantified for future field study of marine mercury. The investigators hypothesize that coccolithophorids and other haptophytes capable of these intracellular reactions may account for a significant portion of the production of volatile mercury in the ocean. If this turns out to be the case, understanding and quantifying these volatilization processes may significantly alter the current understanding of the overall biogeochemical cycling of mercury in the ocean.

For more information, contact John Reinfelder at Reinfelder@envsci.rutgers.edu.

Source: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1634154&HistoricalAwards=false.

Recent Publications

Journal Articles

The list below provides a selection of research articles focusing on mercury.

Human Dietary Exposure

► **Mercury in marine fish, mammals, seabirds, and human hair in the coastal zone of the southern Baltic**
Beldowska, M., and L. Falkowska. 2016. Mercury in marine fish, mammals, seabirds, and human hair in the coastal zone of the southern Baltic. *Water, Air, & Soil Pollution* 227:52.

► **Persistent DNA methylation changes associated with prenatal mercury exposure and cognitive performance during childhood**
Cardenas, A., S.L. Rifas-Shiman, G. Agha, M.F. Hivert, A.A. Litonjua, D.L. DeMeo, X. Lin, C.J. Amarasiriwardena, E. Oken, M.W. Gillman, and A.A. Baccarelli. 2017. Persistent DNA methylation changes associated with prenatal mercury exposure and cognitive performance during childhood. *Scientific Reports* 7:288.

► **Mercury distribution in organs of fish species and the associated risk in traditional subsistence villagers of the Pantanal wetland**
Ceccato, A.P.S., M.C. Testoni, A.R.A. Ignácio, M. Santos-Filho, O. Malm, and S. Díez. 2016. Mercury distribution in organs of fish species and the associated risk in traditional subsistence villagers of the Pantanal wetland. *Environmental Geochemistry and Health* 38(3):713–722.

► **Mercury in western North America: A synthesis of environmental contamination, fluxes, bioaccumulation, and risk to fish and wildlife**
Eagles-Smith, C.A., J.G. Wiener, C.S. Eckley, J.J. Willacker, D.C. Evers, M. Marvin-DiPasquale, D. Obrist, J.A. Fleck, G.R. Aiken, J.M. Lepak, A.K. Jackson, J.P. Webster, A.R. Stewart, J.A. Davis, C.N. Alpers, and J.T. Ackerman. 2016. Mercury in western North American: A synthesis of environmental contamination, fluxes, bioaccumulation, and risk to fish and wildlife. *Science of the Total Environment* 568:1213–1226.

► **Mercury exposure and heart diseases**
Genchi, G., M.S. Sinicropi, A. Carocci, G. Lauria, and A. Catalano. 2017. Mercury exposure and heart diseases. *International Journal of Environmental Research and Public Health* 14(1):74.

► **Parental whole life cycle exposure to dietary methylmercury in zebrafish (*Danio rerio*) affects the behavior of offspring**
Mora-Zamorano, F.X., R. Klingler, C.A. Murphy, N. Basu, J. Head, and M.J. Carva III. 2016. Parental whole life cycle exposure to dietary methylmercury in zebrafish (*Danio rerio*) affects the behavior of offspring. *Environmental Science & Technology* 50(9):4808–4816.

- **Aerobic fitness and neurocognitive function score in young Faroese adults and potential modification by prenatal methylmercury exposure**
  Oulhote, Y., F. Debes, S. Vestergaard, P. Weihe, and P. Grandjean. 2016. Aerobic fitness and neurocognitive function score in young Faroese adults and potential modification by prenatal methylmercury exposure. *Environmental Health Perspectives* 125(4):677–683.

- **Global sources and pathways of mercury in the context of human health**
  Sundseth, K., J.M. Pacyna, E.G. Pacyna, N. Pirrone, and R.J. Thorne. 2017. Global sources and pathways of mercury in the context of human health. *International Journal of Environmental Research and Public Health* 14(1):105.

- **Methyl mercury exposure and neurodevelopmental outcomes in the Seychelles Child Development Study Main cohort at age 22 and 24 years**
  van Wijngaarden, E., S.W. Thurston, G.J. Myers, D. Harrington, D.A. Cory-Slechta, J.J. Strain, G.E. Watson, G. Zareba, T. Love, J. Henderson, C.F. Shamlaye, and P.W. Davidson. 2017. Methyl mercury exposure and neurodevelopmental outcomes in the Seychelles Child Development Study Main cohort at age 22 and 24 years. *Neurotoxicology and Teratology* 59:35–42.

Concentrations in Fish and Shellfish

- **Prediction of fish and sediment mercury in streams using landscape variables and historical mining**
  Alpers, C.N., J.L. Yee, J.T. Ackerman, J.L. Orlando, D.G. Slotton, and M.C. Marvin-DiPasquale. 2016. Prediction of fish and sediment mercury in streams using landscape variables and historical mining. *Science of the Total Environment* 571:364–379.

- **Mercury and methylmercury dynamics in sediments on a protected area of Tagus Estuary (Portugal)**
  Cesário, R., C.E. Monteiro, M. Nogueira, N.J. O'Driscoll, M. Caetano, H. Hintelmann, A.M. Mota, and J. Canário. 2016. Mercury and methylmercury dynamics in sediments on a protected area of Tagus Estuary (Portugal). *Water, Air, & Soil Pollution* 227:475.

- **Critical perspectives on mercury toxicity reference values for protection of fish**
  Fuchsman, P.C., M.H. Henning, M.T. Sorensen, L.E. Brown, M.J. Bock, C.D. Beals, J.L. Lyndall, and V.S. Magar. 2016. Critical perspectives on mercury toxicity reference values for protection of fish. *Environmental Toxicology and Chemistry* 35(3):529–549.

- **Climate and physiography predict mercury concentrations in game fish species in Quebec lakes better than anthropogenic disturbances**
  Lucotte, M., S. Paquet, and M. Moingt. 2016. Climate and physiography predict mercury concentrations in game fish species in Quebec lakes better than anthropogenic disturbances. *Archives of Environmental Contamination and Toxicology* 70(4):710–723.

- **Evidence of mercury biomagnification in the food chain of the cardinal tetra *Paracheirodon axelrodi* (Osteichthyes: Characidae) in the Rio Negro, central Amazon, Brazil**
  Marshall, B.G., B.R. Forsberg, M. Thomé-Souza, R. Peleja, M.Z. Moreira, and C.E.C. Freitas. 2016. Evidence of mercury biomagnification in the food chain of the cardinal tetra *Paracheirodon axelrodi* (Osteichthyes: Characidae) in the Rio Negro, central Amazon, Brazil. *Journal of Fish Biology* 89(1):220–240.

- **Bioaccumulation and biomagnification of mercury and methylmercury in four sympatric coastal sharks in a protected subtropical lagoon**
  Matulik, A.G., D.W. Kerstetter, N. Hammerschlag, T. Divoll, C.R. Hammerschmidt, and D.C. Evers. 2017. Bioaccumulation and biomagnification of mercury and methylmercury in four sympatric coastal sharks in a protected subtropical lagoon. *Marine Pollution Bulletin* 116(1–2):357–364.

- **Bioaccumulation of mercury in fish as indicator of water pollution**
  Moiseenko, T.I., and N.A. Gashkina. 2016. Bioaccumulation of mercury in fish as indicator of water pollution. *Geochemistry International* 54(6):485–493.

- **Recent advances in the study of mercury methylation in aquatic systems**
  Paranjape, A.R., and B.D. Halla. 2017. Recent advances in the study of mercury methylation in aquatic systems. *FACETS* 2:85–119.

- **Geographic and temporal patterns of variation in total mercury concentrations in blood of harlequin ducks and blue mussels from Alaska**
  Savoy, L., P. Flint, D. Zwiefelhofer, H. Brant, C. Perkins, R. Taylor, O. Lane, J. Hall, D. Evers, and J. Schamber. 2017. Geographic and temporal patterns of variation in total mercury concentrations in blood of harlequin ducks and blue mussels from Alaska. *Marine Pollution Bulletin* 117(1–2):178–183.

- **Mercury temporal trends in top predator fish of the Laurentian Great Lakes from 2004 to 2015: Are concentrations still decreasing?**
  Zhou, C., M.D. Cohen, B.A. Crimmins, H. Zhou, T.A. Johnson, P.K. Hopke, and T.M. Holsen. 2017. Mercury temporal trends in top predator fish of the Laurentian Great Lakes from 2004 to 2015: Are concentrations still decreasing? *Environmental Science & Technology* 51(13):7386–7394.

Other

- **Evaluating the effectiveness of the Minamata Convention on mercury: Principles and recommendations for next steps**
  Evers, D.C., S.E. Keane, N. Basu, and D. Buck. 2016. Evaluating the effectiveness of the Minamata Convention on mercury: Principles and recommendations for next steps. *Science of the Total Environment* 569–570:888–903.

- **Spatial-temporal dynamics and sources of total Hg in a hydroelectric reservoir in the Western Amazon, Brazil**
  Pestana, I.A., W.R. Bastos, M.G. Almeida, D.P. de Carvalho, C.E. Rezende, and C.M.M. Souza. 2016. Spatial-temporal dynamics and sources of total Hg in a hydroelectric reservoir in the Western Amazon, Brazil. *Environmental Science and Pollution Research* 23(10):9640–9648.

- **Eutrophication increases phytoplankton methylmercury concentrations in a coastal sea—A Baltic Sea case study**
  Soerensen, A.L., A.T. Schartup, E. Gustafsson, B.G. Gustafsson, E. Undeman, and E. Björn. 2016. Eutrophication increases phytoplankton methylmercury concentrations in a coastal sea—A Baltic Sea case study. *Environmental Science & Technology* 50(21):11787–11796.

- **Total mercury and methylmercury response in water, sediment, and biota to destratification of the Great Salt Lake, Utah, United States**
  Valdes, C., F.J. Black, B. Stringham, J.N. Collins, J.R. Goodman, H.J. Saxton, C.R. Mansfield, J.N. Schmidt, S. Yang, and W.P. Johnson. 2017. Total mercury and methylmercury response in water, sediment, and biota to destratification of the Great Salt Lake, Utah, United States. *Environmental Science & Technology* 51(9):4887–4896.

Upcoming Meetings and Conferences

71st Annual Shellfish Conference & Tradeshow
September 19–21, 2017
Welches, Oregon

8th International Conference on Fisheries & Aquaculture
October 2–4, 2017
Toronto, Canada

Interstate Shellfish Sanitation Conference 2017 Biennial Meeting
October 14–19, 2017
Myrtle Beach, South Carolina

2017 State of Lake Michigan Conference
November 7–10, 2017
Green Bay, Wisconsin

The Society for Integrative & Comparative Biology Annual Meeting 2018
January 3–7, 2018
San Francisco, CA

9th International Charr Symposium
June 18–21, 2018
Duluth, Minnesota

2017 Organization of Fish & Wildlife Information Managers
October 1–5, 2017
Chattanooga, Tennessee

10th Indo-Pacific Fish Conference
October 2–6, 2017
Tahiti, French Polynesia

Aquaculture Europe 2017
October 17–20, 2017
Dubrovnik, Croatia

9th U.S. Symposium on Harmful Algae
November 11–17, 2017
Baltimore, Maryland

Aquaculture American
February 19–22, 2018
Las Vegas, Nevada

Additional Information

This monthly newsletter highlights current information about fish and shellfish.

For more information about specific advisories within the state, territory, or tribe, contact the appropriate state agency listed on EPA's National Listing of Fish Advisories website at https://fishadvisoryonline.epa.gov/Contacts.aspx.

For more information about this newsletter, contact Sharon Frey (Frey.Sharon@epa.gov, 202-566-1480).

Additional information about advisories and fish and shellfish consumption can be found at https://www.epa.gov/fish-tech.