PROCEEDINGS

U.S. Environmental Protection Agency Region 9

State-of-the-Science Workshop on Mercury Remediation in Aquatic Environments

EPA Region 9 First Floor Conference Center
75 Hawthorne Street
San Francisco, CA

And Online at http://www.clu-in.org

September 26, 2013

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Executive Summary

The U.S. Environmental Protection Agency (EPA) Region 9 State-of-the-Science Workshop on Mercury Remediation in Aquatic Environments was held on September 26, 2013, in San Francisco, California, and via webinar. The workshop brought together participants and speakers from nongovernmental organizations, academia, private industry, regulatory agencies, the consulting sector and all levels of government (federal, state, local and tribal). They shared the latest information regarding mercury remediation techniques and their effects on levels of mercury in fish tissue and presented a balanced and honest assessment of what is and is not working with respect to remediation. This was driven by concerns resulting from legacy mining activities, aerial deposition and other potential sources of methyl mercury.

The objective was to understand the key mechanisms linking source loads, methylation, and bioaccumulation to guide future remediation decisions. The workshop also served as a stimulus for increased collaboration among the various researchers and agencies. Facilitators were able to ask questions and collect responses from participants on a number of issues. These include two key questions regarding research data gaps and potential mercury remediation pilot projects in Region 9. Tables located at the end of the "Meeting Summary" section of these Proceedings (pp. 31-36) and in responses to an on-line post-meeting survey (pp. 69-70) contain the compilation of participant responses to these two important questions (data gaps and potential pilot studies).

The survey had about a 20% response rate. The majority of the participants seemed very pleased with the workshop. About 65% of the participants said they could now identify techniques for reducing or eliminating mercury at both the source and downstream of the source. Almost 80% said they now understood the knowledge gaps and technology needs in the field. There were a few problems, including occasional audio glitches and the fact that we focused on Region 9 mercury sites. But given budget issues, many were pleased that they could attend free or participate via the free webinar. All of the survey results are attached below, starting on page 53.

The workshop was sponsored by ORD's Office of Science Policy and supported by OSRTI and Region 9 with full webinar participation, with portions of both speakers and participants linking in virtually. Approximately 75 individuals attended the onsite meeting, with more than 225 participants from 11 countries joining via webinar.

Thanks go out to many who played a part, including the speakers and the planning committee, which was led by Michael Gill. Planning committee members included Andy Bain, Ned Black, Chris Eckley, John Hillenbrand, Sue Keydel, Kelly Manheimer, Stephen McCord, Jim Sickles and Clancy Tenley, all from EPA, except Stephen (of McCord Environmental, Inc.). Other support was provided by Jean Balent (EPA), Kevin David (EMS), Krissi Folsom (EMS), Steven Jong (EPA), Kristen LeBaron (SCG), Lori Lewis (EPA), Terri Moldanado (EPA), Peter Riddle (EMS), Matt Small (EPA), Arthur Toy (EPA), Susie Warner (SCG), Ray Workman (EPA) and Linda Yee (EPA).

Archives for the workshop are posted at the following website: http://cluin.org/conf/tio/hg/ . The material posted includes these Proceedings, audio and slide recordings of the live event, all presentation materials, instructor contact information, and some additional handouts.

Agenda

	Hg Remediation in Aquatic Environments Program Schedule **September 26, 2013** **EPA Region 9** **San Francisco, CA**	V. Sept 11, 2013
Time	Speaker / Affiliation / Topic (R=Remote)	
8:30-8:40am (PACIFIC)	Welcome - **Mike Gill**, **Clancy Tenley** (EPA Region 9)	
8:40-9:00am	INTRODUCTION: Framing the Problem / Challenges / Goals **Lori Lewis**, EPA Region 9 (Ground Rules) (5 min) **Ned Black**, EPA Region 9 (Setting The Stage, Pt. 1) (10 min) **Izzy Martin**, The Sierra Fund (Setting the Stage, Pt. 2) (5 min)	
	SOURCE CONTROLS	
9:00-10:15am	**Source Controls – Session 1** **(3 talks @ 20min each + 15 min q&a)** Session Chair: **Stephen McCord**, McCord Environmental - **Michelle Wood**, California Water Board (Fish Mercury Impairment in California Reservoirs – Historic Mines and Other Factors) - **Matt Wilkening**, EPA R10 (Investigation of the Red Devil Mine, Alaska) - R - **Vic Claassen**, UC Davis (Remediation of Scarred Landscapes) - Q&A / Discussion (15 min)	
10:15-10:30am	**BREAK**	

10:30am-Noon	**Source Controls – Session 2** **(3 talks @ 20min each + 30 min q&a)** Session Chair: **Jim Sickles**, EPA Region 9 - **Jim Rytuba**, USGS (Assessment of Remediation of Mercury Mines in the California Coast Range) - **Greg Reller**, Burleson Consulting (Pre- and Post-Remediation Mercury Monitoring Results at Abandoned Mine Sites) - **Charlie Alpers**, USGS (Mercury Contamination and Bioaccumulation from Historical Gold Mining in the Sierra Nevada – Site Characterization and Remediation) - Q&A / Discussion (30 min)	
Noon-1:00pm	**LUNCH**	
	DOWNSTREAM CONTROLS	
1:00 – 2:30pm	**Downstream Controls – Session 3** **(3 talks @ 20min each + 30 min q&a,** Session Chair: **Andy Bain**, EPA Region 9 - **Chris Eckley**, EPA Reg 10 (Mercury Transport and Transformation at the Black Butte Mine Superfund Site) - **Lisamarie Windham-Myers**, USGS (Yolo Bypass - From Micro to Macro – A Recent Synthesis of Mercury Science From the Sacramento-San Joaquin Delta to Evaluate Management Options For Limiting Biotic Exposure) - **Stephen Dent**, CDM Smith (Managing Mercury Enrichment in Freshwater Lakes and Reservoirs with Hypolimnetic Oxygenation) - Q&A / Discussion (30 min)	
2:30-2:45pm	**BREAK**	

2:45- 4:30pm	**<u>Downstream Controls – Session 4</u>** **<u>(4 talks @ 20min each + 25 min q&a)</u>** Session Chair: **Chris Eckley**, EPA Region 10 - **Eli Curiel**, USFS (Peña Blanca Lake Sediment & Mercury Removal) - R - **Carrie Monohan**, Sierra Fund (Combie Reservoir Sediment and Mercury Removal Project) - **Tamara Kraus**, USGS (Removal of Mercury From Surface Waters Using In Situ Coagulation with Metal-Based Salts; Field Study Building on Bench-Scale Study) - **Jesse Lepak**, Colorado Division of Wildlife (Fisheries Management to Remediate Hg Contamination in Sport Fish) – R - Q&A / Discussion (25 min)	
4:30- 5:00pm	Summary and Conclusions NEXT STEPS **(Facilitator: Lori Lewis)** Ideas for 3 Region 9 Hg Remediation Pilot Projects Research Needs / Data Gaps – Ideas to Communicate to ORD, other federal agencies, academic institutions, etc. Summary / Plan for Proceedings	

Meeting Summary

INTRODUCTION AND OVERVIEW

The U.S. Environmental Protection Agency (EPA) Region 9 State-of-the-Science Workshop on Mercury Remediation in Aquatic Environments was held on September 26, 2013, in San Francisco, California, and via webinar. The workshop brought together participants from nongovernmental organizations, academia, private industry, regulatory agencies, the consulting sector and all levels of government (federal, state, local and tribal) to share the latest information regarding mercury remediation, particularly within Region 9. The goals of the workshop were to identify key data gaps and research needs and propose ideas for three potential Region 9 mercury remediation pilot projects. The workshop should also serve as a stimulus for increased collaboration among the various researchers and agencies. Approximately 75 individuals attended the onsite meeting, with more than 225 participants from a variety of countries joining via webinar. This meeting summary is only part of the workshop archives. Other records include audio and presentation recording of all of the presentations, as well as any participant commentary that went along with it. This is posted on http://cluin.org/conf/tio/hg/.

Welcome
Mike Gill and Clancy Tenley, EPA Region 9

Mike Gill welcomed the participants to the meeting and explained that previous mercury workshop meetings on the topic were held in 2000 and 2011. It was time for the Agency to provide an update regarding mercury remediation, which is a priority for EPA, particularly in states with mining legacies. This workshop should provide "real world" stories about mercury remediation and mitigation with the goal of providing new answers and ideas about mercury remediation to the practitioners.

Clancy Tenley welcomed the participants on behalf of Region 9 and thanked them for attending the workshop to share their expertise. Mercury is a problem in western states, with three Superfund mercury mining sites alone within a short driving distance of the EPA Region 9 office. The California Water Board has reported that methylmercury is the pollutant that poses the most widespread potential health risk in the State as a result of the mercury-contaminated fish caught in California lakes, with 21 percent of these lakes being rated as unsafe for fish consumption. Currently, 41 states have fish consumption advisories in place for methylmercury in their lakes. Mercury is a potent neurotoxin, and methylation of mercury increases complications in terms of remediation and human health problems. The goal of the meeting is to identify data gaps that need to be filled and pilot projects that could be initiated to decrease mercury toxicity in aquatic environments. The fact that representatives from many countries are attending the workshop indicates this is a significant, widespread problem. The workshop should have tangible results.

Introduction: Framing the Problem/Challenges/Goals
Lori Lewis and Ned Black, EPA Region 9, and Izzy Martin, The Sierra Fund

Lori Lewis explained the logistics of the meeting, which would include small group discussions of specific questions. Representatives from various sectors were brought together to share their expertise. She reiterated that the participants were to consider data gaps that need to be filled and pilot projects that could be initiated to decrease mercury toxicity in aquatic environments.

Ned Black displayed a map of the EPA-lead Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mercury mine sites within Region 9, noting there were many State-lead sites not shown on the map. EPA has taken action at many of the mine sites, but the Agency acknowledges there is a great deal that still is not understood. Of the four Region 9 sites on the National Priorities List (NPL), EPA is not confident that it can break the exposure pattern at two, and mitigation and remediation options at the other two sites are still being explored. The Agency has taken emergency removal authority at seven other sites, but long-term monitoring is not normally part of those projects. Remedial investigation includes characterizing the nature and extent of the pollution, developing a conceptual site model, and selecting a risk-based clean-up goal. The focus of this workshop was the next step of the Superfund process, the feasibility study. The "holy grail" of the process is implementation of the Record of Decision, which describes the action that will be taken at a site.

Dr. Black provided examples of remediation challenges, such as a lack of correlation between fish methylmercury levels and mine source contamination in three Arizona watersheds, which disrupted the conceptual plan to remediate the mine sites. One general assumption is that successful remediation requires source control, but experience has proven that is not straightforward. Another challenge is that mercury methylation and subsequent biomagnification in the food web can be hyperefficient. Also, air deposition of mercury cannot be ignored as a source, funding for removals and remediation are scarce, and stakeholders prefer that money be spent on successful projects.

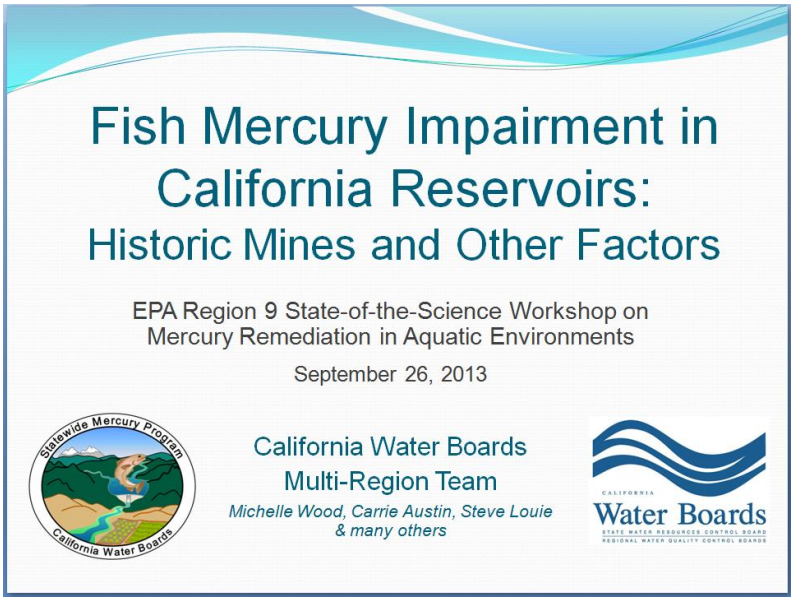
Izzy Martin explained that 150 years ago in the search for gold, nearly every river in the Sierra Nevada was dammed and the water diverted to power machines to blow apart mountains. The rubble caused the city of Sacramento to flood repeatedly and filled more than one-third of the San Francisco Bay with hydraulic sediment. Mercury was mined in coastal California and transported to the mountainous areas where it was used to amalgamate gold. Millions of pounds of mercury were left in the watershed as a result of these practices. The waste remained for a long time after gold mining operations ceased, emitting toxins into the water, fish and people. When the environmental and cultural impacts of these practices finally were examined, a key part was consulting with tribes because of their knowledge of these impacts. The Sierra Fund mission is to increase public and private investment to restore and protect the communities and resources of the Sierra, and addressing mercury contamination falls within this mission. The Sierra Fund established a working group of federal, state and tribal governments; nonprofit organizations; and water agencies to address the issue via three strategies. The first strategy was to educate the public about how to protect themselves from exposure. The second strategy was to establish real projects to make real progress. The third strategy was advocacy. As a result of the advocacy, the state of California is considering two water bonds, both of which address mercury remediation of mines. Also, the Sierra Fund was awarded a $15.5 million grant the day prior, $2.2 million of which will be devoted to mercury remediation.

SESSION I: SOURCE CONTROLS

SESSION MODERATOR: STEPHEN MCCORD, MCCORD ENVIRONMENTAL

Fish Mercury Impairment in California Reservoirs: Historic Mines and Other Factors

Michelle Wood, California Water Board



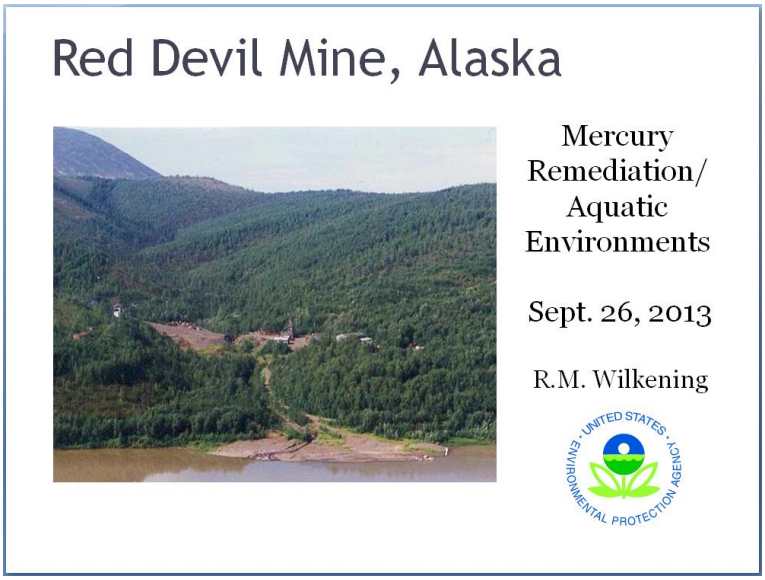
Michelle Wood explained that California has developed its Statewide Mercury Control Program for Reservoirs to address methylmercury contamination in fish by quickly and measurably reducing fish mercury levels. Because the issue is complicated with multiple important factors, the key question is: Where might mine remediation enable measurable and timely mercury in fish reductions? The California Water Board is interested in obtaining feedback in regard to this question. The program was initiated because many reservoirs throughout the state have elevated fish mercury levels. It is encouraging that reservoirs at higher elevations versus lower elevations have lower fish mercury levels, and a predator fish, black bass, also displays low mercury levels. A dataset was collected from approximately 350 lakes and reservoirs indicating that approximately 50 percent were impaired; as California has more than 1,000 reservoirs, the program potentially could encompass more than 500 reservoirs. Also, because mercury in fish is a complicated issue, reducing contamination from sources may not solve the problem. Many reservoirs with fish mercury contamination have sediment mercury levels close to background. Although there is a significant statistical correlation between sediment mercury concentrations and fish mercury concentrations, there is a great deal of variability that is not explained by sediment mercury concentrations. As a result of the multiple factors in play, source control may not provide a uniform solution for mercury remediation in California reservoirs.

When 30 watershed and reservoir variables were examined, three were determined to be of equal importance and assumed to explain more than 80 percent of the variability in fish mercury concentrations: (1) total aqueous mercury concentration, (2) the ratio of aqueous methylmercury concentration to chlorophyll-*a* concentration, and (3) annual average water level fluctuation. These factors relate to methylmercury sources, methylation potential and bioaccumulation at the food web base. Each of these has different aspects that may be controllable. Also, because of geologic formations along the coast, some reservoirs are in naturally mercury-enriched areas; many reservoirs are affected by the numerous amounts of historical mercury and gold mining sites in the state. When reservoir fish methylmercury levels, atmospheric deposition rate and mine data were combined, results indicated that many reservoirs with fish mercury concentrations above the target level were not located downstream of mining sites. As expected, however, those reservoirs with the highest fish methylmercury levels were associated with

extensive mercury mining. These data, indicating the influence of multiple factors, led to the formation of the key question described above.

To answer this question, desktop GIS-based analysis was conducted that examined three factors: (1) high reservoir sediment mercury compared to background, (2) mine sites localized to a relatively small watershed area, and (3) mines within 10 to 20 kilometers (km) of reservoirs. Results indicated that 53 of the 74 mercury-impaired reservoirs have at least one recorded upstream mine or prospect. Of these 53 reservoirs, only three "probably" and two "maybe" were expected to make timely and measurable improvements from mine waste remediation. When two neighboring reservoirs (San Antonio and Nacimiento) were compared, mercury in the Nacimiento Reservoir appeared to be able to be quickly controlled via mine remediation. This reservoir had an aqueous methylmercury to chlorophyll-*a* ratio five times greater than that of the San Antonio Reservoir. The three equally important variables identified above were analyzed with the GIS-based approach, but it is possible that other factors (e.g., mine processes, mine productivity) may need to be considered. To explore the various tools available, researchers should have realistic expectations of where quick improvements are possible from mine waste remediation. The California Water Board looks forward to coordinating with stakeholders to explore methods to prioritize specific sites within a watershed.

Investigation of the Red Devil Mine, Alaska
Matt Wilkening, EPA Region 10



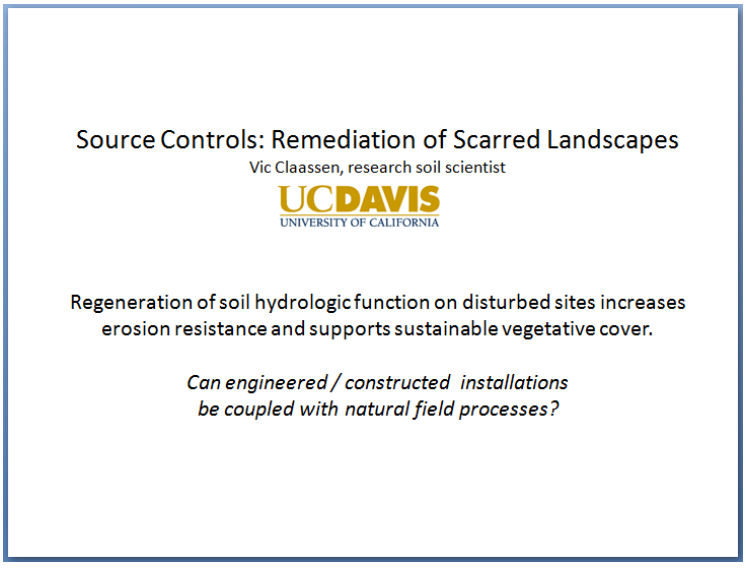
Matt Wilkening explained that the 190-acre Red Devil Mine in Alaska, which was actively mined from 1933 to 1971, has been abandoned, and EPA is performing cleanup with the Alaska Department of Environmental Conservation (ADEC). Approximately 1,400 tons of mercury has been produced from the south-central region of Alaska, the region in which the mine is located, representing 99 percent of all Alaska-produced mercury. The Red Devil Mine produced nearly 87 percent of mercury within the state. The mercury ore is predominantly cinnabar. The Bureau of Land Management (BLM) began sporadic CERCLA investigations of the mine in 1989 until EPA and ADEC began their formal oversight in 2010.

Mr. Wilkening displayed a 1974 satellite image of the surface features of the mine, which included a trench, sluice gulley, settling ponds, bulldozed area, roads and sluice deltas. The mine is located on the south bank of the Kuskokwim River, which is the main transportation source to and from the mine. In addition to the ongoing CERCLA investigation, BLM has been performing a large-scale fish mercury study in the Kuskokwim River and its tributaries. This area of the

investigation includes Red Devil Creek, which bisects the Red Devil Mine processing area and is eroding the contaminated material. The sampling area for this mercury in fish study is large compared to the localized CERCLA investigation. Water and sediment sampling results indicated that the Cinnabar and Red Devil Creeks have elevated mercury levels compared to other creeks in the sampling area. BLM also is performing watershed health assessments using aquatic insects and applying metrics that include species richness and pollution tolerance values. BLM examined the metrics to determine whether differences existed between streams with a history of mining and reference streams considered to be in pristine condition. Total mercury levels in aquatic insects in Red Devil Creek were found to be significantly elevated compared to other streams. Preliminary data from Cinnabar Creek show similar results. Surprisingly, data from Red Devil and Cinnabar Creeks indicate that the number of intolerant taxa (those species sensitive to pollution) within these creeks are similar to reference streams, indicating that although research has demonstrated that aquatic insects are sensitive to metal contaminants, the aquatic insects in Red Devil Creek appear to be relatively insensitive to mercury, arsenic and antimony, in spite of the elevated tissue concentrations.

Predatory fish tissues also were examined for total mercury, and generally, all of the sampled fish displayed detectable mercury levels, with several of the major tributaries showing the highest levels of fish mercury. In 2011, Alaska released a fish consumption advisory recommending decreased consumption of major game fish by children and pregnant women; these fish, however, are important to the local subsistence lifestyle. Finally, the CERCLA investigations have included health assessments based on arsenic, and concluded that the public health risks will need to be addressed. The timeline for the CERCLA cleanup includes public meetings whose timing does not conflict with subsistence lifestyle activities and early action at the processing area to begin in the summer of 2014. The proposed Record of Decision will be released in 2014 or 2015, with the remedial design and action planned for 2015 to 2016.

Source Controls: Remediation of Scarred Landscapes
Vic Claassen, University of California, Davis



Vic Claassen explained that his laboratory is attempting to decrease sediment transport from disturbed sites to zero. Regeneration of soil hydrologic function on disturbed sites increases erosion resistance and supports sustainable vegetative cover. The question is whether engineered and/or constructed installations can be coupled with natural field processes. Because is not possible to implement projects at all of California's 47,000 abandoned mine sites, the researchers are investigating whether intensive revegetation can immobilize

sediment in lieu of constructed projects. For example, a well compacted grading job can lead to a potential infiltration problem. Without infiltration, rainfall accumulates as overland flow, and the runoff mobilizes sediment, including surface-sorbed colloidal mercury. The challenge is to ensure that organics on graded slopes remain in place. There are several necessary design elements for the sustainable revegetation of drastically disturbed sites, including correction of soil hydrology, chemistry and fertility and the use of site-adapted plants and microbes.

Dr. Claassen described a case study applicable to mercury remediation. The area displayed fractured geology, insufficient infiltration and chronic surface erosion. Hydrus-2D software was used to develop a dynamic model of water infiltration and lateral flow, specifically following a 25-year, 1-hour storm event. The model allows the researchers to determine what can be treated in terms of such an event. To mitigate implementation problems, manual fracturing using handheld equipment is completed in remote locations to avoid the need for access roads. Another aspect of site substrate hydrology is the retention of adequate moisture in soil pores for summer plant growth; once this is accomplished, the desired plants can be grown in the area. The same general strategy with basic principles can be used for all sites, with specific aspects tailored according to each site's unique needs. Dr. Claassen summarized that stability includes both surface erosional and geotechnical stability, and erosional stability requires sustained plant growth.

Question-and-Answer Session/Discussion

The participants were invited to ask the session speakers specific, clarifying questions about their presentations.

What is the connection between mercury and chlorophyll-a? It involves concerns about the food web and organisms at the bottom of the food web bioaccumulation.

How do chlorophyll levels affect methylation and fish mercury levels? Chlorophyll does not necessarily affect methylmercury production; rather, it is a factor of biodilution as mercury becomes more diluted as it is taken up into the food web.

The participants were asked to form small groups to discuss the ideas introduced during the session that intrigued them. The various groups and online participants reported the following concepts during the event. These and more responses are included below in a table (verbatim).

- The three identified factors (chlorophyll, sediment mercury concentration and water level) and the implication that cleanup of Superfund sites will not be as effective as previously thought.

- There is a desire to explain the variability that was presented during the session. Is chlorophyll the best "explainer"? Is organic matter helpful in increasing understanding? Biomagnification occurs, but an explanation of methylation rate is needed.

- Lakes and reservoirs are very different and cannot be put in the same category; the same is true for mercury and gold mines.

- The relationship between chlorophyll-*a* concentrations and fish methylmercury concentrations.

- The soil hydrology and revegetation approach as a remediation tool, especially considering that a "low-tech," less-engineered method appeared to be a good solution.

QUESTION 1

You've heard folks frame the problem, provide challenges and goals and also some ideas about source control. At this point, what stands out for you so far? What is intriguing to you?

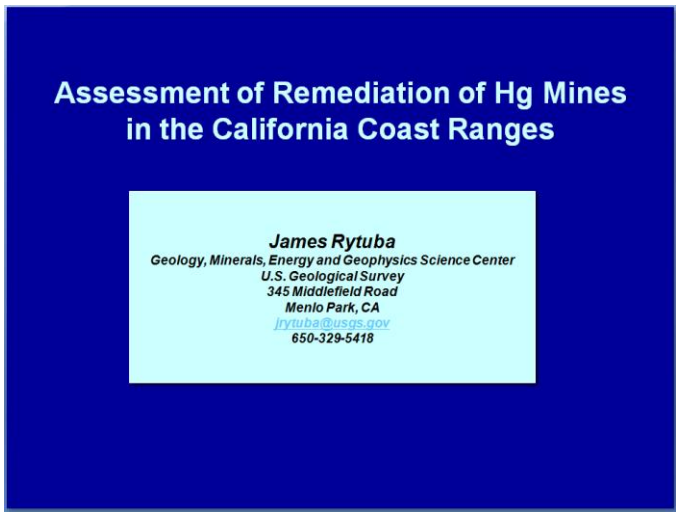
NAME	RESPONSE
Rosemary Hartley	Ensuring future proposals have the ability to implement effective solutions to meet MeHg level goals prior to creating increased MeHg issues.
Johnette Shockley	The multiple controlling factors that control Hg Concentrations both in water and sediments (i.e. Chlorophyl A, reservoir water levels).
Richard Engstrand	Is there an economic factor to these discussions?
Lisa Wallender	Very intrigued with soil stabilization, "low tech", less engineered solutions
Kendra Zamzow	Fluctuating water reservoir levels and impact on MeHg -- is that related to redox influences on methylation? That was intriguing.
Jane Reyer	Is there any discussion about moderating the degree of fluctuation in water levels to address mercury methylation. I know there are a lot of players in that and it would be difficult to get agreement, but just wondering if anyone is trying that.
Lori Verbrugge	While talking about reservoirs...I'd like to learn more about prevention. What mitigation measures are most effective when a new dam/new reservoir is being planned?
Carolina Risolo	1. How to prevent hg contamination? 2. What do you do in reservoirs or lakes with high elevated concentration of hg in fishes? 3. What to do with vegetation contaminated with mercury? 4. Do you monitor hg in human beings?
YUKTA DURVE	Kindly elaborate on infiltration
Kerensa King	Nutrient interaction(s) with MHg body burdens in fish
Nathan Kelsall	Dealing with sites on the East Coast it strikes me how the discussion on CA reservoirs highlighted something that is apparent in the literature and my sites that there often aren't 1-to1 correlations between biota Hg and the immediate environment.
Carl Reese	What intrigues me so far is that there is a relationship between the chlor a and MeHg concentrations in fish.

Vincent Maiden	Are contaminated floodplain soils a significant source area (i.e run-off, groundwater interaction, etc) for contamination observed in the aquatic environment?
Chance Asher	As a regulator in a state cleanup program, I am very interested in the initial findings regarding "quick" results from remediating mine sites. Does anyone have more thoughts as to what the focus of the research question should be?
John McKernan	With respect to the Fish Hg impairment talk, what similarities (water chemistry, hydrology, Hg source speciation) exist between the mining impacted and non-impacted reservoirs with elevated Hg fish tissue?
Dario Lozada	Maybe the methylmercury….. How I can test in the environment? Which equipment?
Harry Ohlendorf	From Michelle's talk: There is no expectation of quick benefit from just reducing min-related input - need a balance of approach that considers multiple factors influencing Hg in fish.
Arve Misund	The connection between MeHg and Chlorofyl A
Jamille	I missed the first session, but what I can think of is stricter control (law enforcement)
Jeffrey Hess	The idea of enhancing non-impacted food source to reduce relative impact of methylmercury on aquatic like is intriguing.
Clay Patmont	Mercury remediation is clearly more complex, expensive, and potentially daunting than many other types of remediation, especially in aquatic/sediment systems. There is clearly a need to think outside the box to develop effective solutions.

SESSION 2: SOURCE CONTROLS
SESSION MODERATOR: JIM SICKLES, EPA REGION 9

Assessment of Remediation of Mercury Mines in the California Coast Range
Jim Rytuba, U.S. Geological Survey (USGS)

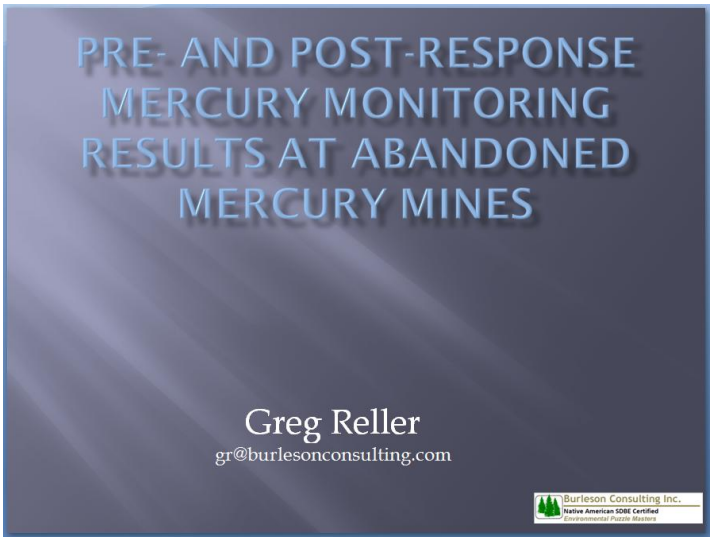
Jim Rytuba stated that of the 550 mercury mines in the California Coast Range, three are Superfund sites, seven small mines have been completely remediated, and eight sites are being remediated. Monitoring of the sites following remediation has been limited, however. To remediate the mercury mine sites, mercury mine wastes are removed from the mine site and watershed and isolated at an onsite repository. Acid mine drainage is rerouted to settling ponds, and creeks are reconstructed. Finally, to minimize erosion, slopes are stabilized



and capped with topsoil to encourage re-vegetation. Dr. Rytuba described an emergency response cleanup undertaken from 2004 to 2005 in the upper part of Rinconada Creek. Waste and tailings had been discarded in the river, destroying stream morphology and contaminating the river. Revegetation following removal of the waste and reconstruction of the creek was successful. Although 100 percent of the tailings from the bank in the mine area were not removed, mercury concentration in water during high flows was substantially reduced downstream from the mine. Further downstream there is a legacy of mine tailings in bank deposits. This site was monitored for 2 years prior to remediation and 5 years after remediation. There has been a substantial decrease in mercury concentration in the water except where tailing bank deposits continue to release mercury into the water during rain events. The same trend is seen in fish and invertebrates.

Dr. Rytuba described the remediation of a Superfund site, which focused on acid mine drainage. Because of the high mercury content of acid mine drainage, the drainage was redirected so that it did not interact with the mine waste. Although there is biodiversity of invertebrates above the mine site, there is little biodiversity downstream. Waste rock and tailings released into the creek significantly increased sediment loads to the watershed, and mine tailings have been redeposited in another creek, leaving a legacy of mercury-contaminated material far downstream from the mine. Downstream sediment analysis indicated that the source of the contamination downstream was waste rock, which led the researchers to question whether it was the sole source of mercury contamination in fish. Analysis of fish indicated that aquatic insects were the mercury source for steelhead trout. The same types of analyses at the Buena Vista Superfund site could determine whether tailings released into the lake during mining activities are the main source of mercury in fish, which could direct remediation efforts. Finally, mercury has been studied in the relatively benign current climate, but California averages one "Atmospheric River 1000 Storm" (ARkStorm) every 100 years, and the last occurred in 1861 and 1862. Remediation and legacy contamination must be considered in the context of future conditions, including those of an ARkStorm.

Pre- and Post-Remediation Mercury Monitoring Results at Abandoned Mine Sites
Greg Reller, Burleson Consulting



Greg Reller explained that many CERCLA cleanups occur at abandoned mines that affect downstream reservoirs and are intended to reduce mercury entering the system. The CERCLA requirements driving these cleanups are based on mercury in fish tissue, but fish tissue may not show the desired response following remediation. Many of the same primary and secondary source and pathway issues pertain to mercury and gold mines, and the same approach of identifying the mercury source and controlling it can be applied. Other mercury sources (e.g., atmospheric

deposition, ambient soil, sediment) can complicate remediation efforts and provide opportunities for bioaccumulation; these sources must be considered in the response action. There are many factors that interact within watersheds, lakes and reservoirs that affect mercury levels in fish, leading to the question: Will the response action affect fish tissue mercury concentrations and in what timeframe? Other aspects that need to be considered is what will be measured to evaluate cleanup effectiveness, the availability of pre- and post-response data for comparison, and whether the measurements are related to the mine site.

Mr. Reller described the Sulphur Bank Mercury Mine and nearby Clear Lake, which has significantly elevated mercury concentration levels in sediment. Three different response actions occurred at the mine in 1979, 1992 and 1999. Mercury levels in adult large-mouth bass have declined over time, although this does not necessarily demonstrate causality because other occurrences besides the response actions (e.g., nutrient management, hydrologic factors) could account for the trend as well. The data for juvenile large-mouth bass are scattered, and there does not appear to be a relationship between mercury concentration and fish length. Lake sediment capping is another response action planned for the mine site. Another California mine site is using tailing stabilization and revegetation as forms of remediation. Mercury concentrations in fish declined by nearly one-half following tailing stabilization, but because there are many other factors involved, correlation has not been confirmed. It is important to be careful when relating the control action to decreases in fish tissue mercury concentrations; additional studies are needed to determine correlation. Because there are many factors to consider in addition to mercury source control, it is necessary to understand how they do and do not interact in each different water body.

Environmental Geochemistry and Remediation of Abandoned, Mercury-Contaminated Gold Mines in the Sierra Nevada
Charlie Alpers, USGS

Charlie Alpers reiterated California's mercury and gold mining history, noting that atmospheric mercury from mine sites is deposited well outside of the state's borders. Approximately 5 million kilograms of mercury was lost during gold processing in the Sierra Nevada mountain ranges. Significant gold dredging occurred in all rivers that drain the Sierra Nevada, and mercury still can be found in sluice tunnels and their foundations, including beads of mercury in sediment. Present-day recreational miners continue to disturb these sites and release mercury. In addition to sluices, underground systems (e.g., drainage tunnels), hard rock mining and stamp mills also lost large amounts of mercury during processing. Many environments throughout California (e.g., mountain streams above reservoirs, foothill reservoirs,

floodplain deposits) transport and transform mercury. The mercury cycle is an important feature related to Sierra Nevada mercury, a complex element with complex chemistry.

Five sites in the Bear-Yuba Watershed were sampled in a 1999 pilot project. The results of the bass fish tissue sampling initiated further exploration of the food web in the Camp Far West Reservoir, which displayed a methylmercury slope similar to other studies and a similar rate of methylmercury biomagnification with increasing trophic level. The researchers also examined the seasonality of chlorophyll-*a*, which drives variability. Methylmercury was found to be increased in the spring and summer, out of phase with the chlorophyll-*a* cycle. The fall-winter phytoplankton bloom is triggered by phosphorus in inflowing water, whereas spring is the key season for zooplankton growth and methylmercury bioaccumulation. The mass load of methylmercury inflow exceeds in-reservoir production, and the methylmercury bioaccumulation in upper trophic levels is dependent on methylmercury uptake in plankton, which has strong seasonal cycles. The various studies have indicated that mercury "hot spots" occur in the Sierra Nevada, and there appears to be persistent contamination from upstream sources following remediation. Also, bioaccumulation depends on seasonal food web dynamics.

Dr. Alpers identified some remaining information gaps, including baseline data on mercury and methylmercury loads in mining-affected watersheds and in reservoir sediments, wildlife health effects, mercury methylation and bioaccumulation studies, and modeling of mercury cycling in rivers and reservoirs.

Question-and-Answer Session/Discussion

The participants were invited to ask the session speakers specific, clarifying questions about their presentations.

Most studies appear to have been completed on lakes and reservoirs. Are there studies in streams, particularly related to subsistence fish? Trout in Sierra Nevada streams tend to be lower in mercury compared to other fish. Lower rivers below major dams tend to have higher mercury levels. Studies in the delta consider commonly eaten fish, and salmon tend to be low in mercury.

Why did some of the California Coast Range results vary in whether total mercury was equal to or greater than methylmercury? Although this is common, there is no clear explanation.

Within the 550 mercury mines in the California Coast Range, are only 10 associated with acid mine drainage, or was this number from a smaller subset? That number is an estimate from the 550 mines. Acid mine drainage is a limited problem among mines, and approximately one-third of these mines have been remediated.

How confident is Dr. Alpers that methylmercury is the prime route for bioaccumulation? Have vapor or colloidal organic mercury been examined for their contribution to bioaccumulation? Although Dr. Alpers is not aware of such studies, microbiological studies in the laboratory show that mercury needs to be in the form of the 2+ ion before bacteria will synthesize it into methylmercury. Recent studies showed that mercury in the zero ionization state can be oxidized and methylated simultaneously.

The participants were asked to form small groups to discuss how practitioners can ensure that mercury cleanup in one location will prevent contamination of fish from other media. The various groups and online participants reported the following during the event. These and more responses are included below in a table (verbatim).

- An integrated watershed view is necessary. It is not possible to guarantee that a project aimed at the source will have downstream benefits unless the problem is examined in an integrated manner and the overall effects on the reservoir are explored.

- A theme that has emerged is that it is not possible to completely eliminate all sources of mercury in the environment, but it is possible to decrease the mercury entering the food chain, ultimately decreasing human exposure.

- If the type of mercury found in fish in various locations can be isolated, the mercury source can be identified and controlled. Only 1 percent tends to be methylmercury, so reactive mercury must be considered and controlled.

- The practice of recycling mercury via the world mercury market must be stopped because mercury contamination problems are being recreated in the Third World.

QUESTION 2

Methyl mercury can move from one media to another….to and from air, the water column and sediment. How can we be assured that cleaning up mercury in one place will prevent contamination of fish from other media? Or is that futile?

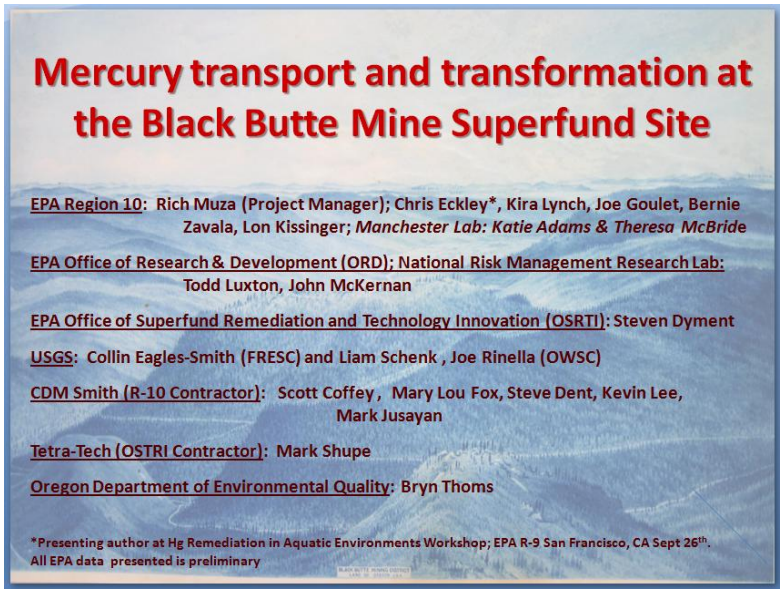
NAME	RESPONSE
Rosemary Hartley	Good point about wildlife whose diet is fish. Too often we feel limiting human consumption of fish is all that is needed to reduce effects. This is off this topic but cannot get back to presentation that discussed wildlife. Sorry.
Johnette Shockley	We will have to understand the geochemistry in detail, and design the remediation and accommodate for those phase changes.
Kendra Zamzow	Are coal fired power plants the primary CURRENT source of mercury (nationally, not just CA), and can we expect a drop in soil and water contamination with new proposed Hg control rules?
Albert Loveridge	Unless the mechanisms are understood, and they seem to differ from site to site, you cannot be assured that you will prevent fish contamination
Paul Randall	Two of the main factors determining the exposure of organisms to Hg are: the amount of inorganic Hg in sediments that is converted to MeHg; and geochemical conditions. Failure to remediate is due to not understanding site and source controls.
Carolina Risolo	We cannot be assured, but will do reduce mehg in food web.

Jim McNamara	Some observations at an estuarine NPL site in coastal GA seem to indicate that methylation is rate restricted; highest levels of MeHg were found near lower, rather than higher total Hg samples. Methylation is primarily through sulfate reducing bacteria.
Kerensa King	I don't think you can be assured that it will. I'm faced with a situation like this now. Stabilizing stream banks to prevent Hg laden soil from entering a stream vs. atmospheric deposition that would still enter a system.
Janis Cooke	Cleaning up mercury from a mine site won't prevent contamination of fish due to mercury from atmospheric deposition. But it still may be worth doing to limit the portion of contamination due to the mine legacy.
Emmet Curtis	The answer lies in the question, "Is the system saturated with total Hg?". A system only produces a certain amount of methylmercury based on the geochemistry of the system. If the system is still saturated after remediation then the fish will not change.
Angela Matz	We can't be sure, but it is NOT futile. Re: first talk - we need to be efficient and spend limited dollars wisely, but lose the "futile".
Sonal Iyer	It may not totally prevent it, but if done correctly (and disposal also done correctly) it will help lower the fish concentrations thereby making it available for food consumption and for general ecosystem. Ref: Greg's presentation for support.
Svetoslava Todorova	Maintain conditions that prevent methylation
Simon hockin	If I understand correctly, methylation occurs primarily under anaerobic sulphate and iron reducing conditions - so reducing inputs into these environments and managing methylation within them should be the primary targets for remediation.
Allen Hemberger	My experience is that Hg is bound up in seds and fish tissue, and not in the water column (at an impoundment at a defunct munitions plant). Get rid of the seds, and remove the fish, and the source is mostly gone. Long term fish tissue monitoring required
Liyang Chu	Any studies done to compare MeHg in uncooked vs. cooked fish tissue? If the concern is consumption of fish, and MeHg is very volatile, it seems to me that cooking can allevite health concerns.
Kirby Tyndall	I think that this is a particularly difficult question to answer since it is likely that fish have always contained some level of mercury, so "cleaning" up can be especially problematic.
Harry Ohlendorf	Not necessarily futile, but probably not well understood without mass balance modeling of the system, considering aquatic and terrestrial sources as inputs to what is bioaccumulated by the fish.
Jeffrey Hess	I do not think it is futile, but this is a key question in the effectiveness evaluation for any remedy considered and it needs to be methodically addressed in planning any proposed remedy from a chemical and biological point of view.

Clay Patmont	All of this really speaks to the need for adaptive management - make an informed decision on where to start remediation, proceed incrementally, monitor how it's working, and adjust subsequent management actions and objectives accordingly.

SESSION 3: DOWNSTREAM CONTROLS
SESSION MODERATOR: ANDY BAIN, EPA REGION 9

Mercury Transport and Transformation at the Black Butte Mine Superfund Site
Chris Eckley, EPA Region 10

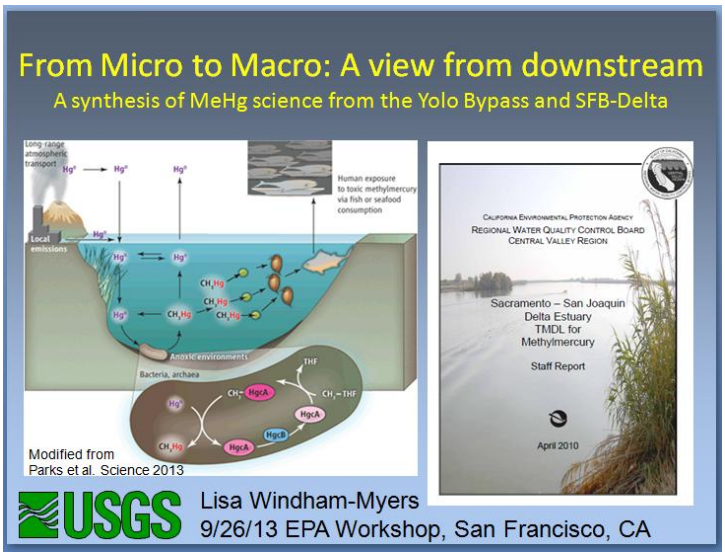


Chris Eckley explained that the deposit at the Black Butte Mine in Oregon, which operated from 1890 to the late 1960s, primarily is cinnabar. A river drains from the site to Cottage Grove Reservoir approximately 15 km downstream. Mercury levels of fish in the reservoir are the main driver for site remediation. There are two types of mercury from two sources, old and new furnace tailings. Site assessments conducted since the mid-1990s by the Oregon Department of Environmental Quality (ODEQ) and EPA resulted in a 2007 removal action to reduce tailing transport to surface water via slope stabilization and capping the tailings. There were three different action levels depending on mercury solubility. ODEQ performed a study 1 year following removal and found that Furnace Creek, located in the tailings area, could contribute 50 to 75 percent of the mercury mass entering the reservoir. In 2010, the site was designated a Superfund site. Initial Superfund sampling included a storm event. Results showed a large increase in particulate mercury during the storm event in Dennis Creek, with the concentration of mercury on mobilized particles being less than the fine sediment concentration in the creek. Although Furnace Creek also showed a large increase in particulate mercury, the mercury concentration on mobilized particles was greater than the fine sediment concentration. Mercury also may come from other sources (e.g., internal sediment resuspension, terrestrial erosion), and preliminary data indicate that there is some dissolution of mercury in high concentrations.

Several unknowns (e.g., methylation potential of inorganic mercury released from the mine, role of watershed forestry operations, effects of water-level changes) regarding the connection between mercury mine releases and methylmercury accumulation in fish in the Cottage Grove Reservoir do not allow for the assumption that the load correlates with fish bioaccumulation. Initial Superfund sampling also indicated that there is no thermal stratification in the water

column in the reservoir. Winter and spring total and methylmercury levels are similar with depth, with relatively low methylmercury concentrations. Forthcoming summer data may show increased methylmercury. Methylmercury generally is seen in the top 2 centimeters of sediment at most sites. Sites subject to water level changes that increase methylation need additional seasonal data to determine cause and effect. Future work at the mine site will include more storm event sampling, groundwater measurements, and human and ecological risk assessment. Future work in the reservoir will be aimed at understanding the bioavailable fractions of inorganic mercury and other variables that affect methylmercury production.

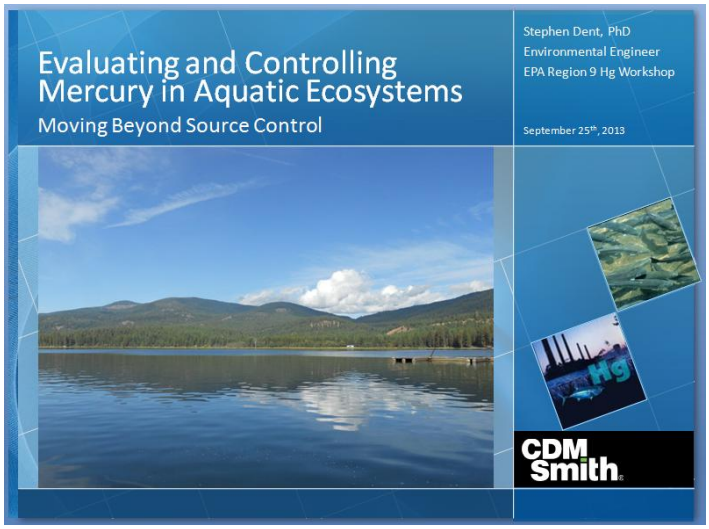
From Micro to Macro: A View From Downstream—A Synthesis of Methylmercury Science From the Yolo Bypass and San Francisco Bay Delta
Jacob Fleck, USGS (for LisaMarie Windham-Myers, USGS)



Jacob Fleck explained that, in terms of where methylmercury loading to the San Francisco Bay Delta originated, 50 to 60 percent of the methylmercury comes from tributaries, with the remainder coming from habitats within the delta. Agricultural lands account for 90 percent of these loads, and because they are highly managed, these habitats offer opportunities for control. Mercury production is controlled by a complex system of balances, and linkages are equally important to the ultimate fate of methylmercury. Mr. Fleck provided the key findings of a synthesis of 17 mercury studies performed in the delta. He noted that slowing water enhances fish methylmercury bioaccumulation, high soil carbon may produce increased methylmercury, rewetting of dried wetlands can enhance methylmercury production, temporal variability in matrix concentrations can be orders of magnitude different, and spatial variability can relate to different initial conditions or management practices. A methylation study in the Yolo Bypass indicated that wetlands are methylmercury sources in winter, with the exception of permanent wetlands, which are year-round sinks. Summer methylation is a mixed, complicated process. Seasonal wetlands primarily discharge dissolved mercury, which is important because the dissolved fraction is thought to be more available for methylation. Surface water concentrations change during a 24-hour diel cycle, and the effects are greatest in summer conditions. Continuous monitoring rather than "snapshots" of conditions are needed because seasonality is important in terms of fluctuations throughout the year. Data showed six-fold variations in mercury concentrations in soil during the one year it was analyzed, so this variability must be considered when measuring methylmercury. Seasonally decoupled methylmercury cycling was seen in the Yolo Bypass rice fields. Transpirative demand may have been driving the diel effect. The researchers have examined three different delta rice fields, which are the most globally abundant wetland type in temperate and tropical latitudes whose conditions may enhance

mercury methylation. When methylmercury export is examined from season to season, hydrology drives seasonal changes; seasonal export is not a function of methylmercury production. There still are many science gaps regarding methylmercury loads that must be addressed. To move from micro to macro, production, transport and bioaccumulation must be considered.

Evaluating and Controlling Mercury in Aquatic Systems: Moving Beyond Source Control
Stephen Dent, CDM Smith



Stephen Dent illustrated the scope of mercury issues in the United States by noting that every state has at least one mercury fish consumption advisory. He explained that lake eutrophication is important because oxygenated water helps to keep sediment buried; anoxic water causes methylmercury accumulation. Three main technologies for delivering oxygen to the hypolimnion are the bubble plume, line diffuser and submerged contact chamber, the latter two of which are more passive. A linear diffuser system that delivers a plume to lakes was employed in the state of Washington's Twin Lakes. The bottom of North Twin Lake was completely anoxic, and fish were trapped within a small range of depth. The working hypothesis of the project is that the maintenance of an oxygenated sediment-water interface and hypolimnion would reduce the iron, manganese and methylmercury concentrations in the water column and biota. Conditions in the oxygenated lake were examined for 4 years, and metals and mercury decreased following oxygen delivery, although some pockets of anoxia were present. Results were fairly similar between the oxygenated and reference lakes in the summer, with increased mercury in zooplankton as a result of increased habitat. Sediment is very sensitive to a lack of oxygen, and when the diffuser system is restarted, mercury mixes in the hypolimnion and remains for several days. A column that releases oxygenated water at the sediment-water interface and avoids upward induction (bubble plume) may be more appropriate.

Dr. Dent summarized that an oxic sediment-water interface is not consistently maintained, and design issues are of vital consideration. Negative feedback was observed in the oxygenated lake, and the mercury cycle is intricately linked to iron and manganese cycles. The sampling plan design is critical for tracking performance, and the system must be consistent with the design targeting the sediment-water interface. Hypolimnetic oxygenation can be used to control mercury accumulation in lakes and reservoirs with proper design and maintenance. Finally, there continues to be a large data gap in evaluating the application of hypolimnetic anoxia remedies and management strategies for controlling the mercury cycle.

Question-and-Answer Session/Discussion

The participants were invited to ask the session speakers specific, clarifying questions about their presentations.

What was the arrangement of the introduced oxygen? What is the relation between its geometry and the locations at which data were collected? The diffuser line was placed close to the center of the lake, approximately 1 meter (m) above the sediment-water interface, and the samples were taken approximately 20 m perpendicular from the bubble plume. The transects were fairly homogenous horizontally throughout the water column except in the near-shore area.

Were ecological differences between sediments that are always exposed and those that are always submerged compared at the Black Butte Mine? A number of parameters (e.g., sulfate, sulfides) were analyzed in addition to total mercury, but only the mercury data have been analyzed. Currently, the trends for other parameters are not known.

Was uptake of mercury into the root zone and the plant itself examined in the San Francisco Delta studies? These measurements were collected, and Lisa Windham-Myers has this information.

Please clarify the effect of eutrophication on mercury methylation in sediments. There are several studies that have examined the effects of eutrophication and hypolimnetic anoxia on mercury methylation, with the majority showing that methylation occurs at the sediment-water interface. Typically, a combination of newly methylated mercury and re-released methylmercury accumulate in the bottom waters above the sediment-water interface.

The participants were asked to form small groups to discuss how source control measures versus downstream controls are balanced when deciding to clean up mercury, particularly given that remediation of mercury sites can take decades and cost millions of dollars. The various groups and online participants reported the following during the event. These and more responses are included below in a table (verbatim).

- Source control is appropriate in some situations, whereas downstream controls are appropriate for others. Determine what process is responsible and then control that process.
- Mass balance is important to identify how much mercury is entering, moving around in and leaving the system.
- Time is a problem with source control; it is important that short-term engineering solutions buy time, although those solutions may not be permanent.
- The conventional wisdom is to first remediate upstream to avoid recontamination downstream, but often the risk of recontamination is given too much weight.
- There appears to be a number of downstream control efforts.
- It is necessary to develop feasible downstream control measures.

QUESTION 3

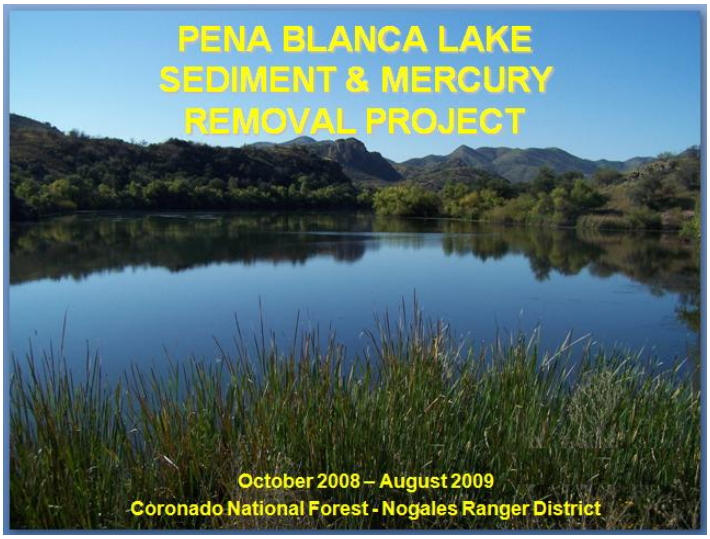
Given that remediation of mercury sites can take decades and cost millions of dollars, how do we balance source control measures vs. downstream controls when deciding how to clean up the mercury?

NAME	RESPONSE
Rosemary Hartley	We should recognize the costs up front for future mining or development proposals. Too often mitigation is summarized into a paragraph within a proposal and considered adequate.
Johnette Shockley	Evaluate the potential for remaining tailings, as Au valuation increases, causing re-suspension of older tailings (modern methods of mining making this more attractive).
Kendra Zamzow	Sources need to be understood re: the potential to methylate, either in place or downstream. Understand the driving forces of methylation to elucidate the more effective areas to focus remediation money.
Carolina Risolo	Both are important to be done.
Nathan Kelsall	Having some sort of mass balance is important to identify how much mercury in entering from outside sources, leaving the system, and what is moving about within the system.
Robert Nunes	If there are unacceptable human health and ecological risks which are attributable to mercury, then all measures, whether they relate to source or downstream controls, should be evaluated and, if feasible, implemented in a timely fashion to reduce risks.
Janis Cooke	We need more development of feasible downstream source control measures (example - in the Delta) before we can determine whether source control would be more or less effective than downstream control.
Robert Burgess	If the source can be controlled, downstream controls should not be necessary. However, in cases in which source control or remediation is not feasible, priorities should be based on risk (bioavailability, receptors, methylation, etc.).
Harry Ohlendorf	Consider each site independently and focus on its contribution to environmental hazard (human health or eco) to see what might be feasible to make a measurable reduction in risk vs. spending that amount of resources on downstream risk reduction.
Susan Turnblom	An attempt should be made to address source control, but keeping in mind that the other less controllable sources (atmospheric) may have a significant influence on a lake or reservoir. I think more energy should be put on reducing methylation.
Jamille	Source control measures should have more priority
Jeffrey Hess	Perhaps basing decisions on comprehensive risk evaluations for both human and ecological risks. Having a comprehensive baseline of threatened receptors is a good start on assessing the most "bang for the buck" in evaluating remedial actions.

Clay Patmont	The primary focus should be on effective source controls consistent with EPA's Sediment Remediation and other guidance, but downstream controls also have a place if they can be demonstrated to be more cost-effective than further source controls.
Ralph Turner	The conventional wisdom is to clean up upstream first to avoid recontamination of downstream, but often the risk of recontamination is given too much weight, nor is mitigation of that risk even considered. Never ignore such risk.
Sonal Iyer	Focus on immediate exposure area and routes to prioritize. Follow-up with adaptive management-but use good data.
A. Dianne Kopec	Eliminate the source. Control downstream effects.

SESSION 4: DOWNSTREAM CONTROLS
SESSION MODERATOR: CHRIS ECKLEY, EPA REGION 10

Peña Blanca Lake Sediment and Mercury Removal Project
Eli Curiel, U.S. Forest Service



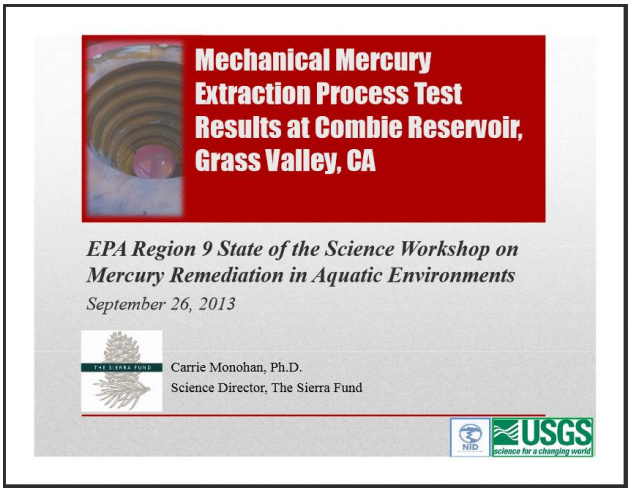
Eli Curiel explained that Peña Blanca Lake is located in Arizona, approximately 4.5 miles north of the U.S.-Mexico border. Fish tissue samples collected in 1994 showed concentrations of methylmercury greater than the EPA and U.S. Food and Drug Administration health criteria; assessment began in 1995, and remediation actions occurred at a mercury mill site upstream of the lake in 1999 and 2000. Additional analyses and inspections occurred in 2005, 2007 and 2008. The mercury removal project took 316 days and included lake draining, water and sediment testing, and excavation of sediment to consolidation cells at a cost of nearly $3 million; approximately 1,300 tons of mercury-contaminated soil were removed from the mine site. Lake water sampling in 2008 indicated that mercury levels still were high at sampling locations at depths greater than 7 m. To remove contaminated sediment at the bottom of the lake, the lake was completely drained over a period of nearly 2 months; the large percentage of clay soils found in the lake bottom took an unanticipated amount of time to dry. Sediment excavation began in January 2009, with excavated sediment placed in multiple consolidation cells adjacent to the lake. Excavated depths varied from 2 to 20 feet. In April 2009, sediment cores were collected and analyzed for mercury, lead and arsenic. Of the 160 samples collected, all but 37 of the samples were above CERCLA Response Action Goals for at least one of the tested metals; total mercury was detected above CERCLA levels in 70 samples.

Following excavation, two below-grade upstream sediment traps were constructed to allow sampling and testing of incoming sediment for mercury, and the Arizona Game and Fish Department installed new fish habitat structures. Clean fill was used to cover the consolidation cells, and confirmation sampling and testing were performed to ensure that the lake bottom was clean. Seeding and mulching were performed on 10 acres. Although the plan had been to refill the lake slowly over the course of 1 to 10 years, the lake filled up in one weekend in January 2010 following significant winter rainfall, providing re-inoculation of total mercury attached to sediment particles. Fish were reintroduced by the Arizona Game and Fish Department. Sampling for a number of analytes, including inorganics, nutrients and metals, occurred in June and September of 2012 and 2013 and indicate a 67 percent reduction of methylmercury in the sediment. Lake morphology (e.g., depleted oxygen in summer), strong reducing conditions and a continued influx of sediment-bound mercury influence the production of methylmercury in the lake. Additionally, mercury is present within the parent rock formations of the Peña Blanca Watershed, although no concentrated ore deposits are known, with cinnabar occurring as traces in fissure veins. Temperature, microbial activity, organic carbon availability, dissolved oxygen and pH control the cycling of methylmercury in the lake. The thermal stratification of the lake places severe stress on the fish, which cannot avoid exposure to methylmercury.

Analysis by the Arizona Department of Environmental Quality (ADEQ) indicates a downward trend in total and dissolved mercury, whereas the methylmercury trend has remained flat. ADEQ will continue to collect fish tissue samples annually to determine human health risks. According to ADEQ, mitigation can be achieved through reduction of sediment entering the lake, biofiltration prior to runoff entering the lake, aeration of deeper waters to break stratification, and periodic application of alum. Mr. Curiel highlighted some lessons learned from the project, such as the need for additional analyses to determine morphometry and characteristics of the lake and watershed, the necessity of employing effective dredging methods that avoid large fish kills, and the need to pursue inexpensive methods and/or technologies to increase dissolved oxygen levels. Although $2.86 million was spent on the project, there still is a methylmercury problem in the lake.

Mechanical Mercury Extraction Process Test Results at Combie Reservoir, Grass Valley, California
Carrie Monohan, The Sierra Fund

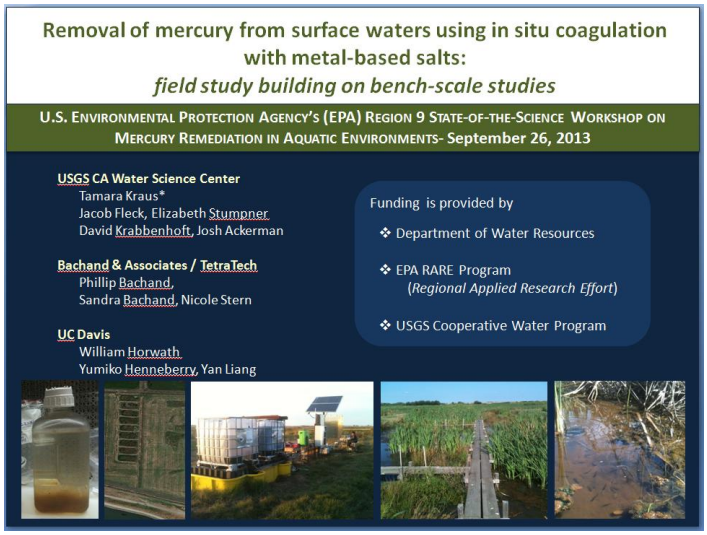
Carrie Monohan explained that mercury sources upstream of the Combie Reservoir, including the Malakoff Diggins mine site, leak during rain events, with mercury bound to fine silts and clays. The landscape surrounding the mine is unstable. Because mercury does not naturally occur in the Sierra Nevada, there should be a finite amount of mercury, but this is not the case. Mercury used during hard rock and hydraulic mining still is entrained in the river gravels of Deer and Greenhorn Creeks. Mercury-contaminated sediment became methylated and has been



uptaken by fish, which are commonly consumed by the human population in the area. The project location is the Bear River, and dredging is being used to address the mercury source of the Combie Reservoir. The current sediment can be dredged in a project lasting 3 to 5 years, and then dredging can be repeated in 10 years. A centrifuge is used as the mercury removal component. Four equipment tests were performed and percent removal of mercury calculated; results indicated that 88 to 95 percent of the material was accounted for, and the equipment worked properly. Sampling techniques and data analysis are key to determine accurately whether the equipment and the process are working.

Following dredging, 94 percent of elemental mercury was removed, but some mercury still is bound to silt and clay. The samples taken of the head material were not an accurate representation because of the "nugget effect." Mercury attached to the fine-grained material was not removed by the equipment, and methylmercury and reactive mercury did not change as a result of the processing. Turbidity treatment is key to reducing mercury in the environment. The next steps are to perform additional equipment tests with spiked materials, publish the results, measure the multiple project benefits and secure additional project funding. The approach used at Combie Reservoir has the potential to be used at other Sierra Nevada reservoirs and rivers. See the video of the Combie removal equipment shown during this talk here: http://cluin.org/conf/tio/hg/resource.cfm .

Removal of Mercury From Surface Waters Using In Situ Coagulation With Metal-Based Salts: A Field Study Building on Bench-Scale Studies
Tamara Kraus, USGS



Tamara Kraus explained that coagulation is the aggregation and subsequent removal of material in the water column through the formation of particles that precipitate out of solution. It is a ubiquitous drinking water treatment in the United States and has several environmental applications (e.g., removal of particles, dissolved organic carbon and phosphate). The USGS project addresses several issues, including methylmercury total maximum daily load. The goal is to determine whether coagulation alone can remove mercury and how the addition of floc material affects the biochemistry of wetlands in terms of methylation and subsequent bioaccumulation. Coagulant will be added to untreated source water, flow through the wetland and outflow to the river. Because mercury(II) and methylmercury are associated primarily with dissolved organic carbon, and coagulation removes dissolved organic carbon, the question is whether the dissolved mercury will be removed as well. Laboratory studies indicated that coagulation removed up to 80 percent of dissolved organic carbon and methylmercury from solution and 97 percent of inorganic mercury.

Following the laboratory studies, a field study measuring inflow and outflow water was performed to compare three treatments, including a control treatment. Results indicated that the coagulation treatments reduced filtered total mercury concentrations by 60 to 85 percent. There are differences in the effects of wetland passage by season and coagulation treatment. Preliminary data indicate that untreated wetlands are a source of filtered total mercury in the spring and summer. The inflow data show that coagulant addition immediately converts dissolved to particulate mercury, whereas the outflow data show that particulate material is retained in the wetlands, resulting in significantly lower total mercury concentrations. Results from November to May suggest that the treatment wetlands reduce total mercury outflow concentrations by 40 to 75 percent. Overall, both coagulant treatment systems lower surface water total mercury concentrations in the wetland. More sampling and analysis will be completed to tell the "1 year story." Mosquito fish will be analyzed to examine the effects of the coagulation-wetland systems on mercury bioaccumulation. Water and sediment quality and plant growth will be assessed, and mesocosm studies using isotopic-labeled mercury will be performed in the treatment wetlands to determine mercury cycling. In the future, longer term effects and the transferability of the system will be explored.

Fisheries Management to Remediate Mercury Contamination in Sport Fish
Jesse Lepak, Colorado Division of Wildlife

Jesse Lepak stated that Colorado began to collect fish samples for mercury analysis in 2004, with the goal of providing fish consumption advisories. The bioenergetics model is used to estimate mercury concentrations in sport fish using predator growth rates and what and how much they consume. Tissue chemistry is used to determine the long-term diet of sport fish. For example, in the Brush Hollow Reservoir, mercury concentrations level off after fish (walleye) reach a weight of 2 pounds. Female fish supplement their diet with prey lower in mercury, so they have lower mercury concentrations than would be expected for their weight. The project goal was to determine whether simulated management strategies (e.g., altering growth, switch to rainbow trout diet) could reduce mercury in male fish following the establishment of a male baseline model. Simulation indicated a slight increase in walleye mercury concentration using a half weight gain strategy and a slight decrease with a double weight gain strategy. A simulated switch to the rainbow trout diet combined with doubling weight gain significantly decreased mercury concentrations in walleye. A midlife simulation of high-calorie, low-mercury gizzard shad diet also reduced mercury concentrations. Because these are simulations, actual results may vary.

To determine whether responses happened as quickly as in the simulations, a whole-lake management action was tested experimentally with northern pike in a 25-hectare lake. Rainbow

trout were provided as a higher quality option to the native crayfish diet. A pond component was included to verify lake results. Initial sampling included gastric lavage to determine diet and measurement of length and weight. The fish were tagged and released into the lake or pond for repeat measures at 2 months and 1 year. Pond results indicated that the northern pike population reverted to its original diet by 1 year. Lake northern pike that gained 25 percent of the original body weight saw an equivalent reduction in mercury concentrations. Prior to the experiment, 50 percent of the pike exceeded advisory levels, with 35 percent of those removed from the advisory following the experiment. After 1 year, however, the bioaccumulation process began again, and mercury levels were similar or higher than the original measurements. The implications of the experiment are that providing low-mercury, high-calorie (i.e., quality) prey has the potential to reduce sport fish mercury rapidly, and it is more cost effective and ecologically sound to manage for prey species already present. Even if quality prey is present, individual sport fish may exhibit elevated mercury. The general patterns observed by the researchers were present across the Colorado landscape following analysis of fish mercury concentrations in 50 reservoirs. Those with fish consumption advisories included large, piscivorous fish. The researchers concluded that food web structure is extremely important and can change rapidly through management and stochasticity. Caution must be used because some actions may increase bioaccumulation.

Question-and-Answer Session

The participants were invited to ask the session speakers specific, clarifying questions about their presentations.

For those water bodies in Colorado that do not have fish consumption advisories, is it because they have not been tested? The fish have been tested and have mercury levels below the safe consumption limit.

Why do some dredging projects require drainage, whereas others require water? This depends on a variety of factors present in different water bodies. For example, the Combie Reservoir could not be drained because it would never dry enough to be excavated; therefore, the project was designed to include an electric floating dredge.

Are cost-per-cubic-yard estimates available for each of the techniques? This information is being calculated for the Combie Reservoir project.

Does the aluminum used in the coagulation project pose any toxicity to the biota? The researchers are examining alum concentrations, fish growth and plant health. There does not appear to be any persistent toxic effects. The data will be available soon.

SUMMARY AND CONCLUSIONS/NEXT STEPS
SESSION MODERATOR: LORI LEWIS, EPA REGION 9

In concluding, the participants were asked to consider what they would like to know more about in order to move forward with mercury remediation. That is, what are the data gaps in the field? During the event, participants offered these following thoughts and ideas.

Following the responses mentioned during the event are two tables that compile responses collected from both the in-person attendees (via post-it notes) and from webinar participants (verbatim). The first table (question 4) responds to the data gaps question and the second table (question 5) responds to the question about possible pilot studies within Region 9.

- There is a need to define measures of success.
- Total daily maximum loads should be changed to total daily maximum concentrations as a way of evaluating the success for mine remediation without the need for a similar storm-level event to obtain comparable numbers.
- Using stable isotopes to determine the source of mercury in fish will significantly increase the knowledge about how to best remediate an area.
- Research about air injection is needed.
- Research is needed about the potential fate and transport of mercury in groundwater that may be used as drinking water.
- Increased numbers of data-gathering stations are needed as well as long-term monitoring of key indicators to examine long-term trends and determine whether remediation was successful.
- An amendment for *in situ* treatment of contaminated sediment could be developed.
- What effect does legacy debris have?
- A better understanding of the food web is necessary. Gut analysis could be performed to determine what species are part of the food web.

Mr. Tenley thanked the presenters and facilitators, and Mr. Gill thanked everyone who had helped to plan the workshop. The meeting was adjourned at 4:44 p.m.

QUESTION 4

What data gaps exist? What research needs should we communicate to others (e.g., ORD, academia, federal agencies) that would help move us forward on mercury cleanup?

NAME	RESPONSE
Richard Engstrand	What empirical data exist that prove harm to humans from consuming contaminated fish IN CALIF upstream watersheds?
Rosemary Hartley	Historical records of human activity on the landscape are not always digitized so something like log drives on river systems may not be considered in an analysis of possible Hg sources.
Kendra Zamzow	Impacts on wildlife and birds
Kendra Zamzow	What are the differences in mg/kg risk-based cleanup goals? Do they differ by state? What else drives the numerical goal?
Jane Reyer	Effective models to predict mercury levels at surface water venting locations after transport through groundwater.
A. Dianne Kopec	The link between hg in sediment and hg in biota, in relation to benthic and pelagic food webs.
S. Xiah Kragie	Competitive biogeochemical pathways given the chemical mixtures found in contaminated sites (i.e., solvents, petroleum products, other metals, etc)
Albert Loveridge	Mechanisms by which mecury moves to riparian and terrestrial foodwebs from aquatic sources.
Cory Koger	Realistic remedial action objectives.
Paul Randall	EPA ORD (Office of R&D) National Program Directors have stated that Hg is a low priority. EPA scientists therefore are working on other issues. Need to communicate to EPA Fed community Reg. 9 and national needs.
eli curiel	Need more data on sediment transfer rates in watersheds.
carolina risolo	Human health statistica about mercury intoxication, proven evidence. We need an educated community aware about this problem.
Xiaochun Zhang	Effect of hydrodynamic processes and hence in-situ sediment dynamics on the fate and transport of mercury and methylmercury.
Janis Cooke	Field testing and validation of MeHg control methods that could be feasibly implemented by "downstream" land managers (e.g., wetlands, agriculture, reservoirs).
Miguel Madrid	Fingerprinting & forensic analysis.
Cynthia Herzog	Dangers to the human population.
Dwight Leisle	Distribution between elemental Hg and methyl Hg. The MHG analysis is more costly and not often completed, however MHG is the form that is more biologically available.
Patricia Bratcher	How do we design wetlands in areas with potential mercury contamination? Should they be ephemeral, perennial? Possibly we shouldn't make wetlands in these areas?

Clay Patmont	One of the most pressing research needs is to better understand the effectiveness of reactive amendments or caps that can be cost-effectively placed in aquatic systems. There are encouraging results using biochar, activated carbon, manganese oxide.
Ralph Turner	We need either more data for, or more synthesis of, Hg in river systems, as opposed to lake/reservoir systems.
NA	Data Need - What is the role of demethylation in explaining variability in fish tissue concentrations?
NA	Need to prove benefits of dredging technology on downstream MeHg levels as this technology is applicable to reservoirs across CA as well as shipping channel dredging in mercury contaminated sediment in delta and San Francisco Bay.
NA	Lots of good studies are occurring. However, no one is pulling this information together in the form of usable guidance to help the site characterization process. For example, key data to collect, the how, where and when to sample. This would help getting the many agencies on the same page.
Charlie Alpers	Long term monitoring of key indicators, e.g. bass in Camp Far West reservoir (NV County), trout in key rivers, etc. Gauging stations in key locations to get trends in loads Mercury isotopes in fish, sediment and water and atmospheric deposition and reactive Hg (II) in all media More monitoring so that Hg modeling can be done KEY PARAMETERS: - total, methyl and reactive mercury in water and sediment - gauging stations in rivers - reservoir water column
Carrie Austin	Data Gap - Hg from CA retorts is widespread, i.e., Hg emitted from retorting in past that landed in Calif. landscape Question: Is this source of Hg getting into food web? If so - where is it on landscape? What is transport mechanism? How to fix it?
NA	Understand important sources of MeHg - the Reactive Pool. Challenge the idea of QUANTITY of Hg being the key driver of remediation efforts.
Stephen McCord	Start at the source (turn off tap) Evaluate as an integrated system (watershed) Account for background, uncontrollable sources in setting downstream targets.
Jim Weigand	What are the tradeoffs for adding nitrates, oxygen, water, etc. to reduce rate and load of MeHg on other aquatic processes / life forms? What transfer of industrial applications using films with demethylating bacteria is possible for applying to MeHg-rich streams flowing into reservoirs / lakes / deltas?

NA	Revegetation as sediment reduction strategy - Characterize evapotranspiration potential to reduce subsurface percolation or saturation (for different plants or regions) - Plant organic matter inputs that might drive methyl mercury production in sediments or inside soil aggregates
NA	What is the conversion rate from calcium waste to bio-reactive Hg and what drives the rates?
NA	Systemic work with nutrient amendments to interfere with mercury methylation Parallel work with impacts on chlorophyll-A and relationships between chlorophyll-A and bioaccumulation of Hg
NA	<u>Data need</u> Many of the studies done to date do not attempt to really understand how Hg enters the food web. Specially, the geochemistry and temporal influences.
NA	<u>Data Gap</u> What info do we need to know to avoid another Pena Blanca tragicomedy? [Lots of insights were provided today]
Colin Moy	<u>Data Gaps / Research</u> - Impacts of water chemistry, fishery management, and water circulation reservoirs - Differences between lakes vs. reservoirs
David Moore	- Better understanding of receptor behavior in different systems (to inform spatially, explore exposure models to better prioritize sites for remediation) - Better understanding of Hg cycling in different systems and targeting of bioavailable components - Better understanding of food web dynamics in particular systems (actually do gut analysis to understand what different species are eating) - Does vegetation result in translocation? And / or enhancement of methylation?
NA	How are the legacy debris control dams in the upper watershed - Sierra Nevada - functioning to hold back Hg?
NA	<u>Data Gap</u> Caution-→ Know well the question you are trying to answer, and how result will be used. People frequently advocate for Hg mass balance studies, but they don't often explain how result could be used to design remediation.
Carrie Monohan	If Hg isotopes in fish reflect the source of Hg, then we should get isotope data from bass in reservoirs to see if Hg contaminated fish is from atmospheric sources or upstream AMLs. (RE: Jim Rytuba's presentation)

John McHugh	<u>Data Gap</u> 3-D characterization of soil and water mercury - How evenly distributed is Hg? What degree of spatial sampling is representative? How does reservoir management relate to methyl mercury formation? (e.g., lower water levels in the summer.)
NA	Effect on wildlife
NA	Is methyl mercury taken up by rice plants?
NA	Need fish tissue data from upstream and downstream lakes and reservoirs – - to complete human consumption guidelines, - as well as provide a baseline for evaluating whether the cleanup measures we are taking will make a difference down the road
NA	What will the impact of global climate change (precipitation becomes H2O instead of snow) affect Hg discharge from reservoirs?
NA	Identify (using isotopes?) the relative contribution of retort Hg recycled in terrestrial environment to fish Hg compared to tailings in the stream bed and reservoirs.
Michelle Wood	We need more before/after mine waste remediation monitoring, but not just fish MeHg data. It would be very helpful if remediation effectiveness could be evaluated using pre- and post-remediation rating curves (e.g., plots of (a) water THg concentrations versus discharge and (b) Suspended sediment concentrations versus discharge), rather than just THg concentrations or loads. That way, we can evaluate level of success even if stronger or more frequent storms occur during the post-remediation monitoring period than during the pre-remediation period. (Example - Figures 2 and 3 in: Kirchner, J.W., C.A. Austin, A. Myers and D.C. Whyte. 2011. Quantifying remediation effectiveness under variable external forcing using contaminant rating curves. Environmental Science & Technology, 45: 7874-7881.)

QUESTION 5

Where do you think potential future mercury remediation pilot projects should/could occur in Region 9?

NAME	RESPONSE
Kendra Zamzow	Studies at the Navajo generating station area would be interesting -- does it have Hg controls? Will it need to install them? Remediation project over Hg capture at NGS period would be interesting.
Carol Evans	The EPA requirements for the Navajo Generating Station will reduce aerial deposition by half due to retrofits. There are cumulative impacts from the San Juan and 4 Corners plants. Four corners is facing a retrofit as well. There will be less impacts.
Carolina Risolo	I am from Argentina! Sorry
Kerensa King	A pilot test to irrigate the revegetated areas in the created wetlands. The Truckee River drains into Pyramid Lake which is a terminal lake.
Janis Cooke	Consider Davis Creek and Davis Creek Reservoir - it has mercury mine tailings in the reservoir, loading ongoing from upstream, and introduced warm water fish (bass).
Marcus Jones	Steptoe Creek/Comins Lake, White Pine County, Nevada
Patricia Bratcher	Clear Creek, Shasta County. We are going to start a dredger sorting project to capture mercury while also creating salmon spawning habitat. It is funded by ERP ($4.5 million), plus the feds (USBR, FWS). We are also planning to create wetlands.
Carrie Austin	California Reservoir where: <Michelle Wood's proposed factors> - Reservoir bottom sediment Hg elevated - Localized / confined mine site so possible to remediate it - Short stream reach so little contribution after mine site remediated ---> Excellent pre-and-post monitoring Paired Reservoir Pilot Tests in California Fully reversible - Nitrate addition to reduce methylation Pair - control and treatment Paired Reservoir Pilot Tests in California Fully reversible - Nutrient addition to increase Chlorophyll-A by < 2 times, up to about 2-5 ug/L - Oligotropic and mildly eutrophic reservoirs - Careful selection reservoir so don't cause bluegreen algae issue
NA	Pilot Project to look at ways to remove sediment from the reservoirs on the Feather River? (Reservoirs are filling up with sediment and compromising PG&E hydropower generation.)

	Pilot Project - Malakoff Diggins State Park remediation activities
Carrie Monohan	At multiple AML sites in a single watershed that contribute to the same reservoir, e.g.: Alpha / Omega, Relief Hill, Malakoff Diggins that all flow into the South Yuba River and Englebright Reservoir
Jim Weigand	Look at 3 watersheds for pilot projects with adaptive management and research - Russian River: mines from headwaters to near coast (What amount of mercury enters the ocean from an Hg-rich watershed with mines) - Cache Creek tributaries to Cache Creek Settling Basin (Hg clean up / management in mine vs. non-mine drainage) - Yuba River (comparison of new technologies for source and sink controls on Hg)
NA	Combie Reservoir Project (testing impact of mercury removal from this or stream impoundment)
NA	Representative hydraulic mine with drain tunnels, pit lake and former surface sluices Hydraulic mine sites are present on federal, state and private lands; lessons learned would benefit multiple stakeholders
NA	Do an in-depth investigation at a large lake or reservoir with documented high Hg levels, such as Lake Nacimiento, where fishing, including subsistence fishing, occurs. Scale is especially interesting because of lake's size and the tradeoffs that remediation will entail.
NA	Pilot Project - Look at a legacy mine with surface water discharge of turbid water - The “Thai iced tea” water that has a current mining operation that could do remediation of the legacy mining discharges through their reclamation plan
NA	Pilot Studies: - Addressing MeHg control in "downstream" systems such as wetlands, rice fields, drainage ditches, duck clubs to help meet TMPLs - Complete pilot sediment removal project at Combie Reservoir as well as associated research on downstream impacts / benefits
NA	Feeder where silty clay is disaggregated by forcing material to move upslope against a water spray under 35psi through a 5mm screen to: - a centrifugal pump to a SWECO classifier which screens to 2mm - Orange Eriez magnetic separator which removes magnetic minerals - vertical SALA pump which chews the materials apart

List of Unanswered Questions

These questions were posed by the webinar audience to get clarification of various presentations, but were unanswered due to time limits. They are included here for completeness.

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LIST OF UNANSWERED QUESTIONS	
NAME	QUESTION
Kendra Zamzow	An Arizona lake was drained to get to the sediment to remove it; Dr. Monohan talked about needing water to use a floating dredge. Can they discuss that apparent difference?
Jim McNamara	Please provide some contact info re the tidal marsh monitoring program in Richmond CA that Mike just mentioned. We are closing on a complete FS for a cintaminated etuarine system in coastal GA.
Steve Finn	What is the basis for the 0.2 mg/kg meHg value?
Kendra Zamzow	Do mg/kg risk based cleanup goals change in each state?
A. Dianne Kopec	Were the fish Hg concentrations normalized by size or, better yet, age?
Harry Ohlendorf	It would be helpful if speakers were clear about whether Hg concentrations in fish are on wet- or dry-weight basis.
Steve Finn	Why compare sediment THg to fish meHg?
Chance Asher	I would like to know if the 303(d) listings in the reservoir are for fish tissue, water or sediment?
Clay Patmont	Could Michelle explain the fish tissue MeHg multiple factors regression relationships further? Specifically, can she show us the regression slide again and hypothesize on why these relationships occur?
Lori Verbrugge	While talking about reservoirs, I'd like to learn more about prevention. What mitigation measures are most effective when a new dam/new reservoir is being planned?
Stephen Geiger	Question for Michelle: what is the connection between MeHg and chlorophyll?
Simon hockin	Can I please have a little more info on the significance of Chlorophyll A and why this is a key indicator rather than other potential routes for methylation such as anaerobic microbial activity in sediments ? thanks
Lori Verbrugge	Where is Cinnibar Creek? Is it associated with Red Devil mine; is it being remediated?

Sheila Abraham	Have you looked at the EPT (ephemeroptera; plecoptera; tricoptera) aquatic index? This was a sensitive index when we evaluated PCBs, even when the gross aquatic indices did not show effects.
David Glaser	Why would we hypothesize a resident in the processing area of these mines?
Sheila Abraham	Does the risk evaluated from arsenic consider the relatively new bioavailability factor? It probably won't make a different to any risk management necessary but I was curious.
Clay Patmont	Matt noted that there wrere "tough bugs" in streams within the Red Devil Mine area. Is he suggesting that benthic invertebrates have adapted to mercury, or is it possible that the mercury may not be toxic?
Lisa Wallender	Q for Michelle - please explain the relationship between MeHg and Chlor-a.
YUKTA DURVE	please explain infiltration
Tara George	Question for matt: what kind of cancers did you see at the Red Devil site?
Chance Asher	As a regulator in a state cleanup program I am very interested in the initial findings regarding "quick" results from remediating mine sites. Does anyone have more thoughts as to what the focus of the research question should be?
Lisa Wallender	I would like to learn more about the second two variables that Michelle mentioned - the relationship between MeHg and Chlor-a, and the relationship between reservoir level fluctuations and Hg in fish tissues (I deal with WQ issues at Nacimiento Reservoir, which has significant surface level changes). Can Michelle (or anyone else) point us to a resource where we can learn more about these factors? Thank you.
Nadine Benoit	What's the scale for rainfall?
Matthew Terry	Question for Matt Wilkening: Are there any plans to evaluate Hg concentrations in local populations of subsistence -based communities (humans)?
Kendra Zamzow	For Charlie Alpers, relevant to microbial methylation discussion, new article in Env Sci and Tech: Mercury methylation by novel microorganisms from new environments (Cynthia C. Gilmour, Mircea Podar, Allyson L Bullock, Andrew Mitchell Graham, Steven Brown, Anil C Somenahally, Alexander Johs, Richard Hurt, Kathryn L Bailey, and Dwayne Elias Environ. Sci. Technol.).
Kendra Zamzow	I may have missed this, but can the presenter discuss the difference between dissolved THg vs Hg(II)?
Xiaochun Zhang	why only the surficial sediment was analyzed? Interested in seeing vertical distribution of entire soft sediment deposit. Any information about how thick the soft sediment is in the area?

Darius Ostrauskas	Q for Chris Eckley - summary only for Mine Site and Reservoir - what about the River?
Randy Boston	For Chris: have you compared compare ecological differences (biology present, organic carbon, etc) between the sediment that becomes exposed and the sediment that is always submerged?
Clay Patmont	Could Stephen Dent comment on the highly successful nitrate addition to Onondaga Lake in Neew York? Fish tissue mercury appear to have declined remarkably in that system.
Clay Patmont	Could Eli Curiel discuss how the management decision to remove sediments in Pena Blanca could have been improved? The sediment removal (which was very expensive) doesn't seem to have been successful.
Nick Dallman	Re: Pena Blanca Lake - Does ADEQ have a theory why Hg levels were still high after the clean-up?
Ralph Turner	Wonder whether Hg vapour in air was measured during dredge treatment trial.
Jesse Lepak	Is there any speculation on whether physical removal of mercury will translate to reductions in mercury concentrations in fish, or might the results Eli Curiel presented be expected?
Kerensa King	Jean, one last question. Someone mentioned at the end there that you could tell a Hg source (atmos. depo, mining, etc) from the isotope present in fish. Who mentioned that, I didn't catch the name?
James Smoot	Is there anyone that might be a point of contact for a pilot study for methyl mercury remediation in surface water?

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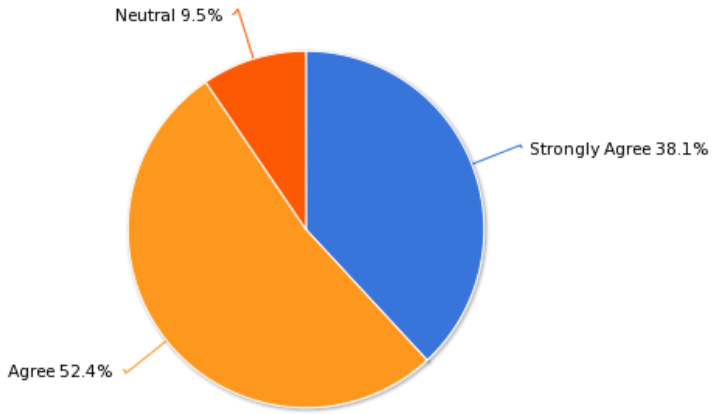
Survey Results

Survey: State of the Science Workshop: Mercury Remediation in Aquatic Environments - September 26, 2013

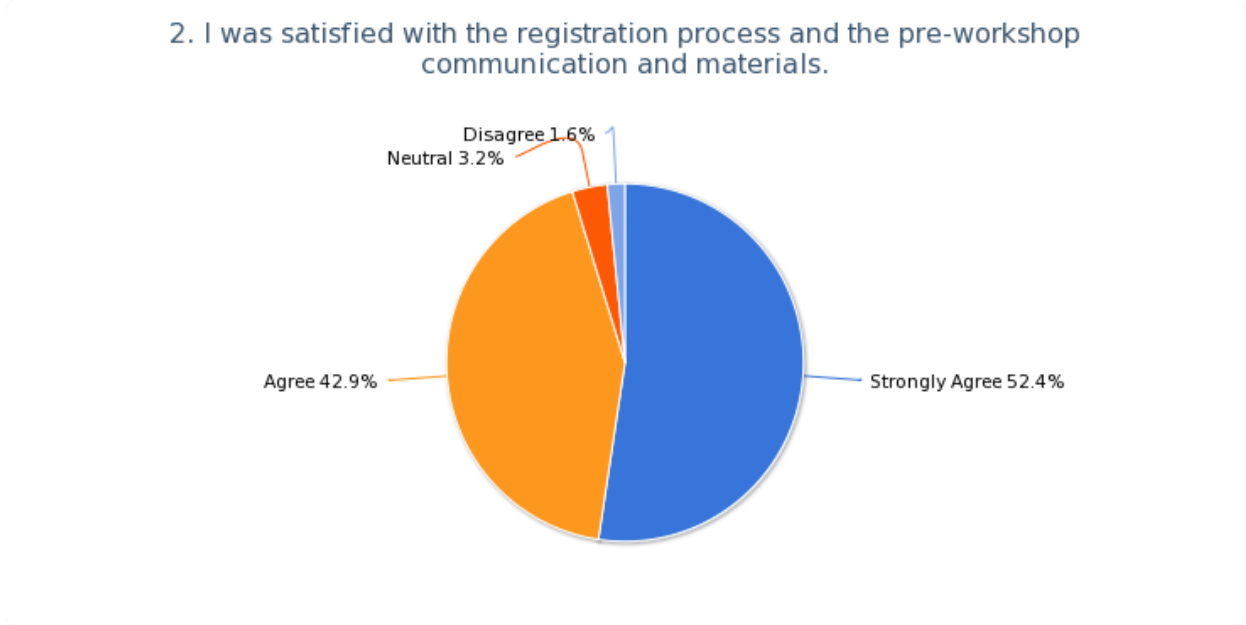
The organizers sent out a survey, which had about a **20%** response rate. Some highlights include the following observations. Most of the participants either "strongly agreed" or "agreed" (**90%**) with the organization, content, agenda, and goals of the workshop. The majority (**70%**) also believed the practices identified in the workshop would lead to a better selection of remedies to clean up mercury sites. About **65%** of the participants said they could now identify techniques for reducing or eliminating mercury at both the source and downstream of the source. And finally, almost **80%** said they now understood the knowledge gaps and technology needs in the field. Many contributed their own thoughts on data gaps here, but more gaps and needs are tabulated earlier under the Summary and Conclusions. Given the current austere funding climate and the cost of travel, many appreciated the free webinar availability. Of course, there were some problems (Region 9 centric, audio issues for webinar folks, no free coffee). But overall, participants seemed to find the workshop valuable. The compiled survey results follow.

1. I was well-informed about the goals/objectives of this Workshop.



Value	Count	Percent
Strongly Agree	24	38.1%
Agree	33	52.4%
Neutral	6	9.5%
Disagree	0	0.0%
Strongly Disagree	0	0.0%

Statistics	
Total Responses	63

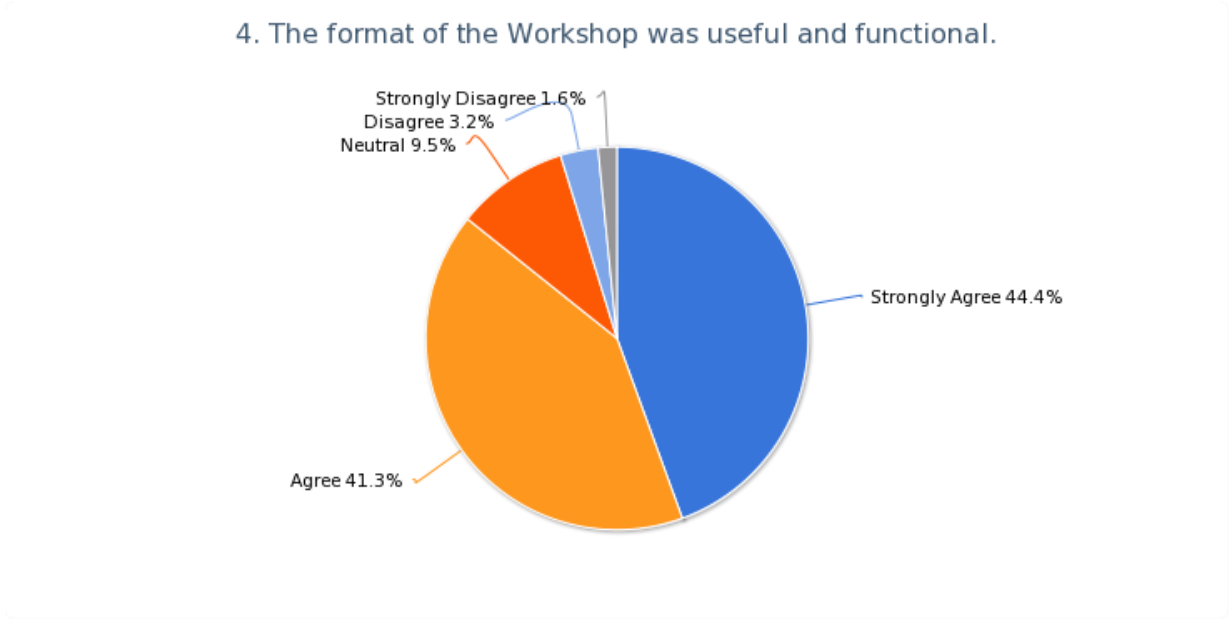


Value	Count	Percent
Strongly Agree	33	52.4%
Agree	27	42.9%
Neutral	2	3.2%
Disagree	1	1.6%
Strongly Disagree	0	0.0%

Statistics	
Total Responses	63

Value	Count	Percent
Strongly Agree	33	52.4%
Agree	24	38.1%
Neutral	5	7.9%
Disagree	1	1.6%
Strongly Disagree	0	0.0%

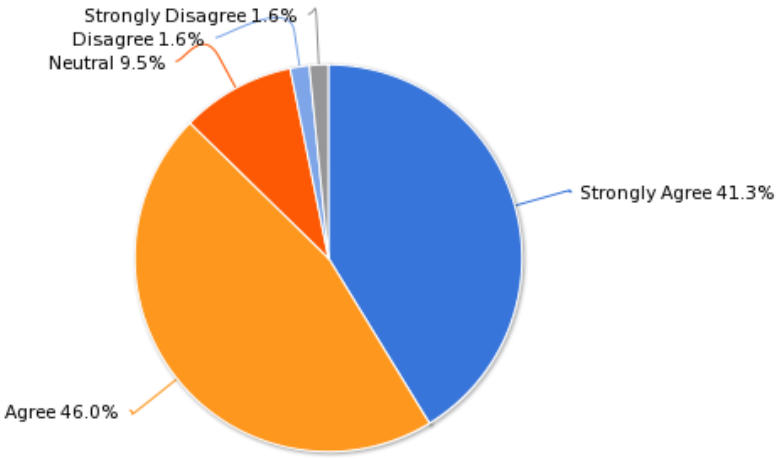
Statistics	
Total Responses	63



Value	Count	Percent
Strongly Agree	28	44.4%
Agree	26	41.3%
Neutral	6	9.5%
Disagree	2	3.2%
Strongly Disagree	1	1.6%

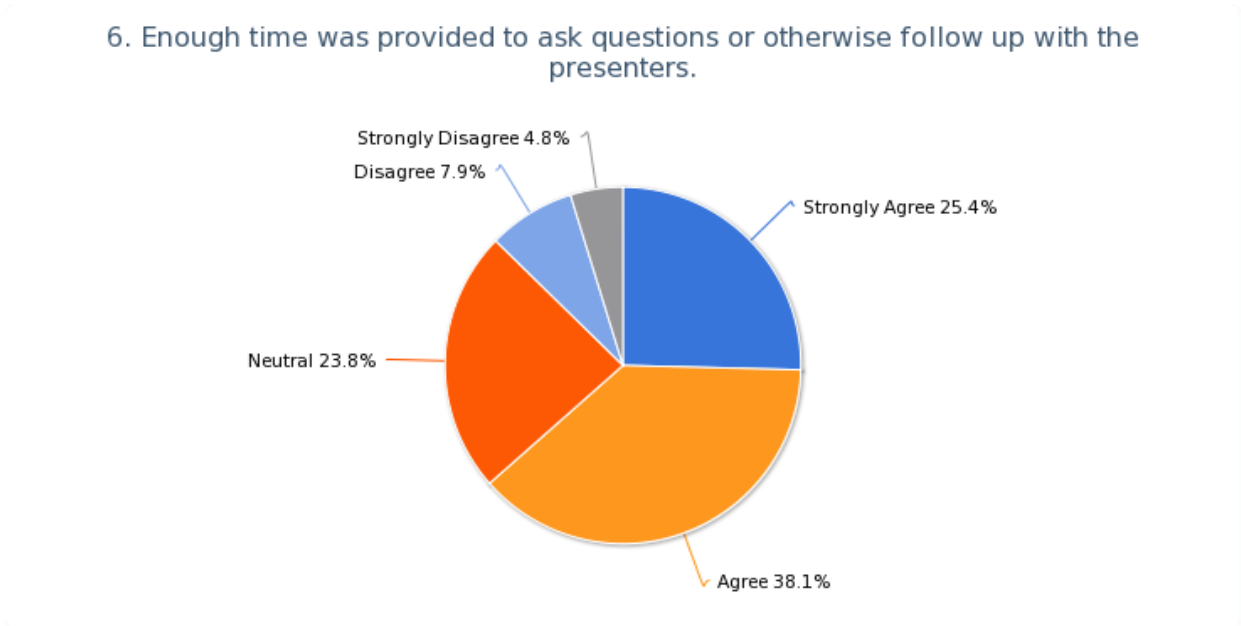
Statistics	
Total Responses	63

5. Given the time allotted, the amount of material covered was appropriate.



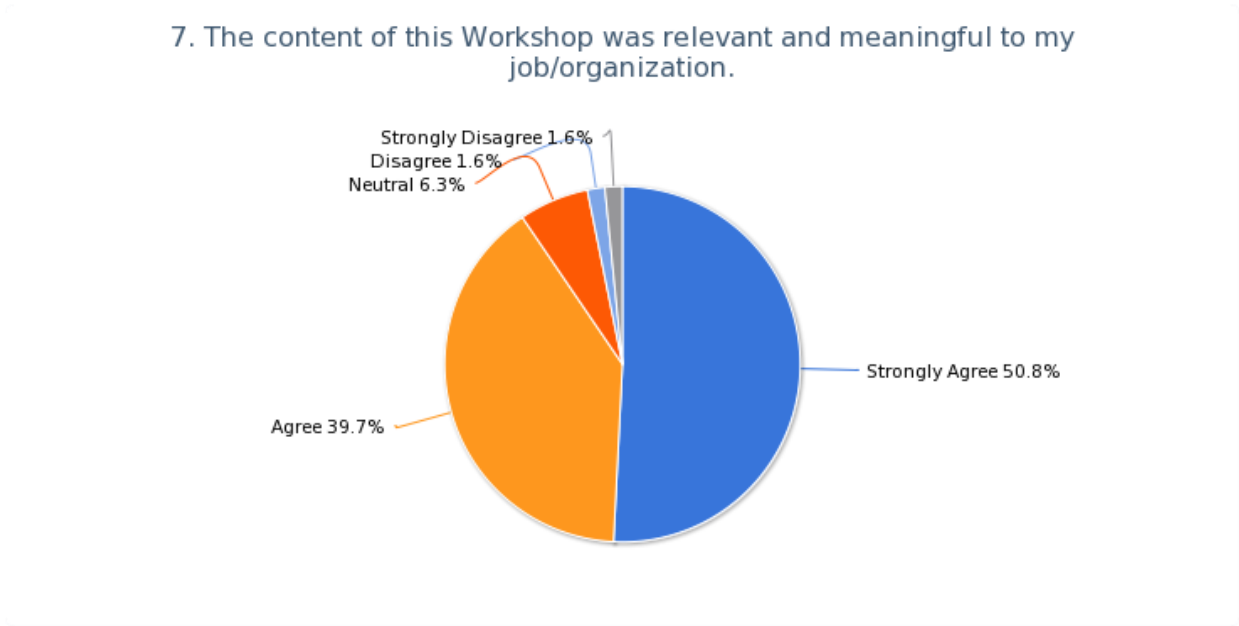
Value	Count	Percent
Strongly Agree	26	41.3%
Agree	29	46.0%
Neutral	6	9.5%
Disagree	1	1.6%
Strongly Disagree	1	1.6%

Statistics	
Total Responses	63



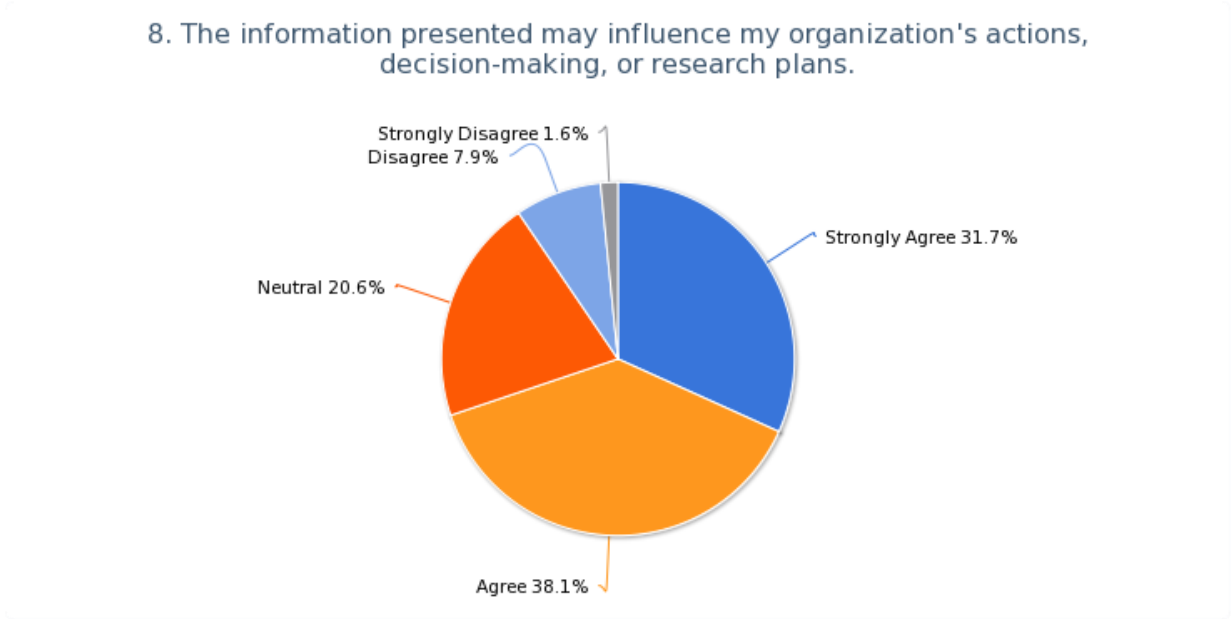
Value	Count	Percent
Strongly Agree	16	25.4%
Agree	24	38.1%
Neutral	15	23.8%
Disagree	5	7.9%
Strongly Disagree	3	4.8%

Statistics	
Total Responses	63



Value	Count	Percent
Strongly Agree	32	50.8%
Agree	25	39.7%
Neutral	4	6.4%
Disagree	1	1.6%
Strongly Disagree	1	1.6%

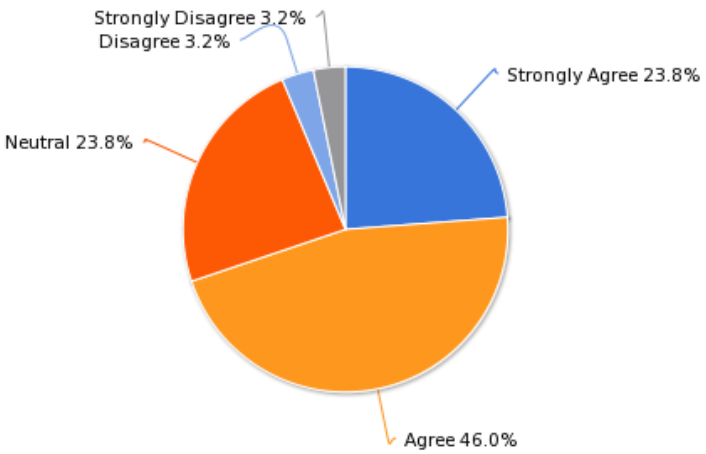
Statistics	
Total Responses	63



Value	Count	Percent
Strongly Agree	20	31.8%
Agree	24	38.1%
Neutral	13	20.6%
Disagree	5	7.9%
Strongly Disagree	1	1.6%

Statistics	
Total Responses	63

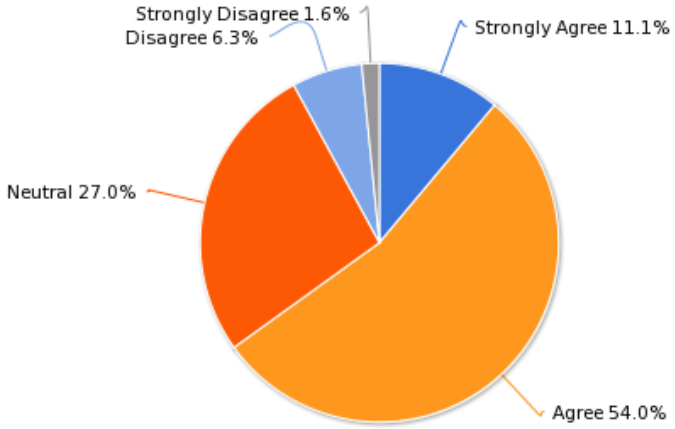
9. The concepts and practices identified during this workshop will lead to better selection of remedies to reduce mercury contamination in aquatic environments.



Value	Count	Percent
Strongly Agree	15	23.8%
Agree	29	46.0%
Neutral	15	23.8%
Disagree	2	3.2%
Strongly Disagree	2	3.2%

Statistics	
Total Responses	63

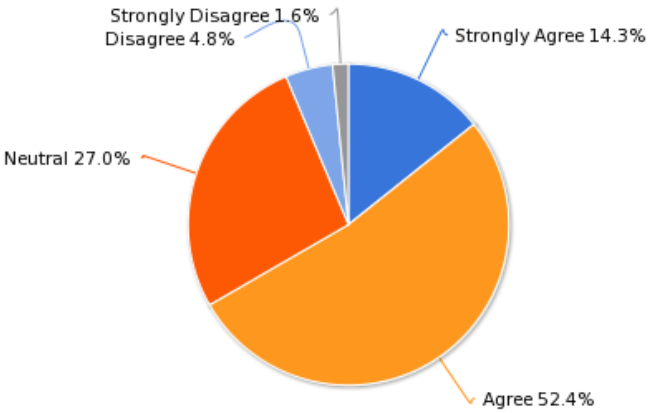
10. As a result of the workshop, I can now identify source control options for reducing or eliminating mercury contamination and understand their limitations.



Value	Count	Percent
Strongly Agree	7	11.1%
Agree	34	54.0%
Neutral	17	27.0%
Disagree	4	6.4%
Strongly Disagree	1	1.6%

Statistics	
Total Responses	63

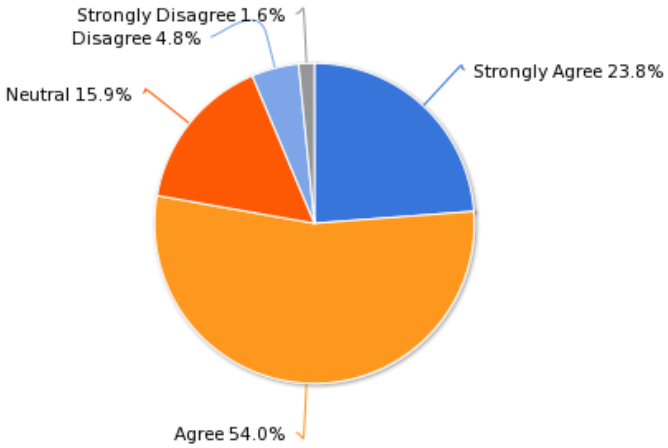
11. As a result of the workshop, I can now identify downstream control options for reducing or eliminating mercury contamination and understand their limitations.



Value	Count	Percent
Strongly Agree	9	14.3%
Agree	33	52.4%
Neutral	17	27.0%
Disagree	3	4.8%
Strongly Disagree	1	1.6%

Statistics	
Total Responses	63

12. After this workshop, I have a better sense of the knowledge gaps and technology needs for conducting appropriate remediation of mercury in aquatic environments.

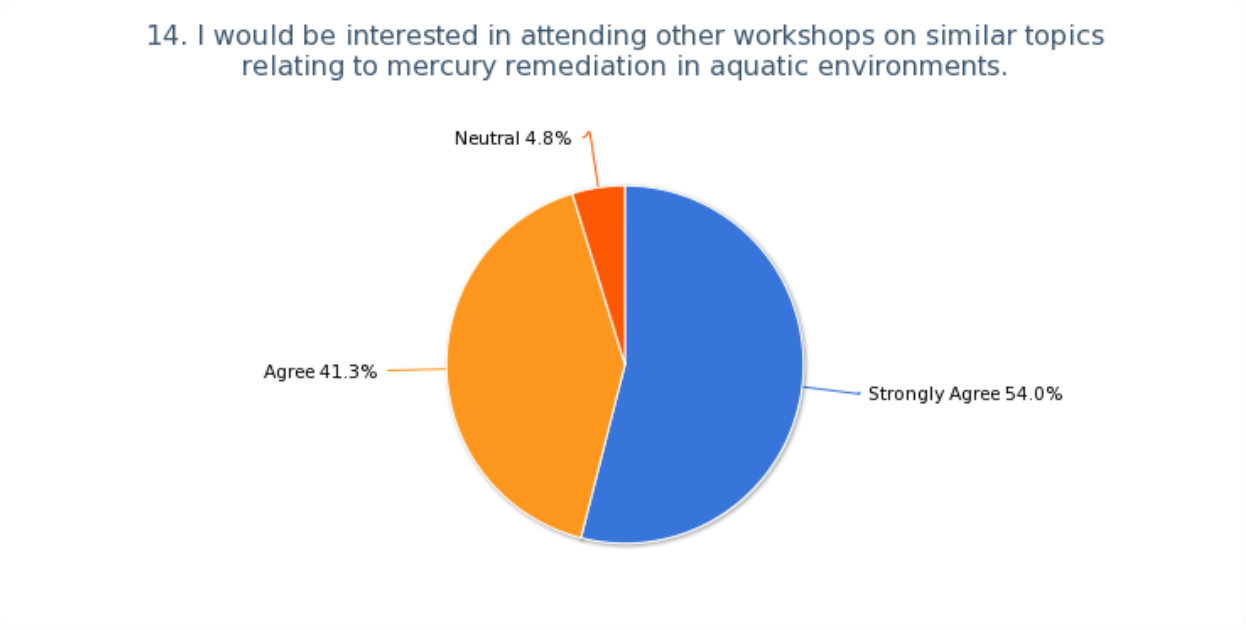


Value	Count	Percent
Strongly Agree	15	23.8%
Agree	34	54.0%
Neutral	10	15.9%
Disagree	3	4.8%
Strongly Disagree	1	1.6%

Statistics	
Total Responses	63

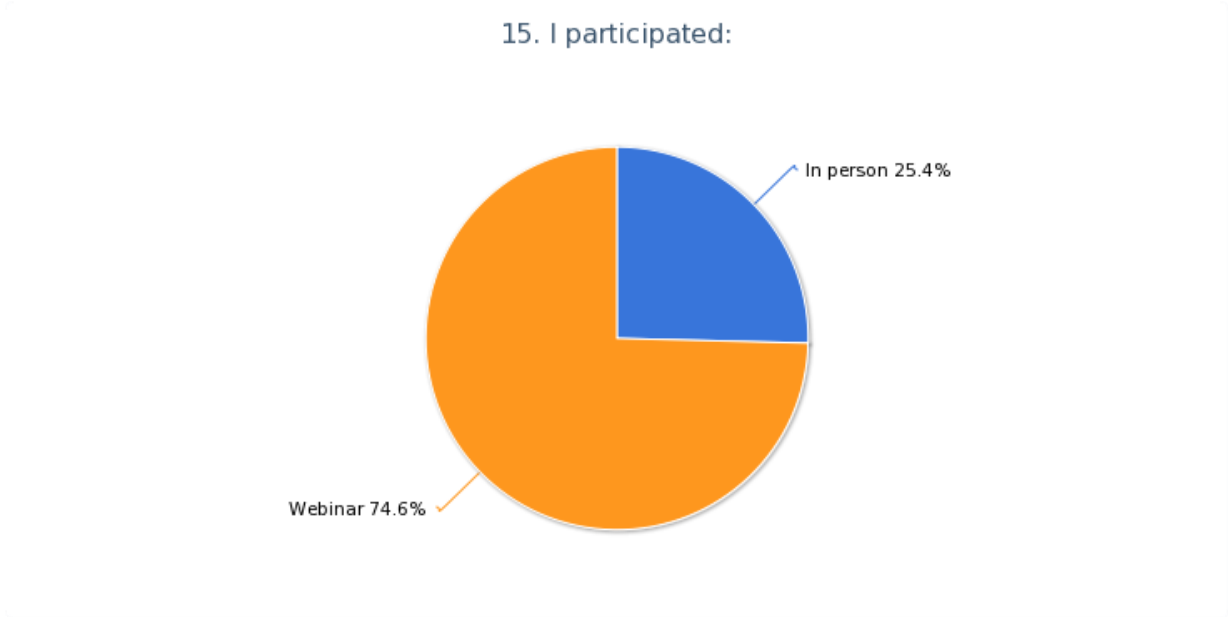
Value	Count	Percent
Strongly Agree	21	33.3%
Agree	30	47.6%
Neutral	6	9.5%
Disagree	5	7.9%
Strongly Disagree	1	1.6%

Statistics	
Total Responses	63



Value	Count	Percent
Strongly Agree	34	54.0%
Agree	26	41.3%
Neutral	3	4.8%
Disagree	0	0.0%
Strongly Disagree	0	0.0%

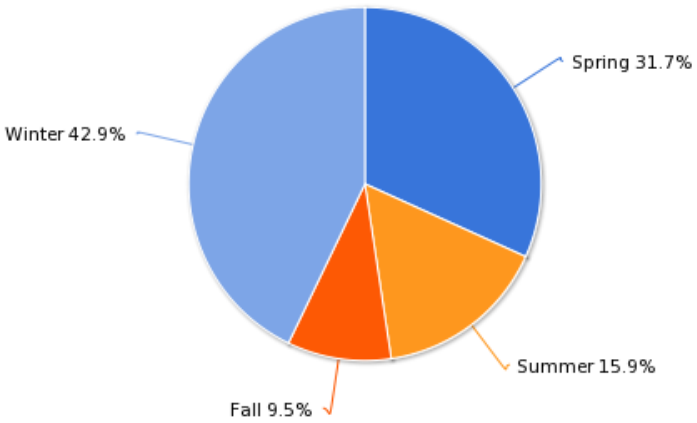
Statistics	
Total Responses	63



Value	Count	Percent
In person	16	25.4%
Webinar	47	74.6%

Statistics	
Total Responses	63

16. If we were to have a follow-up workshop on Hg Remediation, is there a time of year that works best for you?



Value	Count	Percent
Spring	20	31.8%
Summer	10	15.9%
Fall	6	9.5%
Winter	27	42.9%

Statistics	
Total Responses	63

17. During the workshop, you heard various mercury remediation in aquatic environments research needs and data gaps expressed by participants. We also discussed potential pilot study ideas that could be pursued within EPA Region 9, should funding be available. Let us know if something came to mind that you didn't get a chance to express during the workshop or wish to reiterate. We appreciate your input!

Count	Response
1	Cannot add anything substantial to what had been discussed.
1	Extend it to 1.5-2 days to accomodate more case studies
1	I'm in GA (Region IV)
1	More detail on studies and usefullness reltated to isotopes of mercury
1	NA
1	None
1	Not in Region 9.
1	Proving technology about mercury removal through dredging seems especially important
1	collaboration with miners/claimholders on upstream watersheds - they know all the hotspots.
1	in 2000, EPA had program in place that actually removed mercury - what happened to it ?
1	n/a
1	na
2	nothing
1	In the areas of Alaska and California where there appears to be high levels of subsistence fishing, it would be important to carry out evaluations and monitoring of Hg concentrations and/or side effects in these communities with human subjects. There seems to be no shortage of need for projects and funding in EPA Region 9; however, I think it would be beneficial to try to expand the focus of Hg remediation projects to an international and global scale...since Hg is a global problem and there could be important benefits from that level of collaboration. In EPA Region 9, I think that it would be interesting to explore the applications of using artificial constructed (dry or wet) wetlands for removing dissolved organic content, fine sediments, clay and silt from the water flow. Also, the use of instream passive sediment collectors could provide an interesting remediation technique; this is relatively new technology that is being used for sediment management without dredging...the benefit is that it is an in situ application that does not disturb the bottom sediments...hence the passive collection devices that use pumps to move and clear the sediment to appropiate storage areas as needed.
1	I would recommend pilot studies under different conditions, hardrock, estuaries and see if there is a way to provide guidance in these differing conditons. Also, gold in tailings is also becomming economical, guidance in remining these tailings would be advantageous.
1	I need help with conservation measures for the Navajo Generating station lease renewal. I would have liked to hear ideas with continued MeHg inputs and not just old mining cleanup.
1	Hlope EPA can work on a pilot remediation project on hydraulic mines in the Sierra Nevada watershed.
1	modelling -- it would seem that the available models aren't all that greatat at predicting Hg fish tissue concentrations in existing water bodies (or of more interest to my position, future water bodies, such as hydroelectric dam reservoirs). What models are available, what are the pros/cons, data needs, etc.

Count	Response
1	I was the one that mentioned the project in Nevada. What I put down was the extreme nutshell version. There are two listed species present in the lower Truckee River, including one (Cui-ui) that is found no where else. Feel free to contact me if there are questions/interest (kerensa_king@fws.gov).
1	Influences on methylation and demethylation. Possibly data gaps on methylation organisms given new research on methylation biomarkers?
1	I already contributed mine thanks, but were you going to distrbute a list of all the ideas you recieved
1	The criteria used to determine the healthy level in fish tissue was not always the same between presenters. For example, sometimes it was 0.3 and others it was 0.2 ppm dry weight. Since the whole goal is preventing mercury toxicity in people and fish, it would be great if the problem could be defined and framed with carefully defining the extent, threat, and action levels necessary (legally that is) for protection. Like any sort of toxicity, these thresholds should consider mercury species, magnitude,duration, and frequency.
1	I personally would like to know more about wetlands restoration and its effects on mercury in different climates and environments.
1	The magnitude of the issue was well defined. Regulators, policy makers, scientists, and public stakeholders will need to collaborate to solve this problem for future generations.
1	Would like more information on relationship between MeHg and Chlor-a and MeHg and lake level fluctuations (reference?)
1	State and federal funds should be appropriated to address this legacy problem especially downstream impacted areas.
1	The linkages between floodplain deposits of Hg-contaminated soil and Hg in fish when the original point source has been eliminated needs more work, especially on means to control this secondary source without having to destroy riparian forests and vegetation.
1	My particular Hg issue is in brackish/salt water environment which is somewhat different than the material that was presented.
1	Although seasonal wetlands rather than permanant may increase methyl mercury in Delta, what about upstream situations with lower temperatures, more natural / complex type wetlands, lower amounts of DOM. i.e. will seasonal wetlands creation in upstream areas be a Hg problem?
1	Testing a technology that would allow concurrent treatments for nutrients and mercury. Most of the lakes that are impaired by mercury have eutrophication problems as well. I will be more than happy to lead such an effort.
1	Two key ideas should be pursued: (1) Pathway interruption of MeHg production --> from elemental Hg to reactive Hg(II) to MeHg; and (2) uptake of MeHg into plants (i.e. Tule) -- then harvesting the plant and proper disposal.
1	I think there are critical data gaps in the use of in situ treatments to remedy the accumulation of mercury in the aquatic ecosystem. I would like to see some pilot studies that evaluate several lake treatments, such as hypolimnetic oxygenation or other technologies that work to address hypoxia in the bottom cold water portion of productive lakes.

18. What did you appreciate or find most valuable about this Workshop?

Count	Response
1	A variety of topics regarding Hg remediation and assessment.
1	Array of information presented
1	Confirmation of my understanding of methylation mechanisms/processes.
1	Data plots and pictures of the sites.
1	Excellent allocation of time for both questions and discussion
1	Excellent information, and well organized.
1	Hearing what others are doing and getting to know who the contacts are in this field.
1	I appreciate that Eli Curiel's talk included problems, as most talks focus on sucess
1	I appreciated learning about oxygenation systems and their pros and cons
1	Jacob Fleck's presentation had new material I had not considered.
1	Practical ideas that were shared
1	Presentations of studies of factors controlling mercury cycling processes.
1	That I could fully participate from my home office, Also able to add some new folks to my network
1	That each site requires a method tailored to fit its variables.
1	The different ideas on remediation, and the last presenters fish management with MeHg.
1	The format
1	The high level of science that was presented
1	The information/knowledge by the presenters
1	The selected case studies and speakers were extremely relevant and knowledgeable.
1	The variety of projects shared.
1	The variety of topics related to a singular issue.
1	Up stream source remediation issues and examples.
1	Very well organized with a wide variety of related topics.
1	Very well organized. I wish there was a way to account for time differential.
1	example projects and real world experiences
1	face to face interations, the out of state presenters that hard info i had not heard before
1	good range of topics, knowledgable speakers
1	hearing what other jurisdictions do
1	how little we understand the response of MeHg to remedial action.
1	i liked having the webinar option and was impressed how smoothly that went.

Count	Response
1	taking the full day to get all pertinent info presented.
1	the cases
1	the collaborative table discussions
1	the total disregard for spending tax dollars in what will be a 50 year effort, at the least
1	the wide range of topics, state of art on removal; some worked and some didn't
1	Understanding the complexity of Hg remediation; reviewing case studies of what has worked and what has not worked, and how much there is that we still don't understand.
1	Presentation of the depth/breath of the problems to solve mercury bioaccumulation and share ideas with other experts in field.
1	I really like the multi-platfrom delivery -- not overly busy with tech, just giving you lots of options to attend or participate as you wished/were able (and in my case at no charge and with no travel approval required, a huge bonus for gov't employees)
1	It's hard to specify just one item, I'd say the various methods that were mentioned. But the whole workshop was extremely well done.
1	The ability to tie in remotely thus minimizing time and cost. The collection of material and speakers even thought the fresh water environment is not directly relevant to my issue.
1	The facilitation was outstanding. The scientific presentations were good and covered a wide range of topics and fields of interest.
1	Jean Balent as the moderator. . . .kudos for always doing a great job! The workshop didn't hold my attention because I don't work with mining sites. There wasn't much shown on understanding the aquatic system and bioavailability of Hg.
1	The webinar technology was fantastic. I am so appreciative that EPA provides these technical training opportunities; I could not participate if I had to travel.
1	Dialogue among scientists and regulators -- very useful. Was a bit shocked at some of the projects that had been undertaken -- draining a lake without controlling source first or understanding bottom substrate, etc.?? Come on now....we should be way beyond this....

19. What improvements would you recommend for this Workshop?

Count	Response
1	A little more Q&A and discussions for specific presentations.
1	A little more on food chain accumulation - Celia Chen with Dartmouth is good for that info.
1	A room with windows that open.
1	All speakers seemed to have trouble with the technology (audio for example).
1	Audio could be better.
1	Audio quality
1	Better viewing / projection of ppt presentations.
1	Discuss the process of methylation early in the workshop
1	Expand to include the brackish/salt water environment with marsh/food chain impacts.
1	Having the breakout table sessions was not good especially being on the phone by myself.
1	I would only recommend a longer duration or multiple days.
1	More on alternative remedial technologies.
1	More translation of basic science to practical approaches for remediation.
1	More wildlife bent on the discussion and also human impacts.
1	None that I can think of.
1	Provide list of speakers with contact info, like emails/phone #s
1	The fund raising campaign by the Sierra Fund was misplaced.
1	chat room box was a bit fuzzy in purpose
1	have the kinks for the webinar worked out earlier. I found the webinar distracting and annoying
1	none
1	none - it well organized
1	post citations / reports online that were refered to during presentations
1	ppt available before the meeting
1	practice with vol. control. submissions/question box area did not function adequately
1	this appeared to be a region 9 centric workshop
1	More time for questions, not just clarification questions. More discussion with the presenter after each presentation. An organized time to mingle and meet others who are there for the talks.
1	thi is kind of dumb -- I hate videoconferencing, it's just not that exciting to see a talking head, but it would be nice if the presenters added a head shot and a URL to themselves if available
1	My neutral responses above are due to the fact that the Hg sites that I am working on in GA are chlor-alkali plants, one of which cannot account for about 164,000 kg and is located adjacent to an estuary. The other site is located on a river. In neither place are downstream control options (as presented) feasible.

Count	Response
1	Better audio. Also, less about the history of mining in California, which is interesting but took up a fair amount of time.
1	Less of a central focus on California mining/mercury concerns; experiences in other regions and environments.
1	More interaction with the presenters by the people attending via webinar. I'm not sure if they were able to view questions or not. Many of them had their contact info as part of their presentation (and more may be available on the web site in a week or two), but being able to get a hold of some of them sooner rather than later would be very helpful.
1	Presentations: some were hard to read, Charlie Alpers was too fast, no distribution of the presentations (hard copy even)
1	Grouping attendees into groups so that each group can provide answers to specific questions seem unnecessary.
1	I didn't get much out of the group discussion period. I would have preferred a more extensive Q&A after each presentation.
1	Better geographical representation of the presenters. There are great case studies from the Eastern US.
1	An introduction and overview of the Hg cycle at the biogeochemical level, the fate and transport of different Hg compounds, and how different forms of Hg are measured with relative costs might be a good starting point to give everyone an even perspective.
1	Probably pretty obvious: reduce the technical difficulties. Also it would be really great to get the slides ahead of time.
1	Not limiting to mining sites, open it up to east coast sites. . . while outside the EPA region that hosted it, there seems to be more knowledge about Hg in aquatic systems.
1	Panel discussion among presenters about certain of the key questions - especially weighing the benefits of source cleaup vs downstream controls. Snacks or just coffee would have been much appreciated given that it was difficult to leave the building for breaks.
1	Needed to allow for interaction and questions of presenters. Limiting questions to clarfication of information presented was not very useful
1	A couple I would like to have seen covered: urban sources that can be controlled, methylation of mercury (processes) in streams and in coastal tidal marshes.
1	Adjusting the sound quality; various speakers were hard to hear, while some came through very loudly.
1	Remote speakers and presenters were difficult to hear / understand due to the sound system problems.
1	Size of text and figures on screen was too small! better commincation with presenters on the visuals

20. Please share your observations and suggestions about your overall experience at the Workshop

Count	Response
1	Excellent. Thank you for making it available on the internet.
1	Filled a real need.
1	Good information
1	Great format, but could have covered the essential messages in a half day instead of a full day.
1	I learned a lot - thanks again!
1	I thought it was great, we should do it again!
1	Long overdue and shows EPA web site is severly out date information.
1	Nice job, thanks for making it available via webinar.
1	None
1	One of the best I've attended
1	Overall i thought the workshop was excellent
1	Overall, good seminar and well run.
1	Terrific workshop!
1	This was truly and outstanding, even exceptional event. Congratulations!
1	Very good -- enjoyed meeting others with an interest in this complex area.
1	Very good.
1	Very informative, easy to participate and well-organized.
1	Well coordinated with excellent speakers.
1	good
1	great job.
1	i thought the webinar moderator did a good job keeping us virtual participants engaged
1	na
1	need more - long road ahead, maybe monthly?
1	overall - good experience
1	suggest perhaps bringing in outside experts involved in remediation e.g. in canada/Ontario
1	very good indeed
1	overwhelmed at magnitude of possibilities to "conduct further studies" with no actual remediation accomplished
1	It woudld be interesting to wexbex into similar workshops in other EPA regions. Coudl you let us know if there are any

Count	Response
1	The first presentation seemed to portray limited knowlege in aquatic systems. Understanding the water body is an important part of the site conceptual model and understanding Hg in the system. I wasn't seeing much of this.
1	The breakout sessions did not work particularly well for the webinar participants - the result was a limited time for multiple questions from the participants.
1	I think the workshop was very well organized and perfectly targeted. The web interface worked well.
1	I was impressed how smoothly the presentations went given that some of the presenters talked remotely. Great idea for a workshop, we definetely need more of them. I wish I had the opportunity to be there in person. For question #16, I woudl suggest that you allow multiple answers. I would be fine attending a workshop during winter or early spring. Summer time is the sampling season.
1	The audio broke up alot during most presentations over the webinar. Question 16 is not good- it won't let you say it doesn't matter or choose two seasons.
1	Overall well paced and good topics, with the exception of the aeration study, which went on for a little too long. It would have been better to have a cross-section of technologies that have been studied.
1	Exceeded my expectations. The audio connection was lost or marginal at times but I did not miss much.
1	Eight hours in front of the laptop was a little much, but worth it. Appreciate the interactive options for questions. But was difficult to scroll through poll question answers, I could only see 2 lines at a time and could not expand it.
1	The webinar hosting was highly productive and functional. It was a great opportunity to participate in a workshop that I would have otherwise been unable to participate in due to travel contstraints. Very well run.
1	I appreciated that it was free at this time of govenment cuts, and that it was a webinar. Thank you.
1	Since this workshop was focused on sediment remediation would have suggested that technical experts from the Corps should have been included
1	Overalll good. The talks should been previewed/edited by the organizers. One talk on the entire path mercury makes from the earth to the fish would be useful, especially as an intro talk.
1	I am specifically focused on the movement of mercury through groundwater, maybe should have talked to Mike beforehand about whether there would be any presentations pertinent to that topic. When presenters did get into more technical topics of interest, such as speciation in wetland systems, the audio was difficult and the presenters moved a bit too quickly for me to digest the slides and explanation. I ended up leaving early.
1	The way the webinar was set up and functioned was great. Great job by the facilitators and the technical people. A good example of remote meeting participation.
1	The workshop was an overwhelming success. So heartening that attendence was full and there were so many people from around the world attending. Definitely shows need for more like this. Kudos to the Region 9 staff who made this happen!
1	The interactive questions could be developed a bit more; I felt that there was not enough time to properly address and/or discuss some of the proposed questions to allow for appropiate depth of answers; however, I think it is good to get people to interact. There is obviously a need to develop work groups and forums about Hg evaluation and remediation. I hope that these workshops can be continued to be held, and field trips/site visits can complement these meetings.
1	It was great, but too rushed and opportunities to get discussions going seemed quelched in the time crunch.
1	Jean Balent was very efficient in setting up the webinar. The speakers delivered their presentations in a timely manner, thus, eliminating delays in the schedule. Overall, a very informative workshop.
1	Overall the presentations were fine, we just don't get involved much with mercury mining sites, so the specifiic content was less relevant to us than it was to others in Region 9.

Pictures

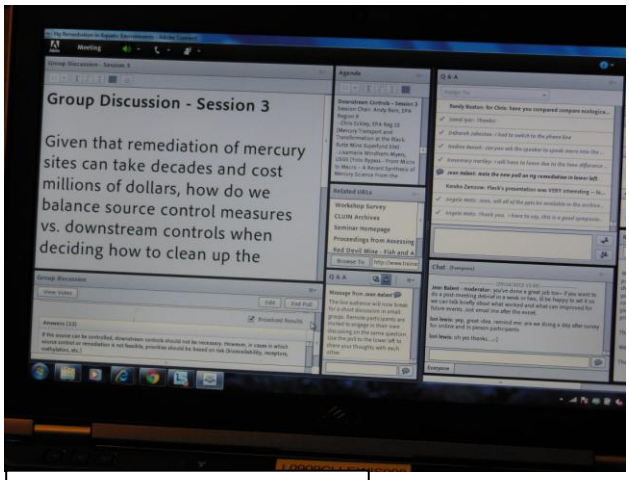
Dr. Ned Black "framing the problem"

Workshop Attendees

Discussions following Session 2

Planning Committee Chair Mike Gill

Session Chairs Andy Bain and Chris Eckley



Monitoring the Webinar

"Most" of the Mercury Workshop Planning Committee

Stephen McCord, Ned Black, Lori Lewis, Andy Bain, Chris Eckley, Mike Gill