NIH's laboratory mercury reduction campaign and its potential applications in health initiatives to reduce public exposure

In the mid-1990s the National Institutes of Health (NIH) began a voluntary initiative to eliminate the use of mercury in medical applications in its research hospital, the Warren G. Magnuson Clinical Center. The intentions of the initiative were to prevent potential human exposures and spills, reduce facility decontamination costs and contribute to state, regional and national pollution prevention goals for persistent, bioaccumulative and toxic chemicals. In 2001 the initiative was expanded into a more organized, agency-wide campaign covering the approximately 5,000 laboratories and other non-clinical areas on all NIH installations in the U.S. The campaign used a Mad Hatter theme in publicity materials to stimulate employee interest, improve awareness of mercury hazards and encourage participation in campaign activities. An unexpected outcome was the high level of public interest in the campaign and the extensive use of its website, brochures and other Mad Hatter themed materials by other government agencies, schools, and thousands of individuals. In 2002 the campaign was cited by the Governor of Maryland as setting a high standard for environmental outreach and education. This evolution of an institutional, laboratory-focused chemical health and safety initiative into a program with broad public health impact is probably unprecedented. Outreach methods used by the campaign have potential applications in national and international public health efforts which are urgently needed to reduce morbidity associated with human exposure to mercury resulting from both spills and dietary intake.

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INTRODUCTION

The National Institutes of Health (NIH) is an operating division of the U.S. Department of Health and Human Services (DHHS) and the primary federal agency dedicated to biomedical research. Its main campus, located in Bethesda, Maryland, is the largest biomedical facility in the world, consisting of over 5,000 laboratories, the Warren G. Magnuson Clinical Center, a 325-bed research hospital (Figure 1) and a large Ambulatory Care Research Facility (ACRF). Other major NIH research facilities are located in the Washington, DC metropolitan area, Montana and North Carolina. In this paper the history of NIH's Mad as a Hatter? mercury reduction campaign, its rapid evolution from an institutional program into a widely used community outreach activity, and its possible applications in national and international public health initiatives to reduce exposure to mercury will be reviewed.

Campaign Beginnings

> *There was a table set out under a tree in front of the house, and the March Hare and the Hatter were having tea at it: a Dormouse was sitting between them, fast asleep, and the other two were using it as a cushion, resting their elbows on it, and talking over its head. 'Very uncomfortable for the Dormouse', thought Alice; 'only, as it's asleep, I suppose it doesn't mind.'*
>
> *The Hatter opened his eyes very wide on hearing this; but all he said was, Why is a raven like a writing-desk?*

Mercury is probably the most ubiquitous and potentially problematic contaminant in biomedical research

Figure 1. The Warren G. Magnuson Clinical Center at NIH.

facilities and waste streams generated by laboratory activities. It is used in a wide variety of items–thermometers, thermostats, switches, fluorescent lighting, vaccines and other biologicals, and occurs in environmentally significant concentrations as a contaminant in many chemicals ranging from janitorial products to analytical reagents. Mercury presents serious potential health hazards to employees, patients and laboratory animals indoors, and it is persistent, toxic and highly bioaccumultative in the environment resulting in adverse impacts on both wildlife and human health. One of the primary drivers for eliminating unnecessary uses of mercury in institutional settings is the high cost of cleaning up spills. Very small volumes of spilled mercury can contaminate large areas above levels of health concern, and options for disposal of contaminated debris remain limited and costly.

Federal hazardous waste regulations governing disposal of mercury have been in place since at least the early 1980s when regulations were implemented. The NIH has had a specific policy governing the disposal of mercury since at least 1979.[1] Regulations and institutional policies at the NIH and elsewhere restricting *use* of mercury were a more recent development. In the last decade elimination of mercury devices such as thermometers and sphygmomanometers, and mercury-containing reagents has become a priority of pollution prevention campaigns in many hospitals and health care facilities.[2,3] In the mid-1990s the NIH began a voluntary initiative to eliminate the use of mercury in medical applications at the Clinical Center and ACRF. The intentions of the initiative were to reduce the potential for human exposure, spills and facility decontamination costs, and to contribute to state, regional and national pollution prevention goals focused on persistent, bioaccumulative and toxic chemicals. Mercury was also specifically targeted for reduction efforts in NIH's Pollution Prevention Plan, established in 1994.[4] Key to the success of this initiative was early efforts by the Clinical Center safety officer to inform medical professionals about mercury hazards and convince them of the suitability and availability of mercury-free devices in both clinical applications and research. Arrangements were then made to procure mercury-free thermometers and blood pressure devices, collect and recycle the mercury from the discarded items. This ultimately led to the removal of over 1,500 devices without a single spill or interruptions in patient care and research activities. The Clinical Center was virtually "mercury-free" and discontinued further purchases of mercury containing items. This set important precedents, demonstrating that hospitals, even those engaged in complex research protocols can operate without mercury devices, and it was believed to be the first Federal health care facility become mercury free.

Expansion as an NIH-Wide Initiative

In 2001 the initiative that began in the Clinical Center was expanded into a more organized, agency-wide voluntary campaign covering the approximately 5,000 laboratories and other non-clinical areas on all NIH installations in the U.S.

OBJECTIVES OF THE EXPANDED CAMPAIGN

The primary objectives of the expanded campaign were the same as those of the previous effort to eliminate use of mercury in the Clinical Center: to reduce potential exposures, prevent spills and reduce clean-up costs, and prevent pollution. A study of persistent, bioaccumulative and toxic (PBT) chemicals in waste streams generated by the NIH confirmed that mercury should continue to be targeted for reduction efforts.[5] Other drivers for broadening the reduction campaign became apparent and resulted in the addition of additional campaign objectives.

Preparing to Meet More Stringent Wastewater Discharge Standards

'I can't go no lower', said the Hatter: 'I'm on the floor, as it is.'

Promulgation of extremely strict discharge limits for mercury in wastewater is occurring in several regions and may be expected to continue throughout the U.S. Compliance with these lowered limits will present significant compliance burdens. For example, in Massachusetts, the Water Resources Authority (MWRA) imposed an effective sewer discharge limitation for mercury of 1.0 μg/L (parts per billion) from its regulated sources. Meeting the standard was a major challenge for hospital laboratories because key substances used in research and diagnostic procedures, reagents in particular, often contained trace amounts of mercury that are usually not listed in the content descriptions. A work group comprised

of institutions that were regulated as sources under MWRA regulations was established in 1994 to examine the problem, develop strategies to determine the sources of mercury in wastewater and reduce the amount of mercury being discharged. The results of extensive studies by the group have been reported.[6]

Mercury water quality criteria for discharges from wastewater treatment plants in the Great Lakes Basin and elsewhere in EPA Region 5 states were recently adopted and are generally 1.3 ng/L (parts per trillion),[7] or approximately three orders of magnitude lower than the MWRA standard. Biomedical facilities and laboratories have been specifically targeted for enforcement actions when these limits are exceeded. NIH anticipated adoption of similarly restrictive standards in the states where it has facilities and recognized the need to be proactive in addressing sources of low-level mercury contamination in wastewater. To meet such standards existing plumbing systems that often contain significant accumulations of mercury will have to be decontaminated or removed. All incoming cleaners, reagents and other products that are ultimately discharged to the sewer will have to be analyzed for mercury content. A searchable computerized database listing approximately 8,000 chemicals used by laboratories, hospitals and other institutions is available[8] and a link to this database was placed on the NIH mercury abatement campaign website. For about 800 listed products, the database includes the results of analytical testing for mercury content.

Avoidance of Mixed Wastes

Mixed wastes (radioactive hazardous wastes) contaminated with mercury, particularly as organometallic compounds, cannot be treated at the NIH hazardous waste facility and may have few or no off-site treatment or disposal options. Disposal options, if available tend to be extremely expensive.[9] Reducing mercury use in laboratories minimizes the potential for generation of mercury-containing mixed wastes from experimental procedures and decommissioning of laboratories that use radioactive materials.

Improving Assessment and Abatement of Mercury Contamination in Facilities Undergoing Decommissioning

NIH installations include many older laboratory buildings that will be decommissioned in the next several years and then renovated or demolished. Some of these projects are of unprecedented scale. Decommissioning and renovation of the Clinical Center building, anticipated to begin in the near future, will involve a total area comparable to the Pentagon. To facilitate these activities and ensure compliance with safety and environmental protection requirements, the NIH Division of Environmental Protection (DEP) was engaged in an initiative to improve and streamline protocols for assessment and remediation of hazardous substances in facilities planned for decommissioning, and to develop guidance for specific substances. DEP became aware that mercury was emerging as a major contaminant of concern in other biomedical facilities undergoing decommissioning yet little information was available on assessment and abatement methods for use in large scale projects as were being planned at the NIH. Studies were planned to develop this information and disseminate it through campaign activities.

Preventing Impacts of Mercury Contamination on Research Outcomes

But what did the Dormouse say?' one of the jury asked. 'That I can't remember', said the Hatter. Like the Hatter, we may not know what the mice are saying.

Contamination assessment studies conducted on biomedical laboratories and other facilities undergoing decommissioning suggest that low levels of mercury are ubiquitous contaminants–in the air, on surfaces of equipment, casework and floors, and in plumbing systems.[10,11] It is also a contaminant in many chemicals used in laboratories[12]–even reagent grade methanol.[13] The presence of mercury contamination in biomedical research laboratories and reagents may be of concern as an extraneous variable that could potentially affect the outcome of research. Aside from it's widely known neurotoxicity, it can be a potent immunostimulant and suppressant, depending on exposure dose and individual susceptibility, and may increase susceptibility to parasitic, bacterial, and viral infections.[14–18] The immunotoxic effects of mercury in animals are the lowest dose/effects yet described (0.4 μg/kg).[19] The need to reduce potential impacts on research outcomes provides another strong incentive to place severe restrictions on the use of mercury in laboratories.

Minimizing risks associated with mercury use in high containment laboratories. Development of measures to protect public health from bioterrorism threats and emerging diseases is a highest priority area of biomedical research. Research protocols require use of high-risk and high-consequence pathogens that must be handled in high containment (biosafety levels 3 and 4 (BSL-3 and BSL-4)) laboratories. Several new containment laboratories are being funded, constructed or renovated by the NIH to meet these needs. Any use of mercury in these facilities, even in small amounts presents potentially serious problems and should be avoided. Spills or releases of mercury in high containment areas may be very difficult to assess and decontaminate, and the presence of trace amounts of the metal may interfere with the immune responses to infectious diseases that are studied in these facilities.[20]

MARKETING APPROACHES

In planning the extended campaign it was recognized that achieving its major goal–the elimination of unnecessary mercury containing items from the workplace, would be largely dependent on attracting employee interest and encouraging their voluntary participation in campaign activities. Removal of mercury containing items from non-clinical areas was only a recommendation; it was not a regulatory requirement or a mandate of mandate of NIH policy. It was understood that the laboratory uses of mercury were well established and resistance to change was anticipated. Some limited uses of mercury are also essential or preferable to alternative materials research and facility

operations so a total prohibition on its use would not be feasible.

Based on experience gained from the mercury elimination initiative in the Clinical Center and similar programs at other institutions it was determined that a successful expanded campaign would need to have these elements:

- Strong marketing tools to publicize the campaign and encourage participation.
- A means to rapidly and economically disseminate information to a large and diverse audience.
- Ensuring buy-in of stakeholders by providing clear justifications for recommended actions, examples of potential impacts on the target audience, e.g., how spills can jeopardize personnel and laboratory operations.
- Require minimal investment of time by participants by avoiding paperwork, providing rapid access to essential information on mercury uses and alternatives, and facilitating disposal of mercury containing items.
- Incentives for participation by both individuals and groups.
- Provisions to collect participant feedback, adjust campaign approaches if needed, and measure success.

Theme Selection

"Twinkle, twinkle, little bat!
How I wonder what you're at!"
"Up above the world you fly,
Like a tea-tray in the sky.
Twinkle, twinkle–"

The Hatter first thought it was a song and couldn't recite the simple rhyme correctly. The real hatters were exposed to mercury used in the hat making process resulting in neurological damage. This could explain Hatter's memory problems and incoherent ramblings.

A Mad Hatter mascot and his exploits in Lewis Carroll's 1865 classic story of *Alice in Wonderland* were selected as the theme for the extended campaign. The story is rich with quotes and situations that allude to mercury issues. These had to be used cautiously, because familiarity the story and mad hatters should not be assumed with today's audiences, particularly children. It was also learned that most people, including members of the scientific community do not know about the real cause of the hatter's madness. Hats popular in the 1800s were made of beaver fur, and later wool. Formulations of chemicals used to make the felt stiff and shiny, (a process curing referred to as carroting or secretage) included mercurous nitrate. Prolonged exposure to mercury vapors led to neurological damage and a constellation of symptoms including uncontrollable tremors, referred to as the "hatter's shakes" or "Danbury shakes" in reference to Danbury, Connecticut where some of the hat factories were located. Other symptoms included visual disturbances, confused speech, hallucinations and psychoses. More detailed information on this subject was published in Alice Hamilton's 1925 classic work *Industrial Poisons in the United States* and more recent literature.[21–25] Explanation of the real origin of the mad hatters provides a good talking point to introduce visitors to campaign exhibits and an excellent entree to further discussions about the need to reduce mercury exposure.

Campaign Logo

A campaign logo was developed from an adaptation of the original black line drawing of the Mad Tea Party scene by Sir John Tenniel appearing in chapter VII of Alice (Figure 2). In the logo the March Hare was replaced with White Rabbit and color was added to improve visual appeal and the NIH Division of Safety's mascot "Mr. Link" (to safety) was inserted into the scene. Mr. Link's message is conveyed by holding a stop sign with Hg with a strikeout symbol pointed at the Hatter. Captions ask the question are you: "Mad as a Hatter?" and then invite the viewer to join the campaign. The logo is used on the header of the campaign website, tee shirts and other promotional items (Figure 3).

Website

A large website, currently being updated was established to support the campaign. It provides an extensive compilation of information on mercury hazards, listings of mercury uses in biomedical applications and alternatives, disposal advice and links to other mercury reduction programs.[26] The website also has interactive features including provisions for submission of online pledges, offers to serve as a campaign volunteer and submit questions. Additional pages for school programs and children were added to the site to support community outreach activities. The website receives extensive use and is the primary and most cost effective vehicle for information dissemination. Other promotional items, described below are used but cannot be widely distributed because of cost considerations.

Hatter's Pledge

A key promotional item of the campaign is the "Hatter's Pledge." Individuals are invited to submit the pledge

Figure 2. Original Mad Tea Party Scene from Alice in Wonderland.

Figure 3. NIH Mercury Campaign Logo.

through the website which signifies commitment to:

- Become more aware of mercury hazards and how to reduce them.
- Survey their workplace for mercury containing items and replace them with mercury-free or low mercury alternatives, if available.
- Report spills.
- Dispose of mercury wastes properly.

The pledge form also included a section where individuals could volunteer for other activities such as serving as a campaign coordinator for their building, working in community outreach efforts or conducting a home mercury audit. Prizes such as Mad Hatter logo tee shirts, "I Made the Pledge" lab door stickers (Figure 4) and other incentives were provided to encourage pledging.

Promotional Materials

A variety of handouts were developed and distributed to promote the campaign. These included:

Brochures. Campaign brochures were created with content specifically tailored to various audiences including laboratorians, industrial tradesman, children and their parents.

Tee shirts. Approximately 1,500 tee shirts with the Mad Hatter campaign logo were distributed as promotional items and prizes at campaign events.

Wallet card thermometers. Reusable, clinically certified, mercury-free fever thermometers are available at low cost. They fit in the back of a credit card shaped plastic holder that was imprinted with the NIH Hatter logo and website address. These made highly practical handouts and were given out as replacements for mercury thermometers turned in at thermometer exchanges (Figure 5a).

Web Cards. Business card sized "web cards" with the website address are distributed at campaign events to assist participants in finding the website.

Figure 4. Hatter's Pledge Sticker.

Campaign Events

Initiation of the expanded campaign was announced in press releases and a global e-mail sent to all of NIH's approximately 200,000 employees. The Campaign kick-off event was held on April 26, 2001 to coincide with other Earth Week events, Take Your Child to Work Day and presentation of the Mercury in Flight award to the Clinical Center by the organization Health Care Without Harm (HCWH). The event featured an educational display, presentations, handouts and a confrontation between the Mad Hatter and Mercury Man, the spiritual leader of the fight against mercury sponsored by HCWH.[27] (Hatter lost the confrontation and was escorted out the door of NIH.) Approximately 1,500 children attended the event.

Since the kick-off event numerous presentations, displays and poster sessions on the campaign have been made at research festivals and professional conferences. Routine health and safety surveys of NIH laboratories and other workplaces are conducted by consultants from the Division of Occupational Safety and Health. If mercury containing items such as thermometers are noted during the surveys laboratory personnel are reminded about the hazards posed and encouraged to replace the items with non-mercury alternatives.

COMMUNITY OUTREACH

Initially, community outreach was not intended to be a major component of

(a)

(b)

Figure 5. (a) Design of Wallet Card Thermometers. (b) Laboratory Thermometers Collected for Recycling.

this campaign. However, significant public interest in the campaign became evident immediately after the kick-off event. This may have been partly attributable to several major mercury spills that occurred at schools in the areas near NIH, raising awareness of mercury hazards. Feedback received from members of the NIH scientific community attending research festivals, booths at professional conferences was similar to the public response: the technical content on reducing mercury use in biomedical applications was useful but the real interest was in materials for teaching their children and to use in working with schools and community organizations in establishing mercury reduction programs. Numerous requests speakers for schools and community organizations were received. Requests for promotional materials with the highly popular Mad Hatter logos soon far exceeded available supplies.

Use of Volunteers

To help meet the demand for community outreach services volunteers were recruited the Hatter's Pledge program and the NIH Alumni Club, an organization of retired NIH employees. Working in partnership with other organizations such as HCWH and the Boy Scouts, local governments, schools numerous displays, educational booths and thermometer exchanges were held in the vicinity of NIH installations. Often these activities were included in community health fairs and presented by the Mad Hatter in person (Figure 8). Hatter campaign materials, including generic versions of logos without NIH branding were made available for downloading from the website and have been widely used in activities ranging from classroom presentations by students to organizing similar campaigns on military installations involving thousands of participants.

CAMPAIGN RESULTS

Hatters Pledges. In the first year of the Campaign approximately 2,500 pledges were received from employees. While the initial design of the website discouraged non-NIH employees from submitting pledges hundreds of pledges from employees of other agencies general public continue to be received. Other public and private organizations have adopted the pledging feature for their programs and track participation by other means.

Replacement of mercury devices. At a single NIH facility, the National Institute of Environmental Health Sciences (NIEHS) campus at Research Triangle Park, North Carolina, over 600 mercury thermometers have been replaced. The total number replaced throughout all NIH facilities is unknown but probably approaches 10,000 units (Figure 5b). Numerous manometers, industrial switches and other mercury devices have also been replaced.

Coulter counters were also found to be a relatively common source of mercury. They are widely used in biomedical laboratories to count and size myriad microscopic particles. The counters depend on numerous switches and gauges to function reliably and accurately and many of these components may contain mercury. During normal operations of the counters mercury spills are unlikely, however, several major spills of mercury have occurred at NIH when the units are moved or handled as surplus. Corrective actions included improving the awareness of personnel using or transporting counters and requiring removal of mercury before units are transferred to surplus. In some cases mercury components in older units can be replaced with non-mercury and newer offered by major manufacturers do not contain mercury.

A few thermometers and other mercury devices are still found on laboratory surveys and some investigators remain reluctant to replace them, particularly in special apparatus where alternative means of temperature or pressure measurement may not be validated or available. Overall, however, the impacts of campaign efforts remain impressive. Prior to the initiation of the

mercury reduction campaign breakage of mercury thermometers was the most common cause of hazardous spills on NIH facilities. Some spills occurring in the Clinical Center, particularly those involving sphygmomanometers, which may contain 100 mL of mercury, resulted in evacuations, significant facility downtime and major clean up costs. Now, spills of mercury in the Clinical Center have been virtually eliminated and greatly reduced on other NIH installations. It will probably take years to remove all mercury devices from NIH installations, but the risks associated with mercury have been greatly reduced by campaign efforts. Each mercury device replaced may be considered a potential spill prevented. It should also be noted that the cost of cleaning up a single large spill may exceed the cost of the entire mercury abatement campaign.

"The Mad Hatter still lurks in many labs and health care facilities that continue to use mercury", said Mercury Man. "When all of these places have adopted the mercury alternatives that are available, he'll go back to Wonderland where he belongs!"

Reducing Mercury Use in New Construction. Mercury free alternatives are available for most common applications such as thermostats, flow meters, manometers, switches, and high intensity discharge lights. NIH Design and Construction Guidance now include prohibitions on installation of mercury switches and other devices in new facility construction.[28] Additional information on risks associated with use of mercury in high containment facilities was also published.[20]

Identification, Evaluation and Reduction of Mercury Sources in Facility Operations. A work plan was developed for identifying and reducing potential sources of mercury in mission related operations of the NIEHS campus. In August 2001, mercury was identified in wastewater discharges by the receiving county (Durham, NC) wastewater treatment facility at concentrations exceeding the allowable limit of 12 ng/L. Analysis of one wastewater sample collected the same month from NIEHS also indicated low levels of mercury that were just above their analytical detection limit of 200 ng/L. Therefore, in 2002, the NIEHS entered into a consent order with the County that required the facility to develop a mercury evaluation and reduction plan. The plan consisted of several elements, including implementation of an institute-wide mercury reduction effort and a mercury awareness program for employees, which were already components of the NIH-wide campaign. The plan also included a review of all products that are used on-site and had the potential to enter the environment, primarily through wastewater discharges. Results of the review indicated that the majority (83%) of all mercury contamination in commonly used products that may enter the sanitary sewer was found to be due to a single product–a toilet bowl cleaner, which is no longer in use. NIEHS has remained in compliance with is concentration limit of 142 ng/L and other wastewater permit requirements since 2001.[29]

Mercury in Decommissioning. Additional information on the occurrence of mercury and other hazardous substances in laboratories, particularly wastewater plumbing systems was needed before new protocols for assessment and decontamination could be developed. Building 3, an abandoned laboratory building on the main NIH campus in Bethesda was selected for study. Sampling and analysis results indicated that mercury was the most common hazardous substance in the building, present as both an intrinsic material (in components used in construction such as fluorescent lighting, switches, flow meters, etc.) and as a contaminant. New procedures were then developed for further assessment of mercury contamination, decontamination and disposal of mercury wastes. These were subsequently evaluated and successfully tested using the building as a pilot project site.[30] Further testing and refinement of these procedures is ongoing in other NIH decommissioning projects. Major findings of the work completed to date are that mercury contamination is ubiquitous in older laboratory facilities (Figures 6 and 7) and costs associated with its remediation may exceed that for asbestos, lead and all other contaminants combined. Avoidance of these costs provides a strong incentive for reducing or prohibiting all unnecessary uses of mercury.

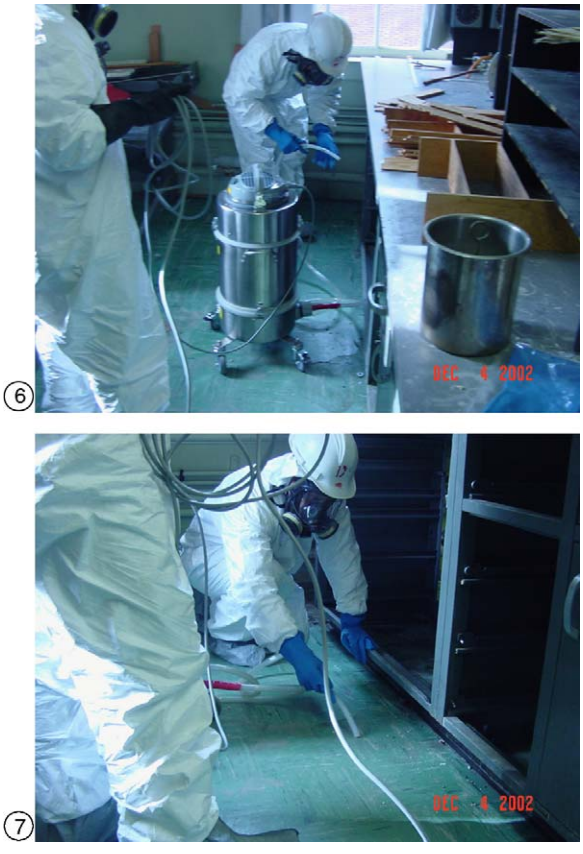
Outreach Activities

Website Visits. Based on limited monitoring, the campaign website continues to receive as many as 1,000 visits per month. Campaign events such as displays at health fairs significantly increase visits for brief periods of time. Between events the number of visits drops off sharply and we believe most visitors find the site by using search engines such as Google. Questions can also be submitted through the website. The most common questions continue to be about how to clean up mercury spills, and health impacts of mercury in vaccines and dental amalgams. A wide variety of subjects are covered:

- The operator of a shopping mall in Manila, Philippines sought information on how to dispose of fluorescent light bulbs in an economically and environmentally acceptable manner.
- A parent was concerned that her son was eating too many fish sticks and wanted to know if he was at risk of mercury intoxication.
- A man in the U.K. dropped his lap top computer and was concerned about mercury vapors from the broken screen.
- Several contacts reported what appeared to be symptoms of mercury intoxication. These were referred to their physicians for immediate evaluation and follow-up.

All questions submitted are answered; however, it requires a significant amount of time and we have limited staff. To reduce the need for individual responses common questions and answers are posted on the website. Because of new medical privacy disclaimer has been added to the contact page to discourage submission of questions concerning personal medical issues.

Assistance to Schools. In the U.S. more mercury spills are reported at schools than any other location. To address this problem the EPA, many



Figures 6 and 7. Cleaning Up Mercury Spilled from Casework During Laboratory Decommissioning Project.

Figure 8. NIH's Mad Hatter on Duty at Community Health Fair.

states and non-governmental organizations have established programs to eliminate mercury in schools. The NIH Campaign has had significant involvement in these efforts:

- Information on mercury safety for children and links to school mercury reduction programs was published in a highly popular brochure titled "Information for Hatters Helpers and Their Parents." Web pages for kids and schools also appear on the NIH campaign website.
- In 2001 the Maryland Legislature passed a bill that included establishment of a program to inventory and remove mercury from schools.[31] The law required the Maryland Department of the Environment (MDE) to collaborate with existing mercury reduction programs in developing mercury outreach programs. The NIH has shared "lessons learned" from its campaign in presentations to Maryland agencies for use in planning and implementing their school programs.
- In 2003 the NIH hosted a national web-based video workshop for teachers in collaboration with the EPA, Maryland educational and environmental agencies and universities titled "*Enhancing Pollution Prevention in School and Laboratory Facilities: Lessons Learned From Mercury Reduction Programs*." The conference has been archived and can be viewed on the NIH Videocasting Website.[32]
- NIH is participating in a working group established by the White House Council on Environmental Quality, Office of the Environmental Executive to coordinate federal agency efforts in improving the environment of the Nation's Schools.

United Nations Environmental Programme (UNEP). Member nations were invited to submit tools for increasing awareness and promotion of mercury free technologies to a clearinghouse established by UNEP Mercury Programme. The submission for the U.S. made by the EPA included a presentation on the NIH Mad Hatter Campaign, which is now available from the UNEP website.[33]

In December 2002 the NIH Campaign was cited by the Governor of Maryland as setting a high standard for environmental outreach and education.[34]

POTENTIAL USE OF THE CAMPAIGN IN NATIONAL AND INTERNATIONAL ENVIRONMENTAL HEALTH INITIATIVES

"In that direction", the Cat said, waving its right paw round, "lives a Hatter: and in that direction", waving the other paw, "lives a March Hare. Visit either you like: they're both mad".

"But I don't want to go among mad people", Alice remarked.

"Oh, you ca'n't help that", said the Cat: "we're all mad here. I'm mad. You're mad".

Impacts of Mercury Exposure on Public Health and the Economy

The impacts of mercury pollution on public health are increasingly evident and suggest an urgent need for efforts to reduce human exposure. In a recent survey it was found that approximately six percent of childbearing-aged women had body burdens of mercury at or above a reference dose, an estimated level assumed to be without appreciable harm.[35] In another recent study using national blood mercury prevalence data from the Centers for Disease Control and Prevention it was found that several hundred thousand children born each year have cord blood levels likely to be associated with loss of IQ.[36] The resulting loss of intelligence causes diminished economic productivity that persists over the lifetime of these children. This lost productivity amounts to $8.7 billion annually (range: 2.2–43.8 billion in 2000 dollars). Loss of IQ is just one of several potential neurological consequences of exposure to mercury.

Approaches to Reducing Public Exposure

Most exposures to levels of mercury that are likely to be result in adverse health impacts result from spills and dietary intake. (Perceived risks are also associated with exposure to mercury vapors from amalgam tooth fillings and ethyl mercury in the form of thimerosal added as an antiseptic to vaccines.)[37] The significance of these exposures is controversial and the use of thimerosal in vaccines is declining.

Both of the major sources of exposure can be reduced by strategies employed in this campaign:

Spills. The same methods successfully used here to reduce spills in biomedical facilities can be used to reduce spills in schools, homes and other areas where the public may be exposed:

- Increase awareness of mercury hazards and where mercury may be found at work, in schools, at home.
- Provide listings of mercury free alternatives.
- Facilitate proper disposal of mercury containing items by using household hazardous waste collection programs and community thermometer exchanges.
- Provide guidance on proper spill clean up methods and links to resources for spill detection and decontamination.
- Outreach efforts should continue to stress mercury safety for children. With its interesting properties and bright shiny appearance children are enticed to play with it. Getting the mercury safety message to teachers, parents and children is critical.

Dietary Intake. Most significant exposures of the general population result from consumption by pregnant women of fish contaminated by methylmercury. Methylmercury is a product of microbially mediated transformations of elemental mercury and inorganic that is released into the environment from anthropogenic (70%) and natural (30%) sources. Until emissions from anthropogenic sources are curtailed and concentrations of mercury are reduced in the food chain the only practical method to reduce human exposure to methylmercury is to encourage changes in fish consumption patterns. This will require significant health education efforts to because of the complexity of the information that needs to be understood and to resolve what appear to be two conflicting messages: eat more fish to improve cardiovascular health, and reduce consumption of fish to prevent excessive intake of mercury. By reducing or avoiding consumption of fish with higher mercury content the benefits of increased consumption of fish can be achieved without excessive exposure to mercury. Campaign methods and the website can be easily modified to improve awareness of the necessary dietary modifications for consumption of both purchased and caught fish:

- Use campaign publicity tools to direct public to the website.
- Provide links to latest EPA–FDA dietary guidance.
- State and local fish advisories for caught fish.

Not the same thing a bit!' said the Hatter. 'You might just as well say that "I see what I eat" is the same thing as "I eat what I see"!'

Potential Benefits of Campaign Methods

Perhaps no national public health problem of the magnitude has ever been addressed for such a minimal investment:

- Successful outreach methods used in this campaign are adaptable and easily scalable.
- Little additional funding would be required to expand the campaign-volunteers, public service ads and the Internet to can be effectively used deliver the message.
- No new drugs need be developed.
- No new regulations to be promulgated.

Alignment with Other National Public Health Initiatives

The evolution of this institutional chemical health and safety initiative into a successful and widely used community outreach activity is probably unprecedented and suggests that the approaches used may have wider applications in health education. Incorporation of the campaign's goals and methods in similar more broadly based initiatives, or direct expansion of the campaign into a discrete program for the reducing public exposure to mercury would also be in concert with cur-

rent national and international health programs. In the U.S. the Office of the Surgeon General (OSG) has established seven major public health priorities for the Nation.[38] A national effort to reduce mercury exposure and associated morbidity would relate directly to and support five of these public health priorities:

- *Disease Prevention*. Prevention priorities include injuries, birth defects and chronic heart diseases–all conditions that can be directly caused by or may be associated with excessive exposure to mercury. Through the U.S. Department of Health and Human Service's initiatives *Steps to a Healthier US, Healthy Lifestyles & Disease Prevention*, and the *Small Steps* Campaign, American families are encouraged to take small, manageable steps within their current lifestyle–versus drastic changes–to ensure long-term health. Eliminating mercury sources in homes to prevent spills and modifying fish consumption patterns to reduce excessive exposure to methylmercury are examples of such steps.
- *Eliminating Health Disparities*. As is the case with many diseases, disparities in mercury exposure and resulting morbidity may occur among various groups because of socioeconomic, cultural, dietary and other factors. Elemental mercury is also used intentionally in folk medicines, cultural and religious practices in many areas of the world. Examples in the United States include certain Afro-Caribbean and Latin American traditions, including Santeria, Palo, voodoo, and Espiritismo. Particularly when such practices involve use in small enclosed spaces there is a potential for high direct exposures of individuals to mercury vapors. Users are often not aware of this route of exposure and its health consequences. Attempts to regulate or restrict cultural and religious practices using mercury by health authorities are contraindicated for several reasons, including the likelihood that practices may just be driven underground. Outreach and education programs involving religious and community leaders, botanica personnel, and other mercury users are preferable.[39] Non-adversarial approaches, such as use of a campaign website and the culturally neutral Mad Hatter themed educational materials could be effective tools in discouraging unsafe practices and promoting use of alternatives.
- *Improving Public Health Preparedness*. Mercury spills are one of the most common hazardous material incidents requiring emergency response. Spills, particularly those occurring recently at schools have potentially exposed large numbers of people and may overwhelm the resources available from local public health and environmental agencies. Public awareness of mercury hazards and appropriate spill containment and decontamination procedures can be achieved through expanded campaign outreach activities. This should enhance preparedness for spills. Eliminating unnecessary sources of mercury, a primary campaign goal, also reduces the probability of spills and the availability for intentional misuse.
- *Improving Health Literacy*. Health literacy is the ability of an individual to access, understand, and use health-related information and services to make appropriate health decisions. The primary purpose of this proposed campaign is to facilitate public access to information on mercury hazards, and apply it to eliminate mercury sources and make appropriate dietary decisions relating to consumption of fish. Achieving these goals will require communication of somewhat complex concepts such as the relevant physical, chemical and toxicological properties of mercury in a manner that can be understood by the general public. This may be the most significant challenge in successfully expanding this campaign. According to the Surgeon General, more than 90 million Americans cannot adequately understand basic health information and people of all ages, races, and income and education levels are affected. Some of the approaches recommended by his office to improve health literacy are already used in this campaign. These include building a robust health information system that provides equitable access (campaign website and links to numerous information sources); developing audience-appropriate information and support services for all segments of the population (web pages, displays, brochures and have been developed for specific audiences); and ensuring that communications are written in plain language that people can understand.
- *Encouraging Children and Adolescents to Make Healthy Choices*. To enlighten young people about the dangers of risky behaviors and the benefits of making health choices the Surgeon General makes direct presentations to students in his 50 *Schools in 50 States* speaking tour. Similar direct communications approaches are used in this campaign–visits by the Mad Hatter to children's programs, demonstrations and distribution of educational brochures. A major focus of campaign outreach efforts has been to reach children and adolescents about the safety and environmental health hazards of mercury, particularly discourage them from playing with it. The campaign website also includes a children's webpage.

Morbidity resulting from exposure to mercury is increasing in our society. While all population groups are affected it primarily affects the most vulnerable among us–the unborn and the very young. This campaign offers just one tool that can be used to in efforts to reduce human exposure to mercury until environmental releases can be better controlled.

We must succeed in these endeavors so our children can recite the rhyme as it should be:

Twinkle, twinkle, little star,
How I wonder what you are.
Up above the world so high,
Like a diamond in the sky.

With senses and intellect unimpaired
Let them experience all the wonder
And discover what they are . . .

REFERENCES

1. National Institutes of Health. *Manual Issuance on Mercury Disposal*; National Institutes of Health; Bethesda, MD, 1979, [Reference Incomplete].
2. Hospitals for a Healthy Environment. *Tools/resources: Mercury*; available at: http://www.h2e-online.org/tools/mercury.htm, accessed 11/18/2005.
3. Sustainable Hospitals-Lowell Center for Sustainable Production. *Mercury Reduction*. **2004**, Available at: http://www.sustainablehospitals.org/HTMLSrc/IP_Mercury.html, accessed 11/18/2005.
4. National Institutes of Health. *Pollution Prevention Plan*; Bethesda, MD, 1994.
5. Rau, E. H.; Alaimo, R. J.; Ashbrook, P. C.; et al. *Environ. Health Perspect.* **2000**, *108*(6), 953–977.
6. Medical Academic and Scientific Community Organization, Inc. *Mercury Work Group Site Index*; http://www.masco.org/mercury/, accessed 11/16/2005.
7. U.S. Environmental Protection Agency. *Mercury Pollutant Minimization Program Guidance*; EPA Region 5, NPDES Programs; http://www.epa.gov/region5/water/npdestek/npdprta.html, accessed 11/16/2005.
8. Medical Academic and Scientific Community Organization, Inc. *Mercury Database*; http://www1.netcasters.com/mercury/, accessed 11/16/2005.
9. Rau, E. H. *Techn. J. Franklin Inst.* **1997**, *334A*, 397–419.
10. Rau, E. H. Presented at the Division of Chemical Health and Safety Technical Session: The Health Hazards of Mercury; American Chemical Society Meeting: New Orleans, LA, 2003.
11. Eustace, D. J.; Walters, M.; Riley, S.; Anderson, M. *Chem. Health & Safety,* **2004**, *11*(3), 16–23.
12. Medical Academic and Scientific Community Organization, Inc. *Mercury Database*; http://www1.netcasters.com/mercury/, accessed 11/9/2005.
13. Liang, L.; Wilhelm, S. M.; Pang, P. *Matls. Geoenvmt.* **2004**, *15*(2), 1968–1971.
14. Shen, X.; Lee, K.; König, R. *Toxicology,* **2001**, *169*(1), 67–80.
15. Silbergeld, E. K.Sacci, J. B., Jr.; Azad, A. F. *Imphrm. Imtox.* **2000**, *22*(4), 685–695.
16. Silbergeld, E. K.; Silva, I. A.; Nyland, J. F. *Toxicol. Appl. Pharmacol.* **2005**, *207*(2 Suppl.), 282–292.
17. Sweet, L. I.; Zelikoff, J. T. *J. Toxicol. Environ. Health B: Crit. Rev.* **2001**, *4*(2), 161–205.
18. Tchounwou, P. B.; Ayensu, W. K.; Ninashvil, N.; Sutton, D. *Environ. Toxicol.* **2003**, *18*(3), 149–175.
19. Silbergeld, E. Presented at the Spring 2003 Meeting of the Allegheny-Erie Chapter; Society of Toxicology: Pittsburg, PA, Spring 2005.
20. Rau, E. H. In J. Y. Richmond (Ed.), *Anthology of Biosafety VIII. Evolving Issues in Containment* (pp. 103–133). American Biological Safety Association: Mundelein, IL, 2005p. 103–133.
21. Dumont, M. P. *Soc. Sci. Med.* **1989**, *29*(9), 1077–1082.
22. Horowitz, M.; Dent, J. *Gastroentrology,* **1994**, *107*(1), 302–306.
23. O'Carroll, R. E.; Masterton, G.; Dougall, N.; Ebmeier, K. P.; Goodwin, G. M. *Br. J. Psychol.* **1995**, *167*(1), 95–98.
24. Waldron, H. A. *Br. Med. J. (Clin. Res. Ed.),* **1961**, *287*(6409), 1961.
25. Wedeen, R. P. *Am. J. Ind. Med.* **1989**, *16*(2), 225–233.
26. National Institutes of Health, Office of Research Facilities Development and Operations. *NIH Mercury Abatement Program*; http://www.nomercury.nih.gov, accessed 11/16/2005.
27. Health Care Without Harm. *Mercury Man Escorts the Mad Hatter Out the Door at NIH; Government Labs Lead the Way with Pledge to Stop Use of Mercury*; http://www.noharm.org/details.cfm?type=document&ID=472, accessed 11/14/2005.
28. National Institutes of Health, Office of Research Facilities Development and Operations. *National Institutes of Health Design Policy and Guidelines*; http://orf.od.nih.gov/policy/, accessed 11/16/2005.
29. National Institute of Environmental Health Sciences. *Identification, Evaluation, and Reduction of Mercury at the National Institute of Environmental Health Sciences*, Poster presented at the Third Annual DHHS Environmental Networking Training Workshop; Bethesda, MD, 2004.
30. Rau, E. H.; Carscadden, J. Presented at the Third Annual DHHS Environmental Networking Training Workshop; Bethesda, MD, 2004.
31. Department of Legislative Services. Maryland General Assembly, 2001 Session. House Bill 75. Environment–Mercury and Products that Contain Mercury; http://mlis.state.md.us/PDFDocuments/2001rs/fnotes/bil_0005/hb0075.PDF, accessed 11/16/2005.
32. National Institutes of Health. *NIH Videocasting*. http://videocast.nih.gov/PastEvents.asp, accessed 11/15/2005.
33. United Nations Environmental Programme, Mercury Programme, The Mad as a Hatter? Campaign for a Mercury Free NIH; http://www.chem.unep.ch/mercury/2003-gov-sub/USA/Control%20201867-Attach2NIH%20Mad%20Hatter%20Campaign1.ppt, accessed 11/14/2005.
34. Glendening, P. S. Personal communication, December 19, 2002.
35. Centers for Disease Control and Prevention. *MMWR,* **2004**, *53*(43), 1018–1020.
36. Trasande, L.; Landrigan, P. J.; Schechter, C. *Environ. Health Perspect.* **2005**, *113*(5), 590–596.
37. Thomas, C. W. *Environ. Health Perspect.* **2002**, *110*(1), 11–23.
38. Office of the Surgeon General. *Public Health Priorities*; http://www.surgeongeneral.gov/publichealthpriorities.html, accessed 11/0/2005.
39. Riley, D. M.; Newby, C. A.; Leal-Almeraz, T. O.; Thomas, V. M. *Environ. Health Perspect.* **2001**, *109*, 779–784.