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Proceedings and Summary Report

Workshop on Mercury in Products, Processes, Waste and the Environment: Eliminating, Reducing and Managing Risks from Non-Combustion Sources

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Baltimore, MD

National Risk Management and Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

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Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

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Abstract

Mercury contamination, both nationally and internationally, has long been recognized as a growing problem for humans and ecosystems, since mercury does not degrade to simpler compounds. Once it is released to the environment, it will always be present in one form or another. Mercury is released to the environment from a variety of human (anthropogenic) sources including plant effluent discharge, fossil-fuel combustors, incinerators, chlor-alkali plants, mining and landfills. Other sources of anthropogenic mercury release include industrial processes and the disposal of products containing mercury. Anthropogenic sources of mercury emissions to the atmosphere include fossil fuel combustion (containing trace amounts of mercury), municipal incineration, medical waste incineration, chlor-alkali plants, and landfills. These emission sources represent a significant contribution to the total mercury released (including natural and re-emitted) in the United States.

A workshop titled, Mercury in Products, Processes, Waste and the Environment: Eliminating, Reducing and Managing Risks from Non-combustion Sources, was held on March 22 - 23, 2000, in Baltimore, Maryland. To facilitate discussions of these issues, the workshop combined a series of presentations at plenary sessions, moderated technical sessions and panel discussions. The topics of these presentations focused on treatment and disposal technologies, stockpile management, and prevention, collection and elimination programs. Presenters were from U.S. Environmental Protection Agency (USEPA), Department of Energy (DOE), state agencies, industry, academia, technology developers, equipment manufacturers, consulting firms, international representatives. The presentations were followed by two panel discussions: the first addressed treatment and disposal of mercury-contaminated wastes and the second addressed prevention, collection, and elimination issues. This report provides a discussion of the overarching issues in mercury treatment, disposal, prevention, collection, and elimination, and a summary of the panel discussions that took place at the close of the workshop.

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List of Acronyms

ANPRM	Advance Notice of Potential Rulemaking
BDAT	Best Demonstrated Available Technology
DLA	Defense Logistics Agency
DOD	Department of Defense
DOE	Department of Energy
EPA	Environmental Protection Agency
FR	Federal Register
GAC	Granular Activated Carbon
Hg	Mercury
HW	Hazardous Waste
LDR	Land Disposal Restrictions
MSW	Municipal Solid Waste
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NGO	Non Government Organization
NRC	Nuclear Regulatory Commission
NRMRL	National Risk Management Research Laboratory
P2	Pollution Prevention
PBT	Persistent, Bioaccumulative, and Toxic
RCRA	Resource Conservation and Recovery Act
SAMMS	Self-Assembled Mercaptans on Mesoporous Silica
TCLP	Toxicity Characteristic Leaching Procedure

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Executive Summary

Section 1
Introduction

1.1 Workshop Structure, Purpose, and Intended Audience

A workshop titled "Mercury in Products, Processes, Waste and the Environment: Eliminating, Reducing and Managing Risks from Non-Combustion Sources," was held on March 22 - 23, 2000, in Baltimore, Maryland.

The purpose of the workshop was to achieve three goals:

1. Convey public, non-profit, and private sector perspectives on the management of mercury in products, processes, and wastes;
2. Present ongoing efforts that address mercury prevention, elimination, non-combustion treatment and disposal; and
3. Identify data gaps and information needs to improve mercury risk management in products, processes, waste and the environment.

To facilitate discussions of these issues, the workshop featured a series of presentations at a plenary session, moderated technical sessions and panel discussions. The topics of these presentations focused on treatment and disposal technologies, stockpile management, and prevention, collection and elimination programs. Presenters were from U.S. Environmental Protection Agency (USEPA), Department of Energy (DOE), state agencies, industry, academia, technology developers, equipment manufacturers, and consulting firms, which included international participants. The technical presentations were followed by two panel discussions: the first addressed treatment and disposal of mercury-contaminated wastes and the second addressed prevention, collection, and elimination issues. Statements captured in Appendix C, Panel Discussion Summary - Treatment and Disposal, are those of the participants, not necessarily the EPA.

This report provides a summary of the key issues pertaining to mercury treatment, disposal, prevention, collection, and elimination, followed by speaker abstracts and a transcript of the panel discussions that took place at the close of the workshop.

1.2 Background

Mercury contamination, both nationally and internationally, has long been recognized as a growing problem for both humans and ecosystems, since mercury does not degrade to simpler compounds. Once released

to the environment, it will always be present in one form or another. Mercury is released to the environment from a variety of human (anthropogenic) sources including plant effluent discharge, fossil-fuel combustors, incinerators, chlor-alkali plants, mining, and landfills. Other sources of anthropogenic mercury release include industrial processes and the disposal of products containing mercury.

Anthropogenic sources of mercury emissions to the atmosphere include fossil fuel combustion (containing trace amounts of mercury), municipal incineration, medical waste incineration, chlor-alkali plants, and landfills. These emission sources represent a significant contribution to the total mercury released (including natural and re-emitted) in the United States. The 1997 Mercury Study Report to Congress indicated that the deposition of atmospheric mercury has increased by a factor of two to five over pre-industrial levels. Reference: (EPA Document Nos. EPA-452/R-97-003 through 010, *http://epa.gov/oar/mercury.html*). Furthermore, most atmospherically deposited mercury is in the form of gaseous or particulate-phase inorganic mercury. Unfortunately, the inorganic mercury released into the environment can be converted, by naturally occurring biological processes, into the highly toxic methyl mercury species.

1.3 Need for Eliminating, Reducing and Managing Risks from Non-Combustion Sources

Mercury has been identified as a persistent, bioaccumulative, and toxic (PBT) chemical, (Office of Pollution Prevention and Toxic Substances) making it a chemical of concern. PBT chemicals are of great concern because they persist in the environment, bioaccumulate in the food chain, and are toxic, posing a significant threat to humans, and ecosystems. Many of these chemicals, including mercury, are of concern because they easily transfer from one media to another in the environment. EPA is in the process of developing a research strategy which aims to address the mercury problem through multimedia initiatives.

Controlling the environmental risks associated with mercury is complicated by several issues: mobility, exposure, and PBT characteristics. Elemental mercury, frequently found in products and processes, volatilizes readily at ambient and combustion temperatures, leading to air emissions from almost every process or product using mercury. Elemental mercury can remain in the atmosphere for long periods of time; thereby being dispersed over a large geographical area. Further, multiple exposure pathways exist for the various mercury species. The most critical concern is the formation of highly toxic and bioaccumulative methyl mercury in water bodies. Thirdly, the PBT characteristics of mercury ensure that it will pose a threat to human health and ecosystems for a long time to come. For these reasons, safe treatment and disposal, and prevention, collection, and elimination of mercury are at the forefront of environmental risk management.

This workshop was divided into two major concurrent session which dealt with (1) treatment and disposal options and (2) prevention, collection and elimination initiatives. Sections 2 and 3 present summaries of presentations made in each of the two respective sessions. Section 4 provides a summary and conclusions from the overall workshop. Material and discussions presented at this workshop reflect the opinions and ideas of the presenters and participants and not the participating organizations.

Section 2
Treatment and Disposal Options

2.1 Regulations Guiding Treatment and Disposal of Mercury Waste

The EPA defines waste with mercury concentrations above a certain threshold (40 CFR §261.24) as characteristically hazardous. These wastes are defined as any waste that is characteristically hazardous based on the concentration of mercury in its leachate, as determined by the Toxicity Characteristic Leaching Procedure (TCLP). EPA was required by the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) in 1984 to establish treatment standards for all listed and characteristic hazardous waste destined for land disposal. The First Final Rule (53 FR 31166, August 17, 1988) established standards for brine purification muds, and the Third Final Rule (55 FR 22569, June 1, 1990) established treatment standards for five more wastewater and nonwastewater codes which contain mercury as the primary hazardous constituent. Some of these standards were revised under the Universal Treatment Standards in the Phase II Land Disposal Restrictions (LDR) Rule (59 FR 47980, September 19, 1994) and further revisions were made in the Phase IV Final Rule (63 FR 28556, May 26, 1998). Mixed wastes, which are radioactive RCRA hazardous wastes, are currently regulated under both RCRA and the Atomic Energy Act of 1954.

There are two recent proposed updates to the rules governing the disposal of mercury-bearing wastes:

Storage, Treatment, Transportation, and Disposal of Mixed Waste, published on November 19, 1999 (64 FR 63464). This proposed rule would provide flexibility to generators of mixed waste in the form of a conditional exemption from the definition of hazardous waste for some types of wastes and activities. The goal of this proposal is to reduce dual regulation for generators, transporters, and disposers in the management of these wastes. Wastes that fall under the specific areas in the proposed rule will be regulated and managed as hazardous waste in accordance with NRC regulations, and will be exempted from RCRA Subtitle C regulations. EPA is currently developing the final rule.

Potential Revisions to the Land Disposal Restrictions Mercury Treatment Standards, published on May 28, 1999 (64 Federal Register 28949). This Advance Notice of Proposed Rulemaking (ANPRM) seeks to begin a comprehensive review of the standards for treating mercury-bearing hazardous waste. The specific goals are to review and update EPA's waste generation and treatment data for mercury-bearing hazardous wastes, present technical and policy issues for public discussion, and determine an avenue by which current mercury treatment standards may be revised. The anticipated proposed rule is scheduled for late 2001.

2.2 State of the Science in Treatment Options for Mercury Waste

The most common techniques currently used for treating mercury-bearing waste are roasting/retorting and incineration. These thermal techniques separate the mercury from the rest of the waste stream and condense it for recovery or removal. The treatment technology used depends on the type of waste being treated. In many cases, a "treatment train" of technologies is used, where one technology is used to pre-treat the waste to remove characteristics that inhibit the effectiveness of another treatment technology.

The need for further research evaluating "treatment trains" was discussed during the workshop. Participants felt that a combination of the technologies listed below and new technologies discussed during the sessions, will be the best possible way to treat mercury-bearing wastes.

Roasting and Retorting Mercury Wastes (RMERC)

During retorting, mercury-bearing waste is sealed in a batch vessel, heated, with the volatile gases released. Mercury vapor is condensed and collected. Roasting mercury-bearing wastes involves introducing air to the hot waste which oxidizes mercury compounds and helps transport them to a condenser. In either process, collected mercury may be purified for resale or reuse through successive distillation. The remaining waste residues derived from the RMERC process must be retested to ensure sufficient mercury removal. If the mercury content of the waste remains above the allowable level (260 mg/kg total mercury) the waste must be roasted or retorted again. Wastes below this mercury content must meet a TCLP mercury standard of 0.20 mg/L prior to land disposal.

Incinerating Mercury Wastes

During incineration, mercury is volatilized from mercury-bearing wastes and converted to elemental mercury in the high temperature regions of the furnace. As the flue gas cools, the elemental mercury is oxidized to ionic forms. Elemental mercury, mercuric chloride, and mercuric oxide, each present in the vapor phase of flue gas, must be captured by various methods, such as adsorption onto porous solids such as fly ash, or removed using a wet scrubber. The efficiency of these mercury-removal methods varies by incinerator and method.

Alternative Treatment Technologies

In recent years, several alternative treatment technologies have been developed to treat mercury-bearing wastes. The need for developing alternative treatment methods arises from complex waste characteristics greater removal efficiency, and/or cost reduction. Some of these alternative processes include:

Removal and recovery technologies. This category includes: (1) acid/chemical leaching, where the mercury is converted to a more soluble form for removal from the waste matrix; (2) carbon adsorption, where mercury is removed from stack gas or effluents and concentrated; and (3) ion exchange, where ions in the exchange resins are substituted for mercury ions, facilitating mercury removal.

Immobilization Technologies. This category includes solidification and stabilization processes, where the mercury is immobilized in a matrix such as cement or flyash for long-term storage and amalgamation, where elemental mercury is mixed with a powdered granular metal to form a semi-solid matrix for long-term storage. Stabilization techniques, such as the combination of elemental mercury with a sulfur mixture to create insoluble HgS can produce a residual which will pass the TCLP. Use of these technologies is dependent on the characteristics of the waste treated.

Thermal/Chemical Oxidation. Thermal and chemical oxidation, is a destruction technology that is frequently used in conjunction with other processes, as part of a treatment train. Oxidation may prepare the waste for retorting or immobilization for disposal.

Developing Technologies. Some developing technologies include nonthermal methods, direct chemical oxidation, acid digestion, and thermal processes such as steam reforming. These methods may be used separately or in conjunction with other treatment processes, such as stabilization.

Additional Treatment Technologies Discussed at the Conference:

Adsorbents/Calgon™ F400 GAC. This granulated activated carbon- (GAC-) based adsorbent was used in a pilot-scale study of removal of mercury from pharmaceutical wastewater generated by the production of thimerosal, a mercury-containing preservative. Treatment with the GAC system reduced the mercury content of the wastewater by a factor of 400, enabling wastewater that was previously disposed of as hazardous waste to pass the TCLP and be considered non-hazardous.

Adsorbents/SAMMS.™ This adsorbent, called SAMMS (Self-Assembled Monolayers on Mesoporous Materials), is a versatile mercury-philic material that can be used to extract mercury from contaminated oil and other waste streams. Studies have shown up to 90% mercury removal using this material, which provides a cost-effective and versatile treatment option. This material was recently developed, and has not been widely available for use.

2.3 State of the Science in Disposal Options for Mercury Waste

There are two possible destinations for mercury separated from mercury-bearing waste: reuse and disposal. Many of the treatment options described in Section 2.2 of this report extract mercury from waste. The extracted mercury is purified for reuse and either returned to the industrial process or resold through the secondary mercury market. The mercury that remains in the waste after treatment is disposed. The regulations described in Section 2.1 of this report govern the mercury content of disposed wastes.

Mercury-bearing waste treatment options are geared towards the type of waste and the disposal method to be used. Some treatment options aim to lower the mercury content to an acceptable level for land disposal. However, others such as amalgamation, solidification, and stabilization, seek to lock the mercury

inside a matrix to enable land disposal of higher quantities of mercury. While the long-term performance of some of these methods may be in question, there are a number of options for mercury-bearing waste disposal.

Landfill Disposal. Wastes that pass the TCLP may be land disposed. The TCLP test is designed to ensure that mercury will not leach out of the waste matrix under landfill conditions. However, concerns about the suitability of the TCLP cast some doubt on this practice, as there is debate whether the TCLP accurately predicts real world landfill conditions. Landfills may be responsible for air emissions due to the low volatilization temperature of mercury, although these emissions may be minimal due to the lack of a carrier gas such as methane. There is also the potential for long-term hazards, such as landfill cracking, with land disposal of mercury. In spite of these issues, landfill disposal after treatment has long been the preferred method of mercury waste disposal.

Subseabed Emplacement. This method of disposal seals solidified waste inside a cannister, which is then placed in deep-sea sediments. The waste form, cannister, sediment, and ocean water should inhibit the migration of hazardous quantities of waste. This method was developed with the intent of isolating radioactive materials for long periods of time to allow the radionuclides to decay to harmless forms. Because mercury is nonradioactive, it presents a permanent environmental threat, and the long-term stability of this disposal method has not been fully studied.

Stabilization. The stabilization of mercury-bearing waste to provide a durable long-term waste form is the objective of many treatment and disposal options. Mercury sulfide, chemically bonded phosphate ceramics are all waste forms which have been used; each having advantages over the other. For example, mercuric chloride is quite soluble; hence, mobile. This type of treatment often reduces the mercury vapor pressure and leachability sufficiently to enable the waste to be disposed of as non-hazardous. However, these are relatively new technologies and there is concern that we many not know the true long-term durability of these waste forms. It has been shown that laboratory experiments often do not properly predict the long-term conditions found in landfills. Since mercury is not radioactive, it does not degrade; thereby, posing a continuous threat to the environment. Many conference participants felt that further research is needed to ensure long-term protection of human health and the environment from these technologies.

Surface, Shallow, and Deep Storage. As mercury stockpiles grow from increased recycling and collection efforts, long-term mercury storage is an option that circumvents some of the uncertainties associated with disposal practices. Doubts about the performance of land-disposed and subseabed disposed wastes under real-world conditions, makes long-term storage options appealing. State-of-the-art surface, shallow, and deep storage have been examined for this purpose.

Deep geological repositories, such as mines, are currently being used in Europe for the long-term disposal of mercury wastes. These repositories have the advantage of reducing the potential for exposure that confronts surface repositories. However, there are concerns that deep-disposed mercury may find a pathway back to the surface in oil and natural gas. Surface storage has the advantage of easier monitoring

for the purpose of intervention in the event that it is needed. While it is possible to monitor deep-disposed wastes, it is difficult to correct a problem should one arise.

2.4 Additional Topics of Concern from Treatment and Disposal Panel Discussion

The purpose of the panel discussion on treatment and disposal was to discuss a) the state-of-the-art of mercury treatment and disposal techniques for mercury wastes and stockpiles, and b) to identify major research needs/directions needed to meet the goal of bringing the state of technologies (or any other options) closer to environmentally safe (including in the long term), cost-effective treatment and disposal processes. The proceedings of this panel discussion are provided as Appendix C in this report. This section highlights the recurring themes that drove the discussion of the panel members and attendees.

The panelists were asked to respond to two sets of questions.

Question A: State of the Art and Significant Advances.

- What are two or three accomplishments described in the treatment and disposal session that may support significant advances in the state of the art in non-combustion options for mercury waste/stockpile treatment and disposal techniques?

- Based on your general knowledge, how would you characterize the state of the art of non-combustion techniques for mercury treatment and disposal with respect to where we currently stand in meeting the goal stated above?

Question B: Research Needs.

- What are three priority research areas you feel are most important to address so that we can make significant steps toward reaching the goal stated above?

<u>Accomplishments Supporting Advances</u>

The panelists listed recent accomplishments they felt were specifically supporting of advances in the state-of-the-art in treatment and disposal. Each of these topics has been discussed in the preceding section. Selections included both technical accomplishments, such as new treatment processes or materials, and regulatory accomplishments, such as the formation of partnerships and the classification of wastes.

- *Mercury sulfide*. The mercury sulfide method of stabilization and disposal is significant because it essentially puts mercury back where it came from.
- *Waste type*. Recent technologies make a distinction between Resource Conservation and Recovery Act (RCRA) wastes and mixed waste mercury.
- *Thermal desorption*. Thermal desorption may be the most sensible technology for mercury-contaminated soils because it can also deal with organics and other species.

- *Formation of partnerships.* The next step in advancing treatment and disposal will come from the formation of partnerships among waste generators, treaters, and regulators, and getting the available technologies out to the field.
- *Electrochemical processes.* Progress in developing electrochemical processes, which could have many future applications, would be welcome. This technology could be improved or modified for use.
- *SAMMS material.* The newly engineered SAMMS material, which may be useable as a drop-in replacement for ion-exchange, appears to have potential.

State of the Art

Many of the panelists agreed that the state of the art in mercury treatment and disposal is good. Effective technologies exist for treating mercury waste containing less than and greater than 260 ppm mercury. These technologies are either commercially available or soon to be available, with the best treatment determined by the specific market and waste. The available technologies are more similar than dissimilar in that they focus on keeping mercury immobile or insoluble. There is no "silver bullet" technology available, or likely to be identified; rather, it is likely that only incremental changes in technologies will occur in the future.

While the panelists agreed on the state of technological availability, several panelists noted that there are problems that need to be solved. One of those that was frequently discussed is the performance and propriety of measurement standards such as the TCLP. Both the technical utility of the test and the propriety of landfilling wastes with low levels of mercury was questioned. Panelists also noted that there are technical issues with many of the currently used treatment and disposal options that require further research, such as the long-term stability of amalgams and macroencapsulation under real-world conditions.

Research Needs

Panelists and the audience were asked to identify priority research needs for mercury treatment and disposal. They responded with the following needs:

- Alternatives to the TCLP. There is a need to identify alternatives to compensate for the inadequacies of the TCLP, which a) only concentrates on one pH range, and is therefore not representative of long-term landfill conditions; b) only provides a static snapshot (18 hours); c) provides no mechanism information; and d) has artificial particle size requirements. Furthermore, there is a need for standardization in testing procedures, with the regulatory and scientific communities in agreement. Standardization will increase confidence in the measurement results.
- Long-term Performance of Disposal Options Under Real-World Conditions. There is a need for further research into the long-term performance of stabilization, amalgamation and macroencapsulation due to the effects of pH on storage and disposal of mercury wastes. Previous testing has assumed a constant pH, which may not be accurate under real storage and disposal conditions, such as a landfill. It must be determined whether fluctuations in pH will reduce the suitability of some storage and disposal technologies.

- Mercury Emissions from Landfills. There is a need for additional research into mercury emissions from landfills to determine the potential for environmental impact from mercury waste following disposal.
- Durable Short-term Storage. There is a need for further research into durable short-term stockpile storage options for elemental mercury.
- International Technology Transfer. There is a need for technology transfer to other countries to communicate the status of the U.S. program on mercury. An international policy forum to discuss reduction of mercury use and consumption was suggested with the provision of international incentives to reduce mercury use and pollution.
- Non-Intrusive Mercury Measurement. There is a need to develop a non-intrusive method for measuring or identifying mercury in waste. Non-intrusive identification of mercury will allow easier identification and disposal of non-mercury wastes.
- Transmutation of Radionuclides. There is a need for further research into the transmutation of radionuclides to discover how can we better identify and treat mercury and mercury wastes.
- Characterization of Hazardous Waste Stream. There is a need for economic and characterization information on the hazardous waste stream. While municipal solid waste (MSW) is well characterized, hazardous waste identification codes (such as D009) yield little information about the waste. More information regarding the waste will enable more efficient recycling, treatment, and disposal.
- Treatment of Commingled Waste. There is a need for further research on the treatment of commingled organics and mercury. Can there be an effective treatment train identified and designated as the Best Demonstrated Achievable Technology (BDAT)?

Other Issues of Interest

Propriety of the TCLP. Attendees expressed concerns about the TCLP on several levels, including the representativeness of the test, the testing procedure, and the interpretation of the results.

The TCLP may not be the most appropriate tool to determine the utility of treatment technologies. The test is also limited by one pH range, which is not necessarily representative of real-world landfill conditions. The test uses a duration of 18 hours, which may not be sufficient to determine the long-term stability of a waste form. Other limitations include: (1) the procedure provides no mechanism information, therefore does not yield sufficient information about the process taking place; and (2) has artificial size requirements that are not representative of real-world landfill conditions. While the TCLP can be an effective leach method for assessing treatment and disposal efficiency, under certain conditions these technical shortcomings may undermine the effort to identify the most appropriate technologies.

Another issue hampering the utility of the TCLP is the lack of standardization in testing procedures. Variations in test conditions may significantly skew the test results further hampering the identification of appropriate technologies. A standardization of the procedure, with the regulatory and scientific communities in agreement, will increase confidence in the measurement results.

The final issue raised with the TCLP, as well as other leach testing, is the assumption that if a waste passes the test, it is safe to put in the ground. Aside from the aforementioned concerns that the test accurately predicts long-term landfill conditions, there is still the question that the big picture is being overlooked. Wastes that pass the TCLP still contain mercury, and each disposal adds more mercury mass to the global pool. This maybe a perception issue, rather than a specific shortcoming of the TCLP.

Stockpile Elimination/Mercury Supply and Demand. The elimination of mercury stockpiles is both a business and environmental issue. Stockpiles were developed for national security purposes and for now can be used to ensure a proper balance between supply and demand. There is movement to eliminate the stockpiles since they pose a potential environmental hazard.

Research and Development. While there have been numerous technologies developed in recent years to facilitate the treatment and disposal of mercury wastes, there is still a need for further research and development to improve current technologies and identify new ones. Regulatory pressure limiting the uses of mercury and enforcement of mercury cleanup regulations would create a market demand for new and improved technologies. This market demand would in turn stimulate research and development, which will lead to additional cleanup, treatment, and disposal.

Treatment Train. The next advances in treatment and disposal technology may be in the form of further development of treatment trains for specific waste types. Waste are commonly treated with more than one technology; however more research is needed to optimize treatment trains.

Section 3 Prevention, Collection, and Elimination

3.1 Current Status of Mercury Prevention, Collection, and Elimination

Mercury prevention, collection, and elimination can reduce the need for treatment and disposal over the long run. These practices intend to on prevent pollution from currently used mercury products, collecting discarded mercury products and mercury waste removal from commerce and the reduction or elimination of mercury use. There are many programs underway in EPA, state and local organizations to facilitate all three of these practices.

3.2 Issues in Mercury Prevention, Collection, and Elimination

Mercury Waste and Product Collection. Municipalities and international communities have undertaken mercury-containing product take-back and collection programs designed to remove all unnecessary mercury from use. These include the voluntary thermometer trade-in programs operating in many municipalities that offer free or discounted digital thermometers in exchange for mercury thermometers, as well as large-scale programs such as Sweden's virtual elimination program which uses inspectors and mercury-sniffing dogs to identify and label mercury-bearing products. While these programs often remove large amounts of mercury from use, two potential limitations to these programs have been identified. One drawback is the potential for inefficient collection practices to result in release of mercury to the atmosphere. This occurs because mercury volatilizes at ambient temperatures; consequently, great care must be taken to ensure that collected products do not break. The second drawback is the increasing saturation of the secondary mercury market. While collection of mercury does remove a potential hazard from the consumer, it may leave agencies with ever-increasing stockpiles of mercury due to the over-saturated secondary market.

Mercury Source Reduction. A long-term method for reducing the need for mercury treatment and disposal along with the hazards from mercury use is source reduction, the preferred method for pollution prevention. Source reduction is the reduction or elimination of the use of mercury in products and processes; thereby, reducing the demand for mercury entering the marketplace. Source reduction efforts may include the utilization of mercury substitutes, such as NewMerc™; the reduction of mercury use in products, such as the low-mercury fluorescent lamps; and the use of alternative technologies, such as digital thermometers versus conventional mercury thermometers. These substitutes may not befeasible for all applications, because they do not reproduce the same characteristics of mercury. However, there are many applications where these substitute chemicals and technologies will be sufficient.

Identification of Pollution Prevention Opportunities. Since pollution prevention (P2) can be applied to a wide range of industries, EPA has taken the lead in identifying P2 opportunities for mercury source reduction. EPA has initiated a P2 Prioritization Assessment which will guide the development of P2 opportunities.

Mercury Dogs. Swedish agencies use mercury-sniffing dogs to identify mercury in products and wastes.

Middle-level Handling of Mercury. Currently, industries that collect mercury-containing instruments such as thermostats and thermometers are not regulated. The government is promoting incentives to encourage collection efforts that are economically viable without releasing mercury into the environment. Regulation of this collection program is typically done at the state and local level. For example, Minnesota regulates collectors under the universal hazardous waste rule and have obtained good oversight of their activities.

EPA received a petition from the Edison Electric Institute to add all mercury-containing devices to the Universal Waste Rule to help better manage these devices. Utilities also use mercury instruments such as temperature and pressure sensors within their processes. EPA has not yet acted on this petition.

3.3 Additional Topics of Concern from Prevention, Collection, and Elimination Panel Discussion

The panel discussion on prevention, collection, and elimination focused on the need to reduce the amount of mercury entering the waste stream through improved pollution prevention techniques, waste collection methods, and source reduction. The proceedings of this panel discussion are included as Appendix B to this report. This section highlights the recurring themes that drove the discussion of the panel members and attendees.

The panelists were asked to respond to four questions:

1. What are the two or three most important insights you want to convey to the audience regarding the management of mercury from non-combustion sources?

2. What are the two or three most critical/essential efforts that need to be undertaken to prevent, eliminate, treat, or dispose of mercury from non-combustion sources?

2. Name two or three data gaps or information needs for mercury risk management from non-combustion sources.

4. Prioritize the two or three most important research needs for managing risks from non-combustion sources of mercury.

Conclusions:

Cooperation. Cooperation is essential both within industries and between industry and regulators. The chlor-alkali industry realized that some plants can manage at mercury control better than others, and they can all learn from each other without engaging in uncompetitive practices. The industry as a whole has realized that working with regulators toward a common goal can allow both parties to maximize their limited resources.

Set Achievable Goals. It is important to set achievable goals in eliminating mercury use and reducing mercury waste. Total elimination is not practical since mecury is mobile and is persistent in the environment (i.e., multimedia). A risk-based approach to determining an acceptable and achievable level of mercury in products processes and waste is more practical. The chlor-alkali industry has publically committed to a goal of a 50% reduction in mercury use (using a 1990-95 baseline) by 2005. A few companies, including Vulcan Chemicals, have set a goal of a 50% mercury consumption reduction based on a 1999 baseline. The industry intends to achieve these goals through cooperation with the regulatory community. Most plants are on track to achieving their goals.

Although the U.S. chlor-alkali industry have not planned a phase-out of mercury in the U.S. any phase-out needs to be well-planned as a cooperative venture between the government and industry. An immediate phase-out could have unintended consequences. For example, any disruption in alkali production could force alkali prices to rise and spur increases in production elsewhere in the world, such as Mexico, where chlor-alkali facilities are subject to less stringent environmental regulations.

Members of the chlor-alkali industry have worked together to address the following issues:

- *Mercury in Sodium Hydroxide.* The chlor-alkali industry's mercury in sodium hydroxide task group is about to release a draft publication that details the best strategy available on minimizing mercury in sodium hydroxide.
- *Mercury Health Issues.* The chlor-alkali industry has also convened a mercury health issues task group that has looked into ensuring that the best science is used to provide worker safety at chlor-alkali facilities.
- *Mercury Balance.* George Gissel stated that Vulcan Chemicals has assessed its mercury balance since 1973. Other chlor-alkali companies have looked toward this example to assist them in establishing a mercury balance. Vulcan Chemicals has given several seminars to the chlor-alkali industry about mercury balance. Through a multi-year evaluation of mercury consumption and purchasing, a facility can gain a better understanding of minimizing mercury consumption and losses.
- *Cross-plant/Cross-industry Sharing for Continuous Improvement.* The chlor-alkali industry formed the mercury control task group to identify the best management practices. This task group has produced two in-plant technology exchange workshops in 1999, with a third planned for 2000. These workshops provide detailed descriptions on using specific technologies.

The chlor-alkali industry has worked with the EPA to address the following issues:

- *Measuring Cell Room Fugitive Emissions.* The chlor-alkali industry formed a mercury emissions measurement task group to work with the EPA toward a common goal of measuring cell room fugitive emissions. The EPA at Research Triangle Park (RTP) developed the protocol. Testing began at the Olin Corporation's Augusta, Georgia, facility. The Chlorine Institute covered the out-of-pocket costs of Olin Corporation and the EPA is underwriting the cost of the equipment and measurements.
- *Revising National Emissions Standards for Hazardous Air Pollutants (NESHAP) regulations.* The EPA worked with the chlor-alkali industry revising the NESHAP regulations. They are conducting audits at five facilities.

Pursue Voluntary Efforts. Although voluntary efforts are not always effective, there are more successes than failures. Experience with the chlor-alkali industry shows that voluntary efforts can yield positive results.

Encourage Office of Solid Waste (OSW) Efforts. The EPA should support OSW in researching alternative disposal technologies.

Enhance Technology Development and Verification Programs. To enhance technology development and verification of alternative mercury technologies, the EPA should look at complementarity between ORD's Small Business Innovative Research (SBIR) program and Environmental Technology Verification (ETV) program.

Support Environmentally Preferable Purchasing. Use federal procurement to achieve environmentally preferable purchasing by reducing mercury in commerce.

International Mercury Flows. The EPA needs to support efforts to measure international flows of mercury. Characterizing the international flows are critical to assessing and addressing background mercury levels. Like many other countries, there is currently neither mercury monitoring nor a mercury inventory in Mexico. At present, Mexico is building its first large scale coal-fired utility plant. Mexican environmental officials have identified that they have three mercury cell chlor-alkali facilities. The Chlorine Institute and Eurochlor are working with their Mexican counterparts to raise their level of concern toward mercury issues as well as raise plant performance efficiencies. An unintended consequence of a rapid closure of mercury cell chlor-alkali plants in the U.S., could be a demand for more chlor-alkali plants in foreign countries with fewer environmental controls.

Virtual Elimination of Mercury Requires Private Sector Cooperation. Previous discussions during the workshop concluded that new regulations restricting mercury use are not likely. Therefore, if mercury is to be removed from the marketplace, government must work closely with the private sector. The challenge is to create positive incentive programs that can encourage the private sector to make business from phasing out mercury use; both in terms of developing alternative disposal technologies and developing chemical

substitutes (such as NewMerc).

Mercury as a Consumer Products Safety Issue. Mercury can be thought of as a consumer products safety issue where it exists in small amounts, such as in thermometers and electronic displays. The most common calls to poison hotlines deal with broken mercury fever thermometers. Although, thermometers and electronic displays represent a small percentage of mercury emissions (especially when compared with utility coal emissions), they still present a risk. It is recommended that the Consumer Products Safety Commission could be used to address the mercury safety issue.

Educating the Public about Mercury Exposures. Although most of this workshop has focused on emissions rather than on exposures, educating the public on exposures is critical. Over 90% of the calls to a poison control center in a certain state was attributed to broken fever thermometers.Yet, while most people may know that there is mercury in their thermometers, they may not be aware of the mercury in their thermostats or cars. The public needs to better understand through communication the risks of mercury in their everyday life.

Categorization. A standard categorization scheme for mercury disposition and contamination starting with products and ending with releases can help communicate risks and corrective action. The Northeast Model Legislation proposes the following categorization scheme:

- Product with elemental mercury
- Product with compounds and chemicals
- Processes
- Waste streams of the three above areas of deliberate use
- Non-combustion incidental releases, including refining, mining, and cement and limestone production

Mercury-free Procurement/Buildings by Government. It is important for the government to become a model for a mercury-free environment by setting an example for the public and industry.

Mercury in Consumer Products. The intentional use of mercury in consumer products should eventually be phased out, including mercury in lamps. A gatekeeper, such as EPA's hazardous waste listing determination, would provide some consistency in how regulations treat industry as well as the consumer. For example, there is no gatekeeper controlling the mercury found in Drano.
Some states have regulations in place, but there is nothing enforced at the national level. Minnesota has a provision in its regulations that prohibit mercury disposal in its solid wastes and wastewaters, where solid wastes include construction and demolition non-hazardous industrial, etc.

<u>Data Gaps and Research Needs</u>

Division of Mercury Sources by Deliberate Use and Trace Contamination of Raw Materials. Categorizing mercury sources by emissions resulting from mercury use and emissions resulting from

contamination of raw materials may be more relevant than categorizing by combustion and non-combustion for the following reasons:

- *Avoids the disparity of equating combustion emissions with coal-fired utility emissions.* As currently defined by EPA, combustion sources include incinerators. Incinerators, however, do not make mercury, but receive mercury from mercury-containing wastes as a result of mercury use in products;.
- *Normalizes the division of mercury sources.* If emissions are categorized on a deliberate use basis, use-related emissions are about 50% of total emissions; combustion basis, where combustion-related emissions constitute about 90% of total emissions.
- *Better consideration of life cycle emissions.* Since incinerator emissions represent the end of a product's life cycle, this type of assessment makes it easier to look at different points along a product's life cycle to assess opportunities to control mercury emissions.

Life Cycle Emissions by Product Type. There is an inadequate understanding of life cycle emissions by product type. Further research may help prioritize mercury collection efforts and target programs to critical sectors. There are some data on mercury emissions from mercury-containing products, however these estimates do not seem to be based on actual measurements. There are better data from incinerators, but these data could also be improved. However, there is a paucity of data regarding emissions estimates from other phases of the mercury product life cycle, in particular:

- Accidental emissions that occur during product use;
- Emissions associated with collecting, processing, storage, and transport of wastes prior to incineration;
- Emissions that occur from landfills, particularly the working faces of landfills;
- Mercury emissions from the use of metal scrap. For example, emissions from mercury switches placed in automobiles are currently not accounted for in EPA emissions estimates, though these emissions could be significant.

Increase Focus on Prevention Opportunities. Currently cost effectiveness data are based on cost effectiveness per mass of mercury collected rather than on the prevention of mercury releases. More emphasis should be place on the following areas for prevention efforts:

- *Auto industry*. There should be more research on this sector since most of the mercury associated with automobiles is ultimately released into the environment.
-
- *Electrical Switches*. Alexis Cain cited data presented by Bruce Lawrence (Bethlehem Apparatus Company) in the plenary session indicating that electrical products, particularly mercury relays in capital equipment, are now the largest user of mercury in the U.S. (even more than the chlor-alkali industry); now estimated at 110 tons per year. Moreover, mercury use in electrical switches has not decreased over the past 20 years.

Mercury Retirement. As the secondary market grows and mercury use shrinks, an "end-game" for mercury must be devised for retiring mercury. The EPA should work with the Department of Energy (DOE) and Department of Defense (DOD) to develop mercury stabilization technologies. Ultimately, all of the mercury in commerce needs to be treated, contained and/or sequestered in a final disposition.

Section 4
Summary and Conclusions

The panel discussions provided a valuable forum for experts to summarize what they saw as the important findings and future steps to reduce risks from mercury over the next several years. As discussed, the state of the science for treatment and disposal of mercury wastes has advanced substantially. Research is now needed to refine the existing technologies and establish cost-effective treatment strategies using the best available knowledge. Efforts to identify mercury pollution prevention, collection, and elimination options will promote environmentally sound risk management practices.

Appendix A
Workshop Agenda

Conference Agenda

DAY 1 - Wednesday, March 22, 2000

Welcome and Opening Remarks - *Douglas Grosse, US EPA/NRMRL*

Plenary Session

Moderator: *Jon Herrmann/Ben Blaney, US EPA/NRMRL*

ORD Research Strategy

The Mercury Marketplace: Sources, Demand, Price and the Impacts of Environmental Regulations - *Bruce Lawrence, Bethlehem Apparatus, Inc.*

Waste Minimization and Elimination - *Harold Charles, US EPA OSW*

EPA's Mercury Action Plan - *Greg Susanke, US EPA OPPTS*

Disposal of Mercury Waste and Stockpiles - *Josh Lewis, US EPA OSW*

Mixed Waste Issues - *Greg Hulet, US DOE/BBWXT Co. and Grace Ordaz, US EPA*

International Perspective - *John Diamante, OIA*

Mercury Information Management Issues - *Jim Ekmann, DOE*

National Implementation of the Universal Waste Rule for Mercury Lamps (Industry Perspective) - *Paul Abernathy, Association of Lighting and Mercury Recyclers*

Regional Perspective - *Jeri Weiss, US EPA Region 1*

State Perspective - *John Gilkeson, Minnesota OEA*

Model State Legislation - *Richard Phillips, Vermont DEC*

NGO Perspective - *Jane Williams, California Communities Against Toxics*

Concurrent Technical Sessions

Session A - Treatment and Disposal Technologies

Moderator - Josh Lewis, US EPA OSW

Mercury Stock Management - *Folke Dorgelo, Netherlands Ministry for Housing, Spatial Planning and the Environment*

Subseabed Emplacement: Long-Term Ultimate Disposition of Mercury Wastes - *Leo Gomez, Sandia National Laboratories*

Case Study of a Polit Scale System for Removal of Organic Mercury from Pharmaceutical Wastewater - *Patrick Cyr, Advanced GeoServices Corp.*

SAMMS Technology - *Nick Lombardo and Shas V. Mattigod, Pacific NW National Laboratory*

Session B - Overall Reduction of Mercury: Phase out and Mercury Management of Stockpiles
Moderator: Anita Cummings, US EPA

Stockpile (DLA) - *Giles LePage and Dale Wilhelm, DOD, DLA*

Mercury Collection Programs in Sweden - *Kristina von Rein, Swedish Environmental Protection Agency*

Mercury Stockpile Management - *Luke Trip, Environment Canada, Implementation Task Force*

Phase-out of Mercury Containing Products - *Folke Dorgelo, Netherlands Ministry for Housing, Spatial Planning and the Environment*

DAY 2 - Thursday, March 23, 2000

Session A - Treatment and Disposal Technologies: Treatment Technologies
Moderator: Mary Cunningham

DOE Mercury Waste Treatment Demonstrations - *Greg Hulet, US DOE/BBWXT Co.*

Return and Recycling of Used High Intensity Bulbs for Recycling and Closed-Loop Mercury Control - *Lester Gress and Jeff Lord, Cleveland Fluid Systems Co.*

Mercury Amalgamation Demos with the DOE - *Clifton Brown, ADA Technologies, Inc.*

Deployment of the Sulfur Polymerization and Stabilization Process as Applied to Mercury Contamination in Soils - *Paul Kalb, Brookhaven Natl. Laboratory and Trevor Jackson, EnviroCare*

Session B - Prevention, Collection and Elimination: The Business Side of the Mercury Problem
Moderator: Ed Weiler, US EPA

Speed Bumps on the Road to Commercialization of New Environmental Technologies - *David Case, Environmental Technology Council*

Commercializing a Safer Substitute for Mercury - *James D. Rancourt, NewMerc Ltd.*

The Business of Mercury Pollution Prevention: Identifying Source Reduction Opportunities and Engineering Trade-Offs - *Kenneth Stone, US EPA/NRMRL*

A PBT Technology Information Clearinghouse (with special emphasis on information relating to environmental technology development and commercialization) - *Frederic H. K. Booth and Kay can der Horts, Waste Policy Institute*

Session A - Treatment and Disposal Technologies: Disposal Technologies
Moderator: Paul Randall, US EPA

Mercury Stabilization in Chemically-Bonded Phosphate Ceramics - *Dr. Arun Wagh, Argonne National Laboratory*

Characterization and Leachability of Stabilized Mercury-Containing Wastes - *Linda Reiser, University of Cincinnati*

Treatment of Wastes Contaminated with Mercury - *Paul Lear, IT Corp*

Treatment of Mercury Bearing Wastes with Thermal Desorption Technology - *Dave Mulkmus, Sepra Dyne Corporation*

Session B - Impacts of Mercury Collection and Elimination Programs
Moderator: Jeri Weiss, US EPA Region 1

Mercury Sniffing Dogs: The Swedish Experience - *Kjell Avergren, Sweden Dog Training Centre*

Mercury Source Reduction and Recycling in Electrical Products - *Ric Erdheim, NEMA*

DSCP Buying Green - *Anthony Armentani, Defense Supply Center Philadelphia*

EPA/AHA Agreement: Reduction of Mercury Waste from Hospitals/Health Care Facilities - *Chen Wen, EPA and Video Presentation, AHA*

Session A - Treatment and Disposal Technologies: Stabilization
Moderator: Paul Randall, US EPA

Permanent Mercury Disposal in Sweden - *Kristina von Rein, Swedish Environmental Protection Agency*

Subseabed Emplacement: Long-Term Ultimate Disposal of Mercury Wastes in Geologic Formations on Land - *Rip Anderson, Sandia National Laboratories*

Session B - Impacts of Mercury Collection and Elimination Programs (Continued)
Moderator - Jeri Weiss, US EPA Region 1

New Strategies for Reducing Mercury Discharges from Boston Area Medical Facilities - *Kevin McManus, Massachusetts Water Resources Authority*

Eliminating Non-Essential Mercury Uses - *Michael Bender, Mercury Policy Project*

Panel Discussion A - Treatment and Disposal

Facilitator: Ben Blaney, US EPA/NRMRL
Panelists: Paul Kalb, Brookhaven National Laboratory
Paul Lear, IT Corp.
Ed Swain, Minnesota OEA
Greg Hulet, US DOE/BBWXT Co.
Fred Charania, US EPA OSW

Panel Discussion B - Prevention, Collection, and Elimination

Facilitators: Doug Grosse, US EPA, Office of Research and Development (ORD)
Jon Herrmann, US EPA, ORD
Panelists: Alexis Cain, US EPA, Region V
John Gilkeson, Minnesota OEA
George Gissel, Vulcan Chemicals
Edward Weiler, US EPA OPPT
Jane Williams, California Communities Against Toxics
Combined Workshop Session - Presentation of Concurrent Panel Findings
Closing Remarks

Appendix B Workshop Abstracts

Table of Contents

Abstracts

The Mercury Marketplace: Sources, Demand, Price and the Impacts of Environmental Regulations

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Bruce Lawrence

Mr. Lawrence is the President of Bethlehem Apparatus Company, Inc., since 1980, and the principal stock holder since 1992. Bethlehem Apparatus Company is the leading company supplying mercury to the U.S. domestic market, as well as the leading mercury retort recycling operation. Mr. Lawrence has been published in the Engineering and Mining Journal for several years in the annual mineral section on the Mercury Market. He has also presented work to EPA on the retort distillation of mercury, 1992.

The Mercury Marketplace: Sources, Demand, Price and the Impacts of Environmental Regulations

Presentation will provide answers to the following questions. Where does the present market for mercury get its supplies? How does recycling of mercury waste materials effect the market? What is byproduct mercury and how does it interact with the more traditional supplies of mercury? Mercury Mining; Who does it and is it still necessary for the supply to the mercury marketplace? Who still uses mercury in products and services? How is mercury used in consumer products? How is mercury used in non-consumer products? How much mercury is in use today? How much mercury is available for the mercury marketplace? Who owns this mercury? Why are there stockpiles of mercury? What changes have taken place in the past few years since efforts have been made to limit mercury use? How much does mercury cost? Has this changed since the onset of environmental regulation? How does price affect the supply and demand of mercury? Are there other effects of mercury pricing?

Waste Minimization and Elimination

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Harold Charles

B.S. in Civil Engineering, University of DC, 1986
M.S. in Waste and Environmental Management, University of MD, 1994
Professional Engineering License with DC and MD, 1997

1987 to 1994, Civil Engineer and Environmental Coordinator, DC Air National Guard at Andrews Air Force Base, 113th Civil Engineering Squadron1994 to 1995, Environmental Protection Specialist, Headquarters U.S. Army at the Pentagon, Environmental Programs Directorate, Pollution Prevention Division

1995 to 1998, Civil Engineer and Environmental Officer, Headquarters Federal Emergency Management Agency, Response and Recovery Directorate, Infrastructure Division, Engineering Branch

1998 to Present, Environmental Engineer, Headquarters Environmental Protection Agency, Office of Solid Waste, Hazardous Waste Management and Minimization Division, Waste Minimization Branch

Mercury is one of the PBT (persistent, bioaccumulative and toxic) chemicals that EPA has focused on over the years.

An overview will be given of how mercury in products and production process is found in waste streams. Subsequently national data of mercury bearing wastes and how they are managed (i.e. treated, recycled, and disposed of) will be highlighted.

Current EPA initiatives focusing on mercury in wastes will be discussed, including pollution prevention initiatives.

EPA/OSW supports waste minimization to reduce mercury in wastes and when not feasible, effective treatment or more Land Disposal Restriction (LDR).

EPA's Mercury Action Plan

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Greg Susanke

Greg Susanke is a biologist, and the manager of EPA's Office of Pollution Prevention and Toxics' Mercury Program. He is currently leading a multi-Office workgroup effort in developing a Mercury Action Plan for the Agency. Greg is also serving as a U.S. representative on the Commission for Environmental Cooperation's Mercury Task Force where he has helped implement Phase I of the North American Regional Action Plan on Mercury, and has assisted in the drafting of its second phase.

EPA's Mercury Action Plan: An Overview

Among the many pollutants that EPA addresses, persistent, bioaccumaltive and toxic (PBT) substances are pollutants of primary concern. It has traditionally addressed these and other pollutants among its single-media offices. However, many pollutants, especially PBTs, can not be fully addressed in this manner because of their cross-media nature. Accordingly, the EPA is committing, through the development of a PBT Strategy, to create an enduring cross-office system that will address the cross-media issues associated with priority PBT pollutants. The PBT Strategy, which is currently being drafted, will integrate the work being done across media offices and between national and regional programs more thoroughly. It will align domestic and international activities more effectively, involve stakeholders, and use measurable objectives and assess performance. This strategy is intended to make the whole of the Agency's efforts on PBT pollutants more than a sum of its parts.

A central element to EPA's PBT Strategy is the development and implementation of national action plans for priority PBT pollutants. Mercury has been selected as one of the first PBT substances to be addressed under this strategy. The Agency is currently in the process of drafting a Mercury Action Plan. Although the PBT Strategy will not be discussed in the presentation, an understanding of its principles, as previously mentioned, frame the context of the action plans.

The presentation will briefly discuss use, release, and risk reduction goals for mercury, as well as the tools to be used to measure progress in achieving these goals. A listing of the numerous source categories/sectors to be addressed will be presented, but the focus of the presentation will be on describing the priority areas

of future action. Mention of these priorities at the time of writing this abstract is not possible, as they are currently being developed.

Disposal of Mercury Waste and Stockpiles

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Josh Lewis

Josh Lewis in an Environmental Engineer in the Waste Treatment Branch of EPA's Office of Solid Waste. He graduated from Cornell University with a B.S. in Environmental Engineering. Josh has worked at EPA for two years, during which time one of his main projects has been the reevaluation of the Land Disposal Restriction treatment standards for mercury-bearing wastes.

Treatment and Disposal of Mercury Hazardous Waste

The original Land Disposal Restriction (LDR) treatment standards for mercury-bearing wastes were promulgated in 1990. These standards, which are still in place, require high mercury subcategory wastes (i.e., wastes that contain greater than or equal to 260 ppm total mercury) to be roasted or retorted to recover the mercury or, if organics are present, the wastes can also be incinerated. Low- mercury subcategory wastes (i.e., wastes that contain less than 260 ppm total mercury) have to meet a numerical treatment standard based on the toxicity characteristic leaching procedure (TCLP). Since 1990, many issues have arisen with the mercury treatment standards, including whether the original premise of incineration as a pretreatment step to mercury recovery is still true; whether there are options for treating high-mercury wastes that are not amenable to retorting; and, since mercury use in industry is on the decline, whether we should still require mercury recovery for high subcategory wastes, or instead allow treaters the option of stabilizing these wastes. Because of these and other issues, EPA has begun a reevaluation of the LDR mercury treatment standards. The first step in this reevaluation was the publication of an Advance Notice of Proposed Rulemaking (ANPRM) on May 28, 1999, which described the issues we have with the current mercury treatment standards and discussed some potential options for amending the standards. We are now evaluating the comments that we received on this ANPRM. In addition, we are involved in two treatability studies that are researching the efficacy of emerging mercury treatment technologies. The end result of our current mercury work will be the publication of a proposed rule on changes to the LDR mercury treatment standards in late 2000.

Mixed Waste Issues

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Grace Ordaz

Ms. Ordaz has been working on EPA mixed waste proposal for the past two years. Ms. Ordaz has also worked at US DOE Office of Environmental Management, Office of Research and Development on mixed waste technology development, and at the MD Department of Environment administering the State Biomonitoring Program under CWA's municipal NPDES permit program. Ms. Ordaz also has experience with the AA county pretreatment program under the CWA, and process design of petroleum plants.

Greg Hulet

Mr. Hulet is the work package manager for the Unique Waste Work Package, which includes DOE's mercury mixed wastes. As such, he coordinates research, development, and technology deployment activities to ensure that all the wastes in the Unique category have a path for treatment and disposal. He has a Masters Degree in Chemical Engineering and ten years experience in waste management and pollution prevention. He also has considerable experience with Naval Nuclear Propulsion Plants. He has been a scoutmaster for 15 years, which, after watching scouts cook for that long, has made him an expert in unique hazardous wastes.

EPA Proposed Rule for Storage, Treatment, Transportation, and Disposal of Mixed Waste

Conservation and Recovery Act (RCRA) to provide a conditional exemption from certain requirements for eligible mixed waste. EPA is requesting public comments on this proposed action.

Mixed waste is a radioactive RCRA hazardous waste. It is regulated under two authorities: 1) the Resource Conservation and Recovery Act (RCRA), as implemented by EPA or authorized states for the hazardous waste component; and 2) the Atomic Energy Act of 1954, as amended (AEA), for the radiological component as implemented by either the Department of Energy (DOE), or the Nuclear Regulatory Commission (NRC) or its Agreement States.

The focus of this proposal is to provide flexibility under RCRA Subtitle C to generators of eligible mixed waste. We are proposing a conditional exemption from the definition of hazardous waste applicable to: low-level mixed waste (LLMW) for storage; and LLMW or Naturally Occurring and/or Accelerator-produced Radioactive Material (NARM) for transportation and disposal. The proposal is expected to reduce dual regulation for generators in the management and disposal of their wastes. This flexibility will enable generators of LLMW who are licensed by the Nuclear Regulatory Commission (NRC) to claim an exemption for storing and treating these wastes in tanks or containers (using solidification, neutralization, or other stabilization processes) without a RCRA permit. This proposal will also provide flexibility for the manifesting, transportation and disposal of eligible mixed waste. Waste meeting the proposed conditions will be exempted from certain RCRA Subtitle C hazardous waste requirements and managed as radioactive waste in accordance with NRC regulations.

International Perspective

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John M. Diamante is the Senior Science Advisor for the EPA Office of International Activities, reporting to the Assistant Administrator and Deputy. His responsibilities are to provide advice, review and oversight on technical and scientific matters and related policy issues concerning the programs and activities of the Office. He is actively engaged in interagency and international cooperative projects concerned with radioactive waste management problems in Northwest Russia. He received his doctorate from New York University based on research in planetary atmospheres conducted at the NASA Goddard Institute for Space Studies in New York. Subsequently, he was employed at several aerospace companies, including TRW Systems and EGandG, and then went on to federal employment with the National Oceanic and Atmospheric Administration (NOAA). At NOAA, he served as a scientific and technical advisor in the National Ocean Service, Oceanic and Atmospheric Research Office and Climate Change Program Office.

Marilyn E. Engle

Marilyn E. Engle is an International Affairs Specialist in the EPA Office of International Activities. She presently is the Agency lead on international transboundary transport aspects of mercury, and has served as lead on international marine and coastal issues, where she initiated Agency activities to shape a Land-Based Sources of Pollution (LBS) Protocol for the Wider Caribbean. She received her BA in Zoology and

Anthropology from Duke University and her Master's Degree from George Washington University. Her experiences include being a Senior Research Technician at Duke University Medical Center working conducting research on non-ionizing radiation sublethal effects. After joining EPA, she was an Environmental Scientist for the Office of Radiation Programs and supported the regulatory program on ocean disposal of low-level radioactive waste before taking her present position in the Office of International Activities. She also co-managed the Arctic Nuclear Waste Assessment Program (ANWAP) while on a recent detail from EPA to the Department of Defense Office of Naval Research, where she focused on preparing a human and ecological risk assessment of the potential for transport from Russia to the U.S. State of Alaska of Russian nuclear wastes dumped into or entering the Arctic Ocean.

Long-Range Transboundary Transport of Mercury: International Dimensions of the Mercury Problem and Opportunities for Cooperative Solutions

We are becoming increasingly aware that we must address mercury, a persistent and bioaccumulative toxic, at local, regional and global scales. In addition to the problem of long-range transport from combustion sources of mercury, such as coal burning, the EPA Office of International Activities (OIA) also sees a need to focus on the long-range transport from non-combustion sources, such as the chlor-alkali industry and mercury in waste streams.

There is growing evidence that the U.S. is being impacted by many atmospherically borne, globally circulating persistent toxics, such as persistent organic pollutants (POPs), and other atmospheric contaminants, including ozone and particulates. There is reason to believe that mercury is similarly being transported to the U.S. from abroad, and that U.S. sources are contributing to the global pool of mercury that is being circulated worldwide. EPA estimates that about one-third of U.S. anthropogenic mercury emissions are deposited in the contiguous U.S., while the remaining two-thirds is transported outside the U.S. and enters the global pool. Correspondingly, estimates suggest that about 35 tons, or 40% of the mercury that is deposited in the U.S. per year, may originate from sources external to the U.S. With the rapid industrialization and increasing use of coal in Asia, and re-industrialization in Russia, this trend is expected to increase. Rapid industrialization will also increase the burden arising from the non-combustion sources.

The mission of OIA regarding mercury is multifold: 1) to improve understanding of international sources of mercury, and the regional and global-scale transport processes; 2) to influence international awareness and actions through international fora; 3) to provide international training and technology transfer in selected countries to bring about reductions in mercury use and emissions; and 4) to facilitate data and information management. Our emphasis to date has been on improving scientific understanding of long-range transport, and on partnering with other countries in cooperative solutions, and through regional fora to collectively influence actions in other countries. Currently, OIA, in cooperation with other EPA Offices, other federal agencies and other governments, is supporting activities such as speciated mercury monitoring and modeling efforts in Barrow, Alaska and in the Ohio River Valley and the Florida Everglades to evaluate international contributions of mercury to U.S. deposition. EPA is also actively engaged in mercury issues

and regional action plans under numerous regional agreements, including the U.S.-Canada Binational Toxics Strategy, the North American Commission on Environmental Cooperation (CEC) involving the U.S., Canada and Mexico, the UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP) Heavy Metals Protocol, and the activities of the Arctic Council, which includes the Arctic Monitoring and Assessment Program (AMAP).

In addition to improving scientific knowledge of transport and fate of mercury sources, we are working through international fora to find opportunities for international cooperative approaches to further: 1) source identification and characterization, particularly with the chlor-alkali sector; 2) pollution prevention, such as taking mercury out of products; 3) environmental capacity building; 4) environmentally sound trade and free market decisions regarding mercury, and 5) informed international policy making concerning mercury.

Mercury Information Management Issues

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Mr. Ekmann serves as the Deputy Associate Director in the Office of Systems and Environmental Analysis. This office is part of the National Energy Technology Laboratory of the U.S. Department of Energy. OSEA assesses the technical, environmental, and cost performance of technologies developed at or under funding from NETL. Staff in the office conduct environmental assessments, detailed engineering reviews in support of RDandD projects. The office also provides a focal point for the laboratory's external communication including technology transfer, and preparation of materials summarizing technical successes.

Information Tools for Mitigation Strategy Development

The need to link technology costs and a comprehensive risk assessment methodology in the context of addressing major environmental contaminants, e.g., mercury and other persistent bioaccumulative toxics (PBTs) has been discussed by a number of authors. Assessments of policy options rely increasingly on multiple tiers of modeling studies informed by large volumes of data. This tendency raises the need to manage

the use of models and the data needed to ensure analytical results that are consistent and of sufficient quality. The NETL has been examining the connection between data, and concepts such as information, knowledge, and wisdom as these relate to the role of advanced fossil fuel technologies in a carbon managed future. We plan to develop a decision support model that would be an information portal to both process-level data and information and to system-level analyses. We believe that this linkage will lead to knowledgeable choices about mitigation technologies and has the potential to clearly communicate results facilitating formulation of wise policy options. We believe that this endeavor offers useful insights to similar information needs and structures for other issues such as mercury /PBTs. This paper discusses both the approach being used to design the decision support system and the linkages between scientific and technical data and information on societal values that are essential to making such a concept useful.

National Implementation of the Universal Waste Rule for Mercury Lamps (Industry Perspective)

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Paul W. Abernathy is the Executive Director of the Association of Lighting and Mercury Recyclers, a national non-profit organization representing members of the mercury recycling industry. Mr. Abernathy has worked for over 25 years in the environmental services industry throughout North America, representing public and private companies and clients. His background includes extensive participation in public policy development and implementation for water quality, air and hazardous substances management. Mr. Abernathy has had experience working with NATO on international exchange of environmental management programs and technologies; was appointed by a California governor to serve on the multi-disciplined State Hazardous Waste Facility "Siting" committee; and presently serves as technical advisor to regional governments in Northern California on hazardous waste management planning, siting and development issues, water and energy conservation, regulatory and environmental compliance, pollution prevention and resource recovery. Paul serves as member of Northern California Green Business Advisory Board.

Mr. Abernathy earned a M.B.A. from Pepperdine University and a B.S. in Biology/Chemistry from the University of Arizona.

National Implementation of the Universal Waste Rule for Mercury Lamps

This presentation includes a brief history of mercury lamp recycling and disposal in the U.S., the public policies that have influenced lamp disposal, highlights of states' programs regulating lamps, and it discusses the latest changes to the Universal Waste Rule effective 1/6/00. EPA's goal is to divert mercury lamps from municipal wastes, and the Association of Lighting and Mercury Recyclers is part of a public-private partnership that is forming to work with business and all state and local governments in the U.S. for implementation of the new rule. This presentation discusses local government roles and options, business and generator options and the educational and resource information being developed.

Spent mercury lamps are considered hazardous waste, but for the most part they have not been managed this way. EPA believes the major reason for the wholesale non-compliance is the lack of awareness and access to information on the part of lamp owners and local governments, which includes nearly everyone. The national recycling rate has been about 12%, which means there are still 500,000,000 mercury lamps disposed in the garbage, potentially exposing people and the environment to mercury. RCRA has always required the proper management of mercury lamps as hazardous wastes, but with few exceptions (MN, FL) there has been little or no enforcement by regulatory agencies. EPA adopted the UWR to include lamps on 7/6/99. *(FR July 6, 1999, Volume 64 Number 128, pp. 36465-36490, and 40 CFR 273)*, effective 1/6/00. The goal of the rule is to increase the recycling rate to 80% and remove regulatory and cost burdens for those who recycle. States may take several possible actions to achieve consistency with RCRA. States may have more stringent policies, but the minimum regulatory criteria must not allow the land disposal of mercury-lamps. Local governments have a responsibility too, through their franchises for solid wastes, HHW programs, SQG programs, pollution prevention programs, landfill operations.

Our recycling association has formed a partnership with Earth's 911, and along with EPA and corporate partners is helping provide information and resources to the states, and working with local governments to adopt and implement programs that encourage recycling and set up a sufficient infrastructure to divert mercury lamps from municipal wastes altogether by making recycling easy, inexpensive and available to business and the public.

The new UWR makes it easier than before and less costly to manage lamps properly. Where RCRA has not been enforced and the compliance rates are low, non-compliant disposal has cost little to generators. Proper lamp management under the UWR represents a small percentage of total lighting costs, and it keeps mercury from being released into the environment. To achieve compliance it is incumbent on states and local government agencies, working with both public and private entities, to ease the burden on generators by making collection and recycling programs for mercury lamps readily available. By sharing information, conducting public-private seminars and workshops throughout the country, offering Earth's 911 resource guide, website and toll-free number we are helping educate people about their responsibility. The national goal is to recycle as many mercury lamps as possible.

State Perspective

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John Gilkeson has worked for the state of Minnesota for 10 years and is currently a principal planner with the Office of Environmental Assistance. During that time John has worked on "problem and special wastes," including medical and infectious waste, household hazardous waste, batteries, lead, electronics, and mercury wastes. John's focus for the past four years has been on the use and management of mercury in products. John has worked on the Minnesota universal waste rule, the federal mercury lamp rule, the federal mercury stockpile issue, and represents Minnesota on the Binational Toxics Reduction Strategy Mercury Work Group. John has also worked with several industries and sectors that use, manage, or release mercury, including oil refineries, thermostat manufacturers, relay manufacturers, automobile manufacturers, the state dental association, demolition contractors, and several mercury recyclers.

Minnesota State Perspective

Minnesota and other states are taking a variety of approaches to understanding, reducing, and managing mercury that is released from a variety of human activities. Though states have differing needs and resources, and must take different approaches, they also have much in common and would benefit from more coordination in laws, rules, programs, and research. Similarly, on a national and international basis, our common interests would benefit from a more coordinated approach to research, programs, and policy. Other public and private sector interests are key players in these processes and have a strong interest in consistent and equitable measures to address mercury nationally and internationally.

In this presentation, Minnesota state agency staff will present their perspective on impediments to and opportunities for advancing local to international mercury reduction efforts in the areas of:

- Environmental research and monitoring;
- Laws and regulations;
- Policies and programs;
- Education;
- Incentives and other measures for voluntary action, including national early reduction credit;
- Coordination among governments, businesses, and NGOs;
- Research and measures for reducing and managing mercury in purposeful use (and waste management);

- Research and measures for reducing emissions from energy and resource sectors;
- Research and measures for reducing emissions from other unintentional use or material reuse;
- Management and disposition of stockpiles and reserves;
- Retirement of mercury removed from commerce; and
- Developing and promoting non-mercury products and processes.

The presentation will include an overview of recommendations from the Minnesota Comprehensive Mercury Reduction Initiative (March 1999) and International Policy Recommendations developed by attendees of the 5th International Mercury Conference in Rio de Janeiro (May 1999).

Model State Legislation

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Richard Phillips

Richard Phillips spent two years designing and overseeing construction of water systems on the Navajo reservation. For the last 30 years he has supervised and managed programs for the Vermont Department of Environmental Conservation. Mr. Phillips managed the construction grant program, the wastewater operation oversight program, the enforcement program and the P2/Assistance programs. He has been responsible for the implementation of Vermont's mercury products labeling and disposal ban law passed in 1998. He has been involved with the development of the regional model mercury products legislation.

Mr. Phillips has a Bachelor and Master's degree from Northeastern University.

Model State Legislation (Northeast States Model)

This presentation is based on efforts of the Northeast States to develop model state legislation. This presentation will describe:

1. The basis for creating model mercury product legislation as recommended in the Regional Mercury Action Plan.
2. The process used to develop the model legislation.
3. The high points of the current draft model legislation which includes the following sections:

Legislative Findings
Definitions
Interstate Cleaning house
Notifications
Phase-out and Exceptions
Labeling
Disposal Ban and Scrap Facilities
Collection
Sales Restrictions
Disclosure
Limitations on Use
Public Outreach and Education
Universal Waste
State Procurement
Enforcement
State Review
Severability Clause
Effective Date
Administrative Fees
Appropriation
Public Notification and Review
Prohibition

4. The remaining steps to adoption as a regional model.

5. The status of state-by-state legislative initiatives.

NGO Perspective

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Ms. Jane Williams serves as the executive director of California Communities Against Toxics, a coalition of 80 community based environmental groups in California. She has a degree in economics from the University of California, Los Angeles and has eight years experience working on environmental issues with a focus on persistent, bioaccumulative toxins, Superfund sites, incineration, and nuclear issues.

She has worked extensively with community-based environmental/public health advocacy groups and Native American tribes on numerous pollution-related issues. Ms. Williams has also worked in Mexico on environmental issues with the Secretaria de Relaciones Exterior, the Instituto Nacional de Ecologia, Commision Nacional del Agua, and with non-governmental organizations in Mexico. She has presented papers at three different conferences in Mexico dealing with pollution and water policy issues.

She is also the Chair of the Waste Committee for the National Sierra Club. This committee has responsibility over many of the Club's pollution related issues including Toxic and Nuclear Waste, Superfund, Brownfields, Nuclear and Chemical Weapons, Solid and Medical Waste, Federal Facilities, and Environmental Justice issues related to waste.

Ms. Williams serves on the board of the California Environmental Research Group, the Clean Air Network, Greenaction, the California Stop Dioxin Exposure Campaign, the Del Amo Action Committee, and the Nonstockpile Chemical Weapons Forum. She is a past member of the Federal Advisory Committee on the Industrial Combustion Coordinated Rulemaking and a former member of the Regulatory Structure Update Technical Advisory Committee on Superfund for the State of California Department of Toxic Substance Control.

NGO Perspective

The United States and Canada agreed to the virtual elimination of persistent toxic substances into the Great Lakes under Article II of the Great Lakes Water Quality Agreement signed November 18, 1987. The current Mercury Action Plan does not serve as an integrated blueprint for actions that will achieve the elimination of mercury emissions into the environment. Forty states now have fish consumption advisories for mercury in fresh water fish due to the continued release of mercury into the air and water. Non-governmental organizations have become concerned about the lack of "linkage" between current EPA policy on mercury and the virtual elimination goal. They have set forth a series of recommendations which they believe would lead to the attainment of this goal, including steps that the EPA should take both in the short term and the long term. This paper will present these recommendations along with the rationale for their adoption.

Mercury Stock Management

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Mr. Dorgelo's role at the Ministry of Housing, Spatial Planning, and the Environment encompasses heavy metals policy, negotiations with the metal industry in The Netherlands – especially concerning the reduction of corrosion and run-off of copper, zinc and lead used for construction and building; recycling of plastics and packaging (waste) containing heavy metals; risk evaluation and risk management of metals (lead, mercury, cadmium, copper, zinc, chromium, nickel, bismuth, tin) and PNAs; and chemicals risk reduction programme of the OECD, Environmental Health and Safety Division (lead, mercury and cadmium). Mr. Dorgelo also participates in the European Commission DG Enterprise working group (chemicals, plastics and rubber) on the 'limitations on marketing and use of dangerous substances and preparations' (Directive 76/769/EEC).

Mr. Dorgelo earned his M.S. in Biochemistry (1974) from the State University of Leiden, has a Teaching Degree in Chemistry and is a registered toxicologist (Dutch Society for Toxicology).
PARCOM Decision 90/3 (1990) aims at the phase-out of the mercury cell process in the chlor-alkali industry in Europe by 2010. About 12,000 tons of mercury in Europe are now in use in this process. It is expected that these mercury stocks from the chlor-alkali industry, when becoming available due to phase-out of the mercury cell process, will end up in worldwide uncontrollable applications with diffuse emissions to air, water and soil. This concern for global transportation, application and emission of mercury is the main reason for the Netherlands to start a project to achieve commitments with industry for an environmentally proper and sustainable handling, transportation and disposal of the mercury stocks.

Mercury Stock Management

Mercury mining in Spain produces about 1,000 tons of mercury per year, mainly for export. No European policy dealing with the primary and secondary flows of mercury exists up to now.

The presentation will focus on the flow of mercury in the Netherlands, including recycling of mercury-containing waste to technical grade mercury. Experiences with two chlor-alkali production plants in the Netherlands phasing out their mercury cell process will be presented.

The actual situation of the mercury stocks in Europe will be presented with some preliminary policy options.

Sub-Seabed Emplacement: Long-Term Ultimate Disposition of Mercury Wastes

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Dr. Gomez has worked in nuclear waste management at Sandia National Laboratories in Albuquerque, New Mexico since 1977. He has been the biological research project manager for four ocean disposal projects and works in the Performance Assessment Department for the Waste Isolation Pilot Plant, a transuranic waste repository in southeastern New Mexico. Before going to Sandia, Dr. Gomez worked on a cancer therapy project at Los Alamos National Laboratory in New Mexico, and worked on a project to detect low levels of transuranic elements in workers at Oak Ridge National Laboratory in Tennessee.

Dr. Gomez has served as a U.S. representative on three international ocean pollution commissions. He is also an editor of the multinational journal, *Radioactive Waste Management and Environmental Restoration*. In addition to his work in nuclear waste management, Dr. Gomez has worked with the Institute of Public Policy at the University of New Mexico investigating the public's perceptions of risk of nuclear technologies. He has also been involved with Sandia's educational outreach activities from kindergarten through the college level.

Leo Gomez earned a Ph.D. in Radiation Biology at Colorado State University in 1973.

Emplacement of Mercury Wastes in the Sediments of the Deep-Ocean?

The primary goal of the U.S. Subseabed Disposal Project (SDP) was to assess the technical and environmental feasibility of disposing of high-level nuclear wastes in deep-sea sediments. Subseabed

disposal, like other geological disposal options, was a multibarrier concept that studied the feasibility of burial of solidified and packaged high-level nuclear waste or spent nuclear fuel in high-integrity canisters, tens of meters within the stable geologic formations of the deep-ocean floor. These deep-ocean floor geologic formations are some of the most stable and predictable on earth. In the subseabed concept the multiple barriers of the waste form, the canister, the clay sediments, and the ocean waters were predicted to delay migration of radionuclides until they decayed to innocuous levels.

The SDP was comprised of the following task groups: Site Assessment, Engineering Studies, Near Field, Sediment Barrier, Physical Oceanography, Biological Oceanography, Radiological Assessment, and Legal and Institutional. The SDP research team developed biosphere transport models to predict the oceanic transport of radionuclides. Researchers also developed the capability to determine and evaluate the risks associated both with normal disposal operations and with potential accidents. Safety assessments contributed to evaluation of the feasibility of the subseabed concept and helped focus required work to answer the feasibility questions. Even though the SDP models were developed to predict the transport of radionuclides, they can be used to predict the biosphere transport of non-radioactive environmental pollutants, such as mercury products and other toxic metals. Many of these pollutants cannot be destroyed or broken down through treatment or environmental degradation, and through physical, chemical, or biological processes will ultimately be deposited in the oceans.

Case Study of a Pilot Scale System for Removal of Organic Mercury from Pharmaceutical Wastewater

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Mr. Cyr has worked in the environmental industry since 1995, practicing environmental, civil, and geotechnical engineering. He has served as project/resident engineer for landfill construction projects and remediation of wetlands. His experience in the environmental field includes removal of contaminants from wastewater, compiling and evaluating data from contaminated sites, civil design, and management of a water

quality database. He has conducted lab testing of samples in an environmental and geotechnical laboratory. He also has experience in design, construction, and testing of pilot plants.

Mr. Cyr earned his Masters degree in Civil/Environmental Engineering (1999) from Villanova University, and his Bachelor of Science degree in Civil Engineering (1996) from Worcester Polytechnic Institute.

Case Study of a Pilot Scale System for Removal of Organic Mercury from Pharmaceutical Wastewater

Mercury discharged to the environment puts the public health and the environment at risk for toxic effects. Organic mercury as thimerosal (a benzene mercury sodium salt: $C_9H_9HgO_2SNa$) is used as an antiseptic and preservative in topical medicines, cosmetics, and vaccines. Hospitals use thimerosal for standard lab tests, such as albumin, herpes, hepatitis, and HIV, etc. Thimerosal and trace amounts of Hg^{2+} are present in wastewater from the manufacture of certain pharmaceutical drugs and quality analysis/control procedures. The scope of this study was to examine the technical feasibility of using adsorption technology for removing thimerosal and inorganic mercury from a pharmaceutical wastewater. Several adsorbents were selected based on their physical and chemical properties and their adsorption affinity for mercury. Batch isotherm and column studies were conducted to determine the most suitable adsorbent for removal of mercury. Results showed that F-400 GAC provided the best results for the removal of thimerosal and Hg^{2+}. A pilot plant was designed, constructed, and tested successfully for treatment of wastewater from a pharmaceutical manufacturing facility.

SAMMS Technology

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Self-Assembled Monolayers on Mesoporous Materials (SAMMS): A Novel Adsorbent for Mercury Removal from Waste Streams

A new class of hybrid mesoporous materials has been developed at the Pacific Northwest National Laboratory for removing toxic heavy metals such as mercury from aqueous and nonaqueous waste streams.

The basis of these novel adsorbent materials are organized monolayers of functional molecules covalently bound to a siliceous mesoporous support. The mesoporous supports are synthesized using surfactant liquid crystalline templates. The resulting mesoporous materials have high surface areas and ordered porosity in the nanometer size range. Functional molecules capable of selectively binding of mercury (thiol groups) are covalently attached to the mesoporous substrates as densely populated monolayers. Mercury adsorption data obtained over an eight order range equilibrium concentrations indicated that thiol-SAMMS can achieve Hg loading as high as ~635 mg/g. The high affinity for Hg adsorption by this material was reflected by K_d values as high as $1x10^8$ ml/g. The data also showed that mercury adsorption by thiol-SAMMS was not affected by the initial form of Hg (nitrate, chloride, and methylated) in solution. A study of mercury adsorption kinetics indicated that thiol-SAMMS bound Hg rapidly (about 99.9% adsorption occurring within first five minutes). Tests showed that neither the pH (2 to 10) or the ionic strength (0.01 to 4M) of simulated waste solutions did not significantly affect the mercury adsorption capacity of thiol-SAMMS. Waste streams containing Hg also typically contain many other cations (Ca, Cd, Cu(II), Fe(II), Ni, Pb, and Zn) and complexing anions (Cl, CN, CO_3, SO_4, and PO_4). Tests were conducted to examine the competitive adsorption effects of these cations, and the complexation effects of anions on Hg adsorption. The results indicated that the mercury adsorption capacity of thiol-SAMMS was not impaired by the presence of these cations and anions that would be present in different types of waste solutions. The reason for this noncompetitiveness of other cations appears to be due to preferential binding of a softer cation (Hg) by thiol functional groups. These adsorption characteristics show that thiol-SAMMS is a versatile and cost-effective material for removing, recovering, and recycling Hg from various types of waste streams.

Mercury Collection Programs in Sweden

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Ms. von Rein has been with the Swedish Environmental Protection Agency since 1990, and is the project leader for the Govermental Assignment that includes both an Action Programme for more efficient collection of used goods and products containing mercury and preparation of a proposal for final disposal in Sweden of mercury-containing waste.

Ms. von Rein has a M.S. degree in chemical engineering.

Mercury Collection Programs in Sweden

Phase-out of mercury

Several years ago Sweden decided that the use of mercury should eventually cease altogether, the target year being 2000. A mercury phase-out means that it is firstly the input of new mercury to society that is reduced. Still, large quantities of mercury are present in goods and products still in use. It has been estimated that in Sweden alone (8 million people) there are hundreds of tonnes of mercury in circulation in products.

Action Programme for the collection of mercury

The Swedish EPA was engaged in an Action Programme (1994 - 1999) as instructed by the government in order to improve the efficiency of mercury collection. The Swedish state had allocated about 20 million SEK for this purpose. The SEPA has given aid to 49 projects as well as carried out several projects of their own.

The SEPA programme has focussed on increasing the collection of hidden mercury in the form of:

- clinical thermometers containing mercury,
- mercury in technical goods and products,
- metallic mercury on shelves and in storage rooms, and
- "historic" mercury (in sinks, floor drains, tubes, etc.).

Many efforts undertaken in the action programme have been aimed at mercury inventory, on one hand identification and labelling of mercury in use and on the other hand collection of worn out mercury and discarded goods and products containing mercury.
A total of 10 – 11 tonnes of mercury has been identified, 6 – 7 of which have been collected and 3,5 – 4 tonnes have been labelled.

New ways of finding and collecting mercury

In different regions in Sweden, specially trained electricians, so-called mercury detectives, were visiting companies, local businesses, municipal sewerages to identify and collect or label mercury- containing products. Also, some projects involved tracing mercury with the world's first mercury dogs, Froy and Ville. The dogs have been searching for mercury in schools and at universities, finding mercury while saving both time and money. Several tonnes of mecury have been found this way. Swedish municipalities and county administrative boards have participated in all projects.

Phase-Out of Mercury-Containing Products

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Mr. Dorgelo's role at the Ministry of Housing, Spatial Planning, and the Environment encompasses heavy metals policy, negotiations with the metal industry in The Netherlands – especially concerning the reduction of corrosion and run-off of copper, zinc and lead used for construction and building; recycling of plastics and packaging (waste) containing heavy metals; risk evaluation and risk management of metals (lead, mercury, cadmium, copper, zinc, chromium, nickel, bismuth, tin) and
PNAs; and chemicals risk reduction programme of the OECD, Environmental Health and Safety Division (lead, mercury and cadmium). Mr. Dorgelo also participates in the European Commission DG Enterprise working group (chemicals, plastics and rubber) on the 'limitations on marketing and use of dangerous substances and preparations' (Directive 76/769/EEC).

Mr. Dorgelo earned his M.S. in Biochemistry (1974) from the State University of Leiden, has a Teaching Degree in Chemistry and is a registered toxicologist (Dutch Society for Toxicology).

Phase Out of Mercury-Containing Products in the Netherlands

The pollution by mercury in the Netherlands is largely caused by mercury-containing products. Closer examination of the Dutch flow of mercury into soil shows that in 1990 over 40% of the flow originated from mercury-containing products. For surface water, a similar percentage comes from mercury-containing products and for sewage sludge over 80% originated from mercury-containing products. This shows that taking product-oriented measures makes a relevant contribution to the reduction in mercury emissions and in addition to the quality of sewage sludge. To determine which products contain mercury and which alternatives are available, an inventory research was carried out.

The data from this research partly forms the basis for the Dutch 'Decree on products containing mercury 1998'. The use of mercury in the Netherlands was estimated at 12.5 tonnes in 1994. Approximately 45% of this can be accounted for by the use of amalgam in dental surgeries. Since 1991, emissions into the environment have been greatly reduced by the use of special amalgam separators. Approximately 40% is

used in various measuring instruments, electro-technical products and in lighting. The remaining 15% is used in batteries, chemicals, pharmaceutical preparations and in the chlor-alkali industry (mercury cell process).

The Decree is intended to achieve the mercury emission reduction objective. Through a ban on the manufacture of and trade in products containing mercury where alternatives are available, the supply of mercury within the economic circuit will be reduced by approximately 35%, or 4.3 tonnes per year. This relates to products such as measuring instruments and electro-technical products. As a result of the Decree, mercury emissions will gradually decrease, because it will take a few years before all the products containing mercury which are in use are replaced by mercury-free alternatives. Starting from the Dutch emission levels in 1990, the emission into sewage sludge, soil and water will decrease by 30%, 20% and 15% respectively. Existing facilities are used for the safe disposal of mercury-containing products.

Demonstration of Mercury Treatment Technologies to Meet DOE Customer Needs

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Mr. Hulet is the work package manager for the Unique Waste Work Package, which includes DOE's mercury mixed wastes. As such, he coordinates research, development, and technology deployment activities to ensure that all the wastes in the Unique category have a path for treatment and disposal. He has a Masters Degree in Chemical Engineering and ten years experience in waste management and pollution prevention. He also has considerable experience with Naval Nuclear Propulsion Plants. He has been a scoutmaster for 15 years, which, after watching scouts cook for that long, has made him an expert in unique hazardous wastes.

DOE Mercury Waste Treatment Demonstrations

Mercury has been used in Department of Energy (DOE) operations in a variety of applications. It has been used as a catalyst in nuclear fuel reprocessing, as shielding, and as a component of isotope separation processes. It is still being used in a number of facilities. Because of its widespread use, mercury contamination can be found at most DOE facilities. Efforts to clean up, treat and dispose the associated wastes are underway. However, for some DOE mercury wastes, until recently, no treatment processes were

available that had been demonstrated to be safe and effective in a radioactive environment. The DOE Mixed Waste Focus Area (MWFA) has been supporting research, development, demonstrations, and technology deployments to ensure that all mercury-contaminated waste can be safely treated and disposed. These activities have been divided into three main areas: amalgamation, stabilization, and separation. Subcategories of separation include removal of mercury from water, extraction from solid matrices, and gaseous emission control.

DOE supported the demonstration of two commercial mercury amalgamation processes. Both successfully amalgamated radioactive waste elemental mercury from DOE sites. The final waste forms met the Land Disposal Restriction for mercury, O.2 ppm by Toxic Leach Characteristic Procedure (TCLP). Vapor pressure data for the waste forms are available.

The MWFA coordinated several commercial demonstrations for stabilization of mercury mixed waste with <260 ppm mercury. Allied Technology Group (ATG), Nuclear Fuel Services (NFS), and International Technologies (IT) performed bench-scale studies using surrogate waste with several species of mercury. ATG, NFS, and GTS Duratek demonstrated their respective processes on actual waste. In all cases the stabilized mercury met LDR limits. Reports covering each of these studies are available from the MWFA. Demonstrations are presently underway to treat >260 ppm mercury waste from Brookhaven National Laboratory (BNL). Sepradyne/Raduce is using their vacuum thermal desorption unit to extract mercury from the waste, while ATG, NFS, and BNL are using stabilization processes to treat the material. DOE is working closely with EPA on this project to acquire data that may support a change in the regulations for treatment of >260 ppm mercury-contaminated soils and sludges. BNL is the only group to have completed testing.

The DOE program for development of a process to extract mercury from solid matrices by non-thermal means is currently on hold because of funding cutbacks. The Polymer Filtration process dissolves mercury in shredded matrices and separates it from the solution using a complexing polymer. The process is ready for pilot-scale demonstration.

Oak Ridge conducted comparison tests of mercury sorbents on mercury-contaminated stream water from their East Fork Poplar Creek. ADA Technologies also tested their mercury sorbent process on the creek water with good results. Reports are available that summarize these two projects.

The MWFA is investigating continuous emission monitors for mercury but units are not available yet for commercial deployment. ADA has made progress in this area and in the area of sorption of mercury from gas streams.

Budget reductions have impacted work on the DOE mercury problems. Hopefully, funding will be available in fiscal year 2001 to bring the work to fruition.

Return and Recycling of Used High Intensity Bulbs for Recycling and Closed-loop Mercury Control

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Return and Recycling of Used High Intensity Bulbs for Recycling and Closed-loop Mercury Control

Mercury is recognized as a highly toxic material and is stringently regulated in waste discharges. The majority of these discharges contain mercury in low concentrations limiting the control and recovery options. Wastes from a variety of industries generate wastewater containing residual mercury, including: lighting, medical, photographic, chloralkali, electronics and power generation.

The lighting industry has begun to address control and the reuse of mercury while they are trying to find substitute materials that adjust the electrical characteristics for the discharge lamp. One company has instituted a return of used high intensity lamps and the recovery of mercury from them. This program helps prevent mercury from entering into the eco-system. Some of the used and crushed glass is washed to insure the complete removal of mercury.

Typical treatment of wastewater requires multi-step processing ending in polishing steps that scavenge or trap residual mercury. These processing schemes result in added treatment costs and generate hazardous waste. A closed-loop mercury control/recovery system can reduce these treatment and disposal costs. The technology under development provides a means of accumulating sufficient mercury that recovery is possible and, at the same time, allows the minimization of the process wastewater by operating in a recirculating loop. Mercury is converted to its ionic form *in-situ* by chemical oxidation to improve solubility and is recovered electrolytically. The recovered mercury is relatively pure depending on the other contaminants present and potentially requires little additional processing before reuse.

Mercury Amalgamation Demos With the DOE

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Mr. Brown is currently the Vice President of Operations for ADA Technologies, Inc. -- a Denver-based technology R&D firm. Mr. Brown has 23 years of experience at Oak Ridge National Laboratory managing and performing R&D related to reactor fuel processing, coal conversion, and environmental processes.

Mr. Brown has B.S. and M.S. degrees in Chemical Engineering. Mr. Brown is also a Professional Engineer.

Recent Advances in Mercury Stabilization Technology

Since the early 1950s, mercury has been widely used throughout the DOE weapons complex. The legacy is contaminated solid waste, soils, and water. The main holders of mercury-contaminated waste are the Oak Ridge Reservation, the Idaho National Engineering and Environmental Laboratory, and the Savannah River Site.

Nationally, the largest categories of mercury-bearing wastes are sludges, soil, and debris. The Environmental Protection Agency subdivided mercury-contaminated solid wastes into three subcategories.

- Radioactively contaminated elemental mercury – treatment is amalgamation
- Low-mercury subcategory – treatment is stabilization
- High-mercury subcategory – treatment is thermal retort, followed by amalgamation if the recovered mercury is radioactively contaminated

ADA Technologies, Inc., has demonstrated and filed a patent for a process to handle radioactive elemental mercury. In recent studies this initial work has been extended to soil matrices that are contaminated with greater than 260 ppm mercury. Results derived from both of these studies will be presented and discussed.

Deployment of the Sulfur Polymerization and Stabilization Process as Applied to Mercury Contamination in Soils

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Paul Kalb is a Senior Research Engineer at Brookhaven National Laboratory. He has a bachelor's degree in mechanical engineering from the State University of NY at Binghamton and a master's degree in nuclear engineering from Polytechnic Institute of NY. Paul has been employed at BNL for 20 years and has concentrated his efforts in the areas of hazardous/radioactive waste management, environmental restoration, and health and safety aspects of emerging energy technologies. Current responsibilities include Principal Investigator for programs on D&D and waste form development for DOE and industry. He has served as a member of several national technical support groups on Final Waste Forms for DOE and EPA, recently currently chaired a team that wrote a WASTECH volume on Stabilization/Solidification, is a member of the Program Advisory Committee for Waste Management Symposia, Inc., and has numerous patents and publications in the area of waste treatment and encapsulation.

Trevor Jackson

Dr. Jackson received his Ph.D. in Mechanical Engineering from Oklahoma State University in 1983. He spent two years as an Assistant Professor at the University of Maryland then progressed into industry. He was the site engineer at the solar energy plants located in the Mojave desert of Southern California, responsible for upgrades of existing plants. In 1988 he joined Science Applications International Corporation (SAIC) in San Diego providing assistance to the EPA in evaluating innovative technologies for the treatment of hazardous waste in the Superfund Innovative Technology Evaluation Program (SITE). He was Project Manager for the evaluation of many different technologies ranging from novel incinerators to bioremediation. In 1998 Dr. Jackson joined Envirocare of Utah, Inc., as Technology Development Manager. In this role he is responsible for reviewing and implementing treatment technologies for mixed low level waste at the Envirocare TSD facility in Utah. Dr. Jackson also upgrades performance of the existing stabilization, micro-, and macroencapsulation technologies.

Treatment of Elemental Mercury and Mercury Contaminated Soil and Debris by the Sulfur Polymer Stabilization/Solidification Process

Elemental mercury contaminated with radionuclides (mixed waste mercury) and mixed waste mercury-contaminated soil and debris, is a problem throughout the Department of Energy (DOE) complex. This presentation describes an innovative process developed at Brookhaven National Laboratory (BNL) and currently being commercialized at Envirocare of Utah, Inc., to immobilize mixed waste elemental mercury and mercury-contaminated soils and debris. The product is a monolithic solid waste form that is non-dispersible, will meet current and newly adopted EPA leaching criteria, and has low mercury vapor pressure. The BNL Sulfur Polymer Stabilization/Solidification (SPSS) process (patent pending) is a two-stage process that chemically reacts with mercury to form a product of low solubility and vapor pressure and then solidifies the product in a solid matrix to further reduce leachability and dispersion of contaminants. Waste forms containing as much as 33 wt% elemental mercury and as much as 60 wt% mercury-contaminated soil were formulated which successfully passed current Environmental Protection Agency Toxicity Characteristic Leaching Procedure (TCLP) criteria as well as the more stringent Universal Treatment Standard criteria that has been approved. In addition, the final waste form products exhibit extremely low leachability when subjected to long-term leaching, and significantly reduced vapor pressure compared with untreated mercury. Bench and pilot-scale development at BNL is complete and plans for commercial deployment at Envirocare's Clive UT mixed waste treatment facility are underway. The process may also be applied for direct and simple treatment of hazardous mercury streams as-generated or produced as secondary wastes from mercury separation technologies.

Commercializing a Safer Substitute for Mercury

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James Rancourt, Ph.D.

Dr. James Rancourt obtained an undergraduate degree in Chemistry at the University of Lowell in Massachusetts. He earned a doctorate in chemistry, with an emphasis on analysis and preparation of electrically conductive plastics, from Virginia Tech. In 1987, Dr. Rancourt founded Polymer Solutions Incorporated, a company that provides innovative technical solutions to polymer and materials programs.

Dr. Rancourt led a research team to develop alternative materials for the mercury metal that is used in electrical switch applications, in 1992, at the request of the Virginia State Government. Dr. Rancourt's team now has four international patents and commercial products. He is the President of NewMerc, Ltd., a company devoted to producing reliable alternative materials to mercury metal for industrial and government applications.

Commercializing a Safer Substitute for Mercury

Mercury metal is a fundamental chemical element that has unusual properties: volatile, electrically conductive, reflective and liquid to low temperatures. Unfortunately, mercury metal, when handled or disposed of improperly, poses environmental and health risks. It is becoming increasingly important that mercury be replace in industrial applications with a less toxic and reliable material. NewMerc, Ltd., has an exclusive, all-fields worldwide license to technology that offers a safe replacement for mercury in many applications.

This presentation will provide a brief description of the impetus for the nonmercury alloy development project, the research approach that was taken and the rationale for the technical solution that has been developed. The presentation will provide information about the composition of the alloy, its method of preparation and application areas. In addition, the properties of the NewMerc alloy, its MSDS sheet and questions remaining for the full-scale implementation of the patented material will be provided. A brief overview of the company structure will also be provided.

The Business of Mercury Pollution Prevention: Identifying Source Reduction Opportunities and Engineering Trade-Offs

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Kenneth Stone is the Engineering Trade-Offs Team Leader for EPA's National Risk Management Research Laboratory, based in Cincinnati, Ohio. Ken has been with the EPA for 18 years and has worked primarily in pollution prevention research with an emphasis on federal facilities and operations. Ken founded and managed the Life Cycle Engineering and Design Program, a cooperative venture with DoD to apply Life Cycle Engineering and pollution prevention methodology to industrial

systems. Ken's team is conducted research to advance the state of the practice of LCE and has completed several LCE case histories on both public and private products and operations.

The Business of Mercury Pollution Prevention: Identifying Source Reduction Opportunities and Engineering Trade-Offs

The demand for mercury in the United States is still growing or declining only slightly in a number of industrial sectors. These include electric lighting, electronic equipment, wiring devices and switches, measurement and control instruments, dental equipment and supplies, laboratory uses, and medical uses. About 190 tons of mercury were used by these sectors in 1997. While EPA is pursuing a number of voluntary initiatives within these industries, information on consumption, use, release and environmental impact is poor. Therefore, an assessment is underway to collect the data needed to identify the potential for source reduction across industry sectors. This assessment will determine in which areas emissions are large and difficult to measure. This assessment will incorporate collaborative activities with industry, including providing systems analysis tools such as Life Cycle Engineering (LCE) and Engineering Trade-Offs (ETO) to help industry determine the economic, energy, and environmental costs and benefits of management options.

The National Risk Management Research Laboratory (NRMRL) has initiated a Pollution Prevention Prioritization Assessment (P2PA), based on evaluation of the potential for source reduction of mercury use in the consumer sector, to identify major needs and opportunities for reduced use and releases. The P2PA will guide the development of at least two evaluations of pollution prevention approaches for mercury using life cycle analysis, and determine the reduction in adverse environmental impacts. The P2PA will also guide the selection of sector activities for evaluation of engineering trade-offs and input/output modeling.

ORD will use research innovative and emerging technologies for reducing reliance on mercury and mercury-containing products in these industries. This investigation will focus on source reduction opportunities. A compendium of technologies and technical solutions will be developed in order to inform the next step of the plan, prioritization.

A PBT Technology Information Clearinghouse

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Mr. Fred Booth is the senior economist at WPI and has more than 25 years experience in leading economic, energy and environmental analysis programs. His experience includes analyses and optimization of energy, economic, and environmental system interactions; development of global climate change decision support tools and programs; development of environmental information systems architectures; systems analysis of local, regional, and national energy policy/regulatory issues; alternative fuels and electric utility demand forecasting; and technology diffusion analyses of advanced energy technologies. He has experience in evaluating the economic implications of proposed amendments to both RCRA and CERCLA. Additionally, his experience includes environmental technology cost analysis model development, econometric analyses, comparative and parametric life cycle cost modeling, innovative environmental technology cost-benefit analyses, and evaluation/demand forecasting for emerging technologies, particularly in energy and environmental markets.

Kay Van der Horst

Mr. Van der Horst is the Associate Director for Environmental Security Programs for WPI, a Virginia Tech owned not-for-profit organization. He is a specialist on domestic and international environmental security concerns with a particular emphasis on stakeholder involvement and risk communication. Currently, he is co-leading for WPI the development of EPA's new "PBT Information, Communication and Decision Support Clearinghouse". His responsibilities also include the development and implementation of Stakeholder Communication, Risk Communication, Training and Community Outreach Programs. Other programmatic areas focus on the development on risk management response and systems engineering. Prior to WPI Mr. van
der Horst has worked in various capacities on environmental security issues for the University of Alaska–Fairbanks, Texas A&M University and various international institutions such as the United Nations and the European Parliament.

The EPA PBT Information and Communications Clearinghouse

Many EPA Offices individually address Persistent Bioaccumulative Toxics (PBTs) in varying contexts. The basic goal of the PBT Initiative is to identify and reduce risks to human health and the environment from current and future exposures to priority PBT pollutants and address them in an integrated manner. Implicit

in achieving EPA's objectives in the PBT initiative is effective, efficient, and focused information management in the context of PBT technical data, scientific data, and communications/outreach efforts. This presentation addresses the key aspects of developing and implementing an EPA/OPPT PBT Information and Communications Clearinghouse. This concept evolved from discussions with representatives of the various EPA Offices and programs represented on the Mercury Task Force.

The structural approach contemplated in the Clearinghouse is straightforward: Develop generic information management structures and strategies that are sufficiently flexible such that they can be adapted to accommodate potentially unique informational dimensions of any PBT, yet are consistent, comparable, and robust. Key features of this approach include: creating processes that support information flows into and from the Clearinghouse, and providing on-going opportunities for stakeholder information inputs in a dynamic information management environment. This approach directly contributes to ensuring cost effectiveness via economies of scale in managing multiple PBT data sets, and enhances the ability of the Clearinghouse to transparently provide user interfaces to similar information management activities at other federal agencies, universities, and research organizations.

The activities conducted in assessing the aspects of developing and implementing an EPA/OPPT PBT Information and Communications Clearinghouse will include:

- Defining the specific mission, objectives, and goal(s) of the PBT Clearinghouse;
- Defining/characterizing alternative PBT Information Clearinghouse structural approaches and the relative strengths and limitations of each structural alternative;
- Identifying preliminary opportunities for programmatic leverage;
- Identifying/characterizing the benefits of the PBT Clearinghouse;
- Identifying/characterizing existing information management activities that could either contribute to, or be considered competitive with, the OPPT PBT Clearinghouse;
- Identifying/characterizing the specific PBT Clearinghouse pre-implementation activities that will contribute to a successful, cost-effective, highly functional PBT Clearinghouse;
- Defining/characterizing stakeholder audiences (and their needs) for the mercury module of the PBT Clearinghouse;
- Identifying critical PBT Clearinghouse Quality Assurance issues, including information consistency, comparability, data validation and verification, and systems configuration;
- Identify international mercury information activities, including DOE/FETC, UAF, UNEP, AMAP, and the European Union; and

- Consideration of risks (technical, information management, performance, schedule) inherent in developing and implementing an activity such as the PBT Clearinghouse.

The EPA PBT Industry Technology Market Forum

Implicit in achieving the objectives of the EPA PBT initiative's guiding principles is the effective, efficient, and focused management of PBT information, scientific data, and communications/outreach efforts. These guiding principles include:

· Addressing problems on multimedia bases through integrated use of all EPA tools;
· Coordinating with and building on relevant international efforts;
· Coordinating with and building on relevant federal programs and agencies;
· Stressing cost-effectiveness (amount of PBT removed per dollar spent);
· Involving stakeholders;
· Emphasizing innovative technologies and pollution prevention;
· Protecting vulnerable sub-populations;
· Basing decisions on sound science; and
· Using measurable objectives and assess performance.

The subject of this presentation is assessing the key aspects of developing and implementing an EPA/OPPT PBT dynamic, stakeholder driven EPA/Industry Technology Market forum that is an integral element of an OPPT/PBT Information and Communications Clearinghouse which will directly contribute to implementing the guiding principles of the PBT Initiative. The EPA/Industry Technology Market Forum:

- Provides Regulatory Compliance Incentives for Industry by Providing Cost Savings Opportunities;
- Eases Regulatory Compliance Support by Providing Industry With Higher Production Efficiency Opportunities;
- Creates a Marketplace for Intercomparable/Verifiable Innovative Technologies;
- Fosters Development of Innovative Technology Developments by Expanding Hidden Technology Visibility; and
- Fosters Global Environmental Technology Improvement and Exchange.

The initial focus of the EPA Environmental Technology Market Forum will be mercury-related information, communications products and services. Though initially driven by a mercury focus, the EPA Environmental Technology Market Forum will be designed to accommodate a larger environmental technology market that addresses technology needs of all other PBTs.

WPI currently also supports the Department of Energy-National Energy Technology Laboratory (DOE-NETL) in the design, development and implementation of its Decision Support Center. The first information module in the Center focuses on DOE's coal combustion-based mercury data collection and analysis program. The NETL effort is also significantly driven by providing comparable technology solutions and information. This project represents both a unique opportunity for OPPT and the Mercury Task Force to apply real-time lessons learned from the NETL program, and additionally, leverage EPA and DOE mercury

program funds to improve the overall programmatic return on investment. Most significantly, the successful creation and implementation of the Environmental Technology Market Forum, in conjunction with the PBT Clearinghouse concept, represents the first of an on-going series of opportunities to leverage limited EPA resources.

Mercury Stabilization in Chemically Bonded Phosphate Ceramics

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Dr. Wagh is working as a materials research engineer at Argonne National Laboratory and has a Ph.D. in physics. His expertise includes radioactive waste management, mineral waste management, and structural ceramics.

With his colleagues who are co-authors of this presentation, he developed chemically bonded phosphate ceramic program for radioactive and hazardous waste stabilization at Argonne National Laboratory, pioneered research on bauxite tailings (high volume residue from alumina refineries), directed projects related to utilization of greenhouse CO_2, and hot gas ceramic cross-flow filters at Argonne National Laboratory, and worked as consultant to alumina industries, that include, ALCOA, ALCAN, and Virgin Island Alumina Co.

Dr. Wagh was a recipient of the R&D-100 Award given by R&D Magazine in 1996 for 'Ceramicrete Binder', and the Pace Setter award by Argonne National Laboratory in 1997.

Mercury Stabilization in Chemically Bonded Phosphate Ceramics *

Mercury stabilization and solidification is one of the challenges for the conventional stabilization technologies. This is because of the stringent limits on leaching of its stabilized products that need to be enforced. In a conventional cement stabilization process, Hg is converted to its hydroxide at high pH which is not a very insoluble compound and hence sulfidation of Hg is considered to be a preferred route which converts it into an insoluble cinnabar (HgS). Unfortunately, efficient formation of this compound is pH dependent. At a high pH, one obtains more soluble sulfate of Hg, in a low pH range insufficient immobilization results due to

escape of hydrogen sulfide, while efficient formation of HgS occurs only in a moderately acidic region. This is the region (pH = 4-8) in which stabilization using Chemically Bonded Phosphate Ceramics is carried out.

This presentation will discuss this kinetics followed by our experience on bench stabilization of various U.S. Department of Energy (DOE) waste streams containing Hg in the Chemically Bonded Phosphate Ceramic (CBPC) process. This process was developed to treat DOE's mixed waste streams. It is a room-temperature-setting process based on an acid-base reaction between magnesium oxide and monopotassium phosphate solution that forms a dense ceramic within hours. For Hg stabilization, addition of a small amount (<1 wt.%) of Na_2S or K_2S is sufficient in the binder composition.

Here we discuss the Toxicity Characteristic Leaching Procedure (TCLP) results on CBPC waste forms of secondary waste streams generated from Hg-containing wastes such as combustion residues and Delphi "DETOX^{SM}" residues. The results show that though the current limit on leaching of Hg is 0.2 mg/l, the results on the CBPC waste forms are at least an order lower than this stringent limit. This low leaching level provides robustness to the process and allows sufficient margin for the variability of Hg content in the waste. The efficient stabilization is attributed to chemical immobilization of Hg as cinnabar followed by its physical encapsulation in a dense matrix of the ceramic.

Using this process, Argonne-West has eliminated Hg-contaminated light bulbs from its inventory. These bulbs were slightly contaminated radioactively and hence this was a typical mixed waste stream. This presentation will provide a brief review on this work as an example of disposal of Hg-contaminated actual waste.

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Characterization and Leachability of Stabilized Mercury-Containing Wastes

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Linda Rieser joined the University of Cincinnati in 1981. She served as Senior Research Associate from 1981 to 1991 and as Academic Director of UC's Accelerated Life Testing and Environmental Research (ALTER) Facility for the last 9 years. Her expertise includes the application of experimental methods to problems involving the solubility and mobility of hazardous and radioactive elements, the origin and remediation waters and soil, and the treatment of hazardous and radioactive wastes.

Characterization and Leachability of Stabilized Mercury-Containing Wastes

EPA's National Risk Management Research Laboratory (NRMRL) in collaboration with the University of Cincinnati established a research program supporting Agency actions on mercury; in particular, the potential revisions to the Land Disposal Restrictions for mercury-bearing wastes. Over the past year, research has been conducted on the characterization and leachability of several mercury waste forms. Wastes studied include mercuric sulfide sludges from several chemical plants, mercuric chloride catalyst used in the manufacture of vinyl chloride, surrogate mercuric chloride and elemental mercury wastes This presentation describes characterization of the stabilized waste samples and analysis of leaching stability. The testing includes TCLP analysis and constant pH leaching tests to determine the potential mobility and stability of the mercury under simulated landfill conditions.

The work to be presented was performed by Paul Randall (EPA) and Paul Bishop, Haishan Piao, Renee Rauche, Linda Rieser, Makram Suidan, and Jian Zhang (UC).

Treatment of Wastes Contaminated with Mercury

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Dr. Lear has over 12 years experience in the treatment of hazardous waste with dewatering, soil washing and stabilization treatment technologies. He has experience in selecting and evaluating treatment alternatives and providing data for preliminary design activities and project equipment specifications. He has conducted research in the area of innovative stabilization systems, including systems for the stabilization of organic contaminants in hazardous wastestreams. Dr. Lear has also conducted research into the stabilization of metals, concentrating on arsenic, mercury, thallium, vanadium, antimony, and beryllium. He has extensive experience in the stabilization of hard-to-treat wastestreams, such as hazardous waste incinerator residues. Dr. Lear has hands-on experience with full-scale remediation activities and specializes in process troubleshooting. He has provided technical operational support to bioremediation, dewatering soil washing, stabilization, thermal, and wastewater treatment activities at remedial sites. He has also managed several pilot- and field-scale technology demonstrations.

Treatment of Wastes Contaminated with Mercury

This presentation will focus on the treatment of wastes contaminated with mercury. Four technologies (heavy metals bioremediation, surface decontamination, stabilization, and thermal desorption) applicable for the treatment of mercury wastes will be discussed, along with data from selected case studies.

Heavy metals bioremediation involves the stimulation of naturally occurring or augmented sulfur-reducing bacteria. These bacteria produce sulfuric acid and reduce the pH of the waste to below 2. Leaching of water through the waste removes the solubilized metals. The metals are then precipitated from the leach solution and sent for metals recovery or disposal.

Surface decontamination combines physical and chemical removal of contamination on the surface of debris such as concrete, block, and scrap metal. Extraction solutions containing chelants or acids are applied to the surfaces, allowed to react, and collected. Vacuum techniques are often applied to remove the extraction solution from semi-porous surfaces such as concrete. Multiple extractions are often required, especially on semi-porous surfaces.

Stabilization of mercury involves re-speciation of the mercury contamination to mercury sulfides. The chemistry required for re-speciation depends on the form of mercury in the waste. The solubility of mercury

sulfides is on the order of 10 mg/L. The mercury sulfides are then encapsulated in a cement matrix.

Thermal desorption involves the direct or indirect heating of the waste to volatilize the mercury. The temperature required for the volatilization depends on the form of mercury in the waste. The volatilized mercury is then condensed in the air pollution control system for recovery or disposal.

Case histories involve the application of thermal desorption and stabilization treatment technologies to mercury-contaminated wastes.

Treatment of Mercury-Bearing Wastes with Thermal Desorption Technology

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Mr. Malkmus received his degree (BS 1979) in Chemical Engineering from Clemson University with specialization toward Environmental Engineering. He has over 20 years experience in the design, startup operation and project management of waste processing systems used in the commercial and energy industries including the Department of Energy and commercial nuclear power plants. Mr. Malkmus has designed large scale, proprietary waste treatment systems incorporating advanced water processing and state of the art waste minimization technologies. He has published several technical papers regarding technology advances through EPRI, US DOE and the International Water Conference.

High Vacuum Rotary Retort for the Recovery of Products and the Minimization of Wastestreams

At a Westinghouse subsidiary, Scientific Ecology Group, Mr. Malkmus served as a fellow engineer responsible for the evaluation, development, and deployment of new technologies for waste treatment applications in addition to serving as a project manager in the Operations Department. Prior to that, he held engineering and operation management positions with VECTRA Technologies, the SCANA Corporation: VC Summer Nuclear Power Plant and the NUS Corporation.

The SepraDyne Corporation has commercialized an extremely cost-effective process for removing and recovering constituents having boiling points below 800°C. The process further provides a highly efficient reduction in the volume of any remaining non-volatilized media. The process material is indirectly heated within a rotating vessel under a high vacuum inert environment. The constituents of concern are volatilized and diffused from the feed material through the off-gas treatment train. Volatile constituents are condensed to liquid through an advanced impinger, chill water system. By operating under high vacuum, the material boiling points are significantly reduced thus enabling the ease of product recovery at lower operating temperatures. There is little decomposition of products due to thermal energy. Since the desorption and product recovery process is performed in an oxygen-free inert environment, there is no generation of furans and dioxins as well as any products of incomplete combustion. All retort off-gases are condensed to liquid eliminating the potential release of toxic substances to the atmosphere and thus permitting the recovery of the constituents for beneficial use. In addition, secondary waste streams are not produced because a steam or gas stripping media is not required to remove and transport chemicals from the processed material.

This paper will provide an overview of SepraDyne vacuum desorption system(s) and outline the technological advances of the indirectly heated high vacuum retort. Also included are the results of several commercial and DOE applications for the separation of mercury from previously classified waste stream sources the minimization of waste sources and the near complete destruction of furans and dioxins.

Permanent Mercury Disposal in Sweden

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Ms. von Rein has been with the Swedish Environmental Protection Agency since 1990, and is the project leader for the Govermental Assignment that includes both an Action Programme for more efficient collection of used goods and products containing mercury and preparation of a proposal for final disposal in Sweden of mercury-containing waste.

Ms. von Rein has a M.S. degree in chemical engineering.

Permanent Mercury Disposal in Sweden

Phase-out of mercury

Mercury is currently being phased out by means of various bans on the use of goods and products containing this metal, the target year being 2000. Also, the export of mercury as a residual product has been prohibited since July 1, 1997. Exports of mercury waste for reprocessing and reuse abroad is not a feasible alternative, at the same time as use of mercury in Sweden is being phased out. The Agency believes that capacity for disposal of mercury-containing waste should exist within the country.

Mercury is one of the most toxic of all pollutants. The burden of mercury on our environment must be reduced since every addition is undesirable. The Swedish EPA believes that it is our generation that must reverse the trend in order to create a healthy living environment for future generations. The question of how to store waste containing mercury ultimately concerns finding a way of detoxifiyng our society.

Disposal of mercury-containing waste

Large quantities of discarded goods are currently in storage pending a solution. Large amounts of waste are also stored in industry, either temporarely or at sites which do not meet long-term environmental safety requirements. The Swedish EPA considers this situation to be untenable. It is therefore essential to find a method for the terminal storage of mercury.

In December 1997, the Swedish EPA presented a report, concluding several years of investigations, to the Swedish government with the conclusion that disposal of waste containing mercury demands a tailor-made solution. The Swedish Environmental Protection Agency believes that mercury-containing waste should be disposed of in such a manner that the mercury leaks to the external environment as little as possible, viewed in a long-time perspective.

Deep storage rock - the best alternative

Alternative solutions have been compared, with a view to finding the form of terminal storage which best fulfils stringent environmental requirements. The alternatives compared are high-quality surface storage, shallow storage in rock and deep storage in rock. These options differ in philosophy and the way in which the surrounding environment must be protected against emissions.

The EPA considers that deep storage in rock is the safest method of storage in the long term, since it is the solution most in harmony with the environment; i.e., nature is used as a barrier and a buffer. The surrounding bedrock will protect the functionality of the storage facility for thousands of years or even longer. This solution can and should also be accompanied by technical measures to further reduce the risk of future emissions and to compensate for our lack of knowledge about the long-term processes governing the dispersal of mercury.

Sub-Seabed Emplacement: Long-Term Ultimate Disposal of Mercury Wastes in Geologic Formations on Land

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Dr. Anderson has 39 years of experience at Sandia National Laboratories and currently is the Project Manager for Sandia activities supporting the Waste Isolation Pilot Plant. Dr. Anderson's responsibilities include: technical analysis, code development, quality assurance, testing, field and laboratory data analysis, geotechnical and geochemical analysis, and incorporating the above into performance assessment calculations for the Waste Isolation Pilot Plant.

Dr. Anderson is an internationally recognized expert in risk and performance assessment. As manager of the WIPP Performance Assessment Department, Dr. Anderson led the construction and preparation of performance assessment analysis for a compliance certification application to EPA which has led to the opening of the first deep geological repository for radioactive wastes in the U.S. Dr. Anderson also has led numerous waste disposal and management efforts, including, but not limited to, the Sub-Seabed High Level Waste Project, the FUSRAP Disposal Program, and the Decommissioned Nuclear Submarine Program.

Dr. Anderson has authored and co-authored more than 50 publications and reports dealing with waste disposal, performance assessment and risk assessment. Dr. Anderson is also the editor of the *Radioactive Waste Management Journal*.

Dr. Anderson earned a B.S. in Chemistry (1957) from Idaho State University, and a Ph.D. in Theoretical Organic Chemistry and Chemical Oceanography (1961) from Oregon State University.

Land-Based Geologic Emplacement of Mercury Wastes

In 1979, Congress authorized the U.S. Department of Energy to build a research and development facility - the Waste Isolation Pilot Plant (WIPP) - to demonstrate the safe disposal of defense nuclear wastes containing transuranic radionuclides. The WIPP, located near Carlsbad, NM, was opened as the world's first nuclear waste repository and received its first shipments of transuranic wastes in March 1999.

The overall process of assessing whether or not a waste disposal system meets a set of performance criteria is known as a Performance Assessment (PA). The WIPP PA, conducted by Sandia National Laboratories,

provided important input to decisions on the safety of a plan of action using a detailed procedure and scientific knowledge. For radioactive wastes, a computationally demanding set of risk-based performance criteria was specified by the U.S. Environmental Protection Agency (EPA). These were quantitative criteria that specified probabilistic limits that had to be met for the first 10,000 years of operation of a nuclear waste facility. The WIPP PA group developed a suite of models to predict future behavior of the facility. The physical, chemical, and geological processes that determined the behavior and evolution of the WIPP site were complex and highly nonlinear. The PA models that describe the processes are complex and technically sophisticated, and can be used to study the feasibility of the disposal of non-radioactive environmental contaminants with infinite half-lives, such as mercury product wastes, in a land-based repository.

Mercury-Sniffing Dogs: The Swedish Experience

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Kjell Avergren

Mr. Kjell Avergren has worked with environmental issues on both a governmental and a consultant level (local, regional and national) since 1980. He has lead the four Mercury Tracing Dogs projects within the Swedish EPA´s mercury collecting program.

The Dog Training Centre in Solleftea and Mercury Decontamination.

Mercury - An environmental problem

Mercury is one of the world's most serious pollutants. One way to protect the environment is to remove the mercury and deposit it in safe storage. The Swedish Parliament has concluded that mercury plays no part in the natural world and the use of mercury should be phased out by the year 2000. In several mercury-collecting projects with the Swedish EPA, the Dog Training Centre in Sollefteå showed that it is possible to obtain low-cost, successful, and rapid results using mercury tracing dogs. The strategy was to work together with many different actors, rather than using new or more regulations. The outcome was remarkable..

Mercury Dogs - The Cost-Effective Solution

In laboratories and chemical store cupboards, in hospitals, doctors' surgeries and dentists' consulting rooms and throughout industry, mercury can be found in sinks, drains and sewage systems. The Dog Training Centre now offers a mercury tracing service using sniffer dogs (The German Shepherd mr Froy and the labrador mr Ville Sigmund) and dog handlers. The service enables the cost-effective recovery of the mercury and prevents it from being dispersed in the environment through refuse or in the sewage system. Using sniffer dogs benefits the environment and the customer's bank balance. Tests have shown that using the dogs protects the environment, saves time and money, and generates goodwill.

More than 3,000 kg of mercury were collected from more than 1,200 schools, 20 universities and many hospitals taking part in different Swedish EPA projects. A number of doctors' surgeries, dentists' rooms, laboratories and business premises also participated in the projects. The dogs traced hidden mercury in sinks and floors in many thousands of buildings. German Shepherd mr Froy and labrador mr Ville Sigmund from the Dog Training Centre in Solleftea, Ltd., saved at the same time up to 3-3.5 million U.S. dollars in reduced decontamination costs. On average 5.300-8.800 U.S. dollars in clean-up costs were saved each working day, resulting in a short pay-off time.

The dogs' achievement has attracted positive publicity from television, radio, newspapers, magazines and on the Internet in both Sweden and abroad. They have been the subject of more than 2,000 items, including 90 television programmes.

The Dog Training Centre is part of the Iris Group, owned by the Foundation of the Visually Impaired, and the company´s profit benefits the visually impaired. Humanity Dog trains guide dogs for the blind and breeds dogs to detect drugs, mould, PCB, oil, fire and mines. As part of its constant effort to improve the environment, the Centre has joined the "Green Trade network", established by the Swedish Trade Council.

Mercury Source Reduction and Recycling in Electrical Products

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Ric Erdheim is Senior Manager for Government Affairs at the National Electrical Manufacturers Association. He represents electrical manufacturers on environmental, occupational health, consumer product safety, and

fire safety issues. He also serves as the Executive Director of the Thermostat Recycling Corporation, an organization formed by the major thermostat manufacturers to operate a wholesaler take-back program for mercury switch thermostats.

Mr. Erdheim spent ten years as a Congressional aide, most of that time as Environmental Legislative Assistant to Senator Frank R. Lautenberg of New Jersey. Mr. Erdheim played a significant role in enactment of the ozone transport and air toxics provisions of the Clear Air Act Amendments of 1990, the Pollution Prevention Act, the Ocean Dumping Ban Act, and the Mercury Containing and Rechargeable Battery Management Act.

Mr. Erdheim graduated from the University of Pennsylvania with a BA in Economics and the George Washington University Law School.

Mercury Source Reduction and Recycling in Electrical Products

Manufacturers have used mercury in batteries, lamps and thermostats. Each has industry has adopted different approaches to reducing environmental exposure to mercury that reflect the unique characteristics of the product.

In the 1980s, battery manufacturers used over 1,000 tons of mercury a year, mostly to make alkaline batteries. In response to environmental concerns, the industry developed alternatives to mercury in virtually all batteries. As a result, the only consumer batteries manufactured today that contain any mercury are button cell batteries. With the phase-out of mercury use by 1993, mercury from alkaline batteries in the waste stream has dropped from 10,000 PPM to less than 300 PM. This level will decline by 50% every two years. This significant decline has been partially responsible for the declines in mercury levels from incinerators.

Lamp manufacturers have reduced the average mercury level in four foot lamps from 48 mg in 1985 to 11.6 mg in 1999. As a result, mercury contained in lamps has dropped significantly. More importantly, use of mercury-containing lamps results in a net decrease in mercury because of the energy efficient nature of the lamps as contrasted with no mercury but energy inefficient incandescent bulbs.

Manufacturers cannot reduce the amount of mercury used in mercury switch thermostats. The average mercury level in these thermostats is 3-4 grams. To address the problem of disposing of a product with such relatively high levels of mercury as compared to lamps, manufacturers have established the Thermostat Recycling Corporation to recapture mercury-switch thermostats. In the first eighteen months of operations in nine states, the TRC has recovered 270 pounds of mercury. This program works because of the unique characteristics of thermostats and is not necessarily a model for other products.

These examples indicate that manufacturers use mercury in a wide range of products for different purposes. The products differ in: units sold, mercury levels, size and product composition, users (businesses/specialized

installers/homeowners) and other factors. Because of these differences, issues involved in waste management vary for each product necessitating different approaches.

DSCP Buying Green

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Anthony Armentani is currently the Program Manager for Lighting Products at the Defense Supply Center Philadelphia. In this position Mr. Armentani is responsible for leading a team of associates in the acquisition, inventory management, technical and quality support initiatives in the management of over 60,000 commercial, non-commercial and military unique lighting items.

Mr. Armentani has over twenty years of federal service, all with the Defense Logistic Agency. He started his career at the Defense Industrial Supply Center (DISC) in Philadelphia as an Equipment Specialist and quickly moved up to Team leader, Supervisor and Branch Chief of the Miscellaneous Hardware and Physical Security Equipment unit in the Technical Operations Directorate. Mr. Armentani spent four years, as the Technical Data Manager at DISC where he was responsible for the acquisition, management and distribution of all the technical data required for competitive procurements at the center. Mr. Armentani spent two years on the Commanders staff at DISC, reengineering the work processes and participated in the development of DSCP's Innovative Logistic Support units that have allowed for a strong customer focus.

Mr. Armentani is a graduate of Rowan University in Glassboro, NJ.

Buying Green

The DSCP presentation will cover the methods and guidelines utilized by the DSCP Lighting Team in the acquisition and support of energy-efficient low-mercury lighting products. The presenter will discuss the DSCP/DLA customer commitment, The advantages and related savings in the use of low- mercury energy-efficient lamps and the projects and partnerships that we nurture and develop to ensure widespread energy-efficient lighting use throughout the federal sector. The briefing will identify Energy and environmental guidelines used in the acquisition of energy-efficient products, various types of low-mercury lamps available through DSCP and what new technologies are on the horizon for federal energy users. The presenters will

also discuss the different ways to research, select and order these energy-efficient low-mercury products from DSCP. Primary presenter for DSCP will be Tony Armentani Program Manager–Lighting.

EPA/AHA Agreement: Reduction of Mercury Wastes from Hospitals/Health Care Facilities

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Chen is currently serving as a team member of the EPA Hospitals for a Healthy Environment (H2E) project, and staffs a number of different workgroups associated with H2E. Prior to working on H2E, Chen served in a number of diverse posts throughout the EPA, including:

- Program manager of the Environmental Justice Through Pollution Prevention Grant Program;
- Program manager of the Pollution Prevention and Insurance Project;
- Vice President Gore's Task Force for Government Reinvention;
- Agency Task Force for Contracts Management Reform.

Prior to joining the EPA, Chen obtained his Bachelor of Arts degree in Political Science from the University of Washington, and his Master of Arts degree in Public Policy Studies from the University of Chicago.

EPA/AHA Agreement: Reduction of Mercury Wastes from Hospitals/Health Care Facilities

EPA's Voluntary Agreement with the American Hospital Association and Its Implications on the Need for Agency Standard for the Disposal of Mercury According to EPA's Mercury Report to Congress, the healthcare industry is the 4th largest source of mercury release. The mercury release eventually find its way into the food chain, and back to humans.

The voluntary agreement between the American Hospital Association - which represent some 85 percent of all healthcare facilities in the United States - and the EPA outlines a number of goals. One of

the stand-outs is to "virtually eliminate" mercury-containing waste by 2005.

Mercury Content of Products Commonly Used by Boston Area Hospitals

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Kevin McManus

Mr. Kevin McManus is the Director of the Toxic Reduction and Control Department (TRAC) of the Massachusetts Water Resources Authority.

Mr. McManus is responsible for implementation of the MWRA's Industrial Pretreatment Program. MWRA currently regulates approximately 1,100 industrial and commercial dischargers in order to control the loadings of heavy metals and organic pollutants to MWRA's new treatment plant on Deer Island. TRAC also works with trade organizations, municipalities and other agencies to reduce toxics from a wide array of non-industrial sources such as hospitals, laboratories, photoprocessors, dental facilities and automotive facilities.

Prior to coming to the MWRA in 1993, Mr. McManus worked for seven years with Metcalf and Eddy, Inc., managing the environmental compliance programs for numerous private and public construction projects. He also worked as General Manager for Offshore Devices, Inc., a marine engineering firm specializing in the manufacture and use of offshore oil spill cleanup equipment.

Mr. McManus has an undergraduate degree in Marine Policy from the University of Rhode Island, a Masters degree in Marine Resource Management from the University of Washington, and a Master of Business Administration degree from Boston University.

New Strategies for Reducing Mercury Discharges from Health Care Facilities

The five-year MWRA/Hospital Mercury Workgroup is a cooperative effort between the Massachusetts Water Resources Authority (MWRA) and Boston-area hospitals and medical facilities to reduce the discharge of mercury-containing products from hospitals to the sewer system. This workgroup identified mercury in many products that have commonly been used in hospitals and other medical facilities, such as blood test reagents and cleaning products. The workgroup has actively researched mercury-free alternatives to many of these products, and developed a mercury products

database which is available to area hospitals and other interested parties.

The workgroup also:

- Developed standards for replacing piping where mercury can accumulate over time;
- Prepared guidance documents for industries detailing mercury compliance problems;
- Assessed loadings of mercury from industrial dischargers in the MWRA sewer service area; and
- Conducted pilot-scale testing of promising mercury pretreatment systems.

A key factor in gaining the cooperation of facilities in the workgroup was MWRA's Mercury Safe Harbor Program. Under this program, MWRA will not escalate enforcement (beyond enforcement orders) against companies that have non-compliant mercury discharges, provided they actively participate in the program and demonstrate progress in reducing their mercury discharges. Under this program, the MWRA has divided its non-compliant mercury dischargers into two groups. Group 1 consists of sewer users whose discharge contains 0.004 mg/l or less of mercury; Group 2 consists of sewer users whose discharge contains more than 0.004 mg/l of mercury. Facilities that operate outside the safe harbor will be subject to escalating enforcement including monetary penalties.

To date, this cooperative effort has resulted in a significant decrease in mercury concentrations from the facilities permitted by the MWRA in the metropolitan Boston region. The 29 major hospitals and medical centers (representing 55 individual sampling locations) were a major source of mercury from MWRA's permitted users. Since 1995, 77% of these sampling locations have achieved compliance (1 part per billion or less), and only 9% remain above 4 parts per billion on a consistent basis. Average mercury discharge concentrations from these hospitals dropped from 22 ppb in 1994 to 2 ppb in 1999.

Eliminating Non-Essential Mercury Uses

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Michael Bender is a consultant to the Mercury Policy Project, a small, nonprofit enterprise dedicated to reducing human exposures to mercury and the virtual elimination of anthropogenic mercury releases. The Project identifies strategic opportunities and works collaboratively with business, government and nongovernment officials toward attaining its goals.

Michael has over 10 years experience in municipal hazardous waste management and has focused on mercury for the past several. From 1995 to 1997, Michael worked to secure the release of the Mercury

Report to Congress and since then has provided input on the Universal Waste Rule and the Mercury-Containing Lamps Rule, the New England Governors/Eastern Canadian Premiers Mercury Action Plan, the North American Regional Action Plan on Mercury and the Agency for Toxics Substances and Disease Registry's mercury reference level.

Michael has a Bachelor of Arts in General Studies and a Masters of Science in Resource Management and Administration from Antioch New England**.**

Phasing Out Thermometers and Other Non-Essential Mercury-Containing Products

The top priority of federal, tribal and state waste hierarchies is source reduction, with special attention paid to eliminating substances in products, like mercury, when they are found to present some of the most profound risks to human health, wildlife and the environment. For mercury-containing products, then, whenever viable, environmentally sound and cost-effective alternatives are identified that contain no mercury, they should become the preference of government procurement programs and strongly supported as the preferred societal choice. For this to occur effectively, non-essential mercury-containing products must be "virtually eliminated" over time by phasing out their manufacture, import and sale. As an interim step, existing products should be collected and properly managed to prevent the haphazard release of mercury indoors or into the environment. There are currently a number of initiatives where both voluntary and mandatory phase-outs of mercury-containing products are being carefully considered, developed or implemented. This paper will present several case study examples.

Appendix C
Panel Discussion Summary - Treatment and Disposal

C.1 Introduction

Two panel discussions were held during the workshop; the first addressed treatment and disposal of mercury-contaminated wastes and the second addressed prevention, collection, and elimination issues. Each panel discussion opened with an overview emphasizing key findings and issues presented during the workshop. After each source panelist briefly discussed what he or she thought were the most critical and controversial issues, an open discussion period was initiated. It was assumed that the issues discussed by the panelists and audience would be based on the list of questions and topics provided to workshop attendees prior to the workshop. The goal of the panel discussions was to work toward consensus on these critical issues.

Panel A contained one facilitator and five panelists. There was a note-taker present to ensure the that the product of the discussions was captured. The focus of the panel and any questions provided to workshop attendees or panelists are included in the written summary generated for each panel session.

C.2 Focus/Emphasis of Panel Discussion on Treatment and Disposal

The purpose of the Panel Discussion on Treatment and Disposal was (a) to discuss the state of the art of mercury non-combustion treatment and disposal techniques for mercury wastes and stockpiles, and (b) to identify major research needs/directions required to meet the goal of bringing the state of technologies, or any other options, closer to environmentally safe (including in the long term), cost-effective treatment and disposal processes.

C.3 Treatment and Disposal Panel Members

Ben Blaney of U.S. EPA NRMRL was the panel moderator and Paul Kalb of Brookhaven National Laboratory, Paul Lear of IT Corp., Ed Swain of Minnesota OEA, Greg Hulet of U.S. DOE/BBWXT Co., and Fred Charania of U.S. EPA OSW served as panelists.

C.4 Questions/Topics for Treatment and Disposal Panel Discussion

The panelists were asked to respond to two sets of questions in turn.

Question A: State of the Art and Significant Advances.

- What are two or three accomplishments described in Session A that may support significant advances in the state of the art in non-combustion options for mercury waste/stockpile treatment and disposal techniques?

- Based on your general knowledge, how would you characterize the state of the art of non-combustion techniques for mercury treatment and disposal with respect to where we currently stand in meeting the goal stated above?

Question B: Research Needs.

- What are three priority research areas you feel are most important to address so that we can make significant steps toward reaching the goal stated above?

C.5 Summary of the Treatment and Disposal Panel

C.5.1 Chair Comments

Ben Blaney, U.S. EPA NRMRL

C.5.2 Panel Member Comments

Paul Kalb, Brookhaven National Laboratory

Paul Kalb presented the following comments in response to Questions A and B.

Regarding the State of the Art:

Effective technologies exist. The state of the art is good from the perspective of where we are now. Effective technologies exist for treating mercury waste containing both less than and greater than 260 ppm mercury. These technologies are either currently commercially available or soon to be available. The available technologies are more similar than dissimilar in that they focus on keeping mercury immobile or insoluble.

Regarding Accomplishments Supporting Advances:

- *Mercury sulfide.* The mercury sulfide method of stabilization and disposal is significant because it essentially puts mercury back where it came from.
- *Waste type.* Recent technologies make a distinction between Resource Conservation and Recovery Act (RCRA) wastes and mixed waste mercury.
- *Thermal desorption.* Thermal desorption may be the most sensible technology for mercury-contaminated soils because it can also deal with organics and other species.

Paul Kalb described the following research needs for performance testing and measurement:

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

Alternatives to the TCLP

There is a need to identify alternatives to compensate for the failings of the TCLP, which (a) only concentrates on one pH range, and is therefore not representative of long-term landfill conditions; (b) only provides a small duration snapshot (18 hours); (c) provides no mechanism information; and (d) has artificial particle size requirements.

Durability of Solid Matrices

There is a need for more data on the durability of solid matrices used to immobilize mercury in waste. We need to understand how the forms will hold up over time.

Paul Lear, IT Corp.

Paul Lear presented the following comments in response to Question B.

Regarding the State of the Art:

- *As good as it will get.* There are many treatment and disposal options - amalgamation, stabilization, thermal treatments - that are almost commercially available. There is no "silver bullet" technology available, or likely to be identified; only incremental changes in technologies will occur from now on.
- *Treatment determined by market and waste*. The available technologies are similar, and for any given case, the best treatment and disposal option will be determined by the market and waste type.

Regarding Accomplishments Supporting Advances:

Formation of partnerships. The next step in advancing treatment and disposal will come from the formation of partnerships between waste generators, treaters, and regulators, and getting the available technologies out to the field.

Paul Lear described the following research needs:

Mercury Emissions from Landfills

There is a need for additional research into mercury emissions from landfills to determine the potential for environmental impact from mercury waste after disposal.

Shortcomings of TCLP

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

There is a need for standardization, with the regulatory and scientific communities in agreement. Standardization will increase confidence in the measurement results.

Ed Swain, Minnesota OEA

Ed Swain presented the following comments in response to Questions A and B.

Regarding the State of the Art:

Are the performance standards appropriate? There is a tendency to draw lines, such as "insoluble" and "no offgassing" when referring to the treatment and disposal of mercury-contaminated wastes, but all of these terms are measures of degree. Just because a waste can pass the Toxicity Characteristic Leaching Procedure (TCLP) does not mean it's environmentally benign, so we need to think of the bigger picture, the total mercury mass in the atmosphere. If all waste is treated, how much mercury will join the global or regional pool?

Ed Swain described the following research needs:

Durable long-term storage

There is a need for further research into durable long-term storage forms for sulfides and matrices.

Durable short-term storage

There is a need for further research into durable short-term stockpile storage options for elemental mercury.

International Technology Transfer

There is a need for technology transfer to other countries to prevent them from making the same mistakes as the U.S.. Ed Swain suggested an international policy forum to discuss reduction of mercury use and consumption, and the provision of international incentives to reduce mercury use and pollution.

Greg Hulet, U.S. DOE/BBWXT Co.

Greg Hulet presented the following comments in response to Questions A and B.

Regarding the State of the Art:

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

There are problems that must be addressed. There are some problems in the current state of the art. Metal amalgams have a vapor pressure similar to elemental mercury, so there are questions about the long-term stability and potential for vapor release of this disposal solution. There are questions about the long-term performance of macroencapsulation methods and materials. While stabilization appears to meet the disposal standards, it is unknown what happens under real landfill conditions with changing pH.

Regarding Accomplishments Supporting Advances:

- *Electrochemical processes.* Progress in developing electrochemical processes, which could have many future applications, would be welcome. This technology could be improved or modified for DOE use.
- *SAMMS material.* The newly engineered SAMMS material, which may be useable as a drop-in replacement for ion-exchange, appears to have potential.

Greg Hulet described the following research needs:

Non-Intrusive Mercury Measurement

There is a need to develop a non-intrusive method for measuring or identifying mercury in waste or matrix. Non-intrusive identification of mercury will allow easier identification and disposal of non-mercury wastes.

Transmutation of Radionuclides

There is a need for further research into the transmutation of radionuclides to discover how we can better identify and treat mercury and mercury wastes.

Long-term Performance of Disposal Options

There is a need for further research into the long-term performance of amalgamation and macroencapsulation.

Fred Charania, U.S. EPA OSW

Fred Charania presented the following comments in response to Question B.

Regarding the State of the Art:

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

The paradigm is changing. The legal standard is 'minimize threat to human health and the environment', and recent technological advances allow us to address this more effectively than in the past.

- Minimizing the threat means considering multimedia issues, such as offgassing and leaching. We must think of the long-term issues, because a waste passing TCLP to go to a landfill is not sufficiently protective. The effects of pH in landfills have not been fully examined to determine the true safety of disposal.
- We need to address mixtures of organics and mercury together. Is there a treatment train that should be designated as the Best Demonstrated Available Technology (BDAT)?
- Little data were received when the Advanced Notice of Proposed Rulemaking (ANPRM) was issued, but data are expected within the next 6 months. Research is a occurring, and data on treatment processes are needed and wanted. The data should be incorporated in the rulemaking docket so the designation of a BDAT can be examined.Fred Charania described the following research needs:

Characterization of Hazardous Waste Stream

There is a need for economic and characterization information on the hazardous waste stream. While Municipal Solid Waste (MSW) is well characterized, hazardous waste codes such as D009 yield little information about the waste. More information regarding the waste will enable more efficient recycling, treatment, and disposal.

Treatment of Commingled Waste

There is a need for further research on the treatment of commingled organics and mercury. Can there be an effective treatment train identified and designated as the BDAT?

Effects of pH on Storage and Disposal

There is a need for further research on the effects of pH on storage and disposal of mercury wastes. Previous testing has assumed a constant pH, which may not be accurate under real storage and disposal conditions, such as a landfill. It must be determined whether fluctuations in pH will reduce the suitability of some storage and disposal technologies.

C.5.3 Open Discussion

Deep Geological Repository for Mercury Wastes

Should we be considering utilizing deep disposal for mercury wastes? Is this a better option than surface disposal?

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

- Deep geological repositories are currently being used in Europe. Mercury wastes are sent down old mines.
- There may be a need to segregate wastes before disposal. A dedicated repository (mercury wastes segregated from other waste streams) would prevent co-disposal problems.
- If the current problems with surface disposal can be solved, surface disposal may be preferable to deep disposal because landfills can be monitored. Deep disposed wastes are difficult to monitor and cannot be moved if they begin to present environmental problems.
- Deep disposal may be preferable to surface disposal, because of the greater potential for exposure from surface disposal. Long-term geological issues such as landfill cracking may also make deep disposal more desirable.
- Mercury from deep geological repositories may find a way back to the surface in natural gas and oil. There is a paper in *Environmental Progress* on this issue by Dr. Wilhelm.

Mercury in Landfills

Are landfills a feasible long-term option for mercury wastes? If not, what should be done about mercury wastes previously disposed of in landfills?

- Mercury-related environmental issues from landfills may be air emissions, rather than leachate.
- Mercury air emissions from landfills are a only minor problem. Without a carrier gas, such as methane, slow diffusion of mercury would occur rather than air emissions.
- There are bacteria in municipal solid waste (MSW) which may create methyl mercury, introducing a major pathway for human exposure as it bioaccumulates in fish.
- There are long-term geological issues with landfill disposal of hazardous wastes, such as landfill cracking.
- If deep disposal becomes the favored option, should previously surface-disposed mercury wastes be mined from landfills? There is little data regarding mercury in leachate from landfills, so it is not known if previously landfilled wastes will be a problem in the future.
- Because of the chlor-alkali facilities closing and the Department of Defense (DOD) eliminating stockpile, handling of existing mercury and mercury waste will take precedence over landfill mining for the foreseeable future, unless landfill leachate begins to pose an environmental hazard.

Stockpile Elimination Effect on Mercury Supply and Demand

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

The long-term effects of stockpile reduction, recycling, and mercury mining should be analyzed to ensure a proper balance between mercury supply and demand. If the stockpile is eliminated, will we need to mine more mercury to meet demand?

- Secondary and byproduct mercury production meets the current demand. As long as we mine materials that coexist with mercury and have mercury recycling, there will always be a plentiful supply of mercury for domestic needs. The secondary production in the U.S. almost meets the current demand.
- Some of the stockpile should be reserved as a cushion for the market and future needs, but the majority should be eliminated.
- Mercury retorters say there is a market for their recycled mercury. If there is a market and use for the product, why remove the product using questionable treatment and disposal techniques?
- The public wants mercury to be retired rather than recycled for future use. We need to convey that recycling mercury reduces the amount mined.
- As mercury use by the chlor-alkali industry is being reduced (it agreed to reduce mercury use by 80%), decommissioned mercury will add greatly to the market supply.
- Mercury recovery doesn't necessarily mean recycling. Recovered mercury could be stored rather than put into use.
- The government used to subsidize mercury mining. Perhaps the government should buy back the mercury to stockpile and dispose.
- Congress should limit the uses of mercury by law to encourage alternatives. There is currently no economic incentive to use mercury alternatives.

Mercury in Wastewater and Direct Discharge

What is the best technology to identify and reduce mercury in wastewater and direct discharge?

- In the Great Lakes, mercury in water can be quantified at 1.0 ng/ml.
- There is no treatment option to the direct discharge level.
- The treatment technologies presented have not been geared toward wastewater treatment, but there are other technologies available.
- Getting mercury down to ppt levels is difficult, and treatment to that level is unreliable. The form of the mercury makes a difference in its treatability.
- Rather than concentrating on treatment of wastewater, we should focus on source reduction, which has greater potential for reducing mercury to acceptable levels in the long-term.

Temporary-/Short-Term Storage for Mercury Wastes and Stockpiles

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

Has short-term storage been considered for the decommissioned mercury stockpile?

- The stockpile is still in the hands of DOD. Additional short-term storage has not been considered because existing short-term mercury storage is not suitable.
- Short-term storage of mercury could be used as a method to regulate the market. To assess the usefulness of short-term storage as a market regulator, we need more information on the economics, future use projects, and supply of mercury.
- The 90-day rule is limited to generator waste and RCRA sites. Elemental mercury that can be used as a product may not be classifiable as a waste.

Formerly Contaminated Sites

Mercury production or use sites exist around the world. What should be done with formerly contaminated production sites?

- No participants were aware of any of international reclamation efforts.
- Mercury cell plants abroad are often converted for alternative uses rather than cleaned.

Improve Material Collection

Collection of mercury waste materials could be improved to reduce emissions and facilitate recycling.

Research and Development

Research and development will not take place in a vacuum; we must create a demand for it. Enforcement of mercury cleanup regulations would create a market for the new technologies that research and development would bring. Enforcement will lead to market demand, which leads to research and development, which leads to better cleanup, treatment, and disposal.

Lessons Learned

All of the problems being addressed at this conference are identical or similar to those addressed in the past for nuclear waste. We should take care to follow the lessons learned from those efforts to avoid making the same mistakes.

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

Applicability of Treatment Technologies

There is currently no one technology which can address all matrix types with significant volumes of waste. We need to focus on getting technologies to work together in a treatment train. The available technologies will always need tweaking based on the type of waste needing treatment. There will never be one technology or approach for all waste streams. Know what you're treating and verify the performance of your treatment technology.

Additional Research Needs. Members of the audience contributed suggestions.

- Characterization of mercury in sediments and research into ecological impacts.
- Methods for faster, cheaper, and better characterization and cleanup, especially non-intrusive characterization.
- Mercury in the presence of radionuclides.
- Separation of mercury from matrices without the use of thermal processes. Chemical-based separation would allow wastes to be incinerated.
- Long-term durability of waste forms in surface storage. Disposal conditions must be reducing, not oxidizing.

Note: Statements captured in the panel discussion are those of participants, not necessarily EPA.

Appendix D
Panel Discussion Summary - Prevention, Collection, and Elimination

D.1 Introduction

Two panel discussions were held during the workshop; the first addressed treatment and disposal of mercury-contaminated wastes and the second addressed prevention, collection, and elimination issues. Each panel discussion opened with an overview emphasizing key findings and issues presented during the workshop. After each source panelist briefly discussed what he or she thought were the most critical and controversial issues, an open discussion period was initiated. It was assumed that the issues discussed by the panelists and audience would be based on the list of questions and topics provided to workshop attendees prior to the workshop. The goal of the panel discussions was to work toward consensus on these critical issues.

Panel B contained two facilitators and five panelists. There was a note-taker present to ensure the that the product of the discussions was captured. The focus of the panel and any questions provided to workshop attendees or panelists are included in the written summary generated for each panel session.

D.2 Focus/Emphasis of the Panel Discussion on Prevention, Collection, and Elimination

The Panel Discussion on Prevention, Collection, and Elimination focused on the need to reduce the amount of mercury entering the waste stream through improved pollution prevention techniques, waste collection methods, and source reduction.

D.3 Prevention, Collection, and Elimination Panel Members

Doug Grosse and Jon Herrmann of U.S. EPA ORD were the panel moderators, and Alexis Cain of U.S. EPA Region V, John Gilkeson of Minnesota OEA, George Gissel of Vulcan Chemicals, Edward Weiler of U.S. EPA OPPT, and Jane Williams of California Communities Against Toxics served as panelists.

D.4 Question/Topics for the Panel Discussion on Prevention, Collection, and Elimination

1. What are the two or three most important insights you want to convey to the audience regarding the management of mercury from non-combustion issues?

2. What are the two or three most critical/essential efforts that need to be undertaken to prevent, eliminate, treat, or dispose of mercury from non-combustion sources?

3. Name two or three data gaps or information needs for mercury risk management from non-combustion sources.

4. Prioritize the two or three most important research needs for managing risks from non-combustion sources of mercury.

D.5 Summary of the Panel Discussion on Prevention, Collection, and Elimination

D.5.1 Chair Comments

Doug Grosse introduced the facilitated panel discussion on prevention, collection, and elimination issues (Panel B). He emphasized that ORD is interested in the thoughts, ideas, and suggestions of the workshop participants.

D.5.2 Panel Member Comments

Alexis Cain, USEPA Region V

Alexis Cain described the following research needs:

Division of Mercury Sources by Deliberate Use and Trace Contamination of Raw Materials

Alexis Cain felt that although the Workshop's division of mercury sources by combustion and noncombustion sources is useful, categorizing mercury sources by emissions related to the deliberate use mercury and the emissions that are related to the contamination of raw materials with trace amounts of mercury is also informative because it:

- *Avoids the confusion of equating combustion emissions with only coal-fired utility emissions.* As currently defined by EPA, combustion sources include incinerators. Incinerators, however, do not make mercury, but receive mercury from mercury-containing wastes as a result of mercury use in products.
- *Evens the division of mercury sources.* If emissions are categorized on a deliberate use basis, use-related emissions are about 50% of total emissions; when categorized on a combustion basis, combustion-related emissions constitute about 90% of total emissions.
- *Improves consideration of life cycle emissions.* Since incinerator emissions represent the end of a product's life cycle, this method of division makes it easier to look at different points along a product's life cycle to assess opportunities to control mercury emissions.

Life Cycle Emissions by Product Type

Alexis Cain contended that there is an inadequate understanding of life cycle emissions by product type. He explained that this research can help prioritize mercury collection efforts.

There are some data on mercury emissions from mercury-containing products, although these estimates do not seem to be based on actual measurements. There are better data from incinerators, but these data could also be improved. However, he contends that there is a paucity of data regarding emissions estimates from some of the other phases of the mercury product life cycle, in particular:

- Accidental emissions that occur during product use.
- Emissions associated with collecting, processing, storage, and transport of wastes prior to incineration.
- Emissions that occur from landfills, particularly the working faces of landfills.
- Mercury emissions from the use of metal scrap. For example, emissions from mercury switches placed in automobiles are currently not accounted for in EPA emissions estimates, though these emissions could be significant.

Increase Focus on Prevention Opportunities

Currently cost effectiveness data are based on cost effectiveness per mass of mercury collected rather than on the prevention of mercury releases. Alexis Cain would like to see more emphasis on the following areas for prevention efforts:

- *Auto industry*. There should be more research on this sector because most of the mercury associated with automobiles is ultimately released into the environment.

- *Electrical Switches*. Alexis Cain cites data presented by Bruce Lawrence (Bethlehem Apparatus Company) in the plenary session that electrical products, particularly mercury relays in capital equipment, are now the largest user of mercury in the U.S. (even more than the chlor-alkali industry) – now estimated at 110 tons per year. Moreover, mercury use in electrical switches has not decreased over the past 20 years.

Pursue Voluntary Efforts

Although voluntary efforts are not always effective, Alexis Cain states that it does not hurt to try, and his experience with the chlor-alkali industry shows that voluntary efforts can yield positive results.

George Gissel, Vulcan Chemicals

George Gissel looks to the first two questions (questions a and b) as supporting a practical approach to mercury management and control and the second two questions (questions c and d) as addressing the longer range issues.

Questions (a) and (b)

George Gissel stressed that the guides to answering the first two questions are cooperation and achievable goals.

- *Cooperation.* Cooperation is key on two fronts:
  Cooperation within the chlor-alkali industry. The chlor-alkali industry realized that some plants are better at mercury control than others, and they can all learn from each other without engaging in uncompetitive practices.
  Cooperation with their respective state agencies and the EPA. By working with regulators toward a common goal of regulations that reduce mercury, both parties can maximize their limited resources.
- *Achievable Goals*. The chlor-alkali industry has publically committed to a goal of a 50% reduction in mercury use (using a 1990-95 baseline) by 2005. A few companies, including Vulcan Chemicals, have set a goal of a 50% mercury consumption reduction based on a 1999 baseline. The industry intends to achieve these goals through cooperation. All plants are on track to achieving their goals.

Members of the chlor-alkali industry have worked together to address the following issues:

- *Mercury in sodium hydroxide.* The chlor-alkali industry's mercury in sodium hydroxide task group is about to release a draft publication that details the best thinking available on minimizing mercury in sodium hydroxide.
- *Mercury health issues.* The chlor-alkali industry has also convened a mercury health issues task group that has looked into guaranteeing that the best science is used to ensure worker safety at chlor-alkali facilities.
- *Mercury balance.* George Gissel stated that his company has assessed its mercury balance since 1973. Other chlor-alkali companies have looked toward Vulcan Chemicals to assist them in establishing a mercury balance. Vulcan Chemicals has given seminars to the chlor-alkali industry about mercury balance, as well as a seminar to the EPA in Boston. Through a multi-year examination of mercury consumption and purchasing, a facility can gain a better understanding of minimizing mercury consumption and losses.
- *Cross-plant/cross-industry sharing for continuous improvement.* The chlor-alkali industry formed the Mercury Control Task Group to identify the best industry practices. This task group has produced two in-plant technology exchange workshops in 1999; it has a third workshop planned for 2000. These workshops provide detailed descriptions on using specific technologies.

The chlor-alkali industry has worked with the EPA to address the following issues:

- *Measuring cell room fugitive emissions.* The chlor-alkali industry formed a mercury emissions measurement task group to work with the EPA toward a common goal of measuring cell room fugitive emissions. The EPA at Research Triangle Park (RTP) developed the protocol. Testing is now underway at the Olin Corporation's Augusta, Georgia, facility. The Chlorine Institute covered the out-of-pocket costs of Olin Corporation and the EPA is underwriting the cost of the equipment and measurements.
- *Revising National Emissions Standards for Hazardous Air Pollutants (NESHAP) regulations.* The EPA worked with the chlor-alkali industry revising the NESHAP regulations. They are conducting multi-day observations at five facilities owned by four companies.

Questions (c) and (d)

George Gissel emphasized that the key to addressing the final two questions is continued consistency from the regulatory community so it can prepare for the future. In particular, he would like to strive toward:

- *Achievable levels of mercury in products.* Total elimination is not practical because it is now possible to measure mercury to the parts per trillion level. A risk-based approach to determining an acceptable and achievable level of mercury is more practical.
- *EPA and industry consensus on regulations.* In the early 1990s, the EPA required the chlor-alkali industry to install thermal recovery units. After the chlor-alkali industry has spent in excess of $15 million, the EPA is rethinking that policy.

Edward Weiler discussed following issues:

Final Disposition of Collected Mercury

Edward Weiler contended that there is a lack of understanding of the final disposition of mercury. As more mercury-containing products are recovered through take-back programs, there will be an increasing need to dispose of that mercury.

- *Emissions from mercury collection.* There are likely to be significant emissions from collection efforts, such as those resulting from accidents, and EPA should potentially rethink Best Demonstrated Available Technology (BDAT) regulations.

- *Alternative disposal technologies.* EPA must encourage the development of alternative mercury disposal technologies. EPA should work with industry to verify

alternative technologies.

- *Business side of mercury problem.* Currently it is difficult to raise the investment capital necessary to establish companies that develop alternative disposal technologies.

Virtual Elimination of Mercury Requires Private Sector Cooperation

Edward Weiler noted that previous discussions during the Workshop concluded that new regulations restricting mercury use are not likely. Therefore, if mercury is to be removed from the marketplace, government must work closely with the private sector. The challenge is to create positive incentive structures that can encourage the private sector to make a business of phasing out mercury use, both in terms of developing alternative disposal technologies and developing chemical substitutes (such as NewMerc). It is difficult to make inroads with a new technology or alternative chemical substitute in the absence of a regulatory hammer.

Mercury as a Consumer Products Safety Issue

Mercury can be thought of as a consumer products safety issue where it exists in small amounts, such as in thermometers and electronic displays. Edward Weiler cited an earlier Workshop discussion that the most common call to poison hotlines dealt with broken mercury fever thermometers. Although thermometers and electronic displays represent a small percentage of mercury emissions (especially when compared with utility coal emissions), nonetheless they represent a risk. Perhaps an entity like the Consumer Products Safety Commission could be used to address the mercury safety issue.

Critical Efforts

Edward Weiler concluded with the following critical efforts:

- *Encourage Office of Solid Waste (OSW) efforts.* The EPA should support OSW in researching alternative disposal technologies.
- *Enhance technology development and verification programs.* To enhance technology development and verification of alternative mercury technologies, the EPA should look at complementarity between ORD's Small Business Innovative Research (SBIR) program and Environmental Technology Verification (ETV) program.
- *Support Environmentally preferable purchasing.* Use the power of the federal procurement dollar toward environmentally preferable purchasing.

- *International mercury flows.* The EPA should support efforts to measure international flows of mercury. Edward Weiler was particularly struck by the magnitude of the international flows. Characterizing the international flows are critical

to describing background mercury levels.

John Gilkeson, Minnesota OEA

John Gilkeson stated that as a state representative, he feels that it is important to collect the mercury-containing products before they are found in wastes and wastewaters. Once mercury is in solid wastes and wastewaters, it is difficult to control and is often released in the environment, especially since Minnesota incinerates most of its wastes.

John Gilkeson discussed the following issues:

Categorization. The Northeast Model Legislation proposes the following categorization scheme:

- Product with elemental mercury
- Product with compounds and chemicals
- Processes
- Waste streams of the three above areas of deliberate use
- Non-combustion incidental releases, including refining, mining, and cement and limestone production

Hierarchy of Actions for Mercury Control.

- Identification of existing uses, sales, and product lines
- Separation from uses and separation from wastes
- Collection and retirement of mercury wastes
- Substitution and elimination of mercury in the future

Model Program for Product Lines and Activities To Be Implemented at the State or Local Level

A model program provides consistency in implementing mercury control efforts.

Prioritization of Mercury Issues

MN OEA prioritizes its mercury issues on the following basis:

- Feasibility
- Effectiveness
- Quantity
- Available information
- Existing working relationship with protected parties and sectors
- Opportunities that might arise

Categories of Mercury Issues.

- "Big easy"
- "Little easy"
- "Big difficult"
- "Little difficult"
- Unknown

"Difficult" is based on cost, practicality, infrastructure, or level of information.

Information Gaps

John Gilkeson identified the following information gaps:

- Control measures for "big difficult" issues such as coal
- The search for a non-mercury dental restorative for dental amalgams
- Cleanup of wastewater treatment plant infrastructure. Mercury is found in hundreds of miles of pipes within buildings and underground
- Mercury found in refineries
- Mercury found in land application of biosolids
- Mercury presence in drugs

Jane Williams, California Communities Against Toxics

Jane Williams reiterated that mercury is a serious threat to the environment. She asked the Workshop to visualize a "mercury-free future."

Key Points

Jane Williams began her discussion by describing the need for a new paradigm for dealing with mercury:

- *National and international implications.* The international implications of the mercury issues such as mercury deposition over the Pacific Ocean should spur us to look at mercury problems in a more holistic way. The U.S. should adopt a "clean hands" policy (developed by the New England Governor's Mercury Action Plan) because even if all mercury emissions ended in the U.S., we would still have a significant mercury problem.
- *Mercury in consumer products should be phased out.* The intentional use of mercury in consumer products should eventually be phased out, including mercury in lamps.

- *No new mercury should be introduced in commerce*. An important step in this direction was the cessation of sales of the national mercury stockpile in the early 1990s. Mercury trade should not be shifted to other countries, particularly Mexico.
- *Mercury education and awareness is key*. It would be difficult to develop the political consensus necessary to deal with mercury issues until government, industry, and the public acknowledge that mercury is a serious problem. Public education is key to raising this consensus.

Interesting Effort

Jane Williams discussed the following interesting effort:

Mercury-free procurement/buildings by government. It is important for the government to become a models of mercury-free thinking to set an example for the public and industry.

Important Scientific Questions

Jane Williams identified the following critical scientific questions:

- *Extent of mercury contamination in ocean fish*. The Food and Drug Administration (FDA) has ceased testing the most common ocean fish; as a result mercury exposures and risks to the public are uncertain.

- *Educating the public about mercury exposures*. Although most of this Workshop has focused on emissions rather than on exposures, educating the public on exposures is critical. Jane Williams also referred to the fact that over 90% of the calls to a poison control center of a certain state was for broken fever thermometers, and while most people may know that there is mercury in their thermometers, they may not be aware of the mercury in their thermostats or cars. Once the public understands the ubiquity and risks of mercury in the environment, ultimately the mercury problem may be handled like the tobacco problem.

- *Mercury retirement*. It is increasingly apparent that an "end-game" for mercury must be devised for retiring mercury. The EPA should work with the Department of Energy (DOE) and Department of Defense (DOD) to devise mercury stabilization technologies. Eventually, all of the mercury in circulation needs to be pulled out and sequestered from the biosphere – and like the nuclear waste debate, this could become a politically painful experience.

D.5.3 Open Discussion

Phase-out of Chlor-alkali Mercury Cell Process

Luke Trip (Environment Canada) asked George Gissel whether the chlor-alkali industry in the U.S. planned to phase out the mercury cell process.

George Gissel responded that various countries have phased out or are planning to phase out the mercury cell process. Japan phased out the mercury cell process in 1985, and Europe is discussing a 2005 or 2010 phase-out.

Although the U.S. chlor-alkali industry has not been informed of a phase-out in the U.S., he said that it would work with the EPA if asked to do so. However, George Gissel stated that any phase-out needs to be well-planned and a cooperative venture between the government and industry. An abrupt phase-out could have unintended consequences. For example, any disruption in alkali production could force alkali prices to rise and spur increases in production elsewhere in the world, such as Mexico, where chlor-alkali facilities are subject to less stringent environmental regulations.

Chlor-alkali Mass Balance

Peter Berglund (Metropolitan Environmental Services, MN) asked George Gissel how the chlor-alkali industry measures its mercury mass balance.

George Gissel responded that a mercury mass balance at a chlor-alkali facility is not a simple case of input minus output equals losses because there are internal inventory points that change on a continuous basis.

Mercury Concentration in Caustic Soda

Peter Berglund noted that an appropriate goal to achieve for mercury concentrations in caustic would be the caustic from a non-mercury cell chlor-alkali facility.

Gatekeeper for Consumer Products

Lester Gress (CFS Environmental) asked that if EPA's hazardous waste listing determination is the gatekeeper for industrial hazardous waste, where is the gatekeeper for consumer hazardous material? If a gatekeeper were in place, there would some consistency in how regulations treat industry as well as the consumer. For example, there is no gatekeeper controlling the mercury found in Drano.

John Gilkeson stated that Minnesota has a gatekeeper in its regulations that prohibit mercury disposal in its solid wastes and wastewaters, where solid wastes include construction and

demolition (C and D) wastes, non-hazardous industrial wastes, etc. He added that they are enforcing these regulations on contractors who do not remove mercury from buildings prior to demolition.

Ed Weiler responded that the logical gatekeeper would be TSCA, but notes that nobody would be willing to go down that road.

With regard to mercury use in consumer products, Anita Cummings (OSW) cited research on recent patent records that finds that there are patented products that still use mercury. EPA is not certain whether these products are being manufactured, but she feels that these products should be tracked. John Gilkeson added that his office had done a patent search of the 1970s and 1980s and uncovered thousands of patents that used mercury.

Local Actions Are Important

John Ackerman (U.S. EPA Region IV) stated that although mercury is a global concern, local releases matter, and local efforts do pay off. There is increasing evidence that local waste incineration and releases are all part of the problem.

Mercury Speciation Is Key

John Ackerman also pointed out that the mercury species is critical to understanding mercury risks. The water soluble Hg (2+) ionic form of mercury is particularly dangerous because it quickly becomes biomagnified. Elemental mercury is also dangerous, but in the near term it does not bioaccumulate. There is a need for speciated data on mercury releases, and therefore there is also a need for better tools to measure mercury. More research needs to be done to make the standard methods and equivalent methods viable tools.

Middle-level Handling of Mercury

John Ackerman raised the issue of regulating middle level handling of mercury. Currently, industries that collect mercury-containing items such as thermostats and thermometers are not regulated. The government needs to ensure that this industry is economically viable and not releasing mercury into the environment. Permitting and regulating for this industry should be done at the local level. These industries typically do not fit in the standard categories.

John Gilkeson stated that Minnesota does regulate collectors under the universal hazardous waste rule and feels they have good oversight of their activities.

Edward Weiler thought that most states probably do not have an answer like Minnesota's, and he feels that there is not much on the federal level either.

Alexis Cain added that EPA received a petition from the Edison Electric Institute to add all mercury-containing devices to the Universal Waste Rule to help it better manage its mercury-containing devices. Utilities also use mercury instruments such as temperature and pressure sensors within their processes. EPA has not yet acted on this petition.

Fate of Amalgam in Sludges

Peter Berglund stated that the fate of amalgams in sludges is a data gap. Sludge is either incinerated and the mercury released to the atmosphere or applied to land. This may be an appropriate research area for the Water Environment Research Foundation (WERF).

Alexis Cain added that University of Illinois research indicates that there is a considerable amount of mercury that is not in the amalgam form, but as soluble mercury in the amalgam wastewater.

Mercury Levels in Common Consumer Products

An audience member from the Northeast Region cited a study completed by the Hampton Roads Sanitation District that found mercury in common household consumer products. For example:

Toothpaste	3.8 parts per billion (ppb)
Deodorant	1.35 ppb
Soap	25 ppb
Laundry detergent	2.4 ppb
Kool Aid	6 ppb
Mountain Dew	158 parts per trillion (ppt)

He added that domestic sewage now contains 100 ppt background levels of mercury. He contends that the EPA or FDA needs to begin a regular program of testing these products for mercury.

Jane Williams responded by stating that she has worked on similar issues with leaded wick candles. She stated that the FDA seems not to be concerned with consumer ingestion of mercury based on its track record on fish testing. She suggests raising this issue with the Consumer Products Safety Commission, reiterating her call for public education and awareness.

An audience member (Judy Schoefen) said that she would be happy to work with Jane Williams to help raise this subject at the next New England Governor's Mercury Task Force Meeting.

Dental Amalgam Health Concerns

Freya Koss (DAMS, Dental Amalgam Mercury Syndrome) asked why the EPA was funding a National Academy of Sciences (NAS) study to determine a safe level of mercury when there is no safe level of mercury exposure.

Freya Koss also added that there is not enough awareness about the hazard of mercury exposure from dental amalgams. For example, she cited an ongoing National Institute of Health (NIH) study that is putting amalgams into children and testing for neurological damage – a clear violation of the Nuremberg Convention. She calls for a meeting with the EPA and FDA to discuss the hazards of dental amalgams.

Jane Williams stated that the NAS study was mandated by Congress to review the methyl-mercury reference dose. She also added that EPA does not regulate consumer products such as dental amalgams. Jane Williams said that she also shares many of the questioner's concerns with dental amalgams. Although she noted that a scientific consensus on dental amalgams has not yet been reached, there clearly is a sub-population that is more sensitive to mercury exposure. She added that Canadian efforts to restrict dental amalgam use is a step in the right direction.

Alexis Cain said that establishing a reference dose for methyl-mercury is not an irrelevant question because mercury exists naturally, and we would have background levels of mercury even if there were no anthropogenic sources of mercury.

John Gilkeson noted that the NIH study is being conducted at the University of Rochester. He also stated that the Agency for Toxic Substances and Disease Registry's (ATSDR's) toxic profile on mercury estimates of the average exposure to dental amalgams overlaps the range of concern for adults.

Ann Ferreira (DAMS) asked, as a person with high sensitivity to mercury, if the EPA had a website listing products that contained high mercury concentrations.

Jane Williams told her that a list is available at www.mercurypolicy.org.

Folke Dorgelo (Netherlands Ministry for Housing, Spatial Planning and Environment) asked if there is a possibility that the NAS study could show that there is no safe level of mercury, meaning that even background levels of mercury levels are not safe.

Conference Proceedings

Lester Gress asked if there will be conference proceedings or a press release to the public.

Doug Grosse responded that there will be proceedings.

Viewing Mercury as a North American Problem

Luke Trip, as a the Chair of the Mercury Task Force for the North American Regional Action Committee, expressed concern over mercury control efforts in Mexico. There is currently neither mercury monitoring nor a mercury inventory in Mexico. Now Mexico is building its first large coal-fired utility plant. Mexican environmental officials have just become aware that they have three mercury cell chlor-alkali facilities. Luke Trip urges "clean hands" across North America.

John Gilkeson commented that if Mexico is to address its mercury issues, the U.S. and Canada will have to directly fund staff time to make that happen. Mexico faces incredible barriers.

George Gissel noted that the Chlorine Institute and Eurochlor are working with their Mexican counterparts to raise their level of concern toward mercury issues as well as raise plant performance efficiencies. He also reiterated that an unintended consequence of a rapid shutdown of mercury cell plants in the U.S. could be a demand for caustic from mercury cell plants in foreign countries with few environmental controls. It takes 5 years to bring up capacity from a plant closure.

Workshop on Mercury Products, Processes, Waste, & the Environment: Eliminating, Reducing, & Managing Risks from Non-Combustion Sources

Baltimore, Maryland, March 22-23, 2000

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