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Report Of The National Technical Forum On Source Reduction Of Heavy Metals In Municipal Solid Waste

REPORT
ON
THE NATIONAL TECHNICAL FORUM ON SOURCE REDUCTION OF HEAVY METALS IN MUNICIPAL SOLID WASTE

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Abstract: The Forum was organized to assess the applicability of analytical process to determine the source reduction potential of specific products containing heavy metals.

Municipal solid waste source reduction as defined by the Conservation Foundation in its report Getting at the Source is 'the design, manufacture, purchase, or use of materials or products (including packages) to reduce the amount or toxicity before they enter the municipal solid waste stream'. For this Forum, the EPA decided to focus on the toxicity side of source reduction rather than volume or amount side and to invite all of the major players interested in the topic of source reduction to discuss source reduction options for particular products containing heavy metals.

FOREWORD

Source reduction is the first of four tiers in EPA's Agenda for Action[1] for integrated waste management. The other tiers in the hierarchy include recycling, incineration, and landfilling. Not creating a waste in the first place is the best option to control solid waste generation, however source reduction is the least studied and understood of the integrated waste management options. Source reduction involves reductions in both volume and toxicity.

EPA is interested in options for implementing source reduction and decided to evaluate three chemicals identified in EPA's "30/50" program list of 17 chemicals. Three heavy metals, lead, cadmium, and mercury, were chosen due to their content in common household or commercial products as well as recent EPA reports describing sources of the three metals in municipal solid waste.

In order to better understand source reduction, EPA sought to determine the implementation obstacles for products that contain these compounds. With an EPA grant, one group, the Conservation Foundation developed a methodology, with the assistance of industry, environmental groups, government and academics to study the issue of source reduction. The conclusion of their study was the report Getting at the Source, which outlines a framework to follow in considering source reduction options and implementing them.

The goal of this forum, through studying six consumer products, was to learn more about source reduction on a practical level, how it could be implemented, and what barriers and obstacles present themselves for the particular products studied and to the process of evaluating options.

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[1] The Solid Waste Dilemma: An Agenda for Action, Office of Solid Waste, February 1989, EPA/530-SW-89-019.

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SECTION 1

EXECUTIVE SUMMARY

1.1 INTRODUCTION

Concerns regarding the toxicity of heavy metals[1] and their presence in solid waste have caused the public and solid waste management officials to focus on the potential for source reduction. The U.S. Environmental Protection Agency (EPA) decided that a forum in which all of the major players interested in the topic of source reduction, the utilization of heavy metals, and the management of municipal solid waste could explicitly discuss options for source reduction for particular products containing heavy metals, would serve a useful function in advancing the state-of-the art in source reduction.

As a result, the National Technical Forum on Source Reduction of Heavy Metals in Municipal Solid Waste (the Forum) was organized to assess the applicability of an analytical process to determine the source reduction potential of specific products containing heavy metals. The analytical process is described in Getting at the Source: Strategies for Reducing Municipal Solid Waste, a report prepared by the World Wildlife Fund and The Conservation Foundation through a grant from EPA. It should be noted that although the report was prepared by the World Wildlife Fund and The Conservation Foundation, the work was conducted by the Strategies for Source Reducing Steering Committee, an inter-disciplinary group formed to analyze approaches to source reduction.

Municipal solid waste source reduction as defined by the Conservation Foundation in its report Getting at the Source is "the design, manufacture, purchase, or use of materials or products (including packages) to reduce the amount or toxicity before they enter the municipal solid waste stream." For this Forum, the EPA decided to focus on the toxicity side of source reduction rather than volume or amount side and to invite all of the major players interested in the topic of source reduction to discuss source reduction options for particular products containing heavy metals.

1.2 GOALS AND OBJECTIVES OF THE FORUM

The key goals and objectives established for the Forum are as follows:

- Evaluate the potential for source reduction for a set of chosen products, and where appropriate, make recommendations on initiatives to remove or reduce heavy metals in the municipal solid waste stream.

[1] Heavy metals is a term frequently used in the environmental field and is derived from a historical designation for certain metals. For the purposes of this Forum, heavy metals include lead, cadmium, and mercury.

- Test the framework for analysis of source reduction potential contained in Getting at the Source in application to specific products and assess its ability to guide interactive discussion and to develop potential initiatives and actions.

- Complement EPA's "33/50" program of voluntary actions by industry to reduce the release of 17 target compounds by analyzing the use of a subset of these compounds in specific products

1.3 SELECTION OF TARGET PRODUCTS

Since one of the goals of the Forum was to analyze specific products, it was necessary to determine which products should be targeted for discussion. The EPA determined that lead, cadmium, and mercury are compounds on the 33/50 list that are of concern in municipal solid waste. In addition, work has already been completed by EPA on the sources of those heavy metals in solid waste, as documented in Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000, and Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000. Four criteria were used to select target products containing these heavy metals:

- contribution to total heavy metal content in municipal solid waste (MSW),

- projected future contribution to total heavy metal content in MSW,

- potential for exposure of the environment or public, and

- source reduction activities to date.

These criteria were applied to products in MSW containing lead, cadmium, and mercury and six products were selected for analysis, two for each heavy metal. For mercury, the target products are fluorescent lights and thermometers. For lead, the target products are soldered circuit boards and cathode ray tubes (CRTs or television picture tubes). For cadmium, the target products are nickel-cadmium batteries and plastic stabilizers.

1.4 STRUCTURE OF THE FORUM

The Forum was two days in duration. Presentations were made to the participants about the rules and logistics of the Forum, the analytical framework in Getting at the Source, and the background information about the products. Participants were assigned to workshops based on their stated preferences, balanced by the needs to limit the number of people in each workshop, and to have all of the major sectors of participants represented in each workshop. Participants then broke into workshops focusing on each of the products. In each of the workshops attempts were made to apply the analytical framework for analyzing source reduction potential that is described in Getting at the Source. This framework provides a step-by-step procedure for evaluating source reduction potential. Each workshop had different experiences in trying to apply this analytical framework, and some workshops were able to proceed further with this analytical process than others.

The Forum was by invitation only, and representatives of industry, academia, government and public interest groups were invited. The organizers of the Forum made significant efforts to identify and invite recognized national experts to participate. One hundred and twenty-five people attended the Forum. Each of the participants was provided with background information about each of the target products, as well as how the target products were selected, and a copy of Getting at the Source prior to the Forum.

1.5 KEY CONCLUSIONS AND RECOMMENDATIONS

Some of the conclusions and recommendations are general in nature, and some are specific to the particular products. Only the more significant conclusions and recommendations are summarized in this Executive Summary.

1.5.1 General Conclusions and Recommendations

Many of the general conclusions and recommendations center on the issue of whether or not an environmental or public health problem had been identified associated with these products that warrants a thorough analysis of source reduction, as called for in the Forum. Different conclusions were drawn by different people regarding this issue and related issues, but this is reflective of the diverse nature of the participants.

Some of the key points made by Forum participants in relation to this issue of the nature or extent of the environmental problems associated with these products are summarized below. It is important to recognize that these points do not necessarily represent the views of the EPA.

- The analysis of source reduction potential, as outlined in Getting at the Source, is designed to start with a consideration of what the problem is, and some participants felt that this question was ignored, and that documentation of the nature and extent of the problem should have preceded selection of a product for consideration of source reduction potential.

- Some participants expressed the view that the background papers implied that in the absence of product-specific environmental impact data, adverse impacts would be "assumed." Some participants indicated that a risk assessment is necessary in order to demonstrate the presence of a public health or environmental problem.

- Some participants felt that data regarding the heavy metals content in landfill leachate and incinerator emissions is sufficient to indicate that there is no problem associated with disposal of products containing these heavy metals. Therefore these participants contended that the analysis of source reduction potential was unjustified. There was general agreement by a majority of participants that the Toxicity Characteristic Leaching Procedure (TCLP) test results are not a sufficient basis for establishing that a problem exists with disposal of a particular product.

- Some participants indicated their belief that there is a perception of risk associated with use of heavy metals in these products and that EPA's response to this perception should be public education to correct misperceptions as well as to foster source reduction where "true" risks are identified.

Other participants felt that there was sufficient evidence to warrant an analysis of source reduction potential, and made some of the following points:

- One of the purposes of the Forum was to gather information and the fact that the Forum resulted in sharing of information that characterizes the nature (or lack of) problems associated with disposal of these products is indicative of one successful outcome.

- Regulatory trends at the federal and state level are likely to continue to increase the costs of using these heavy metals in any manufacturing process. As a result an examination of source reduction potential makes sense from an economic standpoint, even if there is a belief that it is unnecessary from an environmental standpoint.

- Some participants noted that there are environmental problems associated with heavy metals, including emissions (gaseous and liquid) from landfill disposal facilities and combustion facilities, and that these problems are of concern to solid waste management professionals. To the extent that source reduction can address some of these problems, it will be serving a valuable solid waste management function, including potentially reducing the need for control technology at disposal facilities.

- Some participants indicated their belief that the toxicity of these heavy metals, in general, (that is, without relation to particular exposure paths or quantities) is justification for the analysis of source reduction potential, and that additional analyses of environmental or health impact may refine the understanding of the problem, but are not a prerequisite to source reduction analysis.

- It was noted that there is a tremendous disparity between the public's perception of the problems that pose the greatest risk to public health and the environment and the ranking of problems according to a scientific calculation of risk. EPA representatives noted that they cannot simply ignore the public's perception of risk and thus they need to balance addressing problems that represent significant scientific risks and those that the public demands be addressed. Source reduction is an issue that the public is focusing attention on and this Forum is one way to pay appropriate attention to this issue, while at the same time providing application of scientific analysis in the public interest.

There were some recommendations that were made by a number of the participants. These can be summarized as follows:

- Future discussions regarding source reduction should be multi-disciplinary and national in scope.
- Communication must be fostered between EPA and industry regarding issues associated with source reduction.
- The issue of environmental and public health risks associated with products should be further explored, including life cycle analysis, as appropriate.
- The analysis of source reduction potential should clarify and/or justify the distinction between recycling and source reduction.
- The federal government should participate in, or sponsor source reduction research and development, as part of its involvement in the solid waste management hierarchy, which also includes recycling, incineration, and landfilling.
- Many agencies of the federal government are involved in issues related to source reduction, so it is important that policies, guidance and regulations are coordinated among these agencies.

1.5.2 Product-Specific Conclusions and Recommendations

There are a fairly large number of product-specific conclusions and recommendations. Some of the more significant ones are summarized below.

1.5.2.1 Fluorescent Lights [Mercury]

In this workshop 28 source reduction options were identified. These options were grouped into four categories:

1. Fully utilize the useful life of fluorescent lamps.
2. Reach the lowest optimum mercury level without sacrificing current life or efficiency standards.
3. Use fewer lights.
4. Develop alternative lights and lighting systems.

These four categories of options were evaluated and the Table 1-1 summarizes the results of the evaluation.

Table 1-1

Evaluation of Source Reduction Options for Fluorescent Lights

Criteria	Fully Utilize Useful Life of Bulbs	Reach Lowest Optimum Mercury Level	Use Fewer Lights	Develop Alternative Lights & Systems
Effectiveness	+	+ +	+ (short term) + + (long term)	+
Impact on Usefulness of Product	?	0	?	+
Economic Impacts Manufacturers Consumers	 - ?	 - -	 - +	 + +
Environmental Impacts Elsewhere	0	?	+	+
Technical Feasibility	+	+	+	?
Practical Feasibility	?	+	+	?

Key: + Positive; - Negative; 0 Neutral; ? Unknown.

Two source reduction options were determined to have the greatest potential for being effective in the short-term: 1) reaching the lowest optimum mercury level; and 2) using fewer lights. With regard to these two options, the following conclusions were reached:

- Reaching the lowest optimum mercury level can be achieved through reduction in the mercury dose introduced into fluorescent lights, and/or through identification of alternative glass types or coatings to reduce the consumption of mercury during the life of the lamp.

- Using fewer lights can be achieved through:
  - modifying consumer behavior regarding usage,
  - amending building codes to modify amount of light needed per unit area,
  - modifying design philosophy to incorporate use of daylighting, and
  - switching to newer, lighter fluorescent bulbs.

Two other key conclusions and recommendations that were made are as follows:

- The analysis of source reduction potential should involve lighting systems (bulbs plus fixtures) and not just the bulbs.
- The regulatory status of spent fluorescent bulbs should be clarified.[1]

1.5.2.2 Thermometers [Mercury]

The analysis of thermometers was broken down into two categories, one for household thermometers and one for commercial and industrial thermometers. This was done because the nature of the thermometers is very different in these two categories of application.

Seven source reduction options were identified for household thermometers:

1. Eliminate/substitute for mercury with electronics.
2. Formulate an international performance standard for durability.
3. Educate consumers about proper use, maintenance and disposal of thermometers.
4. Streamline manufacturing process to reduce in-house waste and rejects.
5. Address issues of unlevel playing field with imports.
6. Establish programs for research and development and technology transfer.
7. Increase life span.

Fourteen source reduction options were identified for industrial thermometers:

1. Replace some instruments with electronics.
2. Reduce bore size of thermometers.
3. Fill thermometers with alternative substances.
4. Substitute soda-lime glass for leaded glass.
5. Increase life span through armoring of thermometer.
6. Increase life span through annealing of glass.
7. Increase life span through encapsulation.
8. Increase life span through use of engineering plastics or more durable glass.

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[1] On February 11, 1993 (subsequent to the Forum), EPA issued a Notice of Proposed Rulemaking (Federal Register Vol. 58, No. 27) that is designed to facilitate recycling of materials that are often regulated as hazardous waste. In addition, in January 1993, EPA issued a fact sheet entitled "Fluorescent Lamp Disposal" which provides answers to frequently-asked questions about fluorescent lamp disposal.

9. Establish an international performance standard.
10. Educate consumers about proper use and maintenance.
11. Streamline the manufacturing process to reduce in-house waste.
12. Borrow/share instruments.
13. Establish a level international playing field.
14. Establish governmental research and development and technology transfer programs.

The following are the source reduction options that were determined to have the greatest potential for household and industrial thermometers:

- Establish a "pay or play" system which would hold importers to the same standards as domestic manufacturers.

- Develop consensus on international performance standards.

- Develop a public education campaign.

- Support research and development for new technologies and processes.

- Make existing technology transfer opportunities more apparent, and promote their use.

- Increase life span of products through promotion of existing technologies and investigation of new ones.

- Reduce the bore size of industrial thermometers.

- Overcome barriers to revising industrial standards to allow modifications to products and processes.

1.5.2.3 Soldered Circuit Boards [Lead]

In this workshop it was concluded that the two major uses of tin/lead solder in circuit boards must be analyzed separately, since there are different issues associated with each use. One use of solder is as an etch-resist in the manufacture of the circuit board, and another is to connect components to the circuit board. Three source reduction options were identified for use of solder as an etch-resist:

- change the coating material to a lead-free formulation,
- change the manufacturing process/technology, and
- use alternative materials for circuit boards.

For use of tin/lead solder as a connecting medium, the following source reduction options were identified:

- use a different material, such as adhesive,

- increase the density of the circuit board so that fewer interconnections are necessary, and

- use of a totally new technology or process.

The participants in this workshop felt that an evaluation of these options could not be undertaken because it would require discussing proprietary data, and because the evaluation framework was not deemed applicable to this industry or application. However, general discussion about the issue of source reduction did occur. The participants wanted the conclusions of the Surface Mount Council Report White Paper, An Assessment of Use of Lead in Electronic Assembly adopted, with some modifications. Some of the key modified conclusions are as follows:

- Tin/lead solder has certain properties such that no currently viable alternative provides a complete replacement.

- Lead-free joining systems are currently being investigated.

- The most promising lead-free materials that can be used to replace tin/lead solder in some applications are alloys of tin, with additions of bismuth, antimony, silver, copper or indium. Major changes in the manufacturing processes would have to be made to accommodate these substitutes.

- There are a number of data deficiencies that need to be addressed in relation to lead-free solders, including performance, manufacturing and environmental issues.

1.5.2.4 Cathode Ray Tubes [Lead]

Eleven source reduction options were identified in this workshop:

1. Substitute zirconium for lead in the faceplate.

2. Increase use of projection televisions.

3. Flat panel liquid crystal displays (LCD's).

4. Increase product life of CRTs to 15 years.

5. Lower voltage used in electron guns contained in CRTs.

6. External shielding as a substitute for lead in the funnel glass.

7. Substitute for "frit," which is the term for the glass solder used to join the faceplate to the neck.

8. Substitute barium or strontium for lead.

9. Impose a luxury tax on screens over 19 inches.

10. Lower lead concentrations in the funnel glass.

11. Changing the X-ray standards to allow for greater exposure, which would allow for lower quantities of lead to be used in the glass in CRTs.

The evaluation of these options is summarized in the matrix shown below.

Table 1-2

Evaluation of Source Reduction Options for CRTs

Option	Reduction Achievable	Technical Feasibility	Cost	Environmental Trade-off	Perform
1. Zirconium	+	+	-	0	0
2. Projection TV	+1/2	0	-	-	-
3. Flat Panel	++	?	-	?	?
4. Longer life	0	+	-	0	0
5. Lower voltage	++	++	+	0	--
6. External Shielding	+++	++	-	--	0
7. Substitute for frit	+1/2	+	-	--	-
8. Barium/ Strontium Substitute	+++	-	-	-	—
9. Luxury tax	0	-	-	0	1/2
10. Lower lead in funnel	0	++	-	0	-
11. Change X-ray standards					

Key: + Positive; - Negative; 0 Neutral; ? Unknown.

As a result of this evaluation, two short-term options and one long-term option were ranked as having the greatest potential. The two short-term options are zirconium substitution in the faceplate of the CRT and lower voltage CRTs. The long-term option is development of flat panel technology, which would replace the CRT. It is important to note that although the participants in this workshop went through the exercise of evaluating and ranking options, they did not want that to be taken as an endorsement that any source reduction measures are necessary related to CRTs.

A number of implementation strategies were identified for use of zirconium in faceplates. This is an existing technology, so the implementation strategies are designed to foster its use. Two key obstacles were identified in implementing this option: 1) overseas suppliers provide about 30 percent of the glass used in U.S. CRTs; and 2) major retooling of the CRT glass manufacturing process would be required, and the faceplate only contains 15 to 20 percent of the total lead in a CRT.

For the lower voltage option, the implementation strategies were ranked, with the highest ranking being implementation of a worldwide standard for voltage. The key implementation obstacle is that lower voltage means a decrease in performance that is likely to be unacceptable to consumers. The strategies for implementing the long-term option of use of flat panel technology involve fostering research and development. The obstacles to this option are not known.

1.5.2.5 Nickel-Cadmium Batteries [Cadmium]

Seventeen options were identified for source reduction of cadmium in nickel-cadmium batteries:

1. Improve the manufacturing process to use cadmium more efficiently.

2. Improve the performance of the batteries without using more cadmium.

3. Education from the industry/manufacturer for the consumer to make better use of the product.

4. Society taking responsibility for efficient use of product.

5. Using products that can use alternating current (AC) electricity, as well as direct current (DC).

6. Making products such that the consumer can remove the batteries and replace them, instead of disposing of the product entirely[1].

7. Education of consumers to purchase more energy-efficient products.

8. Developing products for the consumer with an indicator that shows when the battery needs recharging.

9. Designing a "smart charger" that prevents over-charging a battery.

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[1] According to information provided by The Cadmium Council subsequent to the forum, many states have legislation establishing this requirement and the members of the Portable Rechargeable Batteries Association have agreed to implement this measure.

10. Leasing/renting and sharing of industrial products.

11. Replacing the electrodes in industrial batteries, instead of replacing the entire battery. (Because the nickel electrodes in industrial batteries require replacement more quickly than the cadmium, by replacing the nickel electrode only, the cadmium can be used to its full value.)

12. Improving the life of the battery.

13. Educate consumers not to buy products they do not need.

14. Label batteries for product life.

15. Specialize batteries for particular applications in the consumer marketplace.

16. Substitute other types of batteries that have less environmental impact.

17. Develop smaller products, which will allow batteries to last longer.

These options were categorized into groups:

1. Technological options.
2. Consumer education options.
3. Recycling options.

The participants in this workshop felt that they were unable to comparatively evaluate the options because of lack of information.

Other conclusions and recommendations which were developed include the following:

- Uniform federal guidelines for the regulation of nickel-cadmium batteries should be developed.

- The consumer should be provided with more information about the proper use and disposal of nickel-cadmium batteries.

- Research and development funding should be provided for analysis of sorting and reclamation technologies.

- An EPA-sponsored battery recycling conference should be sponsored.

1.5.2.6 Plastic Stabilizers [Cadmium]

Ten options were identified for source reduction of cadmium in plastic stabilizers:

1. Ban PVC plastics (which are the only plastics that use cadmium-based stabilizers).
2. Establish a user fee for cadmium.
3. Utilize voluntary efforts to reduce use of cadmium.
4. Reformulate plastic stabilizers to utilize substitutes for cadmium.
5. Reduce amounts of cadmium in plastic stabilizers.
6. Design products to increase their useful life.
7. Ban applications in which cadmium-based stabilizers are required.
8. Reduce use of products that contain cadmium-based stabilizers.
9. Establish a government-sponsored bonus for source reduction of cadmium-based stabilizers.
10. Promote use of reusable products that contain cadmium-based stabilizers.

The following matrix summarizes the evaluation of these options.

This evaluation resulted in the selection of three criteria that were considered worthy of further consideration: 1) voluntary efforts; 2) promote reusable products; and 3) establish a user fee for cadmium. There are two points made in relation to these options that are important to note. The participants felt that the second and third options should only be explored if voluntary efforts do not achieve the desired results. In addition, participants did not want the ranking of source reduction options to be considered an endorsement of the need for source reduction in this product.

The primary reason that voluntary efforts were so strongly preferred over the other source reduction options for this product is that efforts to reduce cadmium in this product are well underway. Some participants believe that cadmium will be eliminated from plastic stabilizers within five years, and as a result, the need for other source reduction actions was questioned.

Table 1-3

Evaluation of Source Reduction Options for Plastic Stabilizers

Source Reduction Option	Criterion I: Achievement of SR goal	Criterion II: Other effects of implementing option	Criteria III: Technical Barriers	Does Option Merit Further Discussion?
Ban PVC	++	--	-/+	No, as it is not socially or economically desirable
User Fee	+	-	++	Yes
Voluntary Efforts	+	++	+	Yes
Substitution/ Reformulation	++	++	+	Yes, but it is actually a part of Voluntary Efforts
Reduce Cd Amounts	+	?	++	Yes, but it is actually a part of Voluntary Efforts
Design for Extended Product Life	+	?	+	No, because this is achieved by increasing Cd
Ban Applications Requiring Cd	++	-	+	No, as it is not socially or economically desirable
Reduce Use of Cd-containing Products	+	-/+	-/+	No, as this would require high levels of resources applied to consumer education
Government Bonus for SR	+	?	-	No, because of resources required for implementation
Promote Reusable Products	+	+	+	Yes

Key: + Positive; ++ Highly Positive; - Negative; -- Highly Negative; +/- Positive and Negative Attributes; ? Unknown.

SECTION 2

PURPOSE OF FORUM

2.1 INTRODUCTION

The National Technical Forum on Source Reduction of Heavy Metals in Municipal Solid Waste (the Forum) was organized to assess the applicability of an analytical process to determine the source reduction potential of specific products containing heavy metals. The analytical process is described in Getting at the Source: Strategies for Reducing Municipal Solid Waste, a report prepared by the World Wildlife Fund and The Conservation Foundation. This process had never been applied in a rigorous fashion to specific products, so the Forum was designed to take that next step. This section describes the goals, objectives and structure of the Forum, and summarizes the analytical framework contained in Getting at the Source.

2.2 GOALS AND OBJECTIVES OF THE FORUM

Concerns regarding the toxicity of heavy metals and their presence in solid waste have caused the public and solid waste management officials to focus on the potential for source reduction. The U.S. Environmental Protection Agency (EPA) decided that a forum in which all of the major players interested in the topic of source reduction could explicitly discuss options for source reduction for particular products containing heavy metals, would serve a useful function in advancing the state-of-the art in source reduction, in particular by assessing the application of an analytical process to specific products.

The EPA chose three heavy metals to focus on: lead, cadmium, and mercury. They also determined that the analytical framework presented in Getting at the Source should be used as the basis for evaluating source reduction potential. With this in mind, the following goals and objectives for the Forum were developed:

- Complement EPA's "33/50" program of voluntary actions by industry to reduce the release of 17 target compounds (including lead, cadmium, and mercury).

- Discuss barriers to reducing heavy metals in municipal solid waste stream.

- Make recommendations on initiatives to remove or reduce heavy metals in the municipal solid waste stream.

- Discuss specific products containing these heavy metals chosen on the basis of their contribution to heavy metals in solid waste and the potential for exposure of the public or the environment.

- Test the framework for analysis of source reduction potential contained in Getting at the Source in application to specific products.

It was anticipated that the results of the Forum could be used in a variety of ways, including:

- Use results of Forum as basis for voluntary source reduction activities, as well as future analytical work.

- Results of Forum will be published so that they can be used to stimulate additional activities.

- Potential EPA follow-up activities:

    - monitor source reduction activities and publicize success stories;
    - further research on substitutes or alternatives to heavy metals;
    - provide technical assistance to any industry that wants to reduce heavy metals in their products on a voluntary basis; and
    - continue to evaluate the scientific information associated with the environmental or public health risk posed by constituents of products which end up in the solid waste stream.

2.3 SUMMARY OF ANALYTICAL FRAMEWORK IN GETTING AT THE SOURCE

The analytical framework described in Getting at the Source was developed by an inter-disciplinary group that was formed to address the topic of source reduction. The framework consists of a five step process, which is summarized below.

Step 1: Selecting a Target for Analysis

In this step, a number of criteria can be used to select a target for analysis. The suggested screening criteria are as follows:

- percentage share of the waste stream,
- expected growth in quantity and share of waste stream,
- toxicity,
- wastes generated over the product life cycle,
- special handling considerations,
- availability of information,
- identified alternatives for source reduction, and
- other considerations.

The screening criteria, as described in Getting at the Source, are not meant to be all-inclusive and the point is made that the criteria can be modified to suit their particular application of the framework.

Step 2: Identifying Source Reduction Options

Once a target(s) has been selected, the source reduction options that apply to that target can be identified. In this step of the process, the concept is to only identify options, and not to rank or evaluate them. Getting at the Source lists a number of categories of options that might be considered, including:

- increasing the life span of a product,
- substitution of environmentally preferred materials, and
- elimination of the product.

Step 3: Evaluation of Source Reduction Options

After the identification of source reduction options for a targeted product, these options can be evaluated to select the most desirable ones. To evaluate the source reduction options, three major criteria (with some sub-criteria) are suggested in the framework:

- effectiveness of option in achieving desired source reduction for this product;

- other effects, including impacts on:
  - environmental trade-offs,
  - product performance,
  - product price and sales,
  - manufacturers, retailers, distributors and others,
  - complementary products,
  - alternative products, and
  - recycling and other waste management options;

- technical barriers to implementing the option.

Step 4: Identify Implementation Strategies

For the source reduction options selected through application of Step 3, the strategies for implementing these options are identified. The first part of this step of the analysis is a determination of the obstacles to implementing the selected options. The nature of these obstacles could be any of the following:

- technical,
- informational,
- economic,
- institutional,
- overcoming consumer preferences, or
- overcoming existing public policies.

Once the obstacles are identified, the implementation strategies that address these obstacles can be determined. Getting at the Source lists a number of potential implementation strategies within three major categories:

- education, recognition and voluntary programs;
- economic incentives or disincentives; and
- administrative or regulatory actions.

Step 5: Evaluation and Selection of Implementation Strategies

The last step in the process is to evaluate the implementation strategies in order to select the most preferable ones. The framework suggests evaluating the implementation strategies by asking three categories of questions:

- How does the strategy apply to the option, and would it effectively overcome the obstacles identified?
- How feasible is implementation of this option?
- How burdensome is this strategy?

At the conclusion of this process, there should be a number of preferred source reduction options for the targeted product, and for each of these options, a number of implementation strategies that should be most effective in achieving the desired results.

2.4 STRUCTURE OF FORUM

It was determined that due to the wide range of technical, environmental, economic, and regulatory issues surrounding the topic of source reduction, that the Forum should include representatives of a number of different groups: industry, academia, regulators, and public interest groups. Participants were identified through research on the industries that produce the target products, product associations, pollution prevention organizations, solid waste management organizations, state and federal agencies regulating heavy metals, and international forums. Considerable effort was expended to identify and invite the appropriate people from industry to ensure that the technical issues associated with particular products could be addressed. Target products were selected prior to the start of the Forum. The process used to select these products is described in the next section of this Report.

Background papers were developed for each target product. These background papers describe the nature of the product, the purpose that the heavy metal serves in the product, the quantity of heavy metal used, and source reduction activities to date. The papers were provided to participants prior to the Forum, and are included within each section of this Report addressing the target products.

In order to ensure the appropriate mix of participants from the various groups attending, and to avoid an unmanageably large group, attendance at the Forum was by invitation-only. The small group size for each of the workshops analyzing specific products allowed an interactive process. This was one of the most important aspects of the Forum, since it was believed that only by interaction of all of the participants could the many viewpoints on source reduction be heard and reflected in whatever discussions took place.

With the desire for interaction in mind, the following structure for the Forum was developed:

- the Forum was two days in length;
- an introductory session was held on the morning of the first day of the Forum for all participants to attend, in which the objectives and logistics of the Forum were discussed, along with an overview of the background material on each product;
- the participants were divided amongst six workshops, one for each target product, in the afternoon of the first day and the morning of the second day; and
- during the afternoon of the second day, the results of each of the workshops were presented to the total group of participants.

The list of attendees of the Forum is provided in Appendix A. Each of the attendees was asked to rank their preferences for attending specific workshops, and the attenders were assigned to the workshops based, to the greatest extent possible, on those preferences. The participants in each workshop are listed in the sections describing the results for each target product.

SECTION 3

SELECTION OF TARGET PRODUCTS

3.1 CRITERIA FOR SELECTING TARGET PRODUCTS

One of the key concepts behind the National Technical Forum on Source Reduction of Heavy Metals in Municipal Solid Waste is that the best way to promote constructive discussion on the reduction of heavy metals is to pick certain products to use as the basis for discussion. This allows concrete, rather than hypothetical, discussions to take place which are more likely to result in conclusions regarding the potential for source reduction. With that concept in mind, the Technical Forum was designed around examination of particular products containing the heavy metals being discussed at the Forum: lead, cadmium, and mercury.

In order to select those target products, a set of criteria were developed. The criteria are designed to promote a rational approach to selecting target products. In addition, the criteria are designed to focus on products for which source reduction is at least a potentially important topic.

The criteria developed for selection of target products are summarized below.

1. Contribution to Total Heavy Metal Content in Municipal Solid Waste. In order to focus on source reduction activities that can significantly reduce the amount of heavy metals in the municipal solid waste (MSW) stream, it is important to target products which are significant contributors to the total heavy metal content in MSW. The contribution to total heavy metal content is a function of the concentration of the heavy metal in the product, and the quantity of that product that ends up in MSW. Certain products may contain high concentrations of a particular heavy metal, but due to the fact that those products represent a very small fraction of MSW, even if the heavy metal were totally eliminated from these products the total quantity of the heavy metal in MSW would not decrease significantly. On the other hand, there may be products that have more moderate concentrations of a heavy metal, but due to their prevalence in the waste stream even a slight decrease in the concentration of the heavy metal in these products would significantly decrease total heavy metal in MSW. By selecting products that are significant contributors to total heavy metal in MSW, any source reduction activities identified have the greatest potential to reduce heavy metals in MSW.

2. Projected Contribution to Total Heavy Metal in MSW. As a result of changes to the way a product is manufactured, either already underway or projected to occur, the contribution of certain products to total heavy metal in the waste stream may change in the future. In addition, certain products may stay exactly the same, but their prevalence in MSW may be projected to change in the future, which would also alter their total contribution to heavy metals in MSW. By including this criterion, products

are identified that not only currently contribute significantly to total heavy metals in MSW, but also that are projected to continue to remain significant contributors.

3. Potential for Exposure of Environment or Public. Certain products, due to their chemical or physical nature, may be significant contributors to total heavy metals in MSW, but there is little potential for the environment or the public to become exposed to the heavy metals in these products during their life cycle. A potential example of this is leaded glass (including leaded glass used in television picture tubes), which is a relatively significant contributor to total lead in MSW, but when landfilled the lead is not chemically available to leach out, which is the path for potential exposure of the environment or the public. (In this example, the potential for release of lead during incineration would have to be examined before determining that the total potential for exposure of the environment or public is low). For the purposes of this Forum, this criterion is not applied in any rigorous quantitative fashion, but it is designed to force an examination on a qualitative level of the potential for release of heavy metals during the life cycle of a product when it is being considered as a target for analysis.

4. Source Reduction Activities to Date. In order to maximize the effectiveness of this Forum on source reduction, it is important to understand the work done to date on source reduction for the potential target products. This avoids selecting target products for which the source reduction analysis would be a repetition of work already done, or would not be likely to yield significant results. Thus, several factors should be considered in reviewing the source reduction activities conducted to date in an attempt to determine if a product represents a good target for analysis. These factors are as follows:

   - products for which so little information exists that a determination of source reduction potential is difficult should not be considered as targets for inclusion in this Forum;

   - products for which the analysis of source reduction potential has been relatively thorough and has identified few, if any, future source reduction options (either because they do not exist or because they have been implemented) should not be considered as targets;

   - products for which the analysis of source reduction potential has been comprehensive enough that it is believed that any additional analysis would be repetitive are also inappropriate as target products; and

   - products for which adequate information and analysis is available to identify potential source reduction activities are those most suited to being targets to be included in this Forum.

With multiple criteria, it is important to establish a methodology for applying the criteria since a potential target product may rate high in one criterion and low in another. The following procedure was established to apply the criteria:

A. Use First Two Criteria to Establish Threshold. The first two criteria are the most important, and they can be used as a threshold to come up with a list of potential targets. These two criteria were used to develop a list of those products that are the biggest contributors to total heavy metals in the waste stream and are expected to remain significant contributors. Lists were made for each heavy metal of the products that are the top five contributors to total heavy metal in the waste stream, that are also projected to remain as one of the top ten contributors over the next ten years. The lists serve as the potential target list for further consideration.

B. Determine if Potential for Exposure is Significant. The third criterion would be used as a screen to potentially eliminate products from the short list generated in Step A, above. Since this analysis is qualitative in nature and information may not be available regarding the potential for exposure for each product, the potential for exposure is assumed to exist in the absence of strong evidence indicating that the potential for exposure of the public or the environment is insignificant.

C. Analyze Source Reduction Activities to Date. The fourth criterion can be used to select amongst products that remain after the first two steps. If there is a list of potential target products that is larger than the number desired, the analysis of source reduction activities to date for each of the products can be used to narrow the list.

3.2 SELECTION OF TARGET PRODUCTS

In actual application of the criteria, it was found that the first two criteria provided almost all of the guidance necessary to make the initial determination of target products. Although there were some questions associated with Criterion 3 (Potential for Exposure of Environment or Public) for certain products, the information available was generally insufficient to render a judgement regarding the relative potential for exposure associated with each product, and as a result, the potential was assumed to exist for all products, with no ranking of the products based on this criterion. Therefore, Criteria 1, 2, and 4 were used to select products with the understanding that if it was found during future analyses that the potential for exposure of the environment or public was insignificant for a targeted product, or insufficient information was available to analyze a product, that product would be dropped and the next most appropriate product substituted.

3.2.1 Lead

Criterion 1 - Contribution to Total Lead in Municipal Solid Waste (MSW)

According to Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000, US EPA, 1989, the top contributor to lead in the municipal solid waste stream is lead-acid storage batteries. Starting-lighting-ignition batteries, found primarily in vehicles, contributed 65 percent of the total lead in the municipal solid waste stream in 1986.

The second highest contributor of lead was consumer electronic products, notably television sets, radios, and video cassette recorders. These products contributed 27 percent of the lead in municipal solid waste in 1986. The largest sources of lead in consumer electronics were television picture tubes (which include the tubes used in computer monitors which are often referred to as CRTs), contributing 24 percent of the lead in municipal solid waste, and the solder in circuit boards, contributing 3 percent of the lead in municipal solid waste.

After these two products, the percent contributed by particular products declines dramatically. Glass and ceramics together comprise 4 percent of the lead in municipal solid waste, plastics comprise nearly 2 percent, solder in cans and containers comprise 1 percent, and all other products comprise less than 1 percent. The lead in plastics is from stabilizers and pigments.

Criterion 2 - Projected Contribution to Total Metal in MSW

By the year 2000, two products, lead-acid batteries and TV picture tubes, are projected to contribute 94 percent of the total lead in municipal solid waste discarded. Recycling decreases the amount of a particular product discarded, but it is the rate of recycling in comparison with other products, as well as the total quantity generated that impacts the percentage contribution to total lead discarded. Thus, despite recycling efforts, lead-acid batteries are expected to continue to comprise between 64 and 65 percent of the total lead discarded in MSW, and TV tubes (including CRTs) are expected to increase to 30 percent of the total. As in prior years, the subsequently ranked products are significantly smaller contributors. Glass and ceramic products are projected to comprise 3 percent of the total lead in municipal solid waste in the year 2000 and plastics will comprise 1.1 percent of the total. All other products, including circuit boards in consumer electronics, which ranked as the fourth largest source in 1986, are projected to comprise less than 1 percent of the total lead in municipal solid waste. The lead in circuit boards is projected to decline due to the expected decline in the use of lead in solder, however it is unclear how quickly this will occur. The use of leaded solder in cans has been virtually eliminated and thus, its contribution to lead in MSW is projected to decline very rapidly.

Criterion 3 - Potential for Exposure of Environment or Public

It is unclear if the lead in leaded glass (which is also the source of the lead in television picture tubes) is released to the environment in landfills or incinerators. No clear cut evidence in this regard was found, so the potential for exposure was assumed to exist.

Criterion 4 - Source Reduction Activities to Date

The source reduction potential of lead-acid batteries has been well analyzed with the result being an increased focus on recycling. Thus, lead-acid batteries were considered inappropriate for inclusion in the Technical Forum. The analysis of source reduction potential for pigments (which is the source of lead in ceramics) has been quite thorough and, as a result, it is believed that any analysis conducted as part of this Forum would be redundant.

Application of Criteria

The results of EPA's analysis of current and projected contributors of lead in the waste stream suggest that reducing the lead contributed by two products, lead-acid batteries and TV picture tubes, could have the most dramatic impact on reducing lead in the waste stream. Table 3-1 shows the ranking of contributors to lead in municipal solid waste relative to the criteria used to select products for consideration at the Technical Forum. The evaluation of Criterion 4 eliminated lead-acid batteries and the glass/ceramics category. Although the contribution of circuit boards is expected to decline, it is not clear how quickly or completely this will happen without additional research. Therefore, television picture tubes and circuit boards were chosen as the two target products, with plastics, glass, and ceramics as alternates if either of these products is found to be inappropriate.

TABLE 3-1

RANKING OF PRODUCTS AS SOURCES OF LEAD IN MUNICIPAL SOLID WASTE

Product	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Consider?
Lead-Acid Batteries	1	1	--	Inappropriate	No
Consumer Electronics: TV picture tubes	2	2	--	Appropriate	Yes
Glass and Ceramics	3	3	--	Inappropriate	No
Consumer Electronics: circuit boards	4	-	--	Appropriate	Yes
Plastics	5	4	--	Appropriate	As Alternate
Solder in cans and containers	6	-	--	Appropriate	No

3.2.2 Cadmium

Criterion 1 - Contribution to Total Cadmium Content in MSW

According to Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000, US EPA, 1989, the top contributor to cadmium in the municipal solid waste stream is rechargeable nickel-cadmium batteries.[1] These household batteries contributed 52 percent of the total cadmium in the waste stream in 1986.

The second highest contributor of cadmium is plastics. In total, plastics contributed 28 percent of the cadmium to the waste stream in 1986. More specifically, plastic non-food packaging (such as so-called "blister packs" which are typically bonded to a cardboard backing) contributed 9 percent of the cadmium in municipal solid waste, miscellaneous durable plastic products (such as toys and rigid plastic containers) contributed nearly 6 percent, miscellaneous non-durable plastic products (such as plastic silverware) contributed nearly 3 percent, and furniture and toys contributed 2.6 percent and 2.5 percent respectively.

Cadmium plating in consumer electronics contributed 9 percent of the cadmium in municipal solid waste. Appliances contributed nearly 5 percent, which can be attributed to cadmium plating (1.3 percent) and plastics (3.6 percent) in appliances. Glass and ceramic products contribute nearly 2 percent, and all other products comprise less than 1 percent.

<u>Criterion 2 - Projected Contribution to Total Cadmium Content in MSW</u>

The top six contributors for cadmium remain the same from 1986 to the year 2000, but they change their prominence and order. By the year 2000, the contribution of rechargeable nickel-cadmium batteries to cadmium in the municipal waste stream is expected to increase to 76 percent of the total, due to a projected continued increase in their use.

Plastic products are expected to decline to 14 percent of the total cadmium in municipal solid waste, partially due to a decrease in cadmium in these products and partly due to the increase in the percentage projected for batteries. The cadmium in plastic products is attributed to several durable and non-durable products. Cadmium is used in polyvinyl chloride stabilizers and pigments in plastics. The cadmium in two other top contributors, appliances and consumer electronics, which each comprise over 2 percent of the cadmium in municipal solid waste, is primarily due to the plastics in these products.

The percentage of cadmium contributed by consumer electronics and appliances is projected to decline due to a significant reduction in the use of cadmium plating in these products. Pigments increase from the fifth to the third largest source of cadmium between 1986 and the year 2000 (though the total percentage does not change much), because of this decline in cadmium contributed by consumer electronics and appliances. The only other products contributing over 1 percent are glass and ceramic products, which are projected to comprise 1.4 percent of the total cadmium in municipal solid waste in the year 2000.

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[1] It should be noted that during and subsequent to the Forum, industry representatives questioned the validity of the quantities presented in this report for cadmium projected to be in municipal solid waste, and provided verbal estimates of lower quantities; however, the only written reference for cadmium quantities in the waste stream is that referenced herein.

Criterion 3 - Potential for Exposure of Environment or Public

No issues identified.

Criterion 4 - Source Reduction Activities to Date

All potential target products appear appropriate on the basis of evaluating source reduction activities to date. Source reduction options have been well studied for nickel-cadmium batteries, but not to the point where there is no need for additional analysis at the Technical Forum.

Results of Application of Criteria

Table 3-2 shows the ranking of contributors to cadmium in municipal solid waste relative to the criteria used to select products for consideration. The table shows that nickel-cadmium batteries and plastics should be considered unless they are eliminated through further investigation of issues associated with Criterion 3 or 4. Consumer electronics and appliances should not be considered separately since, in the future, the major contributor of cadmium in these products is expected to be plastics. Thus, it is assumed that if the cadmium in plastics is addressed, then the cadmium in consumer electronics and appliances are addressed. Pigments would serve as an alternative, if batteries or plastics fall out as a result of further analyses related to Criterion 3 or 4. Glass and ceramics are not recommended for consideration because of their relatively low contribution to total cadmium in municipal solid waste. Further investigation of the plastics category revealed that there is cadmium in both pigments and stabilizers added to plastics. The stabilizers are the more significant contributor of cadmium.[1] Stabilizers are added to plastics to protect them from degradation when exposed to heat or light. Cadmium-containing stabilizers are typically added for heat stabilization. Thus, the two products targeted for cadmium are nickel-cadmium batteries and cadmium-based plastic stabilizers.

3.2.3 Mercury

Criterion 1 - Contribution to Total Mercury Content in MSW

According to Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000[2], US EPA, 1992, the top contributor to mercury in the municipal solid waste stream are household batteries, which contributed 88 percent of the total mercury

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[1] It should be noted that during and subsequent to the Forum, industry representatives disputed the values used to determine the contribution of cadmium to the waste stream, and in particular, noted their belief that pigments are a larger contributor than stabilizers. However, no comprehensive source for alternative values has been identified.

[2] In comments during and after the Forum, industry representatives questioned the validity of the numbers in the U.S. EPA report, particularly the assumptions used about the short life span of thermometers which they believe over-estimated the generation rate.

TABLE 3-2

RANKING OF PRODUCTS AS SOURCES OF CADMIUM IN MUNICIPAL SOLID WASTE

Product	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Consider?
Nickel-Cadmium Batteries	1	1	--	Appropriate	Yes
Plastics	2	2	--	Appropriate	Yes
Consumer Electronics	3	4	--	Appropriate	No
Appliances	4	5	--	Appropriate	No
Pigments	5	3	--	Appropriate	As Alternate
Glass and Ceramics	6	6	--	Appropriate	No

in the municipal solid waste stream in 1989. Over 59 percent of the total mercury was from alkaline batteries, 28 percent was from mercury-zinc batteries, and less than 1 percent was from other household batteries.

The second highest contributor of mercury is electric lighting, including fluorescent and high intensity lamps. In total, electric lighting contributed 3.8 percent of the mercury to the municipal waste stream in 1989, 3.7 percent of it from fluorescent lamps.

Paint residues contributed 2.6 percent of the total mercury, fever thermometers contributed 2.3 percent, thermostats contributed 1.6 percent and pigments contributed 1.4 percent in 1989.

<u>Criterion 2 - Projected Contribution to Total Mercury in MSW</u>

The top contributor to mercury in 1989, alkaline batteries, is expected to be greatly reduced by the year 2000. Thus, even though alkaline batteries ranked the highest by criterion 1, it is eliminated from consideration by Criterion 2. The mercury in mercury-zinc batteries, however, is not projected to be eliminated. Although the total tonnage of mercury contributed by mercury-zinc batteries is expected to continue to decline, because of the sharp reduction of mercury in alkaline batteries, mercury-zinc batteries become the largest contributor of mercury in municipal solid waste.

The percentage of mercury contributed by fluorescent lamps is expected to increase, both because of an actual increase in tonnage from these sources, and because of the elimination of alkaline batteries as a source (and resulting reduction in total mercury). Since mercury was banned in the manufacture of paint by the U.S. EPA in the early 1990s, it is anticipated that it will comprise an increasingly smaller portion of the mercury in municipal solid waste.

Although the tonnage of mercury contributed by fever thermometers and thermostats are anticipated to remain about the same from 1989 to the year 2000, the percentage of the total mercury these products contribute increases as the total tonnage of mercury decreases due to the elimination of mercury in alkaline batteries and paint residues.

Criterion 3 - Potential for Exposure of Environment or Public

No issues identified.

Criterion 4 - Level of Source Reduction Activities to Date

Source reduction potential for alkaline batteries has been thoroughly analyzed and source reduction activities are well underway. Therefore, further analysis through this Technical Forum would be redundant. Fluorescent bulbs have also been analyzed for source reduction potential, but in this case it appears that there is a need for further discussion and analysis of the issues identified, making it an ideal candidate for inclusion in the Technical Forum.

Results of Application of Criteria

Table 3-3 shows the ranking of contributors to mercury in municipal solid waste relative to the criteria used to select products for consideration at the Heavy Metals Source Reduction Conference. The table shows that alkaline batteries should not be considered since source reduction measures are already being taken and are expected to completely eliminate alkaline batteries as a source of mercury by the year 2000. Mercury-zinc batteries are worthy of consideration because they contribute a large portion of the total mercury to the waste stream and are expected to continue to. However, batteries in general have been studied relative to their source reduction potential and to avoid focusing too heavily on one type of product (since nickel-cadmium batteries are a target product) other products should be considered. Fluorescent lamps should be considered because they also contribute a large proportion of the total mercury to the waste stream. In addition, the contribution of fluorescent bulbs to total mercury is expected to increase both on a relative and absolute basis. It is recommended that paint residue not be considered since, in the future, its contribution of mercury should decline dramatically. Fever thermometers and thermostats are worth considering, particularly because they have not been analyzed to a great extent regarding source reduction potential, and their relative contribution to total mercury is expected to increase. Therefore, the two targeted products are fluorescent bulbs and thermometers and other measuring devices. The thermometer category was expanded to include other mercury-based measuring devices.

3.3 CONCLUSIONS

The application of the criteria, as well as factors such as achieving "balance" in the list of products and the degree to which source reduction opportunities have already been studied, leads to the selection of six target products. Other potential products of interest have been identified as alternates in case a product is eliminated due to the evaluation of Criteria 3 or 4.

TABLE 3-3

SCREENING OF PRODUCTS AS SOURCES OF MERCURY IN MUNICIPAL SOLID WASTE

Product	**Criterion 1**	**Criterion 2**	**Criterion 3**	**Criterion 4**	**Consider?**
Alkaline Batteries	1	-	--	Inappropriate	No
Mercury-Zinc Batteries	2	1	--	Appropriate	Yes
Fluorescent Lamps	3	2	--	Appropriate	Yes
Paint Residues	4	-	--	Appropriate	No
Fever Thermometers	5	3	--	Appropriate	As Alternate
Thermostats	6	4	--	Appropriate	As Alternate

TABLE 3-4

PRODUCTS RECOMMENDED FOR CONSIDERATION

Metal	**Lead**	**Cadmium**	**Mercury**
Recommended Products	TV Picture Tubes, Electronic Circuit Boards	Nickel-Cadmium Batteries, Cadmium-based Plastic Stabilizers	Fluorescent Lamps, Thermometers and Other Measuring Devices
Alternates	Glass and Ceramics, Plastics	Pigments	Thermostats, Zinc-Mercury Batteries

SECTION 4

GENERAL ISSUES RAISED AT FORUM

4.1 SUMMARY OF MAJOR ISSUES RAISED

Throughout the Forum there were several issues that were raised by a number of participants that were not related to a specific target product, but instead were directed towards the nature and focus of the Forum itself. In some instances, the issues may have been raised in the context of discussions on a particular product, but in review of the discussions held in all workshops it became clear that there were certain general topics which were being raised repeatedly. Thus, rather than summarize those comments and discussion in each of sections on particular products, this section has pooled all of those comments into a centralized location in the document. This appears to be the best way to highlight the important and general nature of these comments and to avoid repetition of the same issues. Important product-specific points raised in relation to these issues are summarized in the sections that address each of the target products.

Many of the general issues that were raised revolved around a central question: "Why are we here?" In many different ways participants questioned whether the EPA had demonstrated that there was a significant enough problem to warrant the type of analysis and attention to the issue of source reduction called for by the Forum. There were many specific questions and sub-issues that were raised in relation to these central questions. The main questions and issues raised can be summarized as follows:

- The analysis of source reduction potential, as outlined in Getting at the Source, is designed to start with a consideration of what the problem is, and some participants felt that this question was being ignored, and that a documentation of the nature and extent of the problem should have preceded any consideration of source reduction potential.

- Some participants felt that the background papers implied that in the absence of product-specific environmental impact data, adverse impacts would be "assumed." This was bothersome to some participants and seemed to them to be a presumption of "guilt." Some participants indicated that a risk assessment is necessary in order to demonstrate the presence of a public health or environmental problem before analysis of source reduction potential is initiated.

- Some participants felt that data regarding the heavy metals content in landfill leachate and incinerator emissions is sufficient to indicate that there is no problem associated with disposal of products containing these heavy metals, and therefore the analysis of source reduction potential was unjustified. There was general agreement that the Toxicity Characteristic Leaching Procedure (TCLP) test results are not a sufficient basis for establishing that a problem exists with disposal of a particular product.

- The question of whether or not EPA should involve itself in product design issues was raised by some participants.

- Questions were raised regarding the appropriateness of focusing only on the disposal-related impacts associated with these products and not fully recognizing the need for a life cycle approach to source reduction analysis.

- Some participants indicated their belief that there is a perception of risk associated with use of heavy metals in these products and that EPA's response to this perception should be public education to correct misperceptions and not to try to implement source reduction.

- It was noted by some participants that there are products that are greater contributors to the total heavy metal content in MSW than the products targeted in the Forum, and that the focus should be on those products.

Although there was no resolution of these issues, some points were made in response to the issues. These can be summarized as follows:

- One of the purposes of the Forum was to gather information and to the extent that the Forum resulted in sharing of information that characterizes the nature (or lack of) problems associated with disposal of these products, then that should be considered a successful outcome of the Forum.

- There are many regulatory trends which are likely to continue to increase the costs of using these heavy metals in any manufacturing process and as a result an examination of source reduction potential makes sense from an economic standpoint, even if there is a belief that it is unnecessary from an environmental standpoint.

- Some participants noted that there are environmental problems associated with heavy metals, including emissions (gaseous and liquid) from disposal facilities and these problems are of concern to the public and to solid waste management professionals. To the extent that source reduction can address some of these problems, it will be serving a valuable solid waste management function.

- Some participants noted that manufacturers are not currently responsible for managing products after use and one participant expressed the belief that source reduction would not occur until manufacturers had that responsibility.

- Some participants indicated their belief that the toxicity of these heavy metals, in general, is justification for the analysis of source reduction potential, and that additional analyses of environmental or health impact may refine the understanding of the problem, but are not a prerequisite to source reduction analysis.

- It was noted that there is a tremendous disparity between the public's perception of the problems that pose the greatest risk to public health and the environment and the ranking of problems according to a scientific calculation of risk. EPA representatives noted that they cannot simply ignore the public's perception of risk and thus they need to balance addressing problems that represent significant scientific risks and those that the public demands be addressed. Source reduction is an issue that the public is focusing attention on and this Forum is one way to pay appropriate attention to this issue.

- Similarly, even though the public's perception of risk may be greater than the actual risk, if the public makes buying decisions based upon that perception, it is prudent to listen and respond to those perceptions. Response can take many shapes, ranging from efforts to eliminate the cause of the perception to increased public education.

Another major topic of discussion in all of the workshops was the issue of recycling. Many participants felt that the distinction between source reduction and recycling was unclear, arbitrary or unnecessary. As a result, there was considerable discussion regarding recycling potential for each of the target products. An attempt was made in each workshop to ensure that source reduction issues were fully explored before proceeding to a discussion of recycling potential. The specific recycling options discussed in each workshop are summarized in the sections of this Report addressing each target product.

The Introduction to Background Papers, which was distributed to all participants of the Forum, discusses some of the issues that are summarized above. Therefore, it is reproduced below.

4.2 INTRODUCTION TO BACKGROUND PAPERS

Background papers have been prepared for each of the target products selected. These papers contain some of the key information necessary to evaluate the source reduction potential of the products, and are designed to ensure that all Technical Forum participants have a basic understanding of the products. The background papers contain information in the following areas:

- the purpose that the heavy metal serves in the product;

- the amount and form in which the heavy metal is used in the product;

- a brief description of the manufacturing process for the product, focusing on the use of the heavy metal in that process;

- a discussion of any data related to the potential for exposure of the public or the environment to the heavy metal of concern;

- a summary of the source reduction measures achieved to date; and

- an assessment of the potential for future source reduction.

Source reduction can be driven by numerous factors, including a concern about public health and environmental impact, meeting regulatory requirements, and satisfying consumer demands. Heavy metals are important candidates for source reduction due to their known toxicities. Lead is a probable human carcinogen and can cause damage to the central nervous system, leading to slow growth and learning disabilities in children. Mercury also can damage the brain and central nervous system, and some forms are highly bio-accumulative. Cadmium is a probable human carcinogen, can cause kidney and lung damage, and also bio-accumulates.

Although these metals have the potential to cause adverse health and environmental impacts, it is only if the public or the environment is actually exposed at a certain level that the potential for these health and environmental impacts actually occurs. Assessing the potential for, and degrees of, human health and environmental impacts from the heavy metals is important in setting priorities for source reduction. When making this assessment, a holistic approach encompassing the complete life cycle of a product is preferable. Life cycle stages that can be included in these assessments are raw materials acquisition, manufacturing, transportation/distribution, consumption, and waste management.

Life cycle assessment (LCA) is a discipline which involves documenting the raw material, energy inputs, and environmental releases for a product, process, or activity through all its stages. From this documentation of environmental burden (known as inventory analysis) an assessment can be made of the impact the activities have on human health and the environment (impact analysis). Life cycle assessments are technically complex undertakings, and, as a result, they have not been completed in a comprehensive fashion for many products. Life cycle assessments have not been completed for the products being studied. However, during the assessment of source reduction potential that will occur at this Forum, life cycle concepts can be used to facilitate discussion.

There is very little data available that describes the behavior of specific products when disposed. In addition, even if there was data to predict the fate of a particular metal in a particular product when it is landfilled or incinerated, the potential for exposure of the public or the environment is dependent upon the control measures in place (e.g. leachate collection systems in a landfill or air pollution control equipment at an incinerator). Since this type of detailed assessment is not available, the information on potential for exposure of the public and the environment in the background papers is general in nature.

It is recognized that the nature of certain products or the control mechanisms in place at disposal facilities may minimize the potential for exposure. One of the outcomes of the Technical Forum may be that for a particular product the potential for source reduction is minimal and as a result the focus for minimizing exposure must be on pollution control measures or recycling. However, the purpose of the Technical Forum is to explore the potential for source reduction, and to reach conclusions regarding the most desirable actions to pursue. The background papers are designed to foster constructive discussion regarding these issues.

SECTION 5

SOLDERED CIRCUIT BOARDS

5.1 BACKGROUND INFORMATION

The Purpose of the Heavy Metal

Lead is combined with tin to form a solder which is used in the production of electronic circuit boards in computers, communications equipment, and consumer electronics, such as radios, televisions, and VCRs.

Tin/lead solder is used in the production of electronic circuit boards in two ways:

- Tin/lead solder is applied to the boards in the manufacturing process to protect the copper from etching during production and from oxidizing, allowing the circuit board to be stored for long periods of time.

- Tin/lead solder is used to attach components to the circuit board.

The American Electronics Association (AEA) advises that a major reason that tin/lead solder is used is because it is a conductive material that bonds aggressively. The low melting point of tin/lead solder is often preferred because of the reduced probability of thermal shock to soldered assemblies during high speed soldering operations. In addition to its ability to bond aggressively at a relatively low temperature, tin/lead solder has other advantageous physical properties including: good wicking tendencies, i.e., the tendency to produce strong bonds by travelling up the holes to mount components to some printed circuit boards; pliancy to resist breakage from vibration; and good electrical conductivity.

The Amount of Lead Used

According to the Institute for Interconnecting and Packaging Electronic Circuits (IPC), lead content in tin/lead solder ranges from 35 to 40 percent, based on the type of alloy required for production. The IPC advises that tin/lead solder containing 60 percent tin and 40 percent lead is the most commonly used solder. The amount of solder used in each circuit board depends on the size and complexity of the circuit board.

According to an EPA report entitled "Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000," completed by Franklin Associates, Ltd. in January 1989 (Franklin study), lead used in circuit board production has been an increasing source of the total lead discarded in MSW (which does not include the amount recycled). Discards of lead from tin/lead solder in circuit boards increased from approximately 1,400 tons in 1970, less than one percent of total lead disposed, to approximately 6,000 tons in 1986, or approximately three percent of total lead disposed. These discards are projected to decline to less than 1,000 tons, or less than one percent of total lead disposed, by the year 2000. This decline reflects a general decrease in the quantity of lead solder used to solder electronic components as reported by the Bureau of Mines (BOM) and reflects changes in manufacturing processes.[1]

It should be noted that some aspects of the methodology used in the EPA report have been questioned. These include the level of recycling assumed for certain lead-bearing products, the products to be included or excluded from the definition of municipal solid waste, and the number of lead-bearing products that end up in the municipal solid waste stream. However, other data is not comprehensive enough to adjust the results in the EPA report.

The Form in Which Lead is Used

Tin/lead solder manufacturers get tin and lead in an ingot form. Tin and lead are melted and stirred to form an alloy and then poured into bars. These tin/lead bars are then sold to electronic circuit board manufacturers.

The Manufacturing Process

Manufacturing circuit boards involves the application of tin/lead solder which is used to maintain the circuit boards solderability, by protecting the copper boards from oxidizing. The oldest manufacturing technique employs the application of tin/lead plating to the circuit board. This process begins with a copper clad circuit board -- a laminate such as fiberglass or epoxy which has been coated with copper on one or both sides. Tin/lead is used as a protective pattern of "etch resist" which is deposited on the copper surface, and the unwanted copper is etched away. This technique produces a copper clad circuit pattern protected by tin/lead plating.

Manufacturers of circuit boards now employ a solder-mask-over-bare copper technique that reduces the amount of solder needed in basic circuit board production. This technique is referred to as "hot air leveling." The IPC advises that this process uses much less tin/lead solder in the manufacturing process than the tin/lead plating process. A solder mask, which is an organic coating such as epoxy, is applied to the bare copper board. The circuit board is then dipped into liquid tin/lead solder and forced air is used to blow excess solder back into liquid solder (hence the term, "hot air leveling"). With this process, tin/lead solder is only applied to the solder joints where the components will be attached, which is about 25 percent of the exposed copper on the board, as compared to covering 100 percent of the exposed copper on the board with tin/lead solder using the tin/lead plating method.

Both tin/lead plating and hot air leveling manufacturing methods are presently in use in the electronics manufacturing industry, however, a comparison of how much each of the processes are being used is not available.

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[1] Data provided by the BOM subsequent to the Forum indicates that the use of lead is stabilizing and has not decreased since 1980 as projected by Franklin Associates. In fact, the BOM has stated that it is likely that total lead soldering in electronics in the U.S. marketplace has increased in recent years due to the proliferation of imported electronic devices.

Additional solder is applied to the circuit boards in both types of manufacturing to attach the components. The soldering process is defined as a metallurgical joining method using a filler metal (the solder) with a melting point below 600 degrees Fahrenheit or 316 degrees Centigrade. The most common soldering technique for both printed circuit board manufacturing and electronic component assembling is wave soldering, according to AEA. This process employs a bath of solder through which the circuit boards pass. In the assembly operations, automated equipment places the electronics components on or in the printed circuit boards, prior to soldering.

Surface mount assembly and through-hole assembly technology are two technologies used to attach electrical components to the circuit boards. With surface mount technology, components are attached directly to the circuit board without drilling or punching holes. Without holes, the components can be densely packed on the board, thereby reducing the size of the board. Texas Instruments cites a 40 percent reduction in size of the printed circuit board assembly over through-hole technology when surface mount technology is used. With through-hole technology, the leads of the electrical components are placed in holes that have been drilled in the circuit board. Usually, the circuit board is soldered on the side of the board from which the leads protrude.

POTENTIAL FOR EXPOSURE TO THE PUBLIC AND THE ENVIRONMENT

The AEA states that the circuit boards from electronics in commercial applications, such as computers and communications equipment, are often recovered and not disposed in the municipal solid waste (MSW) stream. However, at least some of the circuit boards used in consumer electronics do end up being disposed as MSW, but it is not clear what the fate of the lead in the solder is when those products are disposed.

Most of the research done to date on the fate and effects of lead in MSW has been general in nature, and has not focused on lead in electronic circuit boards specifically. For instance, the Lead Industries Association commissioned Industrial Economics, Inc. to prepare a review of the existing studies, resulting in a report entitled, "Potential Human Exposures from Lead in Municipal Solid Waste," (May 1991), which concludes that the fate and effects of lead when disposed are such that adverse exposures to lead are unlikely. This report is based on a range of data regarding the characteristics of leachate from landfills and emissions from waste-to-energy facilities. The only data regarding the fate and effects of lead in circuit boards specifically is in the form of results from tests designed to model disposal conditions in a landfill.

In discussions with the American Electronics Association (AEA) regarding test results of this type for lead in electronic circuit boards, the AEA stated circuit boards that are ground up as part of sample preparation exceed the regulatory threshold for lead in the Toxicity Characteristic Leaching Procedure (TCLP). However, AEA states that when circuit boards are not ground up (which is more representative of disposal conditions), the lead remains bound and encapsulated in the circuit board. AEA advises that if a circuit board merely breaks into several pieces, but is not ground up, lead content will still not exceed TCLP standards. Regardless of its potential for leaching, the potential for exposure to the public or the environment would also depend on the leachate control and collection system used in the landfill in which the circuit boards were disposed. Data regarding the fate of lead in electronic circuit boards when the circuit boards are incinerated has not been identified.

SOURCE REDUCTION MEASURES

Source Reduction Measures to Date

The amount of lead in tin/lead solder has remained between 35 and 40 percent of the tin/lead mixture since this solder has been used, according to the IPC. This amount of lead is necessary in the tin/lead mixture because it is this particular mix of the two metals which results in its desired properties. Therefore, it is not possible to reduce the lead quantity in the tin/lead solder mix.

Advances in production techniques have tended to reduce the amount of solder employed in both printed circuit board manufacturing and in attaching electronic components. For example, the "hot air leveling" circuit board manufacturing technique substantially reduces the amount of solder applied to the circuit board. With this method, only about 25 percent of the exposed copper on the circuit board is covered with tin/lead solder as compared to all of the exposed copper being covered using the tin/lead plating technique. However, circuit boards that have tin/lead plating have a longer shelf life than those manufactured by "hot air leveling," which can make them advantageous when boards have to be stored for long periods of time before components are attached to them.

Conventional through-hole assembly technology is being replaced by surface mount electronic assemblies, contributing to reduction in solder used to attach components to circuit boards. In the through-hole technology, solder fills the hole through which the component leads are inserted. In surface mount assemblies, there are no holes on the circuit board and smaller quantities of solder are needed to affix components to pads on the circuit boards. The surface mount assemblies also allow denser packing of components and thus allow manufacturers to reduce the surface area of the circuit board.

Although several substitutes for tin/lead solder have been identified (see below), none of them match tin/lead solder in terms of cost and performance and thus they have not been used extensively to date.

Potential for Future Source Reduction

Tin/lead solder is economical and its performance is highly regarded in the electronics industry and it will continue to be used in the foreseeable future. A vast amount of work and financial investment have been dedicated to developing complex circuit board manufacturing processes which work well using tin/lead solder. The previously described advances in production techniques made to reduce the amount of solder used in circuit board manufacturing are anticipated to continue.

Industry is investigating additional ways to reduce the use of tin/lead solder in circuit board manufacturing. For example, in October 1990, a consortium of 19 printed circuit board users, manufacturers, and suppliers was formed to find ways to eliminate waste and promote environmental soundness in the circuit board manufacturing industry. The consortium is looking at ways to reduce and/or eliminate tin/lead solder in circuit board manufacturing, but not in component assembly. The consortium will present its findings to the IPC in October 1992. In addition, a draft report entitled, "An Assessment of the Use of Lead in Electronic Assembly," has been completed by the Surface Mount Council, which is a joint council of the IPC and EIA. This assessment addresses alternatives for tin/lead solder, and although not available at the time this background material was originally developed, it was available prior to the Forum.

The April 1992 U.S. EPA report entitled, "Preliminary Use and Substitutes Analysis of Lead and Cadmium in Products in Municipal Solid Waste," identifies four solder alloys as potential substitutes for tin/lead solder including:

- Bismuth/tin
- Tin/silver
- Indium/tin
- Indium/silver

There are many disadvantages associated with the potential substitutes identified, including higher costs than the tin/lead solder. In addition, the world reserves of indium and bismuth, two of the potential substitutes for lead in the tin/lead alloy, are very limited. Changes in alloys would also require a complete re-evaluation of the entire soldering system.

The bismuth/tin alloy is well suited to the new surface mount technology but may have unacceptably low melting temperatures. The tin/silver alloy can be used to solder silver-plated base metal without significantly solubilizing the silver, however, it is less ductile than indium and bismuth solder alloys. Both bismuth/tin and tin/silver alloys are well suited to the new surface mount technology and compatible with gold and other precious metals. However, their low melting point may not be suitable for high temperature applications, and their cost is as much as 20 times the cost of tin/lead solder.

According to the Surface Mount Council report (referenced above), an alloy invented by Englehard as a lead-free plumbing solder and called Silvabrite 100 has the composition of 95.5 percent tin, 4 percent copper, and .5 percent silver. In addition, Kester, a major manufacturer of solder, has developed a lead-free alloy sold under the name of Kester Aquabond. Its composition is 97 percent tin, 2 percent copper, and 2 percent silver. Its performance mimics that of tin/lead solder in many ways, but its melting point is about 20 to 40 degrees Centigrade higher than that of tin/lead. However, recent telephone conversations with Kester indicate that the company is not manufacturing Kester Aquabond because it does not work as well as tin/lead solder, due to its higher melting point.

Also according to the Surface Mount Council report, a variety of organic polymer based conductive systems have been available for many years. These composite materials have two components: an electrically insulating polymer matrix and particles that conduct electricity such as silver, nickel, carbon, or a variety of metal plated particles. Two major advantages of such materials are the generally lower cure temperatures at which the interconnection is formed (relative to soldering) and the elimination of the need for post-interconnection cleaning. This system would require a complete reconfiguration of the current circuit board assembly process, however.

A bibliography for this background information is presented at the end of this section.

5.2 WORKSHOP PARTICIPANTS

This session was facilitated by Charlotte Frola of SWANA and notes were taken by Dawn Campbell of SWANA. Workshop participants were as follows:

John Bradley, Bull HN Information Systems Inc.
Paul Dadak, Hewlett-Packard Co.
John Hackler, US EPA
Elizabeth Harriman, The Massachusetts Toxics Use Reduction Institute
Michael Kerr, Circuit Center, Inc.
Jane Luxton, Prather, Seeger, Doolittle & Farmer
Harry Makar, US Bureau of Mines
Lelia McAdams, AT&T
Cindy Melton, Motorola Inc.
Jeffrey Miller, Lead Industries Association, Inc. (attended second day only)
Christopher Rhodes, The Institute for Interconnecting and Packaging Electronic Circuits
Gregory Rigo, Rigo & Rigo Associates (attended second day only)
Eric Schaeffer, US EPA
Mark Small, SONY Corporation
Kanji Tamamushi, Panasonic Technologies, Inc.
Clare Vinton, National Center for Manufacturing Sciences
Tom Walker, Industrial Economics Inc. (attended second day only)
Lee Wilmot, HADCO

5.3 GENERAL DISCUSSION

Much of the early discussion in this workshop related to the concern that by including circuit boards in the Forum, EPA was indicating that it had determined that there was a problem with lead from circuit boards, and some participants felt that there was no problem associated with this product. Some participants stated that because soldered circuit boards constitute a relatively small fraction of the total amount of lead disposed in MSW they should not be targeted for source reduction. Many participants felt that the question of actual risk and potentially harmful exposure warrants further study. With many participants believing that the environmental and public health impacts associated with disposal of circuit boards are not significant enough to be of concern, it was difficult to focus discussion on source reduction options. However, there were participants who felt that the life cycle risks of lead use, including occupational, public health, and environmental impacts due to mining, smelting, and use in manufacturing, justified attention to source reduction of lead in circuit boards.

Some general discussion about issues related to source reduction potential did occur. One participant noted that inert gas soldering is currently being tested, and that this results in a reduction in lead use of 30 percent. Another participant noted that there are alternative solders available, but that some customers demand the use of tin/lead solder because of its superior performance in certain applications. The fact that the Japanese are the leader in design technology in this area was noted, and that they are working on development of adhesive solder. One participant stated that the Defense Department is reviewing military specifications in relation to lead use, to determine if a reduction in lead (and other heavy metals and chemicals) can be achieved at a reasonable cost.

5.4 ANALYSIS OF SOURCE REDUCTION POTENTIAL

After much discussion on the issue of whether or not there is a problem that warrants consideration of source reduction options, some substantive analysis of source reduction options did take place. However, a full-blown evaluation of the source reduction options did not occur, for the reasons outlined below.

5.4.1 Determination of Source Reduction Options

In this workshop the two main functions of lead solder in production of a circuit board were analyzed separately. This was in recognition of the fact that source reduction options may be different for the two different functions. Thus, source reduction options were identified for use of lead-based solder as: 1) an etch-resistant coating; and 2) an interconnection material. In addition, a number of options were identified which it was recognized were actually mechanisms for increasing recycling not source reduction. These options are listed separately below.

5.4.1.1 Source Reduction Options for Lead Solder Used as an Etch Resist

The options identified for reducing use of lead in the application of tin/lead solder as an etch-resistant coating are as follows:

1. Change the coating material:
    - pure tin, or
    - nickel.
2. Change the technology:
    - additive plating (which is considered a long-term option),
    - photo ablation, or
    - hot air surface leveling (HASL).
3. Use alternative materials such as ceramics.

5.4.1.2 Source Reduction Options for Lead Solder Used as an Interconnection Material

The following options were identified for reducing use of lead in the application of tin/lead solder as an interconnection material:

1. Use a different material:

   - elastomers,
   - adhesives, or
   - new alloys.

2. Increase the density of the circuit board (including use of multiple layers) so that fewer interconnections are needed.

3. Introduction of a totally new technology or process, which was labelled in this workshop as the "black box" option.

5.4.1.3 Design for the Environment Options

The following options were identified for increasing recyclability, potential for reuse and minimizing impacts during manufacture.

1. Increase useful life. Paradoxically, this could probably be done, but would entail usage of more lead, not less. (It should also be noted that although this option was identified as a recycling options, it is actually an option for source reduction.)

2. Design for disassembly. It was noted that a life-cycle analysis would need to be done to understand if this was an improvement in terms of potential impact on the environment or public health, since disassembly could increase the exposure to tin/lead solder.

3. Make circuit boards more repairable. There are many issues affecting the practicality and desirability of this option. One significant issue that was noted is the fact that repair may not be economical in many instances.

4. Create a spare parts network.

5. Increase manufacturability. This option involves producing a higher quality product more reliably, thus reducing defective parts and rejects, and potentially decreasing waste produced.

5.4.2 <u>Evaluation of Source Reduction Options</u>

After identification of the options listed above, an attempt was made to evaluate these options. However, most of the participants in the workshop felt that they were unable, or were unwilling, to execute the evaluation process. The two main reasons for this (aside from the general concern by some participants that an evaluation of source reduction was unnecessary) were: 1) a belief that a detailed discussion of source reduction options would require divulging proprietary information; and 2) the process for evaluation outlined in Getting at the Source was believed by some participants to be inapplicable to this industry.

5.5 CONCLUSIONS AND RECOMMENDATIONS

Since a formal evaluation of source reduction options was not undertaken according to the prescribed format, a set of most promising options was not identified. However, a number of conclusions were offered in relation to the issue of source reduction, and some of these reflect some judgements that have been made regarding the advantages and disadvantages of types of source reduction options. In addition, conclusions and recommendations were developed by participants in this workshop regarding the evaluation framework contained in Getting at the Source, and the structure of the Forum.

5.5.1 Conclusions and Recommendations Related to Source Reduction

The participants in the workshop recommended that the conclusions of the Surface Mount Council Report White Paper, An Assessment of the Use of Lead in Electronic Assembly be adopted with certain modifications. The modified conclusions can be summarized as follows:

1. Tin/lead solder is economical and highly successful in electronic assembly, has unique properties and will continue to be used for the foreseeable future. At present there is no viable alternative available for complete replacement.

2. Lead-free joining systems for electronic assembly are being investigated, because there is a possibility of restrictive legislation or regulation, and because the costs of using lead may increase through fees, taxes, waste disposal, and administrative costs.

3. In the absence of a lead-free alloy which is a direct replacement for tin/lead solder, the most promising lead-free materials appear to be metal alloys based on tin, with additions of bismuth, antimony, silver, copper and indium. Some of these alloys have been used for component assembly with excellent results; however, their use in printed circuit board assembly would require a complete reevaluation of the entire soldering system, including flux, cleaning, components, substrates, and manufacturing protocols (such as those called for in military specifications). In addition, such changes will require component manufacturers to make significant changes in their component packaging to be compatible with changes in the assembly process. Other alternatives may be anisotropically or isotropically conductive adhesives.

4. Among the many areas of data deficiencies which should be addressed is the performance of lead-free solder alloys and conductive adhesives with respect to the following:

   - the metallurgy of alternative solders and the interaction with base metals;

   - the electrical and mechanical properties of alternative materials;

- corrosion resistance;

- new approaches to fluxing and surface preparation;

- manufacturing and reliability tests for new or existing alloys, and for isotropic and anisotropic adhesives;

- lifecycle cost analysis, including scenarios for fees and availability of materials; and

- potential environmental effects of alternatives.

5. Reduction of lead in solder is not an isolated issue. It is embedded within the larger set of issues which relate manufacturing to materials supply, reuse, and disposal, an approach called "industrial ecology."

6. In addition, a conclusion separate from those in the Surface Mount Council White Paper was that source reduction of lead in the printed circuit board industry was occurring as a result of changes targeted at increasing efficiency of use of materials, miniaturization and, in some instances, customer demands.

5.5.2 Other Conclusions and Recommendations

Conclusions reached regarding the evaluation framework in Getting at the Source are as follows:

1. The evaluation process tended to straddle and not differentiate between the issues associated with recycling and those associated with source reduction.

2. The framework for analysis was difficult to apply to soldered circuit boards because they are a component of consumer products, and are not a consumer product by themselves.

Comments made regarding the structure of the Forum included the following:

1. The overall approach was questionable, in particular the "skipping" of the first step in the process, and the presumption of harm in the absence of confirming data.

2. Some participants in the workshop felt that due to the small contribution of circuit boards to the total lead content in MSW that circuit boards must have been included simply to have two products for each heavy metal.

3. Data sources cited in the background report were incomplete, and should have included data on migration of lead from landfills, and emissions from incinerators.

BIBLIOGRAPHY FOR BACKGROUND INFORMATION

(Note: Any additional information obtained subsequent to the development of the background information is listed in Appendix B.)

"American Electronics Association Design for Environment White Papers," 1992.

"American Electronics Association Oral Statement on S. 2687," before the Subcommittee on Toxic Substances, Environmental Oversight, Research and Development.

"An Assessment of the Use of Lead in Electronic Assembly," Institute for Interconnecting and Packaging Electronic Circuits (IPC), September 1992.

"Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United State, 1970 to 2000," prepared by Franklin Associates for U.S. EPA, January 1989.

October Project Information Packet.

"Potential Human Exposures from Lead in Municipal Solid Waste," prepared for the Lead Industries Association, Inc. by Industrial Economics, Inc., Cambridge, Massachusetts, May 1991.

"Preliminary Use and Substitutes Analysis of Lead and Cadmium in Products in Municipal Solid Waste," U.S. EPA, April 1992.

"Reducing the Lead Content of Municipal Solid Waste Compost in the United States - Draft Report," prepared by Camp Dresser & McKee, Inc. for the Solid Waste Composting Council, Washington, D.C., June 1992.

"Testimony of Jeffrey L. Zelms, President of Lead Industries Association", made before the Subcommittee of Select Revenue Measures, Committee on Ways and Means, U.S. House of Representatives on H.R. 2922. The Lead-Based Paint Hazard Abatement Act, July 1992.

Telephone conversation with Theresa Pugh, Director of Environmental Affairs, American Electronics Association.

Telephone conversation with David Bergman, Director of Technical Programs, Institute for Interconnecting Electronic Circuits (IPC)

Telephone conversation with Karen Matthews, Tektronics, regarding "October Project".

Telephone conversation with Dave Scheiner.

SECTION 6

CATHODE RAY TUBES

6.1 BACKGROUND INFORMATION

The Purpose of the Heavy Metal

Leaded glass is used in the production of television picture tubes and other cathode ray tubes (CRTs), such as those used in computer monitors. In this paper, the term "television picture tube" is used to refer to all applications of CRTs. According to the Electronic Industries Association (EIA), lead is essential in the production of television picture tubes because it absorbs radiation or X-rays produced by rapid deceleration of electrons in the CRT, which would otherwise result in harmful health effects to those watching television or those repairing televisions.

Leaded glass is used in three parts of the picture tube: 1) in the neck surrounding the electron gun, the source of electronic action that creates the television picture, 2) in the funnel that provides structural integrity, and 3) in the faceplate or panel used in the television screen. Lead solder glass or "frit" is used in connecting the faceplate and funnel.

The Amount of Lead Used

Leaded glass in television picture tubes is the major source of lead in consumer electronic products. According to the Bureau of Mines (BOM), 75 percent of lead used in glass is used in television picture tubes (Franklin Associates, 1989). Industry sources indicate that a more reasonable estimate is 65 percent. The funnel and neck of the television picture tube each contain approximately 20 to 30 percent lead oxide. The faceplate contains between two and three percent lead oxide. A higher concentration of lead oxide is needed in the glass in the neck and funnel portions of the picture tube because of the fact that the glass in these areas is thinner and so a higher concentration of lead oxide is needed to provide the same level of protection. Lead solder glass contains 80 to 85 percent lead oxide.

Thomson Consumer Electronics advises that a television picture tube weighs between 20 and 50 pounds, although weights can go as high as 110 pounds. The funnel comprises approximately one-third of the total weight of the television picture tube and the faceplate contains approximately two-thirds. The funnel weighs between 6 and 16 pounds depending on the size of the television, and the faceplate weighs between 14 and 33 pounds. The neck is a small four-inch long piece weighing between three and four ounces. Based on total weight, the funnel contains the largest amount of lead (27 to 72 ounces), the faceplate containing the second largest amount (4 to 16 ounces), and the neck containing the smallest amount (approximately 1 ounce). It is important to recognize that monochrome CRT's contain less lead than indicated in these figures, which are representative of color CRTs.

According to an EPA report entitled "Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000," completed by

Franklin Associates, Ltd. in January 1989, the quantity of lead in glass in television picture tubes disposed has increased steadily since 1970 and is projected to increase in the future. Discards of lead from glass in television picture tubes increased from approximately 10,000 tons in 1970, or six percent of total lead disposed, to approximately 52,000 tons in 1986, or approximately 24 percent of total lead disposed. These discards are projected to increase to 84,000 tons, or 30 percent of total lead disposed, by the year 2000, if present trends continue.

The Form in Which Lead is Used

Lead oxide (PbO) in a powder form is used in the production of leaded glass, and is added to other components such as silica sand during production.

The Manufacturing Process

Lead oxide manufacturing involves mixing metallic lead with oxygen to produce lead oxide. According to Hammond Lead Products, a major manufacturer of lead oxide, the production of lead oxide starts with melting metallic lead (in the form of ingots) in a large melting pot; feeding the molten lead into a barton reactor, which has an agitator that spins molten lead so that it mixed with oxygen and oxidized; and passing the oxidized lead into a settling chamber. From this process, the product is approximately 70 percent lead oxide and 30 percent free lead. To further oxidize the product, the mixture goes into a furnace. This oxidized product is referred to as litharge. To further process the litharge to produce the type of lead oxide that the leaded glass industry requires, the litharge is pelletized in a direct-fired furnace.

Manufacturers of television picture tube glass parts purchase lead oxide for use in leaded glass manufacturing and combine it with other components, primarily silica sand, to produce leaded glass. Three companies in the United States manufacture components for picture tubes. These include Corning Glass Works, OI-NEG, and Thomson Consumer Electronics. Corning Glass Works and OI-NEG sell the picture tube parts (referred to as the glass envelope) to television manufacturers, Thomson Consumer Electronics manufactures leaded glass for its own use in manufacturing picture tubes.

The three main parts of the television picture tube -- the neck, the funnel, and the faceplate -- are soldered together to form a picture tube using a lead solder glass, (sometimes referred to as "frit"). It should be noted that soldering of the faceplate to the funnel is not required in monochrome CRTs (which comprise about 10 to 20 percent of total CRTs produced).

POTENTIAL FOR EXPOSURE OF PUBLIC AND THE ENVIRONMENT

Most of the research done to date on the fate and effects of lead in MSW has been general in nature, and has not focused on lead in television picture tubes. The Lead Industries Association commissioned Industrial Economics, Inc. to prepare a report entitled, "Potential Human Exposures from Lead in Municipal Solid Waste," (May 1991). This report discusses the results of a number of studies of the emissions of lead from municipal solid waste landfills and incinerators and concludes that the potential for adverse exposure is minimal.

Tests using the Toxicity Characteristic Leaching Process (TCLP) have been conducted on ground leaded glass from television picture tubes. Leaded glass from picture tubes that is ground up as part of sample preparation has exceeded the regulatory threshold for lead in the TCLP. This is due to the fact that grinding the glass increases the surface area, and only the lead on the surface leaches. When the leaded glass is not ground up, there is less surface area, so leaching is slight. This is consistent with the physical properties of leaded glass used in crystal, where leaching of lead is extraordinarily slow and slight, and the use of vitrification of lead-bearing waste as a treatment method. It is not clear what the fate of lead in television picture tubes is when the tubes are incinerated.

SOURCE REDUCTION MEASURES

Source Reduction and Recycling Measures to Date

A major leaded glass manufacturer advises that current requirements for radiation protection do not allow for a reduction in lead content presently used in picture tubes. The quantity of lead oxide has remained constant for many years because of this requirement. Thus, we know of no source reduction measures taken to date.

Substitutes for lead have been used to a small extent. For example, zirconium is being used by some manufacturers as a substitute in faceplates, however faceplates contain the smallest percentage of lead in a television picture tube.

Digital Equipment Corporation, Envirocycle, Inc., and Corning Asahi have jointly developed a process for recycling glass from CRTs. Digital recovers CRTs from equipment that is being retired; Envirocycle separates the CRTs from the rest of the equipment, and then prepares the glass for recycling. This process includes removing the electron guns, shadow masks, frames and shields, the aluminum, and phosphor. (The aluminum and phosphor are reclaimed for sale). The glass is then crushed and transported to Corning Asahi. At the Corning Asahi plant, the glass is sampled and X-ray analyzed to determine the quantities of lead, fluorine, and alumina. The glass is mixed with internal manufacturing rejects and virgin glass. Corning Asahi's short-term goal is to manufacture glass composed of 25 percent recycled material.

Potential for Future Source Reduction

The April 1992 U.S. EPA, "Preliminary Use and Substitutes Analysis of Lead and Cadmium Products in Municipal Solid Waste," identifies zirconium as a potential substitute for lead in television picture tube faceplates (which typically contain two to three percent lead). Television manufacturers have already begun to use zirconium-based faceplates that provide better resistance to radiation darkening than lead-based faceplates. While zirconium may be a viable alternative to lead in faceplates, its use would increase the cost of the faceplate by six percent, according to Corning Glass Works. Zirconium products also require higher processing temperatures necessitating changes in manufacturing equipment. Thomson Consumer Electronics also advises that zirconium is not available to many leaded glass manufacturers.

The April 1992 U.S. EPA report identifies strontium and barium as potential substitutes for the lead in the funnel and neck portions of the picture tubes (containing 22 and 28 percent lead, respectively). Small amounts of strontium and barium are presently being used in television picture tubes, but not as a replacement for lead. The amount of strontium and barium required to provide the same level of radiation protection is significantly higher than for lead. As much as 50 percent more strontium carbonate or barium carbonate would be required to provide the same radiation protection at current thicknesses of the funnels and necks of the picture tubes. Since the costs of strontium and barium are higher for than lead, this increase would raise the costs of substitute funnels and necks significantly. In addition, it may not be technically possible to achieve the required concentrations of strontium and barium.

A bibliography for this background information is presented at the end of this section.

6.2 WORKSHOP PARTICIPANTS

This session was facilitated by Robert Peters of SWANA and notes were taken by Patricia Magill of SWANA. Workshop participants were as follows:

George Burris, Thomson Consumer Electronics, Inc.
Joe Collentro
Bob Dodds, Sony Corporation of America
Dan Edelstein, U.S. Bureau of Mines
Bob Ferrone, Digital Equipment Corporation
Cynthia Greene, U.S. EPA, Region I
Ellen Harrison, Cornell University
Ira Leighton, U.S. EPA Region I
Jeff Lowry, OI-NEG TV Products
Jim Maher, Electronics Processing Associates, Inc.
Jim Matthews, Envirocycle, Inc.
George Obeldobel, Big River Minerals
William Rowe, Zenith Electronics
Bill Spangelberg, Hammond Lead Products
Bob Tolliver, Clinton Electronics
Dan Tsuda, Apple Computer, Inc.
Steve Vigil, American Matsushita Electronics Corporation
Tom Walker, Industrial Economics, Inc.

6.3 GENERAL DISCUSSION

A number of clarifying points were made in regard to the background paper, and these are reflected in the version of the background paper contained in this section. Some of the more important points made during the general discussion are as follows:

- There are two important distinctions between monochrome and color CRTs: 1) no solder glass is used in manufacturing monochrome CRTs; and 2) the quantity of lead in the glass is lower in monochrome CRTs than in color due to the lower voltages used in monochrome CRTs.

- A number of foreign manufacturers provide glass components to product manufacturers in the U.S., so even though a television or computer monitor may be assembled in the U.S. the glass components may have been manufactured overseas.

- Grinding up of glass is what causes leaded glass to fail the TCLP test because it increases the surface area of the glass, and the only lead that is leachable is on the surface of the glass. This is why a proposal to require that CRTs be ground and mixed with concrete, or some other material, is considered by some participants in the workshop to be a very poor idea. Once the concrete disintegrates, the glass is in small pieces, meaning that more lead is available to leach.

- Some participants raised the question of whether households should be required to dispose of CRTs in the same manner that industry does -- that is, as a hazardous waste.

- The fact that there are a variety of different compositions employed in the glass used in CRTs limits the opportunities for recycling. The composition of the material used as feedstock for manufacturing glass for CRTs must be known, and the quantities of different compositions carefully controlled, and this makes it difficult to utilize used CRTs as a feedstock.

6.4 ANALYSIS OF SOURCE REDUCTION POTENTIAL

The discussion of source reduction potential started with an assessment of what had been done to date, and what was considered feasible. Many participants noted that if lead could be eliminated from CRTs without compromising the quality and performance of the CRTs, it would have been done already. One place in which there has been some successful substitution for lead is in the faceplate. There are some manufacturers that are manufacturing CRTs with faceplates containing zirconium instead of lead. The zirconium is used because it reduces the browning that can occur in faceplates made with lead. Some participants stated their belief that other than this substitution of zirconium for lead in the faceplate (which contains approximately 15 to 20 percent of the total lead in a CRT), the only way in which lead is going to be eliminated from CRTs is if a totally new technology is introduced.

6.4.1 Determination of Source Reduction Options

A brainstorming session was held in which participants in the workshop were encouraged to suggest source reduction options without imposing any judgement on their practicality or desirability. The resulting list of options is as follows:

1. Substitute zirconium for lead in the faceplate.

2. Increase use of projection televisions.

3. Flat panel liquid crystal displays (LCD's).

4. Increase product life of CRTs to 15 years.

5. Lower voltage used in electron guns contained in CRTs.

6. External shielding as a substitute for lead in the funnel glass.

7. Substitute for "frit," which is the term for the glass solder used to join the faceplate to the neck.

8. Substitute barium or strontium for lead.

9. Impose a luxury tax on screens over 19 inches.

10. Lower lead concentrations in the funnel glass.

11. Changing the X-ray standards to allow for greater exposure, which would allow for lower quantities of lead to be used in the glass in CRTs.

6.4.2 Evaluation of Source Reduction Options

In discussing the options listed above, a number of important points were made, including the following:

- Although projection televisions use a lead-free faceplate, this is not where the majority of the lead is contained, and thus the reduction in lead use associated with this option is limited, and the use of three electron tubes in projection televisions may approach the amount of lead in a single-color CRT funnel.

- Use of zirconium in faceplates will only eliminate 15 to 20 percent of total lead usage in CRTs.

- Large flat panel LCDs are a long-term option because the gap between performance of CRTs and LCDs is too large for them to be considered a viable alternative anytime in the near future. (Small LCDs have already demonstrated limited applications.)

- While increasing the product life of CRTs may seem like an effective source reduction strategy, many of the participants noted that consumers generally purchase new televisions not because their old one no longer works, but because of a desire to own a television with some new feature or technology that isn't incorporated into their existing television. Thus, increasing the useful life of televisions may not have a significant impact on the number of televisions disposed, particularly if technological advances in television continue to occur.

- Lowering the voltage used in CRTs would allow less lead to be used in the glass, since less shielding would be required. However, lowering the voltage significantly decreases the performance of the television (it makes the image less bright) and many participants expressed their belief that consumers would be unwilling to accept this decrease in performance.

- External shielding would involve taking the lead out of the glass and putting it into an external lead shield. While this shield would be removable prior to disposal, this option raises many questions about occupational exposure to x-rays (before the shield is installed) and the potential for the shield to be displaced, thereby exposing the viewer to radiation. In addition, it was noted that using an external shield would increase the bio-availability of the form of lead.

- Substituting non-leaded glass for the glass solder would have a minimal impact on total lead in a CRT.

- If barium or strontium were substituted for lead, the thickness of the glass required would increase substantially, creating processing, manufacturing, and operating problems. In addition, it was noted that the environmental and public health impacts of these metals may not be any less than those associated with lead.

- Lowering the concentration of lead in the funnel glass would not decrease the total amount of lead used, since the thickness of the glass would have to be increased to provide the same level of shielding.

- Changing the x-ray standard to allow for greater exposure to x-rays would allow lower levels of lead to be used in CRTs, but the participants in the workshop did not think that any public health official would give this serious consideration.

The evaluation of the source reduction options identified, incorporating the issues discussed above, was summarized in a matrix, which is shown below.

Table 6-1

Evaluation of Source Reduction Options

Option	Reduction Achievable	Technical Feasibility	Cost	Environmental Trade-off	Perform
1. Zirconium	+	+	-	0	0
2. Projection TV	+1/2	0	-	-	-
3. Flat Panel	++	?	-	?	?
4. Longer life	0	+	-	0	0
5. Lower voltage	++	++	+	0	--
6. External Shielding	+++	++	-	--	0
7. Substitute for frit	+1/2	+	-	--	-
8. Barium/ Strontium Substitute	+++	-	-	-	--
9. Luxury tax	0	-	-	0	1/2-
10. Lower lead in funnel	0	++	-	0	-
11. Change X-ray standards	++	--	+	--	0

Key: + Positive; - Negative; 0 Neutral; ? Unknown.

Based on the evaluations shown, two short-term options were determined to have the highest overall ranking: zirconium substitution in the faceplate, and lower voltage. One long-term option was selected: flat panel technology. These three options were evaluated in terms of implementation strategies and obstacles.

It is important to recognize that these selected options do not reflect a consensus of the workshop participants that these are desirable options to pursue or implement. They simply represent the options that result from application of the evaluation process.

6.4.3 Implementation Strategies and Obstacles for Selected Options

For each of the three source reduction options selected implementation strategies and obstacles were identified. For one of the options a relative ranking of the implementation strategies was performed. For the other two options, the strategies were simply identified.

For zirconium substitution in CRT faceplates, the following implementation strategies were identified:

- financial aid to foster transition to the new technology,
- ban production of lead-based faceplates,
- differentially tax CRTs with lead-based faceplates,
- institute a tax credit for production of lead-free faceplates,
- public education,
- require disposal of CRTs with lead-based faceplates in Subtitle C facilities,
- institute government procurement standards calling for use of lead-free faceplates in CRTs, and
- let the free market dictate.

The implementation obstacles identified associated with this option are as follows:

- overseas suppliers provide about 30 percent of the glass used in CRTs in the U.S.; and
- major retooling of the CRT manufacturing process is required in order to produce zirconium-based faceplates; and
- the amount of money required to retool would be very large and production costs would be higher.

For the option of lowering voltage in CRTs five implementation strategies were identified, and these were ranked in terms of their likely ability to effect change and the acceptability to the workshop participants. These strategies, in the order of ranking (with the first being the highest rated strategy) are as follows:

- implement a worldwide standard for voltage,
- institute a legislative mandate to require lower voltage in CRTs (including in imported CRTs),
- impose taxes on higher voltage CRTs,
- institute government procurement standards requiring lower voltage CRTs, and
- public education.

A number of obstacles to implementing the lower voltage option were identified, which are as follows:

- consumer acceptance of the lower performance, not only in the U.S., but on a world-wide basis;
- production modifications are required, which would mean that there would be a period of lower efficiency in production;
- higher manufacturing costs would result because glass with a lower lead content requires higher temperatures to melt; and
- the development of high definition television would be suspended.

For the flat panel option the implementation strategies reflect the fact that this is a long-term option. The implementation strategies identified are as follows:

- educate other governments regarding the direction the U.S. is heading in regard to environmental issues, so that this can be incorporated into the research and development that is being done on this technology overseas;
- create a consortium in the U.S. to conduct research and development on this technology; and
- find a sector of the market that can accept the lower level of performance currently associated with this technology.

The obstacles associated with implementation of this option are:

- unknown technical, cost, or performance obstacles;
- the new technology may eliminate some manufacturers of the current CRT technology;
- there may be environmental trade-offs associated with this technology that may partially or completely offset any advantages gained by eliminating the lead in the glass of CRTs.

6.4.4 Options for Increasing Recycling of CRTs

Since the discussion of source reduction options often drifted into the area of recycling, an explicit discussion of recycling options was conducted. The options for increasing recycling of CRTs that were identified by the workshop participants are as follows:

- recycling of post-consumer CRTs could be increased through: 1) a deposit fee for the consumer; 2) a disposal fee; or 3) a dedicated tax, with revenues to be used for fostering recycling opportunities;

- a tax credit for the use of used CRTs as feedstock in manufacturing of new equipment;

- eliminate regulation of used CRTs as Subtitle C waste;

- development of a collection infrastructure;

- instituting a ban on disposal of used CRTs;

- using below-ground storage of used CRTs until technology for utilizing them as feedstock is more fully developed;

- increase the percent of cullet used in neck glass;

- public education regarding opportunities for recycling; and

- developing a secondary material market for glass form used CRTs (such as fiberglass insulation).

6.5 CONCLUSIONS AND RECOMMENDATIONS

As noted above, the selection of certain source reduction options was not viewed by the workshop participants as a recommendation or endorsement of these options, but simply the outcome of the evaluation process conducted. Several other conclusions and recommendations were offered:

- The results of the Forum should be shared with all regions of EPA and with other government agencies involved in these issues, so as not to have to repeat the types of discussions held in the Forum.

- There is a need to analyze the environmental and public health impacts associated with the current design of CRTs before any actions are taken in regards to source reduction.

- There needs to be more communication between industry and EPA regarding perception of problems, so that industry can address the areas that are perceived to be problems.

- Many of the workshop participant believe that the data exists that indicates that lead in CRTs is not a problem in MSW.

- Many participants also believe that the results of TCLP tests are not meaningful, as they do not represent actual disposal conditions.

- Cooperative discussions between EPA and industry are needed on a national scope.

BIBLIOGRAPHY FOR BACKGROUND INFORMATION

(Note: Any additional information obtained subsequent to the development of the background information is listed in Appendix B.)

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SECTION 7

NICKEL-CADMIUM BATTERIES

7.1 BACKGROUND INFORMATION

The Purpose of the Heavy Metal

Nickel-cadmium batteries are rechargeable batteries (referred to as secondary batteries as compared to primary batteries, such as alkaline batteries, which are for one-time use only), often used in applications that use large amounts of power, such as portable stereos. Other consumer products that use nickel-cadmium batteries include portable hand tools, cordless and cellular phones, toys, computers, video cameras, electric shavers, cameras, and small appliances such as cordless hand vacuum cleaners. Nickel-cadmium batteries are also used in many commercial and industrial applications.

According to information obtained from the Portable Rechargeable Batteries Association (PRBA), at one time approximately 80 percent of nickel-cadmium batteries sold were contained inside consumer products. The useful life of many of these products was designed to be about the same as the life of the battery. Battery and product were disposed at the same time, with the battery still inside the product. However, in recent years, manufacturers have redesigned products so that nickel-cadmium batteries are contained in a battery pack and are easily removable. Presently, the majority of nickel-cadmium batteries are removable (the exact percentage is not known), and by July 1, 1993, all nickel-cadmium batteries will be removable from consumer applications, at least partially as a result of legislation passed in 11 states that requires that nickel-cadmium batteries be easily removable by this date.

Nickel-cadmium batteries are used for many reasons, including a long life cycle that allows them to be installed in products where batteries are not readily accessible to the consumer. Nickel-cadmium batteries may last over 1,000 cycles, and in some instances, may outlast the useful life of the product. Nickel-cadmium batteries also hold up well to abuse. They are not seriously damaged by overcharging or deep discharging. The higher capacity of these products is an advantage in some applications. Nickel-cadmium batteries also cost significantly less than other rechargeable batteries currently available, with the exception of lead-acid batteries, which are not considered to be environmentally preferable substitutes because of the presence of lead, and their much higher weight per unit of energy which makes them impractical for portable applications. The health impacts of exposure to lead are of equal or greater concern as those associated with cadmium and, as a result, substituting lead for cadmium is not desirable.

The Amount of Cadmium Used

According to information provided by PRBA, nickel-cadmium batteries are composed of a positive nickel electrode, a negative cadmium electrode, and an alkaline solution serving as the electrolyte. Battery manufacturing representatives advise that nickel-cadmium batteries contain between 12 and 15 percent cadmium by weight. The most prevalent size nickel-cadmium battery is a Sub C battery, weighing approximately 1.7 ounces. This type of battery is included in battery packs used with consumer products such as video cameras. In addition, nickel-cadmium batteries are available in traditional D, C, AA, AAA, and 9-volt sizes, as well as a wide variety of specialized shapes and sizes designed for performance characteristics needed by institutional and industrial uses. The traditional sizes range in weight from one-half to two ounces.

According to the Cadmium Council, nickel-cadmium batteries are the largest consumer of cadmium in the western world, representing approximately 55 percent of total use of cadmium. According to an EPA report entitled "Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000," completed by Franklin Associates, Ltd. in January 1989, household batteries (primarily nickel-cadmium batteries) have been the primary source of cadmium disposed in municipal solid waste since 1980. Their growth has been rapid -- they were the fifth highest source of cadmium in 1970. Discards (after recycling) of cadmium in household batteries increased from approximately 53 tons, or 4 percent of total cadmium disposed in 1970, to approximately 930 tons, or 52 percent of total cadmium disposed, in 1986. If this growth continues as projected, discards of cadmium from household batteries will be over 2,000 tons, or 76 percent of total cadmium disposed by the year 2000.

The increase in cadmium disposal is primarily due to the increase in the production of products that use nickel-cadmium batteries, such as portable consumer electronic equipment and in rechargeable devices such as camcorders, and cordless and cellular phones.

The Form in Which Cadmium is Used

Cadmium is purchased by the nickel-cadmium battery manufacturing industry in the form of balls (2-4 inches in diameter), sticks (18 inches long), or blocks, according to a major battery manufacturer. The cadmium is then formed into cadmium oxide or cadmium hydroxide which is used in manufacturing nickel-cadmium batteries. Nickel-cadmium batteries are sold in a "discharge" state, i.e., the cadmium inside the battery is cadmium oxide or cadmium hydroxide. When the battery is charged, the cadmium oxide or cadmium hydroxide converts back to a pure cadmium form.

The Manufacturing Process

Cadmium is produced as a by-product of mining of zinc, and thus reducing use of cadmium in products may not reduce cadmium production, although it could limit its distribution throughout the environment. Nickel-cadmium battery manufacturers form cadmium oxide or cadmium hydroxide from cadmium for use in battery production. The cadmium oxide or cadmium hydroxide forms the active material in the negative electrode of the battery. Cadmium oxide or cadmium hydroxide can be applied in two different ways in battery production: 1) as a paste applied to the grid inside the battery that gives structure to the plate inside the battery, or 2) by impregnation, whereby cadmium compounds in liquid form are chemically or electrochemically introduced, in what is termed a porous sintered plaque structure. Nickel hydroxide forms the positive electrode of the battery.

POTENTIAL EXPOSURE OF PUBLIC AND THE ENVIRONMENT

According to information obtained from PRBA, minimal environmental impact of rechargeable batteries in MSW has been identified in a comprehensive study on sealed nickel-cadmium battery canisters in MSW landfills. This seven-year study, a joint effort by several key Japanese battery manufacturers, suggests that minimal toxic releases have occurred from sealed or punctured battery canisters. While there is no evidence that this has actually occurred, it is conceivable that under certain conditions (particularly acidic environments), the steel canisters could eventually deteriorate and cadmium could leach from the battery. If such leaching were to occur, the potential for exposure of the public or the environment would depend on the leachate control and collection system at the landfill.

The above study also indicates that if nickel-cadmium batteries were incinerated, the cadmium would be largely retained in the fly and bottom ash from the incinerator although some would be emitted to the atmosphere. The leachability of the cadmium in the ash is dependent on the composition of the ash and the conditions in the disposal environment (for instance, the level of moisture and the pH). As with cadmium in nickel-cadmium batteries directly disposed in a landfill, the potential for any cadmium leached from ash to expose the public or the environment would depend on the leachate control and collection system.

SOURCE REDUCTION MEASURES

Source Reduction and Recycling Measures to Date

According to PRBA, a reduction in the amount of cadmium is not possible without proportionately affecting battery performance. Cadmium serves as the electrode itself and cannot be eliminated from a nickel-cadmium battery without rendering the battery useless. Cadmium content has remained constant since the advent of use of nickel-cadmium batteries. Thus, no reduction in cadmium content of nickel-cadmium batteries has been achieved to date.

Also according to PRBA, nickel-cadmium batteries can be recycled, and efforts are underway to develop and implement such programs, although it should be noted that recycling rates for nickel-cadmium batteries are currently very low. Industry efforts include redesigning packaging to label batteries for recycling by July 1, 1993, redesigning products to allow removal of the battery pack, and educating consumers about battery disposal. In addition, nickel-cadmium and nickel-cadmium-containing product manufacturers are planning several pilot recycling programs prior to July 1, 1993. There are nine pilot residential collection programs for nickel-cadmium batteries in Minnesota where legislation prohibits disposal of household batteries as municipal solid waste.

Nickel-cadmium batteries, while recyclable, have only begun to be separated into the recyclable category in existing residential collection programs. Battery manufacturers, however, are recycling a number of nickel-cadmium batteries collected from service centers (the quantity is not known). There is one company in the United States, INMETCO in Ellwood City, Pennsylvania, that is involved in recycling nickel-cadmium batteries.

INMETCO processes the batteries for the recovery of iron-nickel-chrome alloy and produces baghouse dust which they send to another company for the recovery of cadmium, lead, and zinc.[1] In Europe, there are three facilities that are dedicated to recycling of nickel-cadmium batteries and at least three such facilities in Japan. Saft Nife in Georgia collects nickel-cadmium batteries in the U.S. and exports them to their recycling facility in Sweden. In addition, there are other facilities in Europe and Japan that recycle cadmium from a variety of sources, some of which may include pre-separated cadmium electrodes from industrial batteries.

Potential for Future Source Reduction

The most likely option for source reduction of cadmium in nickel-cadmium batteries is the replacement of these batteries with those of a different type. The April 1992 U.S. EPA report entitled, "Preliminary Use and Substitutes Analysis of Lead and Cadmium in Products in Municipal Solid Waste," identifies several potential substitutes for nickel-cadmium batteries including:

- lithium batteries (rechargeable)
- silver-zinc batteries (rechargeable)
- nickel-zinc batteries (rechargeable)
- nickel-hydrogen batteries (rechargeable)
- primary batteries, such as alkaline, lithium, and carbon zinc batteries

It is important to recognize that the environmental impacts of the disposal of the substitutes in relation to those of nickel-cadmium batteries is not known. With the exception of primary batteries, none of the potential substitutes identified in the April 1992 U.S. EPA report have seen much use in consumer products because of technical complications, reduced service life, and high cost. Three of the substitutes identified -- silver-zinc batteries, nickel-zinc batteries, and nickel-hydrogen batteries -- are being used only for military and space applications and are not suitable for consumer products, according to Panasonic, a major battery manufacturer. Panasonic also advises that lithium batteries are possible substitutes for nickel-cadmium batteries, but only in a very limited use. Lithium batteries are presently being used for memory backup in consumer products, such as lap-top computers. Nickel-metal hydride batteries are also a potential substitute but their cost is twice that of nickel-cadmium batteries and they don't adapt to high-drain applications. In addition, many of these technologies are currently in an early development stage. As experimentation and development proceeds for these substitutes, the limitations and the costs of these substitute products may be reduced.

The EPA report indicates that the rechargeable lithium cell is being used to a very limited extent in some consumer applications. Panasonic currently has lithium cells on the market

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[1] The Cadmium Council provided information regarding INMETCO subsequent to the Forum, including the fact that although INMETCO is permitted to process up to 10,000 tons of nickel-cadmium batteries annually, in 1992 they only processed 1,200 tons, due to low nickel and cadmium prices and limited collection of batteries.

(button cells, approximately 3/4 inch in diameter and 1/8 inch thick) for use as memory backup in such products as lap-top computers. Rechargeable lithium batteries have greater charge capacity than nickel-cadmium batteries of a comparable size. However, lithium batteries are at least twice the price of nickel-cadmium batteries, have less than one-half the lifetime of nickel-cadmium batteries, and are more sensitive to abuse, such as overcharging, and they have the potential to explode and their recyclability is not as high as nickel-cadmium batteries. (It should be noted that some of these attributes of lithium batteries have been questioned by battery industry representatives.) Advantages of lithium batteries include their light weight, their ability to provide energy in sub-freezing temperatures, and their high efficiency. Possible applications for lithium batteries include portable cellular phones, lap-top computers, portable radios, and military applications.

Silver-zinc rechargeable batteries are currently in use primarily in military and space applications. Silver-zinc batteries have a very high energy density; however, their cost is five times the cost of nickel-cadmium batteries, and their lifetime is less than one-fifth the lifetime of nickel-cadmium batteries. Nickel-zinc batteries offer a charge density greater than that available from nickel-cadmium batteries. Nickel-zinc batteries also have a higher cost than nickel-cadmium batteries, but a lower cost than silver-zinc batteries. Although its performance is not as high as silver-zinc batteries, it is also not subject to the wide fluctuations in price resulting from speculation in precious metals markets. Nickel-zinc batteries have less than one-tenth the lifetime of nickel-cadmium batteries. Battery manufacturers advise that silver-zinc and nickel-zinc batteries are not suitable for consumer applications.

Nickel-hydrogen batteries are currently found only in exotic applications, such as satellite applications. The hydrogen in the cell is in a gaseous form, and the operating pressure is much higher than other cells, ranging from 3 to 20 times atmospheric pressure, as compared to 0 to 3 atmospheres for a nickel-cadmium cell. Because of these high operating pressures, construction is labor-intensive and very expensive. Thus, even though nickel-hydrogen batteries have twice the cycle life of nickel-cadmium batteries, their high cost makes them impractical for use in consumer products.

Primary batteries, i.e., for one-time use only, such as alkaline, lithium, and carbon-zinc, are possible substitutes for nickel-cadmium batteries, however they are not rechargeable and therefore, replacement costs may be substantial in high discharge applications. In addition, since these are non-rechargeable batteries, the number of batteries requiring disposal would increase.

PRBA identifies sealed lead acid batteries, nickel-metal hydride batteries, and rechargeable alkaline manganese batteries as potential substitutes for nickel-cadmium batteries. New small sealed lead acid batteries are appearing on the market as a substitute for nickel-cadmium batteries and are being introduced into some portable computers, camcorders, and portable cellular phones. Sealed lead acid batteries have greater power but a shorter life and higher cost than nickel-cadmium batteries, and replacing a cadmium-based battery with a lead-based battery is not likely to offer environmental benefits. Nickel-metal hydride batteries are not expected to replace the majority of nickel-cadmium batteries due to their inability to adapt to high-drain applications, such as power tools, and their high cost (twice that of nickel-cadmium batteries). Rechargeable alkaline manganese batteries are presently in a development stage but are expected to directly compete against nickel-cadmium batteries, and eventually, the primary battery market.

A bibliography for this background information is presented at the end of this section.

7.2 WORKSHOP PARTICIPANTS

This session was facilitated by Lori Swain of SWANA and notes were taken by Nancy Thacher of SWANA. Workshop participants were as follows:

Andrea Cohen - State of Vermont, Solid Waste Division
Truett DeGeare - USEPA, Headquarters
Allen Hershkowitz - National Resource Defense Council (attended first day only)
David Hurd - Bronx 2000
David Kelley - State of Florida, Hazardous Waste Division
Greg Keolian - National Pollution Prevention Center
Lori Kincaid - Center for Clean Products, University of Tennessee
Anders Kjallman - Swedish Environmental Protection Agency
Craig Liska - Motorola
Robert T. Loring - Massachusetts Clean Water Action
Charles Monahan - Panasonic
Arnie P. Nilsson - Saft Nife, Inc.
Hugh Morrow - The Cadmium Council, Inc.
Bill Orr - California Integrated Waste Management Board
Dwight Peavey - USEPA Region I (attended first day only)
Mark Schweers - INMETCO
Mac Slayton - Radio Shack
Jayne K. Vicelich - Sony Corporation of America
Rick Watson - Delaware Solid Waste Authority

7.3 GENERAL DISCUSSION

There was considerable discussion in this workshop that did not relate specifically to identification or evaluation of source reduction options. Some of the key points made during this general discussion were:

- There is a need to include in the discussions within the workshop use of nickel-cadmium batteries that are used for other purposes than consumer use. In other words, commercial and industrial applications of nickel-cadmium batteries should be included in discussions of source reduction.

- The issue of whether or not the government, and specifically EPA, should be playing an active role in product design and manufacturing issues. Some participants felt that this is an inappropriate role for EPA, and that industry has the knowledge to design and manufacture the product, and government does not.

- Related to the point above, one participant stated that while industry should be responsible for product design, source reduction would not be incorporated into product design, unless and until industry was economically responsible for management of the wastes their products produce.

- Some participants indicated their belief that a lifecycle approach to the product should have been taken, rather than focusing purely on disposal.

A number of points were made regarding the background paper, and these are reflected in the version of the background paper presented in this section.

7.4 ANALYSIS OF SOURCE REDUCTION POTENTIAL

The participants in this workshop were able to identify a number of source reduction options, and although they felt unable to rank these options, they did group them into categories, and discuss implementation strategies and obstacles for each category.

7.4.1 Determination of Source Reduction Options

The following source reduction options were identified by the workshop participants:

1. Improve the manufacturing process to use cadmium more efficiently.

2. Improve the performance of the batteries without using more cadmium.

3. Education from the industry/manufacturer for the consumer to make better use of the product.

4. Society taking responsibility for efficient use of product.

5. Using products that can use alternating current (AC) electricity, as well as direct current (DC).

6. Making products such that the consumer can remove the batteries and replace them, instead of disposing of the product entirely.[1]

7. Education of consumers to purchase more energy-efficient products.

8. Developing products for the consumer with an indicator that shows when the battery needs recharging.

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[1] According to information provided by The Cadmium Council subsequent to the Forum, many states have adopted legislation with this requirement and members of the Portable Rechargeable Batteries Association have agreed to implement this measure.

9. Designing a "smart charger" that prevents over-charging a battery.

10. Leasing/renting and sharing of industrial products.

11. Replacing the electrodes in industrial batteries, instead of replacing the entire battery. (Because the nickel electrodes in industrial batteries require replacement more quickly than the cadmium, by replacing the nickel electrode only, the cadmium can be used to its full value.)

12. Improving the life of the battery.

13. Educate consumers not to buy products they don't need.

14. Label batteries for product life.

15. Specialize batteries for particular applications in the consumer marketplace. This could also include standardization of battery formats for particular types of products.

16. Substitute other types of batteries that have less environmental impact.

17. Develop smaller products, which will allow batteries to last longer.

Several points were made in regards to these options:

- some participants stated that nickel-cadmium batteries are approaching their theoretical limit on efficiency, and significant increases in product life are not likely;
- labelling of batteries for product life was felt to be impractical by some participants because of the lack of a standard for measuring this;
- many of the substitutions for nickel-cadmium batteries are not feasible in all of the applications that nickel-cadmium batteries are used for; and
- some participants felt that the substitutions for nickel-cadmium batteries are likely to have the same level of environmental and public health impacts as nickel-cadmium batteries themselves.[1]

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[1] In information provided subsequent to the Forum The Cadmium Council states that 1,000 carbon-zinc batteries (which they view as having the energy equivalent of one nickel-cadmium battery) have almost as much cadmium as one nickel-cadmium battery.

7.4.2 <u>Categorization of Source Reduction Options</u>

The participants in the workshop felt that there was insufficient information to prioritize the list of source reduction options developed. The consensus of the group was to divide the list into categories. Three categories were identified: technology, consumer education, and recycling.

7.4.2.1 Options Related to Technology

In categorizing the options, some options were refined or clarifying comments were made. The following are the options included in the Technology category, along with any clarifying comments:

- Increase performance of battery without increasing use of cadmium. It was noted that if batteries were more efficient then the amount of cadmium used would decrease.

- Design products for both AC and DC energy sources.

- Standardize battery formats for particular types of products.

- Miniaturize products. Since miniature products should consume less electricity, fewer batteries would me needed.

- Improve the manufacturing process to use raw cadmium more efficiently.

- Develop an indicator on batteries that indicates when they need recharging.

- Substitute other battery types that have less environmental impact. It was noted that the substitutions are likely to be less efficient.

7.4.2.2 Consumer Education Options

The following are the options included within the Consumer Education category:

- Provide information to the consumer on proper operation of products.

- Provide "smart chargers" to consumers to prevent over-charging. Since over-charging shortens the useful life of a battery, this should result in fewer batteries being purchased and discarded.

- Educate consumers not to buy unnecessary products. It was suggested that local government and industry work together to educate consumers in this regard.

- Leasing of industrial batteries. This would provide incentive for the leasing company to maximize the life of the battery, and would also encourage recycling of batteries, since the battery would be returned to the leasing company and they can more easily recycle the battery than a company that may only have one or two batteries in its manufacturing facility.

- Product labelling regarding energy efficiency of products. This option was expanded to include education to encourage consumers to buy products with longer life spans.

- Develop specialized batteries for particular consumer applications.

7.4.2.3 Recycling Options

The participants in the workshop had a strong desire to consider recycling options. Some participants noted that industry wants to get the cadmium back through recycling efforts. The workshop participants felt that it is important to acknowledge that, in their view, recycling contributes to source reduction, and therefore should be considered a source reduction option. In addition, some participants felt that recycling has the potential to greatly decrease the quantity of cadmium disposed in nickel-cadmium batteries. Two of the options identified were included in the recycling category:

- Leasing of industrial batteries. As noted in the description of consumer education options, leasing of batteries is likely to contribute to increased recycling. One application in which leasing of nickel-cadmium batteries may occur in the future is electric vehicles.

- Replacing the nickel electrode in industrial batteries, to get more useful life out of the cadmium.

7.4.3 Identification of Implementation Strategies and Obstacles

For each category of source reduction options, implementation strategies and obstacles were identified.

7.4.3.1 Technology

The following implementation strategies and obstacles were identified for this category of source reduction options:

- Economics was seen as both an implementation strategy and as an obstacle.

- Technological limitations, such as the theoretical limit on life span, are obstacles.

- Lack of information on substitutes was viewed as a barrier. In particular, environmental information on substitutes for nickel-cadmium batteries was seen as hindering industry from using them in consumer products.

- Consumer demand could be a barrier as well as an implementation strategy. Consumer demand for high performance might limit use of substitutes, but consumer demand for more efficient products could aid implementation of source reduction.

7.4.3.2 Consumer Education

The following are the implementation strategies and barriers discussed:

- Economics was viewed as a barrier to industry, government and the consumer, because funds would have to be sought to pay for public education, and this would ultimately be reflected in the price of the product.

- Consumers are given so much information, that information overload was considered a potential obstacle.

- The inability of consumers to act on the information provided due to lack of comprehension, or their unwillingness to read the information provided were seen as obstacles.

- Using industry trade associations to educate consumers was seen as an implementation strategy.

7.4.3.3 Recycling

For recycling options, the following implementation strategies and obstacles were identified:

- Regulation and enforcement of regulations were seen as both a barrier and an implementation strategy. Regulations can be a hindrance to recycling, but to the extent regulations call for recycling of nickel-cadmium batteries, enforcement of those regulations can be an implementation strategy.

- The lack of a recycling infrastructure, in particular collection and transportation systems and regional processing facilities, is viewed as an obstacle.

- Participation rates are a barrier, since current participation rates in recycling programs indicate a general unwillingness to participate in these programs.

- The need for sorting technologies is viewed as a barrier, and one that may need to be overcome in order to make recycling feasible.

- A deposit/refund system for nickel-cadmium batteries was seen as an implementation strategy to foster collection of batteries for recycling.

- Inaccurate information about how to properly dispose of batteries is an obstacle.

- The need for industry to work together to promote recycling is currently an obstacle, but could become an implementation strategy.

7.4.4 Further Discussion of Recycling Options

Since there was a desire to further explore recycling options, the discussion of this topic was expanded. A number of the key points made during this discussion are as follows:

- The State of Connecticut has established a goal of recovering 90 percent of nickel-cadmium batteries.[1]

- A buy-back system, as opposed to a deposit/refund system, was favored by some participants as a way to foster recycling.

- There are a number of programs already in existence to recover nickel-cadmium batteries from consumer products. These programs include joint efforts between consumer product manufacturers and recycling processors.

- A pilot recycling program is being implemented by the Portable Rechargeable Battery Association in Minnesota. This program will test methods for capturing high percentages of nickel-cadmium batteries, and some participants felt that the results from this program will provide useful information about how recycling rates can be increased.

7.5 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were developed by the participants in this workshop:

- Policy initiatives should be developed that promote the identified source reduction options and remove the barriers to implementation.

- There are several areas in which there are informational needs: 1) information regarding nickel-cadmium batteries needs to be coordinated between industry and government agencies; 2) information needs to be gathered to use as educational material for consumers; and 3) information resources need to be developed for government agencies and industry to use in promoting consumer education.

- Uniform federal guidelines for the regulation of nickel-cadmium batteries should be developed.

- The EPA's role should be environmental protection and not product design.

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[1] According to information provided by Saft Nife subsequent to the Forum, Sweden has introduced similar legislation.

- More research is required in the areas of environmental impacts of nickel-cadmium substitutes and the lifecycle impacts of nickel-cadmium batteries.

- The consumer should be provided with more information about nickel-cadmium batteries.

- Research and development grant funding should be provided for analysis of sorting and reclamation technologies.

- Research and development efforts should be coordinated with the industry's needs.

- An EPA-sponsored battery recycling conference should be sponsored.

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(Note: Any additional information obtained subsequent to the development of the background information is listed in Appendix B.)

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SECTION 8

PLASTIC STABILIZERS

8.1 BACKGROUND INFORMATION

The Purpose of the Heavy Metal

Cadmium, either alone or in combination with barium, zinc, or phosphorous, can be used to form a stabilizer for plastics to retard the degradation of flexible polyvinyl chloride (PVC) from exposure to heat. Uses of flexible PVC include flexible tubes and film for food and non-food applications (such as so-called "bubble packs"), shoes, shower curtains, toys, and artificial leather coating; however, cadmium-based stabilizers are not approved for use in food applications.

The role of stabilizers in PVC is to reduce degradation of the plastic, which discolors and weakens the plastic. Cadmium-containing stabilizers provide these features during processing and throughout the service life of PVC. Barium/cadmium stabilizers also allow higher temperature processing for some PVC resins and impart dynamic and thermal stability to resins processed in calendering (sheet rolling) operations.

The Amount of Cadmium Used

Cadmium-containing stabilizers typically contain from 1 to 15 percent cadmium and usually constitute 0.5 to 2.5 percent of the final PVC compound, according to the Cadmium Council. Solid stabilizers contain between 5 and 10 percent cadmium, but can contain as much as 15 percent. Liquid stabilizers contain less cadmium than their solid counterparts, usually between 4 and 5 percent. Cadmium-bearing stabilizers are the third largest consumer of cadmium in the western world, according to information obtained from the Cadmium Council. Cadmium-bearing stabilizers consume 10 percent of the cadmium in the western world, falling behind nickel-cadmium batteries which consume 55 percent and cadmium pigments which consume 20 percent.

According to an EPA report entitled "Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000," completed by Franklin Associates, Ltd. in January 1989 (Franklin study), discards (after recycling) of cadmium in plastics were 342 tons in 1970 or almost 29 percent of total cadmium discards. Cadmium in plastics peaked at 595 tons in 1978 or approximately 38 percent of total cadmium disposed, and declined to 502 tons in 1986 or 28 percent of total cadmium disposed. In 1986, plastic products containing cadmium ranked as follows: non-food packaging, miscellaneous durables, miscellaneous nondurables, furniture, toys, records, footwear, and others.[1]

Discards of cadmium in plastics are projected to decrease to 384 tons by the year 2000 or 14 percent of total. The decline is generally attributed to concern over toxicity and regulations on the use of cadmium in products such as toys, furniture, and packaging.

The Form in Which Cadmium is Used

The predominant cadmium-containing plastics stabilizers are mixtures of barium and cadmium organic salts, such as cadmium stearate or cadmium laurate. The combination of barium and cadmium salts provides a synergistic effect, with the cadmium salts providing good color stability in initial processing and the barium salts providing good long-term thermal stability during use.

The Manufacturing Process

Barium/cadmium stabilizers are manufactured by stabilizer manufacturers who sell the stabilizers to manufacturers of PVC or PVC products.

Barium/cadmium stabilizer can be manufactured in a number of ways. The starting materials are usually the metals or metal oxides. They are combined with various organic compounds such as naturally-occurring long-chain monocarboxylic saturated (sometimes unsaturated) fatty acids to form the heavy metal organic salts. The salts can be prepared by three general processes:

- direct dissolution of finely divided metals or metal oxides in heated organic acids;

- precipitation from aqueous solutions of metal salts (chlorides or nitrates) and alkali soaps; or

- fusion of metal oxides with organic acids.

For liquid barium/cadmium stabilizers, the production starts from metal oxides. They are dissolved directly in the heated organic acids in the presence of solvents. The water produced during the process is removed and the finished product filtered.

Solid stabilizers are prepared by the precipitation process which uses the classical method of preparing metal soaps using natural fatty acids to give, for example, cadmium laurate or cadmium stearate.

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[1] In comments provided subsequent to the Forum, The Cadmium Council indicated that it disputes the values in the Franklin Associates' report and believes that pigments are a larger contributor of cadmium in plastics than stabilizers. No comprehensive source of alternative values has been identified, however.

EXPOSURE TO PUBLIC HEALTH AND THE ENVIRONMENT

According to a report entitled "Environmental and Health Effects of Cadmium Pigments and Stabilizers in Plastics," completed by the Cadmium Council, there is little potential for leaching of cadmium from cadmium-containing plastics disposed in landfills. In addition, this report concludes that, when incinerated, the majority of the cadmium in plastics would be retained in the flue and bottom ash, with little cadmium from this source being emitted to the air.

SOURCE REDUCTION MEASURES

Source Reduction Measures to Date

According to Modern Plastics Encyclopedia, 1992 edition, barium-zinc and calcium-zinc stabilizers are rapidly replacing barium-cadmium stabilizers in flexible PVC. The first cadmium-free heat stabilizers emerged in the 1950's, but they were not used extensively until the late 1980's, when the escalating price of cadmium generated new interest in high performance cadmium-free stabilizers. According to Modern Plastics, Synthetic Products (Synpro), Akzo Chemical, Argus Division of Witco, R.T. Vanderbilt, and Ferro Corporation have begun manufacturing high efficiency cadmium-free stabilizers. According to Modern Plastics Encyclopedia, barium-zinc and calcium-zinc stabilizers are rapidly replacing the more effective barium-cadmium formulations in most general-purpose applications. New co-stabilizers are being developed to provide stabilization close to that of the cadmium-based stabilizers, and one major stabilizer manufacturer has indicated that barium-zinc stabilizers are as effective as cadmium-based stabilizers in most applications. In addition, calcium-zinc stabilizers have been used in food wrap film. One industry source estimates that approximately 25 to 33 percent of stabilizer users (PVC or PVC product manufacturers) have converted to non-cadmium stabilizers since the mid-1980's and that food packaging and toys have used cadmium-free stabilizers since the 1950's.

Potential for Future Source Reduction

According to a major stabilizer manufacturer, the goal of the industry is to eliminate cadmium from stabilizers and to replace it with barium-zinc and calcium-zinc (in most cases, barium-zinc). In Europe and Japan, cadmium is not being used in plastics stabilizers, as regulations have resulted in manufacturers switching to non-cadmium-based stabilizers. This regulatory trend is occurring in the U.S. as well. The Council of Northeast Governors (CONEG) developed model legislation designed to reduce or eliminate the presence of four metals (lead, cadmium, mercury, and chromium) in packaging. This legislation has been adopted by 13 states. Since some of the plastics containing cadmium-based stabilizers are used in packaging, this legislation has impacted the use of these stabilizers.

As stated above, most U.S. PVC or PVC products manufacturers are well on their way to converting to cadmium-free systems and this trend is expected to continue. According to one stabilizer manufacturer, by the end of 1992, it is anticipated that 50 percent of stabilizer users will convert to non-cadmium stabilizers, and by the end of 1993, it is anticipated that 75 percent will convert to cadmium-free systems. Total phase-out of cadmium-based stabilizers in certain applications is predicted by some industry representatives within five years.

There is a spectrum of attitudes about cadmium-free stabilizers among PVC and PVC products manufacturers. Although some manufacturers have converted to cadmium-free stabilizers entirely, some manufacturers believe that barium-cadmium stabilizers work better in demanding, high-speed operations, such as sheet rolling, and thus are not switching to cadmium-free stabilizers. Also, some PVC processors utilize equipment that is designed to run with cadmium-based stabilizers, and switching to cadmium-free stabilizers would require modification of equipment.

Regulations from OSHA may provide further impetus to convert to cadmium-free stabilizers. A stabilizer manufacturer has indicated that OSHA has proposed new workplace regulations which require a reduction in the exposure of employees to cadmium in the workplace. These regulations are presently on hold, but if passed could provide additional rationale for using cadmium-free stabilizers.

A bibliography for this background information is presented at the end of this section.

8.2 WORKSHOP PARTICIPANTS

This session was facilitated by Robert W. Pease, Jr. of WESTON and notes were taken by Gil Matar of SWANA. Workshop participants were as follows:

Bern Bluestein, Witco Corp. (Argus Division)
Marge Franklin, Franklin Assoc.

Fran Irwin, World Wildlife Fund
Douglas E. Klapper, Akzo Chemicals, Inc.
Carl Lawton, UMASS Lowell
Reid Lifset, Yale Program on SW Policy
Thomas Llewellyn, U.S. Bureau of Mines
Anni Loughlin, USEPA Region I
Mike Marshall, BFGoodrich
Frank W. McKane, Synpro
Robert Putnam, Putnam Environmental Services
Gregor Rigo, Rigo & Rigo, Assoc.
Gary Sadowski, Ferro Corp.
Mitch Silkotch, Akzo Chemicals, Inc.
Larry Verbiar, Ferro Corp.

8.3 GENERAL DISCUSSION

Prior to evaluating source reduction options, the discussion that took place in this workshop focused on issues surrounding the question of whether or not an analysis of source reduction potential is necessary or appropriate. Some of the points raised during this general discussion were as follows:

- the industry has already taken it upon itself to reduce cadmium in plastic stabilizers, and some participants believe it will be totally phased out in some applications within five years, so this analysis of source reduction potential is unnecessary;

- in many companies there has been no research on cadmium-based stabilizers since the mid- to late-1980's, in recognition of the trend towards cadmium-free stabilizers;

- most plastic stabilizers manufactured in Europe and Japan do not contain cadmium, but other foreign countries are using significant amounts of cadmium-based stabilizers;

- some end-users of plastic stabilizers are requiring stabilizers containing cadmium; it is primarily end-user requirements that have to be changed in order for further reductions to occur;

- price is not currently providing a strong impetus for source reduction, although it did provide that impetus in the late 1980's;

- there is a strong market for export of cadmium-based stabilizers to the Far East, so cadmium production will continue for this reason;

- one participant stated that the results of a study currently being prepared indicate that the cadmium in PVC plastics (which is where cadmium-based stabilizers are used) is not bioavailable, based on leaching and incineration tests, however, it was noted that the fate of cadmium in MSW composting has not been studied;

- PVC plastics are not a major contributor to MSW (as defined by EPA);

- there are other, more significant, sources of cadmium in MSW, that should be the focus of source reduction efforts instead of plastic stabilizers;

- some users of plastic stabilizers are expressing concern about using barium-based stabilizers as an alternative to cadmium-based stabilizers;

- there are a wide range of regulatory pressures, including Occupational Safety and Health Administration (OSHA) regulations and the Model Legislation for

Reduction of Toxics Packaging developed by the Council of Northeast Governors (CONEG), to reduce or eliminate cadmium usage; and

- the perception of risk (real or not) is driving interest in source reduction of cadmium; and

- some participants believe the need for analysis of source reduction has not been demonstrated, and an analysis of risk to public health and the environment should be conducted to determine if there is a need to focus on source reduction.

Several clarifying comments were made in regard to the background paper, and these comments are reflected in the version of the background paper presented above. In addition, it is important to note that some participants in the workshop were concerned that proceeding to the step of analyzing source reduction potential would be taken as an endorsement of the need for source reduction, and those participants want it to be clear that they were not endorsing the need for a source reduction analysis by participating in discussion of such an analysis.

8.4 ANALYSIS OF SOURCE REDUCTION POTENTIAL

With the recognition that participation in an analysis of source reduction potential would not be considered an endorsement of the need for source reduction, the members of this group participated in the application of the framework for analysis of source reduction potential.

8.4.1 Determination of Source Reduction Options

Ten options for source reduction of cadmium-based stabilizers were identified, which are as follows:

1. Ban PVC plastics.

2. Establish a user fee for cadmium.

3. Utilize voluntary efforts to reduce use of cadmium in plastic stabilizers.

4. Reformulate plastic stabilizers to utilize substitutes for cadmium.

5. Reduce amounts of cadmium in plastic stabilizers.

6. Design products to increase their useful life.

7. Ban applications in which cadmium-based stabilizers are required.

8. Reduce use of products that contain cadmium-based stabilizers.

9. Establish a government-sponsored bonus for source reduction of cadmium-based stabilizers.

10. Promote use of reusable products that contain cadmium-based stabilizers.

8.4.2 Evaluation of Source Reduction Options

The three major criteria for evaluating source reduction options which are listed in Getting at the Source were applied to the ten options identified. These three criteria are:

- effectiveness of option in achieving source reduction in cadmium from plastic stabilizers;
- other effects from implementing options, such as impacts on performance, price, manufacturers, retailers, distributors, other products, and solid waste management options; and
- technical barriers to implementation.

One of the effects from implementing options that is included within the second criteria, as defined in Getting at the Source is environmental trade-offs. However, the participants in the workshop felt that they lacked sufficient data to make this evaluation, so this sub-criterion was not included in the analysis of options.

The application of the three major criteria to the ten options can be summarized in the table below.

Based on the application of the criteria described, three options were considered worthy of further discussion: 1) establishing a user fee for use of cadmium-based stabilizers; 2) voluntary efforts to reduce use of cadmium in plastic stabilizers; and 3) promote use of reusable products containing cadmium-based stabilizers. As can be seen in the table, it was noted that two of the other options could be considered part of the voluntary efforts option. These are substitution for cadmium in plastic stabilizers and reducing amounts of cadmium used in stabilizers.

Table 8-1

Evaluation of Source Reduction Options

Source Reduction Option	Criterion I: Achievement of SR goal	Criterion II: Other effects of implementing option	Criteria III: Technical Barriers	Does Option Merit Further Discussion?
Ban PVC	++	--	-/+	No, as it is not socially or economically desirable
User Fee	+	-	++	Yes
Voluntary Efforts	+	++	+	Yes
Substitution/ Reformulation	++	++	+	Yes, but it is actually a part of Voluntary Efforts
Reduce Cd Amounts	+	?	++	Yes, but it is actually a part of Voluntary Efforts
Design for Extended Product Life	+	?	+	No, because this is achieved by increasing Cd
Ban Applications Requiring Cd	++	-	+	No, as it is not socially or economically desirable
Reduce Use of Cd-containing Products	+	-/+	-/+	No, as this would require high levels of resources applied to consumer education
Government Bonus for SR	+	?	-	No, because of resources required for implementation
Promote Reusable Products	+	+	+	Yes

Key: + Positive; ++ Highly Positive; - Negative; -- Highly Negative; +/- Positive and Negative Attributes; ? Unknown.

8.4.3 Implementation Strategies and Obstacles for Selected Options

Most of the discussion regarding implementation of the selected source reduction options was focused on the voluntary efforts option.

8.4.3.1 Voluntary Efforts

The following are the key points made during the discussion of implementation of voluntary efforts for reducing use of cadmium in plastic stabilizers:

- A tremendous amount of research and development is currently being conducted by the industry in the area of cadmium-free stabilizers.

- There are two major obstacles to reducing cadmium use in stabilizers. The first is meeting the performance needs of customers with cadmium-free stabilizers, and second is that several years of testing may be required before new materials can be introduced, since many products come with a five-year warranty. The testing initiated in the late 1980's is now coming to fruition.

- It was believed that within five to seven years, voluntary efforts will result in the virtual elimination of cadmium in stabilizers in many applications because there is little or no cadmium-based research being conducted, and the non-cadmium based technologies will surpass the cadmium-based technologies in performance at some point. In certain applications, cadmium cannot be eliminated without a sacrifice in economics and performance.

- There is a need for a source reduction tracking mechanism. It was suggested that the Significant New Use Rule could be used for this, but the effectiveness of this mechanism was questioned. It was also suggested that the Bureau of Mines through its source statistics could track source reduction.

- The voluntary efforts initiated due to price increases in the late 1980's are now continuing due to legislative efforts at the state level, and OSHA requirements.

8.4.3.2 Promote Reusable Products

This source reduction option was considered by the participants in the workshop to be less desirable than the use of voluntary efforts for two major reasons. The first is that the participants believe it would be less effective than voluntary efforts, and the second is that it only addresses a subset of the products containing cadmium-based stabilizers. This second point relates to the fact that it was felt that this option would be applied to containers (as they could be reusable), but that containers are only a minor part of the total use of PVC. Thus, participants stated that this option should only be utilized if voluntary efforts do not accomplish their goals. The implementation strategies that would be used to implement this option would be education and price structure.

8.4.3.3 User Fee

Again, participants felt that this option should be used only if voluntary efforts do not achieve their goals. While this option is preferable to the participants to bans or other regulatory measures, it is less desirable than voluntary efforts because it would have an economic impact on manufacturers and consumers. Since price was the primary rationale for a switch to non-cadmium based stabilizers in some applications in the late 1980's, it was felt that this option would be effective in promoting source reduction.

8.5 CONCLUSIONS AND RECOMMENDATIONS

In addition to ranking the source reduction options, a number of recommendations were developed by the participants in this workshop.

8.5.1 Selected Source Reduction Options

As described above, the source reduction options ranked the highest after application of the evaluation criteria were: 1) voluntary efforts; 2) promote reusable products; and 3) establish a user fee for cadmium. The participants concluded that the second and third options should only be explored if voluntary efforts fail to achieve the desired results. In addition, as was stated previously, some participants wanted it understood that their participation in an evaluation of source reduction options should not be considered an endorsement of the need for source reduction.

8.5.2 Other Conclusions and Recommendations

Other conclusions and recommendations that the participants in this workshop developed are listed below. It should be understood that not every participant agreed with every conclusion listed, but that this represents the major points made during the workshop:

- The problem(s) associated with this product need to be more clearly defined and substantiated with data, and this should have been done at the outset of this process.

- The issue of risk needs to be discussed and resolved prior to starting an evaluation of source reduction potential. An appropriate method for assessing and evaluating risks must be developed, and subsequent steps should be based logically on the information presented in the evaluation of risks.

- The toxicity of cadmium was believed by some participants to be justification for conducting an analysis of source reduction.

- The EPA should have known that source reduction is underway within this industry and focused on some other industry or product as a result. Some participants noted that if EPA did not know this prior to the Forum, then the Forum provided a means to communicate this information, and others stated that industry should be more proactive in making this information available.

- It should have been clearer to participants whether the intent of the source reduction analysis was to focus only on the presence of this product in MSW or on the whole life cycle of the product.

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SECTION 9

INDUSTRIAL AND HOUSEHOLD MERCURY THERMOMETERS

9.1 BACKGROUND INFORMATION

The Purpose of Mercury

The liquid-in-glass thermometer was invented over 300 years ago as a temperature measuring device. Over the years, many other practical applications have been found for the liquid-in-glass thermometer in addition to its earlier use as a primary standard of temperature. These applications include fever thermometers, basal thermometers, and industrial thermometers, and devices which measure pressure, such as barometers and mercury manometers (blood pressure measuring devices). Most barometers (particularly those used in residences) contain no mercury. In addition, there is little information available regarding manometers. Therefore, this background paper focuses only on different types of thermometers.

Mercury has many physical characteristics which make it the choice liquid for use in thermometers where accuracy is critical. Its advantages include a broad temperature span between its freezing and boiling points, its liquid state at room temperature, its nearly linear coefficient of expansion (ability to expand and contract with temperature changes), the relative ease of obtaining mercury in a very pure state, and its nonwetting-of-glass characteristic.

The Amount of Mercury Used

Fever thermometers contain approximately 300 to 600 milligrams of mercury. There is a much wider range of mercury content in industrial thermometers, depending on their type and application. H.O. Trerice Company, a manufacturer of industrial thermometers which would be used in such applications as refrigerated cars, industrial ovens, or on steam lines in manufacturing operations, industrial thermometers usually contain about four to ten times as much mercury as a household type thermometer, or 2400 to 6000 milligrams. Other estimates of mercury use in thermometers are as follows: industrial thermometers contain one gram, and an ASTM precision thermometer contains 2 to 25 grams.

Amount of Mercury Disposed from Thermometers

According to an April 1992 EPA report entitled, "Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000," fever thermometers were identified as a source of mercury disposed from homes and medical establishments. In 1989, an estimated 16.3 tons of mercury were discarded in thermometers, or just over 2 percent of total mercury discards (discards exclude any material recycled).[1] A thermometer manufacturer estimates that 3.3 tons of mercury is discarded annually in thermometers, excluding discards from hospitals. Since it is not known what fraction of the 163 tons estimated in the EPA report was due to hospitals, it is not possible to compare those two estimates. Mercury thermometers are being replaced by digital thermometers, especially in medical applications. Therefore, a gradual decline in discards of mercury from fever thermometers is projected.

The Form in Which Mercury is Used

Thermometers contain elemental mercury (pure form) which is a silver-white liquid, referred to as "quicksilver."

The Manufacturing Process

Manufacturing thermometers involves metering elemental mercury into hollow glass or stainless steel tubing by gravity or a vacuum process and then sealing the glass or stainless steel. Mercury is placed into these tubes at thermometer manufacturing plants. Household thermometers are glass tubes only and mercury is placed into the glass by gravity. There is 300 to 600 milligrams of mercury in fever thermometers. Industrial thermometers may include a glass or stainless steel tube filled with mercury which serves as the temperature sensing probe. Mercury is placed in this type of tubing by a vacuum process.

POTENTIAL FOR EXPOSURE OF PUBLIC AND THE ENVIRONMENT

Most of the research conducted to date on the fate and effects of mercury in municipal solid waste has been general in nature, and has not focused on mercury in measuring devices. This research suggests that very little mercury actually leaches from landfills containing MSW. State regulatory agencies are monitoring landfills to determine if they are significant contributors of mercury in the environment. Air emissions from landfills are another potential route of exposure; however, little information is available regarding the magnitude of these emissions.[2]

Conversations with industry representatives reveal that they are aware of no research relative to the specific fate and effects of disposal of thermometers on the environment.

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1 These numbers were disputed during the Forum by industry representatives who questioned the assumptions regarding life span of thermometers used in the U.S. EPA report.

2 A participant indicated subsequent to the Forum that a Swedish study found significant air emissions from landfills (Lindquist et al 1990).

REDUCTION MEASURES

Reduction and Recycling Measures to Date

Thermometer manufacturers advise that the quantity of mercury presently used in thermometers has remained the same for many years. They have advised that a reduction in the amount of mercury is not possible without affecting performance. It is not possible to make household thermometers smaller because they would not be readable. Thus, no reductions in mercury content in thermometers have been achieved to date.

Since a reduction in mercury content does not appear to be feasible, an alternative for source reduction has been replacement of mercury thermometers with digital products. According to Becton Dickenson, approximately one-third of all fever and basal thermometers are digital thermometers, and the remaining two-thirds are mercury thermometers. The proportion of digital thermometer sales is expected to increase by approximately one percent each year, and the proportion of mercury thermometer sales is expected to decrease by one percent each year. If this trend continues, mercury thermometers will no longer exist after 40 years. An obstacle, however, to the replacement of mercury thermometers is the higher cost of their digital counterparts. Digital thermometers are about 3 to 10 times more expensive than mercury thermometers.

There is some recycling of mercury thermometers. Industrial thermometers are recycled to a large extent; however, household ones are not. Three U.S. commercial facilities presently recover mercury from mercury-containing measuring devices. These include Mercury Refining, Inc. in Albany, New York; Bethlehem Apparatus in Hellartown, Pennsylvania; and Quicksilver Products in Brisbane, California. Mercury Refining, Inc. and Bethlehem Apparatus have been recovering mercury since the early 1970s, and Quicksilver, since 1989. These companies sell recovered mercury back to mercury-containing product manufacturers. In 1991, 25 percent of all mercury demands were met with recycled mercury.

Potential for Future Source Reduction and Recycling

It appears that the greatest potential for reduction of mercury in thermometers is replacement with digital products, since reducing the amount of mercury per thermometer is not feasible. As mentioned previously, if current trends continue, the mercury-based basal and fever thermometers will be completely replaced by digital thermometers in 40 years. Recovery and recycling of mercury would reduce the amount of mercury disposed.

Becton Dickenson advises that it does nota seem economically feasible to recycle mercury from fever and basal thermometers. Although it may be possible to reduce the cost of recycling mercury-based thermometers, it is unlikely that it would become an economically desirable mode of management. Thus, little recycling of these type of thermometers is anticipated. Recycling of industrial mercury thermometers is expected to continue.

A bibliography for this background information is presented at the end of this section.

9.2 WORKSHOP PARTICIPANTS

This session was facilitated by Erica Guttman of the Rhode Island Solid Waste Management Corporation and notes were taken by Carrie Nuoffer of SWANA. Workshop participants were as follows:

Deanne Emory, Miller & Weber, Inc.
Tim Gordon, Becton-Dickinson
Marquita Hill, University of Maine, Dept. of Chemical Engineering
Stephen Jasinski, U.S. Bureau of Mines
John Paul Kusz, Safety Kleen Corporation
Lena Perenius, National Chemicals Inspectorate
John Stewart, H-B Instruments
Richard Sweeting, Florida Medical Ind., Inc.
Joy Taylor, Michigan Dept. of Natural Resources

9.3 GENERAL DISCUSSION

Several clarifying comments were made regarding the background paper provided, and these comments are reflected in the background information presented in this section. One area of concern was the information regarding quantity of mercury in the waste stream cited in the background paper. Industry representatives questioned the validity of the assumptions used in the report cited, and expressed their belief that the quantities are actually much lower.

It was stated that the workshop would address two types of thermometers: those intended for household use and those intended for industrial or laboratory use. Sweden's policy on mercury was discussed, which includes a ban on mercury use as of January 1992. Case-by-case exemptions are made, and instruments containing mercury that were manufactured before the ban do not have to be replaced or destroyed. The ban includes all imports, and is intended to result in eventual phase-out of all products containing mercury.

A Minnesota law targeting reduction in mercury disposal was discussed. The Minnesota law requires that products containing mercury have labels discussing the dangers of mercury and indicating that the product cannot be disposed of as municipal solid waste. Two types of exposure to mercury were discussed: direct contact with mercury vapor and indirect contact through ingestion of food in which mercury has bio-accumulated.

9.4 ANALYSIS OF SOURCE REDUCTION POTENTIAL

In this workshop the analysis of source reduction options was broken down into two separate analyses: for household thermometers and for industrial thermometers. Copies of figures from Getting at the Source were distributed to the participants and used to help in the development and evaluation of options. A separate consideration of implementation options was not conducted, but it can be seen that these issues were incorporated into the evaluation of source reduction options.

9.4.1 <u>Determination of Source Reduction Options</u>

9.4.1.1 Household Thermometers

The following source reduction options for household thermometers were identified by the workshop participants:

1. Eliminate/substitute for mercury with electronics.
2. Formulate an international standard for durability.
3. Educate consumers about proper use, maintenance and disposal.
4. Streamline manufacturing process to reduce in-house waste and rejects.
5. Level playing field with imports.
6. Establish program for research and development and technology transfer.
7. Increase life span through new developments such as coatings or plastic base.

All of these options are fairly self-explanatory, with the possible exception of the "level playing field." The rationale behind this option is that many foreign countries do not subject their industries to the same level of regulation, or require that the products made meet the same type of standards, as in the U.S. A level playing field, as it is often characterized, would mean that imports would be subject to the same regulatory standards as in the U.S., which should result in a more durable product and potentially reduce the amount of waste generated or mercury released during manufacturing.

9.4.1.2 Industrial Thermometers

The following options were identified for industrial thermometers:

1. Replace some instruments with electronics.
2. Reduce bore size of thermometers.
3. Fill thermometers with alternative substances (e.g. mineral spirits, toluene, benzene).
4. Substitute soda-lime glass for leaded glass.
5. Increase life span through armoring.
6. Increase life span through annealing.
7. Increase life span through encapsulation.

8. Increase life span through use of engineering plastics or more durable glass/ceramics.

9. Establish international performance standard.

10. Educate about proper use and maintenance.

11. Streamline manufacturing process to reduce in-house waste.

12. Borrow/share instruments (e.g. between schools, small laboratories).

13. Level international playing field.

14. Establish governmental research and development/technology transfer.

Some of these options may require explanation in order to understand their intent. The bore size is the size of the column that is filled with mercury, and thus reducing its size reduces the amount of mercury required. Substituting soda-lime glass for the leaded glass that is typically used in glass thermometers is an attempt to reduce lead in the product, and is not an option for reducing mercury. Armoring is use of a metal sleeve around a glass thermometer and is designed to reduce breakage. Annealing is a process by which the glass is made stronger, again potentially reducing breakage. Encapsulation is a process by which a glass thermometer is coated in a clear protective coating, such as Teflon.

9.4.2 <u>Evaluation of Source Reduction Options</u>

After the source reduction options were identified for household and industrial thermometers, each of the options was evaluated. The issues discussed for each of the options are summarized below. It will be noted that the issues include identification of advantages and disadvantages, as well as methods for, and obstacles to, implementation.

9.4.2.1 Household Thermometers

The issues discussed for each of the household thermometer source reduction options are summarized below.

<u>Eliminate substitute for mercury with electronics</u>

- Electronics are easier to read and faster.
- Electronics are more expensive, meaning some people couldn't afford them.
- This option would likely reduce mercury, but the environmental impacts of electronics are unclear (battery needed to operate, solder, plastics components).
- Electronics are difficult to recycle.

- This option would displace existing manufacturers of mercury-based thermometers.

- Electronics are durable, and should last at least as long as mercury-based thermometers, if properly taken care of.

Formulate an international performance standard for durability

- Many inferior and less durable products are imported.

- This option would increase the overall quality of product, and provide an incentive to improve product.

- A better product is better for everyone in the industry.

Educate consumers about proper use, maintenance and disposal of thermometers

Streamline manufacturing process to reduce in-house waste and rejects

- Manufacturers report 100% vapor recovery and no emissions from their plants. Safety is ensured by the use of carbon filters and enclosed mercury filling operations.

- Most U.S. companies already do this, but there is a need to target very small "basement" thermometer makers and imports that are not subject to Occupational Safety and Health Administration guidelines.

Level playing field with imports

- Imports are not regulated for health, safety, or the environment, therefore they can be produced more cheaply and there can be releases of mercury during manufacturing.

- Serious ethical issues are involved (e.g. child labor, human rights).

- Unfair competition stymies opportunities for product improvement by U.S. manufacturers because they cannot afford to add more value to their product and remain competitive.

Establish program for research and development/technology transfer

- Many U.S. manufacturers cannot afford to do research and development on their own.

- Industry could benefit greatly from technological advances.

Increase life span through new developments such as coatings or using a plastic base

- The use of plastic bases (instead of glass) is already being done by hand in some manufacturers in Pacific Rim countries.

- The process being used in Pacific Rim countries is extraordinarily labor intensive and considerable work would need to be done to make this option viable for U.S. manufacturers.

9.4.2.2 Industrial Thermometers

The issues discussed associated with each of the source reduction options for industrial thermometers are summarized below.

Replace some instruments with electronics

- Electronics are not as accurate as mercury-based thermometers.

- Electronics have to be recalibrated periodically to National Bureau of Standards levels, which is an expensive procedure.

Reduce bore size of thermometers

- This option would reduce the amount of mercury in the product.

- The thermometers with a reduced bore size could be more expensive to produce.

- There are physical limits to the degree of reduction in bore size.

- The smaller size makes instruments more difficult to read.

- American Society of Testing Materials (ASTM) standards are a barrier to implementing this option, since they specify exact bore sizes and volumes. The procedure to change standards is difficult, and EPA regulations do not change ASTM specifications.

- There are some problems with inferior performance.

Fill with alternative substances (such as mineral spirits, toluene, benzene)

- The substitute may be as toxic as mercury.

- It may be necessary to use a greater volume of the substitute liquid than of mercury.

- The accuracy of instruments using other liquids is unequal to those using mercury, due to mercury's linear coefficient of expansion.

- The performance of substitute liquids is unequal to mercury in measuring very high and very low temperatures.
- It is difficult to change specifications to allow for different materials.
- It is more expensive to produce thermometers with substitute liquids.

Substitute soda-lime glass for leaded glass

- This option reduces the amount of lead but does not affect the quantity of mercury.
- This option might actually increase rate of breakage (due to lower strength of glass), thus creating a larger problem with mercury.
- Using soda-lime glass would reduce production costs.
- This option would reduce life span.

Increase life span through armoring

- Results in a more durable thermometer that is less likely to break.
- Reduces the precision of the thermometer.
- The armor is reusable, easy to remove and replace.
- Adding armoring makes the thermometer more expensive, although some consumers are willing to pay for it.
- An armored instrument will not fit into some existing equipment applications.

Increase life span through annealing

- Results in a more durable product.
- This option increases the thermal stability of instrument, making it less likely to break as a result of thermal shock (a sudden change in temperature).

Increase life span through encapsulation

- The sheath keeps mercury intact in case of breakage.
- The encapsulating material (generally Teflon) is not a good heat exchange medium, which increases the lag time for reading of temperature.
- The encapsulation makes the thermometer slightly more difficult to read.

- It is difficult to remove the Teflon during processing for recycling, and the mercury adheres to the Teflon.

- Encapsulation increases the strength of the instrument.

- This process makes thermometers more expensive, although many consumers are willing to pay for it.

Increase life span through the use of engineering plastics (polycarbonate resins) or more durable glass/ceramics

- This option will strengthen the product, making it less likely to break.

- It would be expensive for manufacturers to retool to use new materials.

- Current alternate materials do not have the "history" of glass for mercury to return to the initial position of rest. Resins have a problem with "returning" or repeating the initial position of rest.

- There is insufficient available data to fully evaluate this option, so research and development is needed.

- There is no existing technology for recycling, in particular separating the mercury from plastic/ceramic.

- It is difficult to change specifications to accommodate new materials.

Establish international performance standard

- The standard would be at least as stringent as the current most durable model.

- This option would improve the quality of the product and durability of the product, and could reduce waste generated during production.

- This option would require increased inspection of imports.

- This option would reduce illegal unmarked shipments of mercury products.

- Research is needed to determine standards.

Educate consumers about proper use and maintenance

- Consumers would know how to use products better, how to reduce risk of exposure to mercury, and how to "repair" the thermometer if the mercury separates into bands.

- The expense involved in education could increase prices.

- This option could generate more paper waste as a result of the informational material provided to consumers.

Streamline manufacturing process to reduce in-house waste

- This option would increase efficiency: fewer errors, rejection, and breakage.

- The manufacturer could hold smaller amounts of mercury on-site to reduce possibility of contamination.

Borrow/share instruments (e.g. between schools, small labs)

- There are logistical barriers to implementation of this option.

- This option would decrease the number of instruments that are manufactured and eventually need to be disposed.

Level international playing field

- This option would enable all manufacturers to compete equally.

- This option would reduce or eliminate low-price inferior equipment.

- There are major political barriers to implementation of this option.

Establish governmental research and development/technology transfer

- Companies cannot afford to do their own research.

- New technology may already exist, but as classified or confidential information.

- Drastic changes in technology may displace existing industries.

9.5 CONCLUSIONS AND RECOMMENDATIONS

The evaluation of the source reduction options resulted in determination of what the workshop participants deemed to be the most important source reduction options. In addition, other conclusions and recommendations were developed as a result of discussions within the workshop. These two categories of conclusions and recommendations are discussed in this section.

9.5.1 Selected Source Reduction Options

The following is the list of source reduction options deemed to have the greatest potential by the workshop participants, along with some recommendations regarding implementation options:

1. Overcome international trade issues through a "pay or play" system of holding importers responsible for compliance on quality standards.

2. Develop consensus on international performance standards.

3. Develop a user-awareness/mercury education campaign:

    - in-store brochures;

    - signs in laboratories;

    - packaging; and

    - governmental multi-media campaign that addresses mercury sources, health effects for humans & wildlife.

4. Support research and development for new technologies and offer incentive programs for the development of measures that would reduce hazardous materials, particularly in the areas of:

    - materials;
    - improving existing techniques; and
    - design for recyclability (e.g. separation of encapsulating materials).

5. Make existing technology transfer opportunities more apparent and promote use of these opportunities.

6. Work to increase life span of products by promoting existing technologies and investigation of potential new ones (armoring, encapsulation, plastics).

7. Work to reduce amount of mercury by reducing bore size.

8. Overcome barriers to revising ASTM (American Society of Testing Materials) and other standards to allow for better methods.

9.5.2 Other Conclusions and Recommendations

Some of the other conclusions and recommendations reached by workshop participants are as follows:

- A kit has been developed to contain and ship mercury for recycling, however the regulation of broken thermometers as a hazardous waste makes use of this method of recovery prohibitively expensive. One of the suggestions was to look at the option of exempting shipping of these materials for recycling, as is done with fluorescent bulbs in the Minnesota mercury legislation.

- A better inventory of mercury sources, including natural sources, should be compiled.

- Better data should be compiled on:
  - where significant exposure to mercury occurs,
  - the toxicological effects of mercury on humans and wildlife, and
  - secondary (indirect) sources of mercury.

- The framework for analysis of source reduction potential in Getting at the Source was deemed cumbersome, although some believed it was a useful tool for generating ideas in an organized fashion.

BIBLIOGRAPHY FOR BACKGROUND INFORMATION

(Note: Any additional information obtained subsequent to the development of the background information is listed in Appendix B.)

"Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000," prepared by Franklin Association for U.S. EPA, March 1992.

Telephone conversation with Tim Gordon, Becton Dickenson.

Telephone conversation with Bruce Jarvie, H.O. Trerice Company.

Telephone conversation with Frank Stagliano, Partlow Corporation.

Telephone conversation with Bruce Jarvie, H.O. Trerice Company.

Telephone conversation with Joan Snyder, Bethlehem Apparatus and company literature.

"Management of Used Fluorescent Bulbs: Preliminary Risk Assessment - Draft Report," prepared by Research Triangle Institute for U.S. EPA, June 1992.

SECTION 10

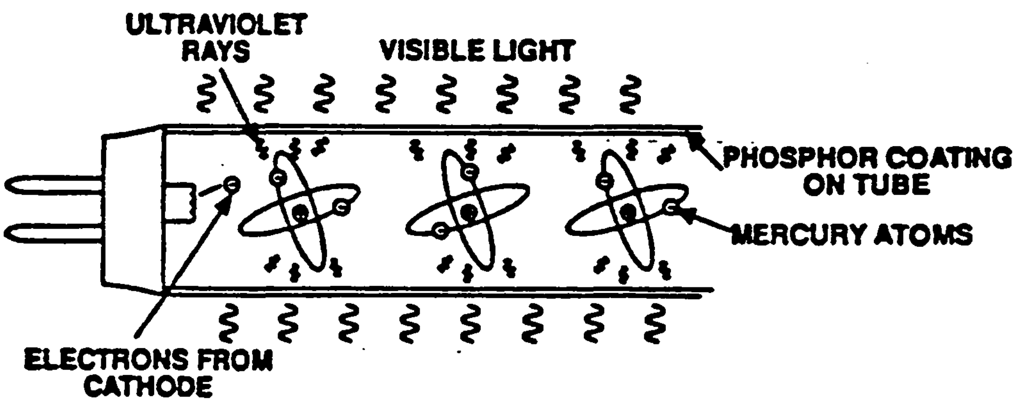
FLUORESCENT LAMPS

10.1 BACKGROUND INFORMATION

The Purpose of Mercury

Low-pressure mercury-vapor lamps are used for fluorescent lighting, commonly used to light offices, schools, other large buildings, and to a lesser extent, homes. The most widely used lamp is a 40 watt, 4-foot tube, although larger and smaller tubes are also used for particular applications. These lamps are preferred for institutional and other applications because of their high efficiency, low operating temperature, and long lifetime. The lifetime of the lamps is about four to five years under normal use.

Mercury is used in fluorescent lamps to produce ultraviolet energy when bombarded with electrons from the emissive coating on the filaments. When excited by electron bombardment, mercury atoms emit energy at wavelengths ideal for absorption by phosphor powder coatings. This ultraviolet energy is absorbed by phosphor powders and converted to visible light. This is the basic operating principle that all fluorescent lamps use. A schematic illustrating this operating principle is shown below.



Source: "The Management of Spent Electric Lamps Containing Mercury." National Manufacturers Association, October 1992.

The Amount of Mercury Used

All fluorescent lamps contain elemental mercury. According to study compiled in December 1991 by the National Electrical Manufacturers Association (NEMA), the average 4-foot, 1.5-inch diameter fluorescent lamp, contained 41.65 milligrams of mercury in 1990. This was a 14 percent reduction from the 48.16 milligrams reported in 1985. One manufacturer reports that their 4-foot fluorescent lamps contain 16 milligrams of mercury. It should be noted that the amount of mercury in fluorescent lamps varies as a result of normal variations in the manufacturing process. The number of standard four-foot lamps produced is projected to increase 3 to 4 percent in the near-term.

Compact fluorescent lamps contain 5 to 10 milligrams of mercury ("Compact Fluorescents, Radioisotopes and Solid Waste", Liebold and Audin, 1992). Compact fluorescent lamps are being marketed as replacements for incandescent bulbs (standard light bulbs), however in some cases, they are replacing standard fluorescent lamps, according to a NEMA representative. NEMA advises that production of compact fluorescent lamps increased by 70 percent from 1988 to 1990.

Amount of Mercury Disposed from Fluorescent Lamps

According to an April 1992 EPA report entitled, "Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000," electric lighting was the second largest source of mercury in MSW in 1989. The mercury in electric lighting comes from ordinary fluorescent lamps and certain high intensity discharge (HID) lamps. (HID lamps are used in street lighting, flood lighting, photography, sun lamps, underwater lighting, and insect lamps, and are not addressed in this background paper.) Of these two sources, fluorescent lamps are by far the largest, accounting for 26 tons of mercury in MSW in 1987, or 3.7 percent of total mercury discards. All lighting sources were estimated to contribute nearly 27 tons of mercury in 1989, or almost 4 percent of total mercury discards. As a result of the expected reductions in the use of mercury in batteries, fluorescent lamps are projected to become the most significant contributor of mercury to the municipal solid waste stream in the future.

The April 1992 EPA report states that mercury content of fluorescent lamps has been reduced over the past five years, but increasing sales will cause the total amount of mercury from this source to continue to increase. New energy-efficient compact fluorescent lamps are being promoted as a replacement for incandescent and older fluorescent lamps at this time, but it is too early to determine whether sales and discards of these lamps will further increase the amount of mercury discarded.

While a few attempts to recover mercury from fluorescent lamps were identified, no basis for projecting a significant amount of recovery from lamps in MSW in the future was found, according to the April 1992 EPA report.

The Form in Which Mercury is Used

All fluorescent lamps contain elemental mercury, which is a silver-white metal. A drop of liquid mercury is placed into the lamps when they are manufactured. The mercury is vaporized when the lamp is turned on and the temperature of the lamp reaches 20 degrees Centigrade. The mercury converts back to an elemental form after the lamp is turned off and when the temperature of the lamp drops to less than 20 degrees Centigrade.

The Manufacturing Process

Fluorescent lamps are manufactured in a number of ways, depending on the manufacturer. Mercury is added to the lamps at the fluorescent lamp manufacturing facility. GTE Sylvania advises that elemental mercury is dropped directly into a fluorescent glass tube using a mercury dispenser. Osram Corporation has a patented process which involves placing a sponge-like ferrous metal pellet which has mercury absorbed into it into glass lamps using a magnetic process (Osram manufactures the metal pellet). Philips Lighting Company also has a patented process that involves mounting a glass capsule containing a predetermined amount of mercury inside the glass tube. Radio frequency waves burst this capsule to release the mercury. Each manufacturer uses a range of techniques during manufacturing, depending on the product being produced.[1]

POTENTIAL EXPOSURE OF PUBLIC AND THE ENVIRONMENT

Most of the research conducted to date on the fate and effects of mercury in MSW have been general in nature, and has not focused on mercury in fluorescent lamps. Information gathered by the Environmental Protection Agency suggests that very little mercury is released from landfills; however, state regulatory agencies are monitoring landfills to determine if they are significant sources of mercury in the environment.[2] In addition, landfill gas emissions could be a source of mercury.

NEMA published a report in the near future entitled, "The Management of Spent Electric Lamps Containing Mercury" in October 1992. This report should contain additional information about the environmental effects of disposal of fluorescent lamps. [This report was presented and discussed at the Forum.]

Tests of spent lamps using the Toxic Characteristic Leaching Process (TCLP) for mercury have been inconsistent according to NEMA. NEMA has held several meetings with EPA to discuss the test results and attempt to sort out the reasons for the inconsistencies. Because of the inconsistencies, EPA initiated a study to assess the regulatory status of fluorescent lamps. Science Applications International Corporation (SAIC) was contracted by EPA to conduct analyses on new and used fluorescent lamps. SAIC's May 1992 report entitled, "Analytical Results of Mercury in Fluorescent Lamps," also showed variable results in TCLP testing.

One issue that has been raised in relation to the environmental impact associated with disposal of fluorescent lamps is the fact that switching from incandescent to fluorescent lighting reduces mercury emissions from coal-burning power plants, due to the lower energy requirements of fluorescents. Several analyses have been conducted to compare the mercury emission reductions to the quantity of mercury in fluorescents, and these analyses indicate that over the life of a fluorescent lamp, the reduction in mercury emissions from coal-burning power plants is greater than the quantity of mercury in a lamp. It should be noted that these studies relate to coal-burning power plants only and the actual trade-off in emissions will depend on the mix of fuels used to generate electricity in a particular area.

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[1] In a comment provided subsequent to the Forum, one industry representative noted that due to variations from bulb-to-bulb that are an inherent part of the manufacturing process, it is necessary to use 140 percent of the mercury required to achieve a certain lamp life, in order to have 50 percent of the bulbs meet that lamp life requirement.

[2] State environmental regulatory agencies in New Jersey, Minnesota, and Florida have prepared reports documenting concerns about mercury emissions and discharges.

REDUCTION MEASURES

Reduction and Recycling Measures to Date

Philips Lighting Company and Osram Corporation advise that projects are underway at all of the fluorescent lamp manufacturers to reduce the amount of mercury used in their lamps. The lamp industry reported a 15 percent reduction from 1985 to 1990. NEMA reports that mercury content in 4-foot fluorescent lamps (the most common type) was reduced from 48.16 milligrams in 1985 to 41.65 milligrams in 1990.

A new fluorescent lamp has been developed that incorporates new phosphor coatings. This lamp, designated T8 (the standard lamp is designated T12), has a mercury content under 20 mg per lamp, not because it inherently requires less mercury than a T12 lamp, but as a result of utilizing more recent manufacturing techniques which allow lower quantities of mercury to be utilized. The T8 lamp costs more than conventional fluorescent lamps due to the use of a rare earth phosphor.

There is no other material that has been found to function as mercury does in a fluorescent lamps. Therefore, substitutes to be considered would have to be other types of lighting. Other types of lighting include incandescent bulbs (which contain lead) and compact fluorescent lamps (which contain smaller amounts of mercury). However, these types of lighting are not realistic substitutes for standard 4-foot fluorescent lamps because of their lower efficiency.

Several states have passed legislation concerning management of used fluorescent lamps.[1] For example, California has instituted a policy (not a regulation) that limits the disposal of fluorescent lamps by a generator to no more than 25 used tubes and/or mercury vapor lamps to be disposed at any one time, or the lamps must be managed as a hazardous waste. Connecticut recently passed a bill that requires establishing a pilot program for collecting and recycling fluorescent lamps at a State facility. Legislation has been introduced in Vermont to ban disposal of fluorescent lamps from MSW, however, it has not passed. The federal limit for conditionally exempt small quantity hazardous waste generator status is 100 kilograms per month (about 350 lamps).

Based on the activity of three fluorescent lamp recycling facilities operating in California, mercury is recovered from two to three percent of fluorescent lamps (based on a yearly consumption of 500 million fluorescent lamps). The reclamation process generally employed by these companies is a dry process that involves the physical removal of the phosphor powder from the lamps, which also removes about 98 percent of the mercury. The California facilities do not distill the mercury for resale, but usually send the phosphor powder to a mercury retorter or in some cases, dispose of it in a Class I hazardous waste landfill. These three facilities include:

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[1] On February 1, 1993 (subsequent to the Forum) EPA issued Proposed Rule that is designed to facilitate recycling of materials that are often regulated as hazardous waste (Hazardous Waste Management System, Modification of Hazardous Waste Recycling Regulatory Program Proposed Rule, Federal Register Vol. 58, No. 27).

- Mercury Technologies Company, Hayward, California - This facility holds a Research Development and Demonstration (RD&D) permit with the State of California to process 600,000 lamps per month (according to NEMA). The facility reclaims phosphor powder (containing mercury). The facility is forming a joint venture with Advanced Environmental Recycling Corporation which has a mercury distilling process in Allentown, Pennsylvania.

- Mercury Recovery Services, Monrovia, California - Facility holds a RD&D permit with the State of California to process 300,000 lamps per month (according to NEMA). The facility removes phosphor powder (containing mercury) and sends it to Mercury Refining, Inc. in Albany, New York, a mercury retorter, which distills mercury for resale.

- Lighting Resources, Pomona, California - Facility holds a RD&D permit with the State of California to process 200,000 lamps per month (according to NEMA). This facility recovers mercury and phosphor powder and sends them to another location for distillation.

Three additional fluorescent lamp recycling facilities have recently come on line including Recyclelite in Minneapolis, Minnesota and Ballast Recyclers in Fargo, North Dakota. The Recyclelite facility opened in early August 1992 and is a MRT facility, a Swedish fully-developed commercial scale system for reclaiming mercury from used fluorescent tubes and powders, as well as other mercury-containing products such as batteries, thermometers, and dental amalgams. The Recyclelite system can process up to 30,000 lamps per day, according to a Recyclelite representative. Based on this figure, the Recyclelite facility could process over 10 million fluorescent lamps per year (based on one shift per day) or an additional 2 percent of mercury consumption per year (based on consumption of 500 million lamps per year), or as much as 6 percent per year if operating three shifts per day. Ballast Recyclers opened in 1992 and operates a dry process for recovering phosphor powder and mercury. Ballast Recyclers will send phosphor powder to a mercury retorter for distillation of mercury. Ballast Recyclers could not provide any information about their capacity, however, they have one contract in place to handle 500,000 lamps. In addition, Advanced Environmental Recycling Corporation (AERC) opened a facility in 1993 in Allentown, Pennsylvania.

There are two commercial mercury retorters in the U.S. that recover mercury from fluorescent lamps, phosphor powders, and other mercury-containing products. These are Mercury Refining, Inc. in Albany, New York and Bethlehem Apparatus in Hellartown, Pennsylvania.

In addition, some recycling is going on at the industrial level. For example, GTE Sylvania has a MRT system (like the Recyclelite facility) in place for recycling mercury from off-spec lamps and other products from their manufacturing operations.

According to NEMA, in 1991, 25 percent of all mercury demands, including fluorescent lamps, were met with recycled mercury. Approximately 450 tons of recycled mercury were used in manufacturing mercury-containing products in 1991, of which fluorescent lamps used about nine tons.

Potential for Future Reduction and Recycling

The lamp industry has indicated to EPA that it believes it will be possible to reduce the mercury content of fluorescent lamps by 30 percent by 1995, as compared to levels in 1990. The industry plans to reduce the average mercury content in 4-foot fluorescent lamps to 26.98 milligrams by 1995. In addition to the technological improvements that allow this reduction in mercury content, there is also a trend towards longer lamp life which should reduce the number of lamps disposed.

There are many recycling programs in the planning stages. This includes the 9 West facility in Tennessee. Based on facility capacity operating one shift per day, the 9 West facility and the recently opened Recyclelite and AERC facilities could process an additional 6 to 7 percent of U.S. fluorescent lamp consumption per year. However, these facilities have the capacity to operate more than one shift per day, and therefore could increase the recycling rate by as much as 18 to 21 percent, if they operate three shifts per day (based on annual consumption of 500 million fluorescent lamps). The Ballast Recyclers facility in North Dakota will further increase the number of fluorescent lamps recycled.

A bibliography for this background information is presented at the end of this section.

10.2 WORKSHOP PARTICIPANTS

This session was facilitated by Jim Fava of WESTON and notes were taken by Chris Voell of SWANA. Workshop participants were as follows:

Mark Bornstein, GTE/Sylvania Lighting Division
Leo Cohen, Mercury Refining Company
Jim Darr, U.S. EPA Office of Pollution Prevention and Toxics
Lois Epstein, Environmental Defense Fund
Terri Goldberg, Northeast Waste Management Officials Association
Eugene Lee, U.S. EPA Office of Solid Waste
Chaz Miller, National Solid Waste Management Association
Emily Moore, Minnesota Office of Waste Management
Karen Rasmussen, General Electric Company
Paul Walitsky, Phillips Lighting Company
Harold Ward, Brown University
Norman Willard, U.S. EPA-Region I
Mike Winka, NJ D.E.P.E., Division of Solid Waste Management
Ed Yandek, General Electric Lighting

10.3 GENERAL DISCUSSION

Comments made regarding the background paper on fluorescent lamps are reflected in the version of the background paper included in this section of the Report. Several participants in the workshop noted that there is currently no feasible alternative to mercury for use in fluorescent lighting, and that even if a substitute were found that it may not work with the ballast technology currently used in the approximately one billion fluorescent fixtures estimated to be in place in the U.S. The mercury content of fluorescent lamps in Europe was discussed, and the fact that although the mercury content is much lower, on average, than in the U.S., the lamps have a useful life that is one half of those in the U.S. Thus, per hour of use, the mercury usage in Europe is equivalent to, or perhaps greater than, that in the U.S.

Two of the major processes for introducing mercury into lamps (dosing) that were deemed to be on the horizon for use in the U.S., and which allow greater control of the amount of mercury, are: 1) use of a metal capsule that is ruptured by sound waves; and 2) use of a mercury strip. (Other technologies and processes are being considered by manufacturers, but are proprietary at this time.) Some participants noted that the mercury strip technology results in lamps with a much shorter life, and that this technology is used in Europe, where typical lamp life is 7,500 to 10,000 hours, instead of 20,000 to 30,000 hours as in the U.S. The speed of dosing was discussed, and the fact that this is a major issue in manufacturing, and limits the options that are feasible.

It was noted that over the life of a fluorescent lamp a portion of the mercury becomes bound up in the glass coatings and metal portions of the lamp, making some of the mercury unavailable for its function within the lamp. The fact that a full-life test must be conducted on any alternative fluorescent technology was discussed as an obstacle to quick results from research and development.

A report prepared by the National Electrical Manufacturers Association (NEMA), The Management of Spent Electric Lamps Containing Mercury (also called The October Report), was discussed. This report summarizes the achievements to date regarding reduction of mercury, and the projected future decrease of about 35 percent (from 1990 levels) by 1995. In addition, the report recommends a comparative risk benefit analysis for evaluating waste management options. The report also makes a number of other recommendations including:

- develop facts on alternatives without delaying implementation of an interim solution;
- assure that the appropriate collection, transportation and processing infrastructure are in-place before waste management requirements become effective;
- prohibit incineration of mercury-containing lamps;
- establish source reduction standards; and
- exclude mercury-containing lamps from definition of hazardous waste when properly managed at Subtitle D facilities or qualified reclamation facilities.

A report prepared by the State of New Jersey, Task Force on Mercury Emissions Standard Setting Preliminary Report, was also discussed. This report examined the issue of mercury emissions from a variety of sources, including municipal waste combustion facilities, utility power plants, hospital and hazardous waste incinerators, sludge digestors, landfills, and crematoria recommended setting very stringent standards for mercury emissions from MSW combustion facilities, to be met with a program including air pollution control retrofit and source separation and source reduction of mercury-containing products.

A number of issues relating to the environmental or health impacts associated with fluorescent lamps were discussed, including the following:

- life cycle analysis is important in addressing the impacts associated with fluorescent lamps, since the reduction in mercury emissions from coal-burning power plants as a result of the energy conserved by switching from incandescent to fluorescent lamps is thought to be greater than the amount of mercury in the lamps;

- concern was expressed by some participants regarding the presence of mercury in compost, and thus the banning of fluorescent lamps from composting facilities[1] was discussed;

- one participant questioned whether 26 tons of mercury disposed on a national basis annually from fluorescent lamps should be of concern;

- one participant noted that 26 states have advisories regarding ingestion of fish due to mercury, and another participant stated that the two main man-made sources of mercury are coal-burning power plants and municipal solid waste combustors; and

- one participant stated that disposal of fluorescent lamps is a costly solid waste management problem.

10.4 ANALYSIS OF SOURCE REDUCTION POTENTIAL

The first step in the analysis of source reduction potential was a brainstorming session to develop a list of source reduction options. These options were evaluated, and implementation strategies discussed. As a result of these discussions, two options were deemed to have the greatest potential in the short term.

10.4.1 Determination of Source Reduction Options

1. Increase use of lamp life. A secondary issue that was raised along with this suggested option was the elimination of group relamping, the procedure by which all fluorescent lamps in a given area are replaced at the same time, regardless of whether or not they are still functioning. This process replaces more bulbs than are necessary, but is deemed the most economical procedure in many companies.

[1] It was noted that these comparisons were based on coal-burning power plants, and actual emission offsets would depend on the mix of fuels in a given region, and these factors need to be incorporated in any life cycle analysis.

2. Reduce mercury level to an average of 20 mg/lamp, without sacrificing life or efficiency of lamps.

3. Conversion to arc lamp. This involves converting from the current standard lamp labelled T12 to a T8 lamp, which is significantly lighter and uses less mercury, but costs much more. The T8 lamp is currently available.

4. Educate consumers on lighting design, use, and efficiency.[1] This should result in more efficient placement and design of light fixtures.

5. Accelerate retooling of manufacturing plants. This would be used as a strategy for reducing dosing amounts and making the dosing process more efficient.

6. Identify new phosphor coatings. By changing the phosphors it may be possible to reduce mercury loss over the life of the lamp.

7. Re-evaluate regulations on lamp placement (building codes and architectural/engineering specs) from an environmental and energy efficiency perspective.

8. Expand/quicken implementation of the Green Lights program.

9. Develop units to identify overall goal for source reduction (nanograms of mercury/1000 lumens or per 1,000 hours). This would result in a means for comparing mercury levels of lamps with different life-spans and lighting intensities. (Although it was not stated in this manner in the workshop, the appropriate unit of measurement would likely be nanograms/lumen-hour, which would account for differing life-spans and lighting intensities in a single unit of measurement. However, it may be technically complex to set a standard on this basis, particularly since there are factors others than lumens of intensity that impact the effectiveness of lighting.)

10. Increase use of occupancy sensor lighting (to shut off lamps when not in use) and daylighting (use of natural light).

11. Reduce foot-candle (light level) requirements and reduce required number of lamps (building codes and architectural/engineering specifications). It was stated that an increase in energy efficiency without a decrease in the foot-candle requirements might not reduce the number of fluorescent lamps used.

12. Establish research and development tax credits for manufacturers.

13. Maximize purchase of recycled mercury.

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[1] The Illuminating Engineering Society of North America is one source of additional information.

14. Maximize group relamping interval and donate usable lamps that are removed during group relamping to charitable organizations.

15. Encourage use of compact fluorescent lamps. Compact fluorescent lamps have lower quantities of mercury per lamp, so their increased use could reduce mercury disposed.[1]

16. Federal government must clarify regulatory status of fluorescent lamps when disposed, to resolve questions about whether or not they constitute a hazardous waste.

17. Establish a multi-sector task force to identify and evaluate source reduction options.

18. Conduct a life cycle analysis to identify the full impacts of the fluorescent lighting industry.

19. Gather and evaluate data on mercury level efficiencies.

20. Create a consortium to identify and conduct research and development efforts.

21. Encourage fluorescent lamp recycling programs.

22. Increase efficiency of lamps and lighting systems through changes in architectural/engineering philosophy and specifications.

23. Continue research and development into developing alternative lamps and lighting systems.

24. Increase research and development into alternative energy sources.

25. Increase regulatory flexibility regarding management of used lamps, so as not to build barriers to lamp recycling.

26. Continue research and development efforts to find a substitute for mercury in fluorescent lamps. The fact that some research and development efforts are hindered by anti-trust laws was discussed.

27. Label packaging with mercury content information.

28. Develop competitive research and development programs. This could include so-called "golden carrot" types of programs, in which large rewards are offered for developing new technologies or processes.

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[1] In a comment provided subsequent to the Forum, one fluorescent lamp manufacturer noted that compact fluorescents are more efficient than incandescent bulbs, but do not last as long and are not as efficient as 4-foot linear fluorescents.

10.4.2 Evaluation of Source Reduction Options

In the process of discussing and evaluating the 28 options summarized above, the workshop participants developed four major categories of options, and grouped each of the options into one of these categories. The discussion of the source reduction options also served to clarify or refine the definition of the option. The potential implementation strategies (and obstacles) for each of the categories was also discussed. The four categories, the source reduction options included in those categories, as well as the implementation strategies discussed for each category are summarized below.

1. Fully Utilize Useful Life of Fluorescent Lamps

The discussion in relation to this group of options started with the topic of group relamping, which is a practice whereby all lamps in a building are replaced regardless whether they are still working or not. In group relamping, a group of lamps will be replaced when the light output from the group has dropped below an acceptable level or the cost of individual replacement is becoming too great. Any individual lamp failures prior to group relamping would be replaced with lamps marked for reuse when the next relamping occurs. Some members of the group felt that this was very wasteful, however others noted that this is often the most efficient means for companies to replace lamps.[1]

The group agreed that maximizing the interval for relamping was prudent. The organizations requesting this service also have a major economic interest in making sure that relamping is not done more often than needed. One participant identified a source for information on relamping: National Association of Lighting Management Organizations in Princeton, New Jersey.

Many in the group thought that giving lamps with useful life left to charitable organizations was a good idea. However, developing the networks to accomplish this was seen as an obstacle. The issue of whether costs and liability were being transferred with the lamps was raised. This could be especially important if the used lamps are regulated as a hazardous waste.

As a result of these discussions, the source reduction options included in this category are as follows:

- decrease group relamping,
- maximize relamping interval, and
- distribute lamps with life remaining.

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[1] In a comment provided subsequent to the Forum, one participant noted that if spot relamping is performed, the initial lighting level might have to be set higher to ensure that lighting levels do not drop below a certain level, thus potentially resulting in more lamps being used and higher energy consumption.

The implementation strategies and obstacles identified for options in this category are as follows:

- consumer (including businesses) education;
- data needs: trade-offs of lighting performance versus long term economics; and
- the transfer of costs/liabilities when distributing used lamps could be an obstacle.

2. Reach Lowest Optimum Mercury Level Without Sacrificing Current Life or Efficiency Standards.

In discussing this category, it was noted that the fluorescent lamp industry is already striving for this goal, as is demonstrated by the reduction in mercury content in lamps over the last five to seven years: from 48 mg/lamp to 27 mg/lamp. It was also noted that there may be a point at which reducing the mercury level adversely impacts the life of the lamp, and therefore the reduction per lamp would not reduce the total amount of mercury disposed in fluorescent lamps. It was in this discussion that the idea for developing a new standard unit for measuring mercury content that incorporates lighting levels and life span arose.

The source reduction options identified within this category are as follows:

- reduction in amount of mercury dose, and

- identification of alternative glass and glass coatings to reduce mercury consumption during life of lamp.

Implementation strategies and obstacles that were discussed in relation to these options are summarized below:

- establish research and development programs, such as those established through the National Cooperative Research and Development Act of 1984;

- establish tax credits for manufacturing research and development efforts;

- gather data on mercury releases from all sources and pathways (including offsets in emissions from power plants associated with use of fluorescent lighting and use of solid waste in compost);

- accelerate retooling of manufacturing plants to allow more efficient dosing techniques; and

- decreasing mercury quantities in fluorescent lamps could have adverse impacts on recyclability and increasing recyclability may increase mercury quantities, so this relationship must be better understood.

3. Use Fewer Lights

Lighting levels in offices have been dropping in the United States since the mid-1970's, according to one fluorescent lamp manufacturer, as a result of energy concerns and desire to eliminate glare on video display terminals. The group discussed opportunities for further reducing use of lights.

In discussing this category of options, it was noted that this category involves a much broader "audience" than the first two categories of options, since it includes households, businesses, architects, building designers and building code writers. Participants in the workshop indicated that motion sensors and daylighting are starting to be applied, and that these ideas could be communicated through national trade and professional organizations to increase their use.[1] The concept of introducing labelling that would include information on mercury content was discussed, and some participants indicated that they would not support this option.

Some participants noted that a multi-sector, multi-industry task force to address source reduction issues would be helpful. In particular, it was pointed out that many of the issues discussed relate to lighting systems -- the combination of bulbs and fixtures -- and that as a result, the fixture industry should be included in any discussions. Participants indicated that they believe that communication between these two industries in regard to source reduction was essential.

Source reduction options included in this category are:

- modify consumer behavior regarding lamp replacement and usage,
- amend building codes to modify foot candle requirements and requirements for number of lamps per unit of floor space[2],
- modify design/architectural philosophy to look at lighting systems and investigate use of more motion sensors and daylighting, and
- lightweighting (switch from T8 to T12 lamps).

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[1] The Department of Energy, Electric Power Research Institute, National Lighting Bureau, National Electronics Manufacturing Association, and the California Energy Commission are disseminating some of this information.

[2] One participant noted after the Forum that the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)/Illuminating Engineering Society (IES) Standard 90.1, Department of Energy regulations for Federal Buildings and California Title 24 are examples of codes containing these requirements.

Implementation strategies identified for these options are as follows:

- change building codes;
- educate consumers, architects, engineers, and code writers;
- accelerate implementation of the Green Lights program;
- establish a multi-sector, multi-industry task force to identify and encourage research and development in relation to source reduction;
- redesign of regulatory structure/approach to recognize that fluorescent lamps are part of lighting systems; and
- implement additional package labeling.

4. Develop Alternative Lamps and Lighting Systems

Participants in the workshop felt that it was important to acknowledge that research and development is currently underway in the lighting industry to develop alternative lamps and lighting systems.[3] It is unclear what the results of these research efforts will be, and whether or not technologies that are not dependent on mercury (or less dependent on mercury) will be identified, but money is being invested by the industry in these areas. It is also important to recognize that alternative lights and lighting systems could take several years to bring to market after development, since manufacturing technologies may have to be altered. In addition, it was noted that although development of alternative energy sources will not reduce the amount of mercury disposed in fluorescent lamps, it could reduce total mercury emissions.

Options that were included in this category are as follows:

- find a substitute for mercury,
- develop more efficient dosing equipment,
- identify alternative energy sources, and
- investigate the use of low pressure sodium lamps for some applications.[1]

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[3] One participant provided information subsequent to the Forum, noting that the Electric Power Research Institute is sponsoring development of "smart" fixtures, and that NEMA is finalizing lighting fixture efficiency labelling, as required by the 1992 Federal Energy Policy Act.

[1] In a comment provided subsequent to the Forum, one participant noted that due to poor color rendition, sodium lamps are generally only acceptable for outdoor applications.

Implementation strategies identified for these options are as follows:

- establish tax credits for research and development,
- institute federal grants for research and development, and
- establish cooperative industry research and development efforts.

Once these four groups of source reduction options were identified, a comparative analysis was performed. This was done using the techniques established in Getting at the Source. Six criteria were used to comparatively rank the four categories of options:

- source reduction effectiveness,
- impact on usefulness of the product,
- economic impacts (evaluated separately for manufacturers and consumers),
- environmental impacts elsewhere in the life cycle of the product,
- technical feasibility, and
- practical feasibility.

Each of the four categories of options was rated in each of the criteria described above, using pluses and minuses to give a relative ranking of the options. The results of this exercise are summarized below.

10.5 CONCLUSIONS AND RECOMMENDATIONS

Based on the evaluation described above, the participants in this workshop were able to determine the source reduction options that they believe hold the greatest potential in the short term. In addition, participants made suggestions and comments regarding the framework for analysis contained in Getting at the Source, and regarding future activities. These two categories of conclusions and recommendations are summarized below.

10.5.1 Selected Source Reduction Options

The evaluation process resulted in the conclusion that there are two source reduction options that have the greatest potential for being effective in the short term:

- reaching the lowest optimum mercury level, and
- using fewer lights.

As was described previously, these are really categories of options, with a number of different specific options and implementation strategies associated with them.

Table 10-1

Evaluation of Source Reduction Options

Criteria	Fully Utilize Useful Life of Lamps	Reach Lowest Optimum Mercury Level	Use Fewer Lights	Develop Alternative Lamps & Systems
Effectiveness	+	++	+ (short term) ++ (long term)	+
Impact on Usefulness of Product	?	0	?	+
Economic Impacts Manufacturers Consumers	 - ?	 - -	 - +	 + +
Environmental Impacts Elsewhere	0	?	+	+
Technical Feasibility	+	+	+	?
Practical Feasibility	?	+	+	?

Key: + Positive; - Negative; 0 Neutral; ? Unknown.

10.5.2 Other Conclusions and Recommendations

In regard to applying the framework for analysis of source reduction potential contained in Getting at the Source, the members of this workshop had these comments:

- The process should start with a better definition of the targets, setting of boundary conditions (specifically in relation to what portion of the life cycle to examine), and a recognition that consideration of systems and/or life cycles may be necessary.

- Multi-sector participation in all future source reduction analyses is essential.

Other comments and suggestions were as follows:

- The definition of source reduction should include systems, not just products.

- Source reduction issues are likely to involve many agencies, and a multi-agency task force to evaluate source reduction at a national level should be established.

- The interaction of agencies should be fostered to develop, refine and implement a national energy policy.

- The relationship between source reduction and recycling should be examined from an environmental, economic and technological perspective (including life cycle analysis) to encourage overall reduction of mercury released to the environment.

- The procedures and applicability of TCLP should be resolved, and the regulatory status of spent fluorescent lamps should be clarified.

BIBLIOGRAPHY FOR BACKGROUND INFORMATION

(Note: Any additional information obtained subsequent to the development of the background information is listed in Appendix B.)

"Analytical Results of Mercury in Fluorescent Lamps," prepared by Science Applications International Corporation (SAIC) for U.S. EPA, May 1992.

"Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000," prepared by Franklin Association for U.S. EPA, March 1992.

"E News, Environmental Affairs Newsletter," Philips Lighting Company, Volume 1, No. 1, March 1992.

Literature from Advanced Environmental Recycling Corporation, Allentown, Pennsylvania.

Literature from Ballast Recyclers, Inc., Minneapolis, Minnesota; Hopkins, Minnesota; and Fargo, North Dakota.

Literature from Bethlehem Apparatus Company, Inc., Hellartown, Pennsylvania.

"Management of Used Fluorescent Bulbs: Preliminary Risk Assessment - Draft Report," prepared by Research Triangle Institute for U.S. EPA, June 1992.

"Special Statistical Study for the Lamp Section (2-LL)," National Electrical Manufacturers Association (NEMA), December 1991.

Telephone conversation with Peter Bleasby, Osram Corporation.

Telephone conversation with John Chilcott, Lighting Resources.

Telephone conversation and meeting with Paul Walitsky, Philips Lighting Company.

Telephone conversation with Frank Dickenson, 9-West Corporation.

Telephone conversation with Bob Roberts, Mercury Recovery Services.

Telephone conversation with Don Burline, Sales Manager, Ballast Recyclers.

Telephone conversation with John Cunningham, Panasonic.

Telephone conversation with Joan Snyder, Bethlehem Apparatus and company literature.

Telephone conversation with Dorene Maniccia, Lighting Research Center.

SECTION 11

CONCLUSIONS AND RECOMMENDATIONS

11.1 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Some of the conclusions and recommendations are general in nature, and some are specific to the particular products. Only the more significant or noteworthy conclusions and recommendations are summarized in this section.

11.1.1 General Conclusions and Recommendations

Many of the general conclusions and recommendations center on the issue of whether or not a significant-enough environmental or public health problem had been identified associated with these products to warrant a thorough analysis of source reduction, as called for in the Forum. Different conclusions were drawn by different people regarding this issue and related issues, but this is reflective of the diverse nature of the participants.

Some of the key points made by Forum participants in relation to this issue of the nature or extent of the environmental problems associated with these products can be summarized as follows:

- The analysis of source reduction potential, as outlined in Getting at the Source, is designed to start with a consideration of what the problem is, and some participants felt that this question was being ignored, and that a documentation of the nature and extent of the problem should have preceded any consideration of source reduction potential.

- Some participants felt that the background papers implied that in the absence of product-specific environmental impact data, adverse impacts would be "assumed." Some participants indicated that a risk assessment is necessary in order to demonstrate the presence of a public health or environmental problem before analysis of source reduction potential is initiated.

- Some participants felt that data regarding the heavy metals content in landfill leachate and incinerator emissions is sufficient to indicate that there is no problem associated with disposal of products containing these heavy metals, and therefore the analysis of source reduction potential was unjustified. There was general agreement that the Toxicity Characteristic Leaching Procedure (TCLP) test results are not a sufficient basis for establishing that a problem exists with disposal of a particular product, particularly if the management option for the product is not a sanitary landfill (e.g., incineration or composting).

- Some participants indicated their belief that there is a perception of risk associated with use of heavy metals in these products and that EPA's response to this perception should be public education to correct misperceptions.

Other participants felt that there was sufficient evidence to warrant an analysis of source reduction potential, and made some of the following points:

- One of the purposes of the Forum was to gather information and to the extent that the Forum resulted in sharing of information that characterizes the nature (or lack of) problems associated with disposal of these products, then that should be considered a successful outcome of the Forum.

- One general, procedural recommendation that was reaffirmed through this forum was that in order for source reduction discussions to be successful, they must be held with multi-disciplinary participants. Where discussions at this forum were most fruitful was when all sectors were represented -- those that have direct responsibility for manufacturing the product (the manufacturing industry), those with direct responsibility for disposal of the product (State and local regulatory agencies responsible for siting and operation and maintenance of disposal facilities), and those that provide research, advise, and give opinion on the disposal of the product (regulatory agencies that conduct research, environmental organizations, and academics). This organizational structure for multi-disciplinary discussions could serve as a model for future forums in which EPA solicits options for source reduction. As cautioned by an industry participant, efforts will also be made so that these discussions can be conducted collectively while protecting competitively sensitive information.

- There are many regulatory trends which are likely to continue to increase the costs of using these heavy metals in any manufacturing process and as a result an examination of source reduction potential makes sense from an economic standpoint, even if there is a belief that it is unnecessary from an environmental standpoint.

- Some participants noted that there are environmental problems associated with various stages of the life cycle of heavy metals, including mining, processing, manufacturing, and disposal and these problems are of concern to solid waste management professionals. To the extent that source reduction can address some of these problems, it will be serving a valuable solid waste management function.

- Some participants indicated that the toxicity of these heavy metals, in general, is justification for the analysis of source reduction potential, and that additional analyses of environmental or health impact may refine the understanding of the problem, but are not a prerequisite to source reduction analysis.

- It was noted that there is a tremendous disparity between the public's perception of the problems that pose the greatest risk to public health and the environment and the ranking of problems according to a scientific calculation of risk. EPA representatives noted that they cannot simply ignore the public's perception of risk and thus they need to balance addressing problems that represent significant scientific risks and those that the public demands be addressed. Source reduction is an issue that the public is focusing attention on and this Forum is one way to pay appropriate attention to this issue.

There were some recommendations that were made by a number of the participants, and as such, they represent some form of consensus, or majority opinion. These can be summarized as follows:

- Future discussions regarding source reduction should be multi-disciplinary and national in scope.

- Communication should be fostered between EPA and industry regarding issues associated with source reduction.

- The issue of environmental and public health risks associated with products should be further explored.

- Life cycle analyses should be used, as appropriate, in the analysis of source reduction.
- The analysis of source reduction potential should clarify and/or justify the distinction between recycling and source reduction.

- The federal government should participate in, or sponsor, research and development in the area of source reduction.

- Many agencies of the federal government are involved in issues related to source reduction, so it is important that policies, guidance and regulations are coordinated amongst these agencies.

11.1.2 Product-Specific Conclusions and Recommendations

There are a fairly large number of product-specific conclusions and recommendations, and some of the more significant ones are summarized below.

11.1.2.1 Fluorescent Lamps

The key conclusions and recommendations related to fluorescent lights are as follows:

- Two categories of source reduction options are the most likely to be effective in the short-term: 1) reaching the lowest optimum mercury level; and 2) using fewer lamps.

- Reaching the lowest optimum mercury level can be achieved through
  - reduction in the mercury dose introduced into fluorescent lamps, and/or
  - through identification of alternative glass types or coatings to reduce the consumption of mercury during the life of the lamp.

- Using fewer lamps can be achieved through:
  - modifying consumer behavior regarding usage,
  - amending building codes to modify the amount of light required per unit area,
  - modifying design philosophy to incorporate use of daylighting, and
  - switching to newer, lighter fluorescent bulbs.

- The analysis of source reduction potential should involve lighting systems (bulbs plus fixtures) and not just the bulbs.

- The regulatory status of spent fluorescent bulbs should be clarified.

11.1.2.2 Thermometers

The following are the source reduction options that were determined to have the greatest potential:

- Establish a "pay or play" system which would hold importers to the same standards as domestic manufacturers.

- Develop consensus on international performance standards.

- Develop a public education campaign.

- Support research and development for new technologies and processes.

- Make existing technology transfer opportunities more apparent, and promote their use.

- Increase life span of products thorough promotion of existing technologies and investigation of new ones.

- Reduce the bore size of industrial thermometers.

- Overcome barriers to revising industrial standards to allow modifications to products and processes.

11.1.2.3 Soldered Circuit Boards

The participants in this workshop wanted the conclusions of the Surface Mount Council Report White Paper adopted, with some modifications. Some of the key modified conclusions are as follows:

- Tin/lead solder has certain properties such that no currently viable alternative provides a complete replacement.

- Lead-free joining systems are currently being investigated.

- The most promising lead-free materials that can be used to replace tin/lead solder in some applications are alloys of tin, with additions of bismuth, antimony, silver, copper, or indium. Major changes in the manufacturing processes would have to be made to accommodate these substitutes.

- There are a number of data deficiencies that need to be addressed in relation to lead-free solders, including performance, manufacturing and environmental issues.

- Another conclusion separate from the Surface Mount Council Report, is that lead use in the printed circuit board industry has been decreased as a result of increasing efficient use of materials, miniaturization, and, in some instances, customer demands.

11.1.2.4 Cathode Ray Tubes

In this workshop, two short-term options and one long-term option were ranked as having the greatest potential. The two short-term options are zirconium substitution in the faceplate of the CRT and lower voltage CRTs. The long-term option is development of flat panel technology, which would replace the CRT. It is important to note that although the participants in this workshop went through the exercise of evaluating and ranking options, some did not want that to be taken as an endorsement that any source reduction measures are necessarily required for CRTs.

A number of implementation strategies were identified for use of zirconium in faceplates. This is an existing technology, so the implementation strategies are designed to foster its use. Two key obstacles were identified in implementing this option: 1) overseas suppliers provide about 30 percent of the glass used in U.S. CRTs (and not all of these suppliers can provide zirconium-based faceplates); and 2) major retooling of the CRT glass manufacturing process would be required. In addition, the faceplate contains only 15 to 20 percent of the total lead in a CRT.

For the lower voltage option, the implementation strategies were ranked, with the highest ranking being implementation of a worldwide standard for voltage. The key implementation obstacle is that lower voltage means a decrease in performance that is likely to be unacceptable to consumers. The strategies for implementing the long-term option of use of flat panel technology involve fostering research and development. The obstacles to this option are not known, nor are the environment impacts.

11.1.2.5 Nickel-Cadmium Batteries

Seventeen options were identified for source reduction of cadmium in nickel-cadmium batteries. These options were categorized into groups: 1) technological options; 2) consumer education options; and 3) recycling options. The participants in this workshop felt that recycling was the preferred option.

Other conclusions and recommendations which were developed include the following:

- Uniform federal guidelines for the regulation of nickel-cadmium batteries should be developed.

- The consumer should be provided with more information about the proper use and disposal of nickel-cadmium batteries.

- Research and development funding should be provided for analysis of sorting and reclamation technologies.

- An EPA-sponsored battery recycling conference should be sponsored.

11.1.2.6 Plastic Stabilizers

In this workshop three source reduction options were found to have the greatest potential, based on the application of selected criteria. These three options are as follows: 1) voluntary efforts; 2) promote reusable products; and 3) establish a user fee for cadmium. There are two points made in relation to these options that are important to note. The first is that some participants felt that the second and third options should only be explored if voluntary efforts do not achieve the desired results. In addition, some participants did not want the ranking of source reduction options to be considered an endorsement of the need for source reduction in this product.

The primary reason that voluntary efforts were so strongly preferred over the other source reduction options for this product is that efforts to reduce cadmium in this product are well underway. Some participants believe that cadmium will be eliminated from plastic stabilizers within five years in certain applications, and as a result, the need for other source reduction actions was questioned.

11.2 EPA CONCLUSIONS

EPA Region I, the Municipal and Industrial Solid Waste Division, the Administrator's Pollution Prevention Policy Office, and the Office of Pollution Prevention and Toxics Substances have reviewed the recommendations of the Forum and comments on the draft of this report, to determine what future actions EPA could take in order to facilitate source reduction. As opportunities arise for source reduction initiatives, the recommendations and lessons learned from the forum will be raised to EPA decision-makers. In addition, several ongoing efforts by the EPA have been identified which will influence some of the six consumer products discussed.

11.2.1 Source Reduction Projects at EPA and the Industry

Source reduction is still an emerging technique for reducing the generation of waste. The EPA is participating in, and sponsoring (as it did in this Forum), a number of projects designed to develop and promote source reduction. Additionally, the industries have initiated some of their own source reduction projects. Those that were discussed as part of the forum as mentioned below.

Municipal and Industrial Solid Waste Division (MISWD)

Source Reduction Section staff, in EPA Headquarters, are working on projects including volume and toxics reduction. Examples of ongoing projects include source reduction outreach to businesses, a source reduction bibliography, a project for Federal source reduction in which EPA is creating a role model program for other Federal agencies to follow, and the identification of toxic constituents of municipal waste. Further information on MISWDs source reduction program can be obtained by calling 202-260-1099.

Additionally, each of the ten regional offices throughout the country have been funding source reduction projects.

Fluorescent Lights

As part of the Green Lights program, technical information is given to the participating corporations on how to minimize the number of lamps needed. This involves lighting design (the use of reflective materials so that fewer lamps are needed in the fixture), delamping (the use of two lamps in a fixture where four were used previously), directing the illumination specifically at the task area, and upgrading to more efficient lamps. Further information on the lighting design criteria given as part of the Green Lights program can be obtained through the Green Lights technical information hotline (202-862-1145), and some of their current documents are part of the bibliography.

The Green Lights program in EPA will continue to solicit new corporate participation to switch over to the efficient use of fluorescent lamps. Therefore, as part of the Green Lights effort, the EPA is continuing to research the appropriate disposal of spent lamps. The newest directive on that subject, published in January of 1993, is part of the bibliography of this report.

Soldered Circuit Boards

In 1992, the Office of Pollution Prevention and Toxics at EPA published the "Preliminary Lifecycle Assessment and Pollution Prevention Assessment for Lead Solder" which is used in printed circuit boards. In that assessment, source reduction opportunities identified were alternative technologies including solderless systems or use of lead-free or reduced lead solder. Further study of this product is not being pursued at this time. This analysis is part of the bibliography.

Cathode Ray Tubes

There are no current EPA activities identified for cathode ray tubes. However, there is independent research and development being conducted by entrepreneurs in the industry to recycle CRT glass that may reduce the amount of CRT glass needed to be disposed.

Nickel-Cadmium Batteries

The Office of Solid Waste at EPA has released a report "Used Dry Cell Batteries - Is a Collection Program Right for your Community". This is a manual that will help communities by providing information on the advantages and limitations of collection programs, how to collect used batteries, and then where the markets are that will reclaim the valuable raw materials. The report also contains case studies of operating collection programs.

EPA conducts an annual Household Hazardous Waste Conference (in 1993 slated for Burlington, Vermont on November 6 - 10, 1993), and recycling of nickel-cadmium batteries will likely be a topic on the agenda.

The Portable-Rechargeable Battery Association (PRBA) plans to establish a nationwide collection program of nickel-cadmium batteries for recycling and it will be piloted in New Jersey and Minnesota in the summer of 1993.

Finally, on February 11, 1993, EPA proposed in the Federal Register the Universal Waste Rule which proposes to exempt the management of battery waste under the RCRA Subtitle C hazardous waste system and instead manage them under a new set of standards, 40 Code of Federal Regulations, part 273. This proposal would require that the generator of the batteries either recycle them or dispose of them as hazardous waste. This rule is meant as a strong incentive to establish and operate recycling programs for batteries including nickel-cadmium batteries.

Plastic Stabilizers

There are no current activities identified for plastic stabilizers. The industry has stated that the use of cadmium as a stabilizer is diminishing on a voluntary basis and that its use may be eliminated in the next five years.

11.2.2 Report Distribution

It was requested that the information gained in this forum be widely distributed throughout the EPA so that other Divisions and Offices within the EPA would have the benefit of the combined knowledge that was represented at the forum. To that end, this report is being distributed to:

- the Pollution Prevention Office,
- the Office of Research and Development,
- EPA's ten Regional Offices, and
- EPA Libraries.

It will be published in:

- the National Technical Information Service (NTIS),
- announced in Pollution Prevention Information Exchange System (PIES), an on-line pollution prevention database, and
- the Solid Waste Information Clearinghouse (SWICH), operated by the Solid Waste Association of North America (SWANA) so that it can be widely accessed.

Additionally, it is being distributed to interested parties in the industry, academia, environmental groups, and Federal, State, and local regulatory agencies that were not able to attend the forum.

APPENDIX A

LIST OF FORUM PARTICIPANTS

Bernard Bluestein
Whitco Corporation
Argus Division
8 Wright Way
Oakland, NJ 07436

Mark Bornstein
GTE
Sylvania Lighting Division
100 Endicott Street
Danvers, MA 01923

John Bradley
Bull HN Information Systems, Inc.
38 Life Street
Brighton, MA 02135

Lawrence Brecker
WITCO Corporation
520 Madison Avenue
New York, NY 10022

George Burris
Thomson Consumer Electronics
600 N Sherman Drive, Inc.
Indianapolis, IN 46206

Andrea Cohen, Chief
Recycling & Resource Conservation
Division of Solid Waste Management
103 South Main Street
Waterbury, VT 05676

Leo Cohen
Mercury Refining Company
790 Watervliet-Shaker Rd.
Latham, NY 12110

Joseph Collentro
11 Grist Mill Road
Acton, MA 01720

Paul Dadak
Hewlett-Packard Co.
175 Wyman Street
Waltham, MA 02254

Jim Darr
US EPA (TS 778)
Office of Pollution Prevention and Toxics
401 M Street SW
Washington, DC 20460

Truett DeGeare, Chief
Recycling and Implementation Branch
US EPA (OS-301)
401 M Street, SW
Washington, DC 20460

Robert Dodds
Sony Corporation of America
16450 W Bernardo Drive
San Diego, CA 92127

Daniel Edelstein
US Bureau of Mines
810 7th Street NW
Washington, DC 20241

Deanne Emory
Miller & Weber Inc.
1637 George Street
Ridgewood
Queens, NY 11385-5342

Norman England
Portable Recharge Battery Association
1000 Parkwood Circle
Suite 430
Atlanta, GA 30339

Lois Epstein
Environmental Defense Fund
1875 Connecticut Avenue NW
Suite 1016
Washington, DC 20009

Bob Ferrone
Digital Equipment Corporation
146 Main Street
Maynard, MN 021754

Marge Franklin
Franklin Associates
4121 W 83rd Street
Suite 108
Prarie Village, KS 66208

Terri Goldberg
Northeast Waste Management Officials Association
85 Merrimac Street
Boston, MA 02114

Tim Gordon
Becton-Dickinson Consumer Prod.
One Beckton Drive
Franklin Lakes, NJ 07417-1883

Cynthia L. Greene
Solid Waste and Geographic Information Section
US EPA (HER-CAN6)
Boston, MA 02203

William Greggs
Porcter & Gamble Co.
6100 Center Hill Avenue
Cincinnati, OH 45224

John Hackler, Chief
Solid Waste and Geographic Information Section
US EPA Region I
JFK Federal Building
Boston, MA 02203

Norman Hairston
Corning Asahi Video
MP VX 22
Corning, NY 14831

Elizabeth Harriman
The Massachusetts Toxics Use Reduction Institute
University Massachusetts, Lowell
One University Avenue
Lowell, MA 01854

Ellen Harrison
Cornell Waste Management Institute
Cornell University
425 Hollister
Ithaca, NY 14853

Allen Hershkowitz
National Resources Defense Council
40 W 20th Street
New York, NY 10011

Marquita Hill
University Maine
Department of Chemical Engineering
Jenness Hall
Orono, ME 04469-5737

David Hurd
Bronx 2000
1809 Carter Avenue
Bronx, NY 10457

Frances Irwin
World Wildlife Fund
1250 24th Street NW
Washington, DC 20037

Stephen Jasinski
US Bureau of Mines
810 Seventh Street, NW
MS 5208
Washington, DC 20241-0

David Kelly
Florida Dept of Environmental Regulation
Hazardous Waste Division
2600 Blair Stone Road
Room 471 E
Tallahassee, FL 32599

Greg Keolian
National Pollution Prevention Center
Dana Building
430 E University
Ann Arbor, MI 48109-11

B. Kerns
Westinghouse Electric Corp.
11 Stanwix Street
Pittsburgh, PA 15223

Michael Kerr
Circuit Board Center, Inc.
4738 Gateway Circle
Dayton, Ohio 45440

Lori Kincaid
University of Tennessee
327 South Station Hall
Center Clean Products
Knoxville, TN 37996-07

Anders Kjallman
Swedish Environmental Protection Agency
S-171, 85 Solna
Sweden

Douglas E. Klapper
Akzo Chemicals, Inc.
300 South Riverside Plaza
Chicago, IL 60606

John Paul Kusz
Safety Kleen Corporation
777 Big Timber Road
Elgin, IL 60123

Bruce Lawrence
Bethlehem Apparatus Co., Inc.
890 Front Street
Hellertown, PA 18055

Carl Lawton
U Mass Lowell
One University Avenue
Lowell, MA 01854

Eugene Lee
U.S. EPA (OS-301)
Office of Solid Waste
401 M Street SW
Washington, DC 20024

Ira Leighton, Chief
Connecticut Waste Management Branch
US EPA (HEL-CAL6)
JFK Federal Building
Boston, Ma 02203

Reid Lifset
Yale School
Forestry & Environmental Studies
Program on Solid Waste Policy
205 Prospect Street
New Haven, CT 06511-21

Craig Liska
Motorola
1501 W Shure Drive
Arlington Heights, IL 60004

Thomas Llwewllyn
U.S. Bureau of Mines
810 Seventh Street, NW
MS 5209
Washington, DC 20241

Bob Loring
Massachusetts Clean Water Action
76 Summer Street
Boston, MA 02110

Anni Loughlin
U.S. EPA (HEC-CAN6)
JFK Federal Building
Boston, MA 02203

Jeff Lowry
OI-NEIG TV Products
711 Southwood Avenue
Columbus, OH 43207

Jane Luxton
Prather, Seeger, Doolittle & Farmer
1600 M. Street, NW
7th Floor
Washington, DC 20036

James Maher
Electronics Processing Associates, Inc.
Building 1A
Foundry Street
Lowell, MA 01852

Harry Makar
U.S. Bureau of Mines
810 Seventh Street, NW
MS 5208
Washington, DC 20241

Michael Marshall
BF Goodrich Geo Vinyl Division
6100 Oak Tree Blvd.
Cleveland, OH 44131

James Matthews
Envirocycle, Inc.
320 North Jensen Road
Vestal, NY 13850

Lelia McAdams
AT&T Corp.
131 Morristown Road
Room B-2240
Basking Ridge, NJ 07920

Joseph McHugh
Sony Display Tube Co.
16450 W Bernardo Drive
San Diego, CA 92127

Frank W. McKane
Synthetic Products Co.
1000 Wayside Road
Cleveland, OH 44110

Cynthia Melton
Motorola, Inc.
1301 E Algonquin Road
MS 1014
Schaumburg, IL 60196

Charles Miller
Miller & Weber, Inc.
1637 George Street
Ridgewood
Queens, NY 11385-5342

Chaz Miller
National Solid Waste Management Association
1730 Rhode Island Avenue, NW
Suite 1000
Washington, DC 20036

Jeffrey Miller
Lead Industries Association, Inc.
295 Madison Avenue
19th Floor
New York, NY 10017

Charles Monahan
Panasonic
2 Panasonic Way
7A-2
Seacaucus, NJ 07094

Emily Moore
Minnesota Office of Waste Management
1350 Energy Lane
St. Paul, MN 55108

Hugh Morrow
The Cadmium Council, Inc.
12110 Sunset Hills Road
Suite 110
Reston, VA 22090

Arne Nilsson
Saft Nife, Inc.
251 Industrial Blvd.
P.O. ox 7366
Greenville, NC 27835

George Obeldobel
Big River Minerals
150 N Meramec Avenue
Suite 400
St. Louis, MO 36105-375

William Orr, Chief Risk Evaluation Branch
Research and Technology development Division
California Integrated Waste Management Board
8800 Cal Center Drive
Sacramento, CA 95826

Dwight Peavey
Toxics and Radiation Section
Air, Pesticides & Toxics Management Division
U.S. EPA (ATR)
JFK Federal Building
Boston, MA 02203

Lena Perenius
National Chemicals Inspectorate
Box 1384
S 17127
Solna Sweden

Robert Putnam
Putnam Environmental Services
2525 Meridian Parkway
RTP, NC 27709

Karen Rasmussen
General Electric Company
3135 Easton Turnpike
Fairfield, CT 06431

Christopher Rhodes
The Institute for Interconnecting and Packaging Electronic Circuits
7380 N Lincoln Avenue
Lincolnwood, IL 60646

Gregor Rigo
Rigo & Rigo, Associates
One Berea Commons
Suite 2111
Berea, OH 44017

William Rowe
Zenith Electronics
2407 W North
Melrose Park, IL 60160

Gary Sadowski
Ferro Corporation
7050 Krick Road
Walton Hills, Ohio 44146

Frank Scardiglia
Synthetic Products Co.
1000 Wayside Road
Cleveland, OH 44110

Eric Schaeffer
U.S. EPA Pollution Prevention
MC 2201
401 M Street SW
Washington, DC 20460

Mark Schweers
INMETCO
P.O. Box 720
Ellwood City, PA 16117

Mitch Silkotch
Akzo Chemicals, Inc.
5 Livingston Avenue
Dobbs Ferry, NY 10522

Mac Slayton
Radio Shack
1400 One Tandy Center
Fort Worth, TX 76102

Mark Small
SONY Corporation
15450 W Bernardo Drive
San Diego, CA 92127

William Spangelberg
Hammond Lead Products
236 Parker Drive
Pittsburgh, PA 15216

John Stewart
H-B Instruments
P.O. Box 770
Collegeville, PA 19426

Polly Strife
Environmental Health & Safety
111 Power Mill Road
MS02-3/B16
Maynard, MA 01754

Richard Sweeting
Florida Medical Ind., Inc.
PO Box 493000
Leesburg, FL 34749-300

Kanji Tamamushi
Panasonic Technologies, Inc.
9401 West Grand Avenue
Franklin Park, IL 60130

Todd Tator
Sanyo Energy Corp.
2001 Sanyo Avenue
San Diego, CA 92173

Joy Taylor
Michigan Department of National Resources
Air Quality Division
PO Box 30028
Lansing, MI 48909

Robert Tolliver
Clinton Electronics
6701 Clinton Road
Rockford, IL 61131

Dani Tsuda
Apple Computer, Inc.
10260 Bubb Road
MS 56-A
Cupertino, CA 95014

Larry Verbiar
Ferro Corporation
Bedford Chemical Division
7050 Krick Road
Walton Hills, OH 44146

Jayne Vicelich
SONY Corporation of America
1 Sony Drive
Park Ridge, NJ 07656

Steve Vigil
American Matsushita Electronics Corporation
1400 West Market Street
Troy, OH 45373

Clarence Vinton
National Center for Manufacturing Sciences
900 Victors Way
Ann Arbor, MI 48108-17

Paul Walitsky
Philips Lighting Company
200 Franklin Sq. Drive
Somerset, NJ 08873-680

Tom Walker
Industrial Economics, Inc.
2607 Massachusetts Ave.
Cambridge, MA 02160

Harold Ward
Brown University
Box 1943
Providence, RI 02912

Rick Watson
Delaware Solid Waste Authority
P.O. Box 455
Dover, DE 19903

Wendy White
Shea & Gardner
1800 Mass Avenue, NW
Washington, DC 20036

Norman Willard
US EPA (ATA)
Air, Pesticides and Toxics Management Division
JFK Federal Bldg.
Boston, MA 02203

Michael Winka
New Jersey Department of Environmental Protection and Energy
Division of Solid Waste Management
840 Bear Tavern Road
Trenton, NJ 08625-0414

Lee Wilmot
HADCO Corporation
21A Manor Parkway
Salem, NH 03079

Ed Yandek
General Electric Lighting
Noble Road
Nela Park
East Cleveland, OH 44112

APPENDIX B

BIBLIOGRAPHY OF ADDITIONAL BACKGROUND INFORMATION

Subsequent to the development of the background papers on each of the target products, additional background information was obtained that was not included in the Bibliographies for the background papers. Some of this information was provided by Forum participants during or after the Forum. The listing provided in this Appendix indicates the additional information obtained, by target product.

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