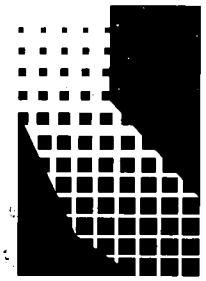
HOUSEHOLD BATTERY WASTE MANAGEMENT STUDY



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HOUSEHOLD BATTERY WASTE MANAGEMENT STUDY

FINAL REPORT

March 1992

Report Prepared by Contract Number IWM C1026

California Environmental Protection Agency
Integrated Waste Management Board

DISCLAIMER

Ernst & Young prepared this independent report under contract number IWM C1026 with the California Integrated Waste Management Board. This study was prepared to fulfill reporting requirements of State Senate Bill 1813 of 1990, and State Assembly Bill 3530 of 1990 (both now codified as Public Resources Code).

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A workshop was held on May 6, 1992 to make this report available for public review and comment. The California Integrated Waste Management Board neither endorses nor approves of the views, opinions, findings, or conclusions set forth in this independent report. Additionally, the report may not necessarily reflect the position of the Administration of the State of California.

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March 31, 1992

Mr. H. Fernando Berton
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California Integrated Waste Management Board
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Sacramento, California 95826

Dear Mr. Berton:

Ernst & Young is pleased to present our Final Report on the *Household Battery Waste Management Study*. This report presents an analysis of the management of household batteries as a part of the California municipal solid waste stream. The study was authorized by State Senate Bill 1813, and State Assembly Bill 3530.

The management of household batteries is a complex and evolving hazardous waste regulatory issue. While this study does not provide all the answers to outstanding environmental health and safety issues concerning the hazardous nature of household batteries, it does provide several key recommendations which clearly appear justifiable at this time concerning the management of California household batteries. These recommendations include the need for new household battery legislation and the need to clarify existing regulations concerning the hazardous nature of household batteries.

During the course of this study we have received helpful input and insight from yourself, and from a variety of industry and governmental sources. These sources are listed in Appendix D to this report.

We also wish to thank the California Department of Toxic Substances Control for their considerate response to our letter request for information. A copy of their reply is provided in Appendix C to this report.

Finally, we would like to acknowledge our three subcontractors who helped us on this study. They are Mr. Eugene Tseng, Esquire (Agoura Hills, California), an environmental and legal consultant specializing in municipal solid waste and hazardous materials management, Dr. George E. Mayer (Pittsburgh, Pennsylvania), a Chemist and Principal Scientist with The Battery Technology Center, and Gainer & Associates (Arcata, California), a consulting group which specializes in assisting community recycling throughout California.

We appreciate the opportunity to be of service to the California Integrated Waste Management Board. If you have any questions concerning this report, please contact Dr. James A. Gibson in our Sacramento office at the above telephone number.

Very truly yours,

Ernst + Young

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Executive Summary

EXECUTIVE SUMMARY

The California Integrated Waste Management Board commissioned Ernst & Young to perform this study on household battery waste management. Senate Bill 1813 and Assembly Bill 3530, both passed during the 1990 Regular Session of the Legislature, authorized the Board to conduct a study on the disposal and potential recyclability of batteries typically generated as household waste. This report provides results of the legislatively mandated study.

Below is presented a synopsis of this study. Section VI of the report summarizes study findings and recommended household battery waste management strategies.

Overview of California's Household Battery Waste Management Problem

Millions of household batteries are purchased annually in California with sales of these batteries projected to increase nearly fifty percent over just the next eight years (by the year 2000). Most consumers of household batteries are not aware of the fact that all the household batteries they dispose of as part of their municipal household solid waste are presently legally considered hazardous waste in the State of California. Any material legally considered hazardous waste is supposed to be properly disposed in a hazardous waste disposal facility. California is thus presently in the position whereby all household batteries are required to be disposed in a hazardous waste disposal facility, but in fact, almost all household batteries are currently illegally disposed in municipal landfills.

Historically, mercury and cadmium have been the two toxic metals of concern in household batteries. However, the new generation of household batteries ("mercury free" alkaline and carbon-zinc) would not legally be considered hazardous waste by California's regulations concerning mercury content. This is due to the efforts of the battery industry over the past several years in nearly eliminating mercury from these battery types. However, California's present regulations still classify these two common household battery types as hazardous waste due to their zinc content. California is the only state in the United States which considers these two common household battery types to be hazardous waste due to their zinc content.

The State of California presently appears to inappropriately regulate household batteries. On the one hand, all household batteries, at least on paper, are legally considered hazardous waste. On the other hand, almost all household batteries are knowingly disposed as municipal solid waste. Partly because California has defacto categorized all household batteries as hazardous waste, the State has undermined its ability to effectively regulate those household batteries which should be truly managed as hazardous waste. Thus, California has the most stringent regulations concerning household battery waste management, but, in fact, little is being effectively done because of existing laws that conflict, a lack of education and enforcement, and the prohibitive economics of collection and disposal for all household battery types.

This study suggests that California may be over-regulating alkaline and carbon-zinc batteries, which comprise approximately 80 percent of all household battery sales in the State, while effectively under-regulating nickel-cadmium batteries, which comprise approximately 13 percent of household battery sales (a portion that is expected to increase over time). If the State's current regulations concerning alkaline and carbon-zinc batteries were effectively enforced, the hazardous waste facility disposal costs alone could easily amount to $20 million, or more, a year. In contrast, few sources would argue that nickel-cadmium batteries should not be classified and effectively enforced as hazardous waste due to their cadmium content. The State of California needs to bring its regulation and management of household batteries as hazardous waste back into a more realistic and cost-effective balance.

The importance of this recommendation is due to the exorbitant costs of collection and disposal of hazardous household batteries. Because the overwhelming proportion of household batteries collected by household battery waste management programs could potentially be alkaline and carbon-zinc batteries, this recommendation could greatly increase the cost-effectiveness of future household battery collection and disposal programs.

Definition of Household Batteries

Household batteries are defined as alkaline, carbon-zinc, mercuric oxide, silver oxide, zinc air, and lithium primary (non-rechargeable) batteries; and nickel-cadmium secondary (rechargeable) batteries. Household batteries also have been referred to as "consumer batteries", "dry cell batteries", or "small household batteries". Many household batteries are utilized in commercial, industrial, and institutional settings, and are not just limited to "household" applications. Household batteries do not include lead-acid automobile batteries.

Uses and Applications of Household Batteries

Portable power offered by household batteries has become an increasingly important component of everyday life. Sales of household batteries are projected to increase nearly 50 percent in California between 1992 and the year 2000. Major factors in this growth include a large increase in per capita consumption, and changes in market share, product mix, and consumer market trends.

Alkaline batteries will continue to be the dominant type of household battery, accounting for an estimated 68 percent of household batteries sold in the year 2000. Nickel-cadmium batteries are expected to receive an increasing share of the household battery market, accounting for 17 percent of the market by the year 2000.

Many consumers do not recognize how many batteries they use during everyday activities. The vast majority of nickel-cadmium batteries are sealed inside consumer products. In many cases, consumers may not even realize that their products contain a nickel-cadmium battery. Also, in many cases, nickel-cadmium batteries are not easily

removable from battery-operated devices. These are all major impediments to the proper disposal of nickel-cadmium batteries as household hazardous waste.

The Hazardous Nature of Household Batteries

Household batteries make up only approximately 0.005 percent, by weight, of California's municipal solid waste. Concern over household batteries is not with the volume of waste they comprise, but with the amount, and toxicity, of their heavy metal components. Household batteries contain metals which are known to have adverse effects on human health and the environment.

Mercury, cadmium, and lead are the three toxic metals which are of primary national concern in municipal solid waste. Mercury is found in most types of primary household batteries. Cadmium is a major component of secondary household batteries. Lead-acid batteries are not considered a household battery, hence lead is a toxic metal which is not of concern with respect to household batteries.

Historically, household batteries have contained significant levels of mercury and cadmium. However, the level of mercury may be less of a concern than in the past, owing to the efforts of the battery industry in nearly eliminating mercury from the most common types of household batteries. For example, mercury content in alkaline batteries has decreased from approximately 1 percent in the early 1980's to less than 0.025 percent currently. Starting in 1992, several U.S. battery manufacturers began producing mercury-free alkaline batteries.

Cadmium, on the other hand, is a growing concern because nickel-cadmium batteries represent an increasing share of the household battery market, and nickel-cadmium batteries represent the single largest source of cadmium in municipal solid waste. Primary, or non-rechargeable, batteries contribute more than eight percent of the total mercury found in municipal solid waste, whereas rechargeable nickel-cadmium batteries contribute more than fifty percent of the total cadmium found in municipal solid waste.

Household Batteries of Concern in the Waste Stream

Household batteries as an item targeted for special waste management are currently receiving attention from local, state, and federal environmental agencies. Presently, in California, all household batteries are legally considered household hazardous waste.

Within California, most household batteries, in spite of their legal hazardous waste status, are presently disposed of with other municipal solid waste in a sanitary landfill. A small percentage of household batteries are segregated and brought to a household hazardous waste collection program. Most hazardous waste collection programs take the used household batteries to a hazardous waste disposal facility.

The term "battery recycling" is a misnomer. Collected batteries are not directly remanufactured into new batteries or other products. Battery recycling refers to metal reclamation processes which entail the extraction of one, or more, of the metals contained

in batteries. In the United States there presently are limited opportunities for the reclamation of metals from household batteries. For example, there is only one facility in the United States that will reprocess both mercuric oxide and silver oxide button cell batteries. Also, there is only one domestic United States processor of nickel-cadmium batteries. There are no reclamation facilities for alkaline, carbon-zinc, zinc air, or lithium batteries.

Considerable uncertainty exists in defining appropriate household battery waste management strategies. Reasons for this uncertainty include the following:

- Health and environmental effects from toxic metals in household batteries are uncertain
- Mercury content has been reduced in the most common primary household battery types
- Federal and State of California regulations concerning household batteries are inconsistent and not definitive
- Participation rates in collection programs for household batteries are low
- Reclamation opportunities for metals contained in household batteries are limited because of economic feasibility
- Hazardous household battery waste collection and disposal is expensive for local governments
- Collection and separation processes for household batteries may pose hazards due to concentrating the waste.

While current laws and regulations in California designate all household batteries as hazardous waste, nickel-cadmium batteries may currently pose the greatest risks due to their high levels of cadmium. For purposes of relative comparison, the amount of cadmium in a single nickel-cadmium battery is roughly equivalent to the amount of mercury in over 400 low-mercury alkaline batteries of the same size. Nickel-cadmium batteries should clearly be targeted for diversion from the municipal solid waste stream and properly disposed as hazardous waste.

Mercuric oxide button cells and to a lesser extent, other button cells, also should be cause for concern due to their mercury levels. Finally, low-mercury and mercury free alkaline and carbon zinc battery types are starting to be recognized as a relatively small risk when present in the municipal solid waste stream.

Actual health and environmental impacts from the disposal of household batteries are not well known. The contribution of mercury and cadmium in the environment resulting from household battery disposal is uncertain, and depends on the type and number of batteries disposed, the method of disposal, and characteristics of the specific disposal processes.

The solid waste management system is intricate, and household batteries in mixed municipal solid waste can travel many different pathways, and be subjected to several

different processes before their final disposal. It is yet to be conclusively determined how the amount of metals contained in household batteries contribute to the level of these metals found in the environment, or in municipal solid waste.

With enactment of AB 939, and subsequent amendments to the California Integrated Solid Waste Management Act, there has been increased interest in the development and implementation of source reduction, curbside collection of recyclable materials, household hazardous waste collection, material recovery facilities, and composting facilities to meet the State mandated waste diversion goals. As a result, the potential battery pathways in municipal solid waste have become even more complex.

Special health and safety concerns arise when household batteries are included in municipal solid waste destined for incinerators or compost operations. In these instances, there is greater opportunity for the metals of concern to escape into the environment, either through incinerator ash and air emissions, or elevated metal content in compost.

The magnitude of the potential hazards associated with battery incineration or composting is still unclear because scientific data specifically linking household batteries to the potential hazards of toxic metals is non-existent. California presently has only three operating municipal solid waste mass burn incinerators. However, California has approximately 40 operating composting facilities, with over 200 additional composting projects now being planned.

Within California, nickel, silver, and zinc also are regulated toxic metals. The level of zinc metal alone in most types of primary household batteries could cause them to be considered hazardous household waste in California, even though they might not otherwise be classified hazardous due to their mercury content. Only in California are alkaline and carbon-zinc batteries legally considered hazardous waste due to zinc content, because no other states are known to have established a standard for zinc. Also, household batteries contribute only approximately two percent of the total zinc contributed by all other uses. Zinc is found in all sectors of the economy, with products containing zinc used for construction, transportation, and machinery purposes.

Recommended Household Battery Waste Management Strategies for California

The California Integrated Waste Management Board now has the opportunity to take initiative regarding household battery waste management. The recommendations summarized below respond to problems discussed in this report and place the Board in a leadership role concerning the management of household battery waste. The recommendations include legislation aimed at content limitations, product labelling, product bans, and making secondary batteries more easily removeable from products. Because the Board is responsible for solid waste and household hazardous waste management statewide, facilitating a dialogue with the Department of Toxic Substance Control and the Battery Industry regarding the zinc regulation as applied to household batteries is consistent with the Board's mission of effective and safe management of solid waste and household hazardous waste.

Five major recommendations concerning household battery waste management are made for further consideration by the California Integrated Waste Management Board. These recommendations will require a more active future role on the part of the State to assist in the management of hazardous household batteries. These recommendations are as follows:

1. **Develop Specific Legislation for Household Battery Regulation**, including:

   - Mercury content limitations for alkaline and carbon-zinc batteries
   - Standardized product labelling requirements for nickel-cadmium batteries
   - Targeted battery product ban for mercuric oxide button cells
   - Specifications that nickel-cadmium batteries be easily removeable from battery-operated products.

Specific provisions for recommended household battery legislation are shown on the opposite page.

It should be noted that subsequent to completion of this report, in early April, 1992, Senate Bill 2579 was introduced into the United States Senate. This bill provides very similar provisions to the legislative recommendations of this report. The recommendations of this report were formed independently of any knowledge of the recommendations contained in U.S. Senate Bill 2579. The status of this federal bill passing is unknown at this time. If this bill becomes federal law, the Board may want to reevaluate the need to pass its own State legislation. If the federal bill does not pass, California should take a leadership position with its own State household battery legislation.

2. **Facilitate Dialogue With the Department of Toxic Substances Control and the Battery Industry Regarding California's Hazardous Waste Regulations As Applied to Zinc in Household Batteries**

Only in California are alkaline and carbon-zinc batteries legally considered hazardous due to zinc content, since no other states are known to have established a standard for zinc. The California Integrated Waste Management Board needs to facilitate discussions with the Battery Industry and the Department of Toxic Substances Control concerning this issue. Staff from the California Environmental Protection Agency may also want to help coordinate the discussions between the two State entities and the Battery Industry.

The Battery Industry may want to present documentation and evidence to the State showing results of Waste Extraction Tests on various stages of actual household battery decomposition. The Battery Industry may argue to modify existing California regulations to provide a zinc toxic substances exemption specifically for just household batteries.

Recommended Household Battery Legislation

Battery Type	General Provision	Specific Provision
Alkaline	Mercury Content Limitation	Limit mercury content in alkaline batteries to 0.025 percent, by weight, by July 1993
Alkaline	Mercury Content Limitation	Limit mercury content in alkaline batteries to 0.0001 percent, by weight, by January 1996
Carbon-Zinc	Mercury Content Limitation	Limit mercury content in carbon-zinc batteries to 0.0001 percent, by weight, by July 1993
All Button Cells	Battery-Operated Product Labelling	Require button cell batteries and packaging to identify the type of battery and need for proper disposal by July 1993
Mercuric Oxide	Product Ban	Ban sale of mercuric oxide button cell batteries by January 1996
Nickel-Cadmium	Product Labelling	Require nickel-cadmium batteries and packaging to identify the type of battery and need for proper disposal by July 1993
Nickel-Cadmium	Battery-Operated Product Labelling	Require battery-operated products using nickel-cadmium batteries and packaging to identify battery type used and the need for proper disposal by July 1993
Nickel-Cadmium	Batteries Removable from Products	Require all battery-operated products using nickel-cadmium batteries be manufactured so that the batteries are easily removeable by the consumer

3. Review and Revise Existing California Regulations Which Affect Household Batteries

In addition to more stringent criteria for defining hazardous waste, California does not categorically exempt household hazardous waste from the hazardous waste designation, unlike the federal government. Also, in California small quantity generators are not exempted from requirements of the regulations. As a result, the same restrictions placed on hazardous wastes generally also apply to household batteries in California. However, there is a State transportation exemption for small quantity battery transport and an exemption on transport requirements if the batteries are sent to a metal reclamation facility.

All of the above California regulations should be reviewed by the State with regard to household batteries to determine if there should be some additional special waivers for household batteries. Existing State hazardous waste regulations should not act as an impediment to local governments and private businesses who need to collect, store, and transport household batteries for proper hazardous waste disposal.

Existing regulations may need to be able to allow a broadening in the number of participants in household hazardous waste programs to include more businesses and manufacturers. Also, local governments should not be constrained to having separate hazardous household battery waste events just because there may be no proven and available recycling technology for the majority of household batteries.

4. Develop and Implement a Statewide Education Program for Hazardous Household Batteries

Under current law, any household battery which is designated as household hazardous waste should be separated from the municipal solid waste stream. A large number of California consumers do not realize that household batteries are presently considered hazardous waste. Because consumers do not generally know this, the effectiveness of household hazardous waste collection programs are seriously undermined. The public's willingness to separate out batteries depends on the perceived health and environmental risks associated with each battery type.

The State of California presently considers all household batteries as legally hazardous. On the other hand, the Department of Toxic Substances Control currently publishes a brochure which states that primary household batteries should be replaced by the "non-hazardous alternative" of secondary batteries. Consumers thus may be receiving conflicting signals about the hazardous nature of household batteries.

The State should develop and implement a statewide education program on the various types of household batteries, and the special requirements for disposal. The education program should include the following areas:

- Description of the various types of household batteries

- The varying contribution of toxic metals in different battery types
- Proper disposal of button cells and nickel-cadmium batteries.

The State needs to help relay a consistent message to California consumers regarding the collection and disposal of household batteries. If consumers are advised to collect certain household batteries, there needs to be provided a proper form of disposal. Consumers should not be advised to collect any household batteries which are not considered hazardous waste. It should also be noted that with any narrowing of hazardous battery designations, there will be a greater need to educate the public on differing battery types. This can only be accomplished with a standardized consumer product labelling system.

5. Further Develop Hazardous Household Battery Collection and Disposal Strategies

The present method of collection available for household batteries is through household hazardous waste collection programs. Two problems are encountered here. The first is that many California cities and counties still have not implemented programs for the collection of household hazardous waste. The second is that most current household hazardous waste programs do not even solicit household batteries, even though they do usually solicit automobile batteries. The cost involved in collecting household batteries is very expensive. The costs of collection and disposal of household batteries as hazardous waste may presently cost on the order of up to $4,000 a ton in California. Collection programs operating outside California have demonstrated that return-to-retailer and curbside collection of household batteries also may be effective collection mechanisms. The State needs to encourage some alternative collection programs for household batteries.

Existing household hazardous waste programs sponsored by city and county governments should be the present primary mechanism for hazardous household battery collection. These battery collection programs should focus on the required collection and hazardous disposal of nickel-cadmium and button cell batteries. However, if additional battery collection efforts are considered necessary (for example if a community has an incineration or compost operation) then collection programs should extend to retail outlets and curbside collection programs.

As the State develops regulations for expanded compost operations as part of AB 939 diversion requirements, it should give special consideration to the treatment of household batteries. The presence of batteries presents some problems for compost materials, especially in mixed-waste compost projects. The Board has to address the issue of having special requirements for collecting household batteries from mixed waste that is destined to a compost operation. Every attempt should be made to sort whole nickel-cadmium batteries out of this mixed waste stream and ensure that these batteries are not shredded.

The ultimate decision on what type of household batteries to collect may affect decisions on how best to collect batteries. Return to retailer collection may be highly suited for button cell batteries and even nickel-cadmium batteries where consumers are looking for a specific type and size replacement battery.

Consideration should be given to identifying ways to facilitate the collection and disposal or reclamation of nickel-cadmium batteries, particularly for applicable product manufacturers and battery manufacturers. The State may ultimately want to encourage that battery collection programs be set up by manufacturers.

I. Introduction

I. INTRODUCTION

This report provides an analysis of the disposal and recyclability of batteries which are typically generated as household waste. The report was prepared for the California Integrated Waste Management Board (CIWMB) to be submitted to the California State Legislature by June 1, 1992. The overall purpose of this study was to:

- Identify potential risks of used household batteries in the waste stream
- Assess waste management options available to reduce potential risks caused by household batteries. These options include:
  - Source reduction
  - Reuse
  - Alternative methods of disposal
  - Recycling
- Develop policy recommendations regarding household battery waste management for California.

This study of household batteries was authorized by Senate Bill (SB) 1813 and Assembly Bill (AB) 3530, which passed during the 1990 Regular Session of the Legislature. Copies of these two Acts are provided in Appendix C to this report.

This report describes the effects of used household batteries on municipal solid waste landfills, incinerators, and compost operations, including potential threats to human health and the environment. The report also discusses the potential recyclability of used household batteries including collection systems, recycling technologies, availability of recycling facilities, and impediments to recycling. Finally, this report includes a number of recommendations on potential strategies for household battery waste management. These recommendations could ultimately form the basis for legislation, regulation, or further study.

The remainder of this introduction section is organized as follows:

- Study Background
- Study Objectives
- Study Scope
- Study Methodology.

A. Study Background

For purposes of this study, household batteries are defined to mean primary or secondary batteries, including alkaline, carbon-zinc, mercuric oxide, silver oxide, zinc air, lithium, and nickel-cadmium batteries. Household batteries do not include lead-acid batteries, such as those used in automobiles. Household batteries include those batteries typically used for hearing aids, cameras, watches, toys, computers, calculators, flashlights, lanterns, power tools, portable radios, television sets, hand held vacuums, clocks, and many other consumer and household items. Household batteries also have been referred to as consumer batteries, dry cell batteries, or small household batteries.

The term household battery is somewhat misleading since not all household batteries are used in the home. The term is used to define the general type of battery, not specific uses. Many household batteries are utilized in commercial, industrial, and institutional settings. For example, household batteries are used in computers, cordless phones, calculators, pagers, tape recorders, and other products all with common uses in business environments. The use of household batteries in non-residential environments is significant, although not a majority use, and is within the scope of this study.

Excluded from this study are a wide range of special purpose batteries. These may include batteries used in commercial, industrial, or military applications. Such special purpose batteries represent a significant portion of the total number of batteries produced and used in the United States. The contribution of these special purpose batteries to the California waste stream is beyond the scope of this study, which focuses specifically on general purpose batteries which are typically used within the household, and disposed with other municipal solid waste. Also excluded from this study are solar cells.

Household batteries generally fall into one of two categories:

- *Primary Batteries* - Primary batteries are non-rechargeable batteries constructed so that only one continuous or intermittent discharge is obtained

- *Secondary Batteries* - Secondary batteries are rechargeable, that is they can be recharged following partial or complete discharge by reversing the flow of electrical current; secondary batteries can be reused many hundreds of times.

There are several types of primary household batteries, most of which contain some amount of mercury. The two most prevalent types of primary batteries are alkaline and carbon-zinc. Nickel-cadmium is the most prevalent type of secondary household battery. Other types of secondary batteries have been developed and are being sold in the United States; however, at this time, they represent a relatively small portion of the secondary battery market. These other secondary battery types include small sealed lead-acid, nickel-metal hydride, and rechargeable alkaline manganese batteries.

Household batteries, as an item targeted for special waste management and reclamation, are currently receiving attention from local, state, and federal environmental agencies. The issue of household hazardous waste is particularly relevant in California where a variety of legislation and regulation is affecting the management of solid waste throughout the State. The issues involved with household batteries are complex and far reaching.

It is generally acknowledged that mercury, cadmium, and lead are three toxic metals which are of primary concern in municipal solid waste[1]. Mercury is found in most types of primary batteries. Cadmium is a major component of nickel-cadmium rechargeable batteries. Lead-acid batteries, which are about 50 percent lead by weight, have been excluded from the scope of this study. This study's premise is that mercury and cadmium are the metals of primary concern in household batteries. The study focuses primarily on the amounts and effects of these two metals in the waste stream as a result of household battery disposal[2].

Concern over household batteries is not with the volume of waste they comprise, but with the amount and toxicity of their heavy metal components. Specifically, this study has attempted to address the following two key issues:

- Under what circumstances do used household batteries potentially constitute hazardous waste?
- Should used household batteries be subject to additional regulation governing their content, use, and disposal?

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1 United States, Office of Technology Assessment, Facing America's Trash: What Next for Municipal Solid Waste, OTA-O-424, October, 1989.

2 It should also be noted that in California zinc, nickel, and silver are considered toxic substances at threshold concentrations and are regulated by the State of California, Environmental Protection Agency. Most primary batteries contain zinc, silver oxide batteries contain silver, and nickel-cadmium batteries contain nickel.

Current disposal methods for household batteries could allow the release of hazardous metals into the air and/or water resources. Nearly all municipal solid waste collected in California is landfilled. While all new landfills are lined and include leachate collection and treatment systems, many older landfills are unlined. There is a potential for toxic metals to escape into the environment through groundwater. Mercury and cadmium also are a potential concern in incinerators and compost operations.

The contribution of mercury and cadmium in the environment resulting from household battery disposal is uncertain, and may depend on: 1) the type and number of batteries disposed, 2) the method of disposal, and 3) specific characteristics of disposal processes. For example, potential risks associated with the disposal of household batteries in landfills could be dependent upon a host of factors, including the following:

- Metal content of various types of batteries
- Physical state of batteries when landfilled (intact, crushed, shredded, etc.)
- Degree of compaction in the landfill
- Moisture content in landfill
- Amount of leachate produced
- Soil composition
- Presence of landfill lining and leachate collection systems.

Similar factors could influence the fate of toxic metals contained in household batteries when they are incinerated or composted.

Most local and state agencies in the United States currently have limited, or no, waste management programs aimed specifically at household batteries. While a few states have passed legislation specifically targeting household batteries, considerable uncertainty exists in defining appropriate waste management strategies. Reasons for this uncertainty include the following:

- *Health and Environmental Effects Are Uncertain* -- Although household batteries have been identified as a significant source of mercury and cadmium in municipal solid waste, it is difficult to

demonstrate the consequences of household batteries in the waste stream

- *Mercury Content Has Fallen* -- In the past decade, battery manufacturers have drastically reduced the amount of mercury in the most common types of primary batteries

- *Guidance From Federal and State Regulators Is Not Definitive* -- While mercury has been identified as a metal of concern in municipal solid waste, the U.S. Environmental Protection Agency decided not to include mandatory programs for separation of household batteries in municipal waste combustors. Also, common battery types pass many toxicity tests, and household hazardous waste is excluded from federal hazardous waste designation

- *Participation Rates in Collection Programs Are Low* -- Public awareness, convenience, and frequency of battery disposal all affect participation rates in existing collection programs

- *Reclamation Opportunities Are Limited* -- Many of the collected batteries are either disposed in hazardous waste landfills or stored for possible future reclamation

- *Alternative Disposal Is Expensive* -- Household battery disposal in a hazardous waste landfill or recycling via metal reclamation facilities may cost thirty times more than disposal as municipal solid waste

- *Collection and Separation Processes For Household Batteries May Pose Additional Hazards* -- Batteries may still be discharging when discarded, creating the potential for a fire or explosion, and the ultimate disposition of collected batteries may be uncertain.

The term "battery recycling" refers to a metal reclamation process that entails the extraction of one or more metals, most commonly silver, mercury, or nickel from used batteries. Cadmium is also reclaimed from household batteries in Europe and Japan; however, there currently are no facilities in the United States which directly reclaim cadmium from used household batteries. Section IV of this report further describes metal reclamation opportunities available in the United States for household batteries.

Battery manufacturing technology is rapidly changing. Collection and reclamation programs that were designed for the technology in existence may be obsolete in a few years. For example, collection programs designed to reclaim mercury from household batteries were undercut during the 1980's when manufacturers eliminated about 90 percent of the mercury content in alkaline and zinc-carbon batteries. Programs which then targeted

mercuric oxide batteries, containing 30 to 40 percent mercury, were again undercut when batteries without mercury were designed for the same purpose, allowing substitution of battery types (e.g., substitution of zinc air button cells for mercuric oxide button cells in hearing aids).

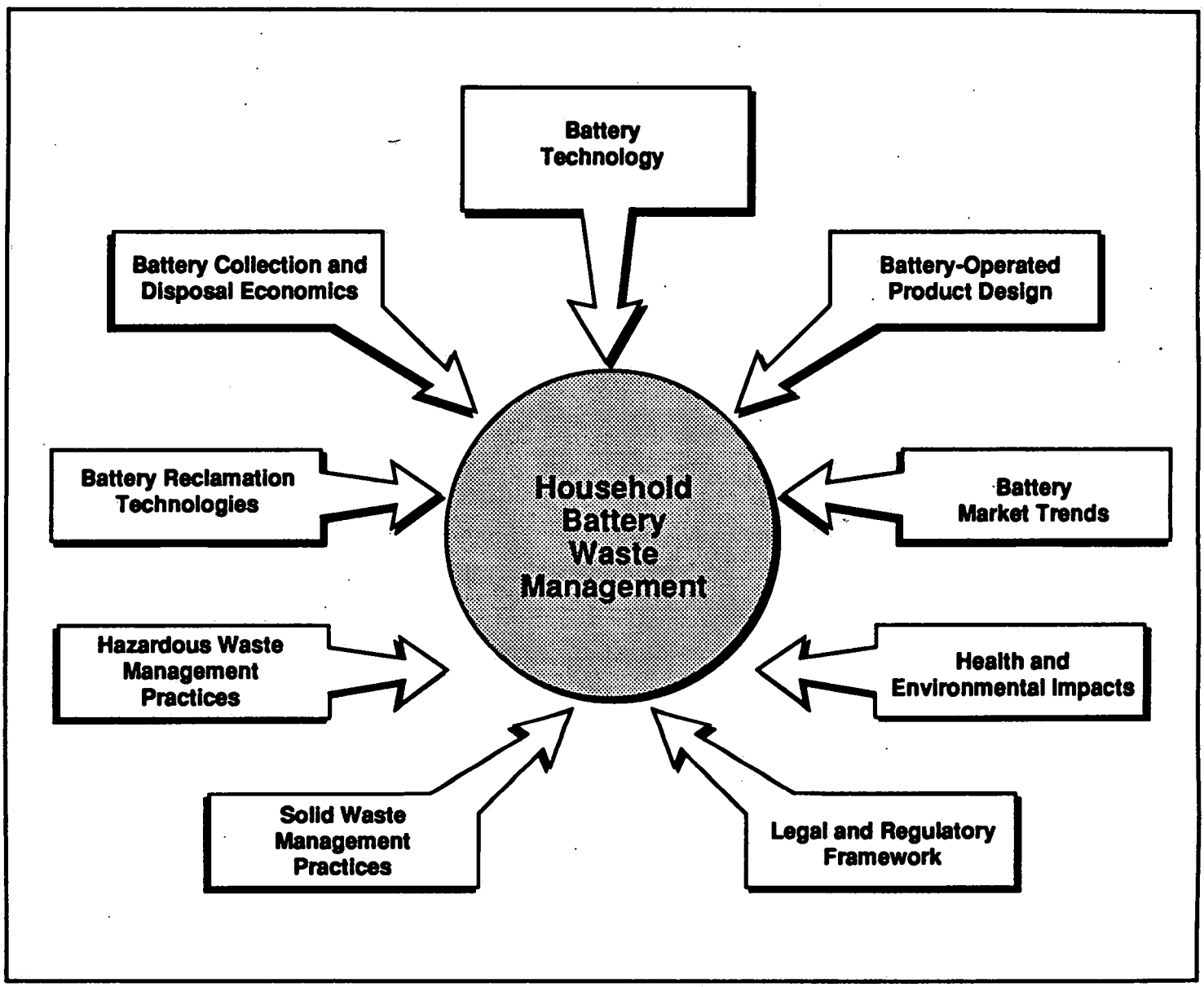
B. Study Objectives

The preceding pages outline some of the complex issues surrounding waste management options for household batteries. In this study, we attempt to sort through these, and other issues, and develop an applied, *common sense* approach to household battery waste management, given the current state of knowledge concerning household batteries and their waste management risks. **Exhibit I-1,** on the following page, illustrates a number of factors which affect this study and which are discussed in future sections of this report.

The goal of this study was to review and make recommendations on the disposal and potential reclamation of household batteries, including effects household batteries have on existing waste management practices. Specific objectives of the study included the following:

- Review the extent to which the disposal of household batteries in municipal landfills, incinerators, and compost operations may pose potential hazards to human health and the environment
- Evaluate the potential recyclability of household batteries, including a review of collection systems and metal reclamation technologies
- Identify potential hazards created by the collection, sorting, transportation, and storage of household batteries, or resulting from the recycling and materials recovery processes for household batteries
- Analyze existing household battery collection and alternative waste battery management programs, including education programs, source reduction, collection programs for used household batteries, and disposal and recycling options
- Determine whether existing legislation and regulation encourages or impedes efforts to effectively manage household battery waste
- Recommend household battery waste management strategies and policy options for consideration by the State Legislature and the California Integrated Waste Management Board.

Factors Influencing Household Battery Waste Management



C. Study Scope

The scope of the study was to assess potential hazards from the disposal of household batteries, including potential risks to human health and the environment, and to evaluate, in terms of reducing potential hazards, the effectiveness of household battery waste management options. The study was designed to utilize existing information, data, and research, which are cited in Appendix A, collected from a wide variety of sources including government publications, technical literature, industry data, market research information, and existing and proposed legislation. This study did not involve any primary research on the health and environmental risks of household batteries, or field or laboratory investigations such as battery chemical analyses or waste characterization studies. We relied entirely on available secondary information and, to the extent possible, took steps to validate this existing information.

This study of household batteries included the following tasks:

- Conducted a thorough literature search of information from previous household battery studies
- Summarized the legislative history to-date related to management of household batteries
- Evaluated historical battery sales trends and developed sales projections by type of household batteries sold in California
- Reviewed the effects of used household batteries on municipal solid waste landfills and incinerators, including any threats to human health and the environment
- Assessed the potential recyclability of used household batteries, including recycling technologies and their effectiveness
- Identified the potential adverse effects on human health or the environment resulting from exposure to household batteries during the recycling process, including collection, storage, transportation, and reclamation of reusable materials
- Reviewed costs of disposing or recycling household batteries
- Reviewed existing and potential collection systems for household batteries, including:
  - Voluntary collection systems
  - Deposit systems

- Inclusion with other household hazardous waste collection programs

- Developed recommendations on the need for legislation, regulation, or further studies relating to the disposal or recyclability of used household batteries.

D. Study Methodology

Our study approach takes into account that incomplete information currently exists on solid waste materials flow and the actual quantities of toxic materials culminating in landfills or incinerators. During the course of this study, we held extensive discussions with representatives of the battery industry, product manufacturers, and personnel involved with household battery collection and disposal programs. We also have discussed many of the issues surrounding household batteries with legislative staff and other government officials at the local, state, and federal levels concerning the current status and future direction of household battery legislation and regulation.

In conducting this study of household batteries and developing our recommendations for legislation and further studies, we utilized the following methods to research and analyze household battery issues:

- Collected and reviewed background documents of the battery industry and battery collection programs, including:
  - Operating data, where available, of current local collection and processing programs, including information on numbers of household batteries collected, and operating and start-up costs of collection programs
- Conducted a review of current legislation, including:
  - Source reduction requirements which must be fulfilled by manufacturers
  - Collection, processing or recycling programs which are to be managed by municipalities and other local agencies
- Examined historical battery sales data and projected future sales based on industry and consumer trends
- Assessed the relative contribution of household batteries to toxic metals in the waste stream, including identifying other sources of metals and the relative proportion contributed by waste household batteries
- Identified the potential pathways from a variety of waste management processes which metals from household batteries can enter the environment , including landfilling, incineration, composting, collection and transfer, and recycling

- Determined whether used household batteries are considered hazardous waste, and the extent which hazardous waste regulations apply to household battery waste management
- Assessed the state of battery design and technology, including the identification of new battery developments or types, the stage of development, degree of substitution within current battery types, and potential toxic metals contained in new battery designs
- Reviewed the roles of local and state governments and household battery manufacturers in waste battery management.

The remainder of this report is organized into the following sections:

II. Classification and Sales of Household Batteries

III. Hazardous Nature of Household Batteries

IV. Household Battery Waste Management Practices and Economics

V. Existing Household Battery Waste Management Programs

VI. Summary of Study Findings and Recommended Household Battery Waste Management Strategies.

This report also contains the following four appendices:

A. Bibliography

B. Local, State, Federal, and International Legislation

C. Legislation Authorizing the Household Battery Study

D. Letters Requesting Information for the Household Battery Study and State Response Letter

1. **State of California Environmental Protection Agency Letter, and Response Letter**
2. **Battery Manufacturers, Product Manufacturers, Environmental Groups, and Other Interested Party Letter.**

II. Classification and Sales of Household Batteries

II. Classification And Sales Of Household Batteries

Household batteries are frequently thought of as a single product or commodity even though they come in various shapes and sizes, and have slightly different uses and characteristics (long-life, heavy duty, rechargeable, etc.). Actually, there are a variety of different types of batteries within the household battery category. Each type has unique physical and chemical characteristics, and more importantly, each type raises different issues regarding environmental risk and proper disposal.

This section of the report describes the various types of household batteries, their characteristics, and component materials. Next, battery applications are reviewed along with a sample of typical household uses. In addition, this section describes demographic trends, consumer preference shifts, product mix changes, and other factors affecting household battery sales. The final subsection reviews historical battery sales and projects future household battery sales in California.

This section of the report is divided into the following four subsections:

- Types of Household Batteries
- Uses and Applications of Household Batteries
- Trends in the Use and Application of Household Batteries
- Historical and Projected Sales of Household Batteries.

A. Types of Household Batteries

A variety of batteries are used daily in and around the home by consumers who desire the convenience of portable power. Consumers usually neither know or care what is inside each battery cell they use. Household batteries consist of various electrochemical processes which enable portable power and combine various materials which produce batteries with varying characteristics, such as power, operating time, shelf life, and cost. While battery types are frequently interchangeable, some battery applications require specific types of batteries for optimal performance.

Batteries consist of two electrodes immersed in an electrically conducting medium called the electrolyte. A battery transforms chemical energy into electrical energy. The two electrodes used in batteries have different electrical potentials. When immersed in the electrolyte, a reduction-oxidation (redox) reaction occurs. As chemical ions flow between the electrodes, electrical current is produced in an external circuit[3]. **Exhibit II-1**, on the following page, schematically illustrates the electrochemical process in a battery.

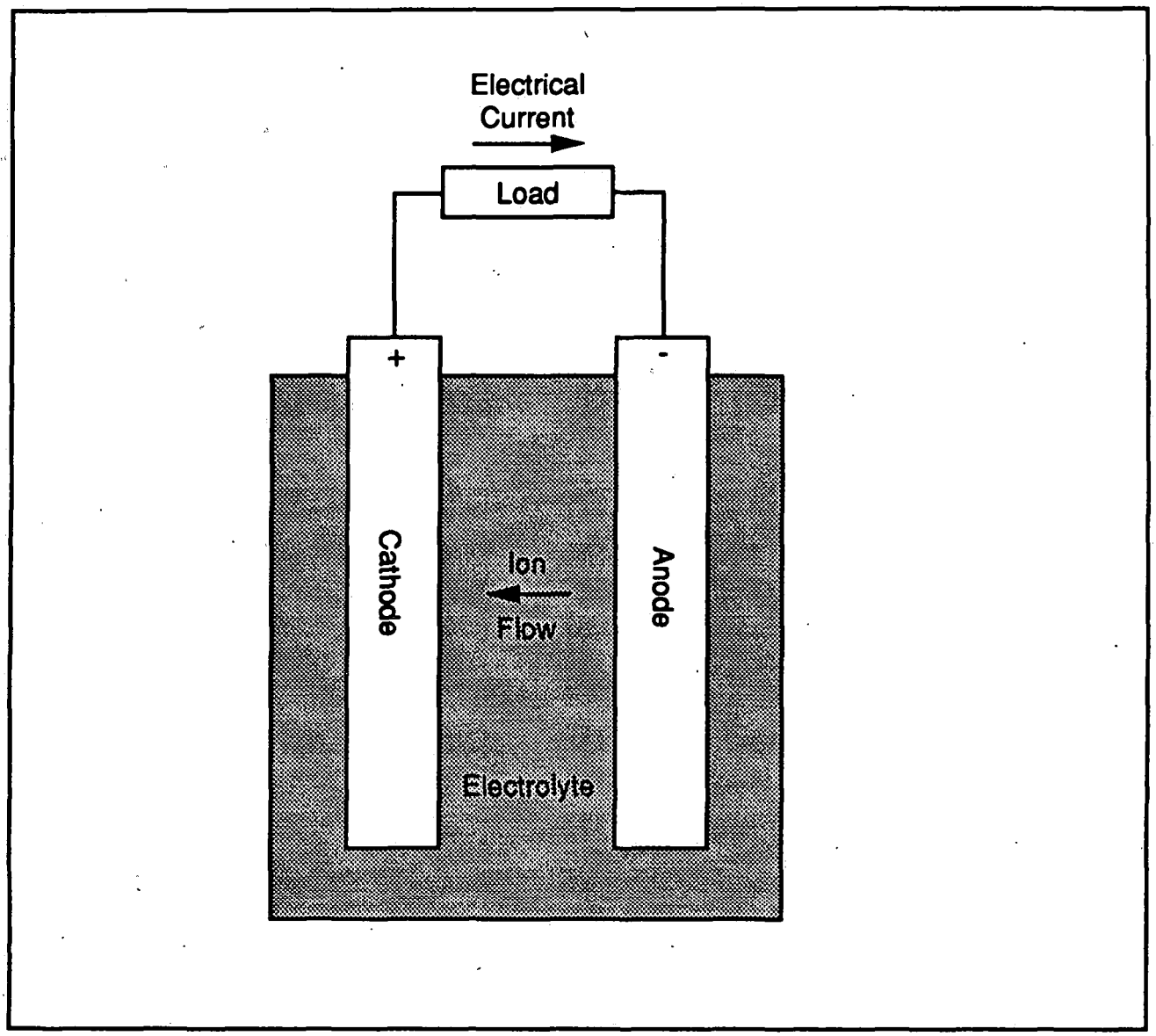
Battery types differ because they use different materials for the electrodes and/or electrolytes. Household batteries also are available in a variety of shapes (button or coin, cylindrical, or prismatic) and sizes. **Exhibit II-2**, on page II-4, provides a summary of the various types and sizes of household batteries. The positive electrode is called the cathode, and the negative electrode is called the anode. As mentioned in Section I, there are also two general categories of household batteries. *Primary* batteries are non-rechargeable, and *secondary* batteries are rechargeable. General characteristics of each battery type are summarized below.

- *Alkaline* - Alkaline batteries contain a zinc anode and manganese dioxide for the cathode. The zinc is in a powdered, highly porous form that oxidizes rapidly. The electrolyte is a strong alkali solution, typically potassium hydroxide or sodium hydroxide. As a result, alkaline batteries provide five to eight times the service life of carbon-zinc batteries[4].

3 Say, M. G., Electrical Engineer's Reference Book, London, 1986

4 Goldberg, Terri L., et al., Source Reduction of Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives, prepared for the Northeast Waste Management Officials Association, May 1991

Battery Schematic



Source:

Linden, D. (ed), Handbook of Batteries and Fuel Cells, McGraw Hill book Co., New York, 1984

Household Battery Components

Battery Type	Common Battery Sizes	Cathode	Anode	Electrolyte
Primary Batteries				
Alkaline	D, C, AA, AAA, 9V	Manganese Dioxide	Zinc	Potassium Hydroxide
Carbon-Zinc[a]	D, C, AA, 9V	Manganese Dioxide	Zinc	Ammonium Chloride or Zinc Chloride
Mercuric Oxide	Button[b]	Mercuric Oxide	Zinc	Potassium Hydroxide or Sodium Hydroxide
Silver Oxide	Button	Silver Oxide	Zinc	Potassium Hydroxide or Sodium Hydroxide
Zinc Air	Button	Atmospheric Oxygen	Zinc	Potassium Hydroxide
Lithium	Button[c]	Manganese Dioxide	Lithium	Organic Solvent
Secondary Batteries				
Nickel-Cadmium	D, C, AA, AAA, 9V	Nickel Oxide	Cadmium	Potassium Hydroxide

a/ Includes "General Purpose" and "Heavy Duty" batteries.
b/ Larger sizes of mercuric oxide batteries are manufacturered for special commercial, industrial, and military purposes. These larger sizes are not considered household batteries due to their special uses.
c/ Lithium batteries are also available in C, AA, and 9V sizes; however, these sizes currently represent a negligible part of the market.

Sources:

National Electric Manufacturers Association, Written Statement of the National Electrical Manufacturers Association and the Battery Products Alliance Concerning Household Battery Disposal, no date

Balfour, Raymond L., *Household and Other Batteries: Source Reduction and Recycling*, presented at the 10th Annual Resource Recovery Conference of the U.S. Conference of Mayors on behalf of the National Electrical Manufacturers Association and the Battery Products Alliance, July 12, 1991

- *Carbon-Zinc* - Carbon-zinc, also called Laclanche, batteries are typically sold as "general purpose" and "heavy duty" battery types. Carbon-zinc batteries contain the same electrode materials as alkaline batteries; however, ammonium chloride (general purpose) or zinc chloride (heavy duty) are typically used as the electrolyte[5].

- *Mercuric Oxide* - Mercuric oxide batteries have more mercury, as a percent of total weight, than any other household battery type. The reason is mercuric oxide is used as one of the electrodes. Furthermore, it is impossible to reduce the amount of mercury in this type of battery without a corresponding reduction in the energy content of the battery[6]. Household uses of mercuric oxide batteries are limited to button cells, which are typically used for hearing aids. Commercial, industrial, and military applications exist for larger-sized mercuric oxide batteries.

- *Silver Oxide* - Silver oxide batteries are often used in place of mercuric oxide batteries for premium, longer life button cells[7]. These batteries also contain significantly less mercury than mercuric oxide batteries.

- *Zinc Air* - Zinc air batteries are a relatively recent innovation in battery technology. Atmospheric oxygen acts as the cathode. In these batteries, the space normally occupied by the cathodic material (mercuric oxide or silver oxide) is filled with zinc anode, resulting in a doubling of service life. Zinc air batteries must be exposed to the atmosphere to function; therefore, they are not used in applications such as watches which have a relatively tight seal[8].

- *Lithium* - Lithium batteries are another recent innovation in battery technology. These batteries use lithium rather than zinc as the anode. Actually, there are a number of different lithium battery types as there are zinc battery types. Because lithium batteries are a relatively new type of household battery, with a small fraction of the battery market, this report addresses lithium batteries as a single type. Lithium batteries are available in a variety of sizes, and are used in cameras, calculators, pacemakers, watches, and computers because of their long life. They have the longest shelf life of any battery, losing only one percent of their power per year[9].

- *Nickel-Cadmium* - Nickel-cadmium is by far the most common type of secondary battery available for household applications. Nickel oxide is used for the anode and cadmium is used for the cathode. Nickel-cadmium batteries typically only last about one-third as long

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5 Arnold, Karen, Household Battery Recycling and Disposal Study, Minnesota Pollution Control Agency, June 1991

6 Balfour, Raymond L., *Household and Other Batteries: Source Reduction and Recycling*, presented at the 10th Annual Resource Recovery Conference of the U.S. Conference of Mayors on behalf of the National Electrical Manufacturers Association and the Battery Products Alliance, Washington, D.C., July 12, 1991

7 Goldberg, 1991

8 Balfour, Raymond L, Materials Presented in Meeting with CIWMB and Ernst & Young on October 24, 1991

9 Goldberg, 1991

as alkaline batteries. However, they can be recharged hundreds of times providing repeated use and a reduction in waste generation. It is estimated that approximately 80 to 85 percent of nickel-cadmium batteries are sold inside consumer products, possibly without the knowledge of the consumer[10].

As suggested above, batteries of the same shape and size are physically interchangeable; however, their different chemistries produce differences in performance and cost-effectiveness. Therefore, consumers tend to purchase different batteries for different applications. For example, there are some differences in cell voltage. A nickel-cadmium cylindrical battery often cannot be used in place of alkaline or carbon-zinc batteries because of lower voltage (1.2 volts verses 1.5 volts per cell). Second, there is a difference in effective cell impedance. For example, alkaline cells work better than carbon-zinc cells for high-current applications such as for photo flashes. Third, there is a difference in shelf-life. Shelf-life is often limited by open-circuit losses; these losses result from small amounts of metallic impurities, such as lead or iron, in the battery which create miniature primary cells within batteries and eventually consume the zinc electrode[11]. Mercury has been historically used to minimize this problem. In recent years, battery manufacturers have added different types and amounts of proprietary additives to minimize these open-circuit losses.

In addition to the batteries listed in Exhibit II-2, there are an increasing number of alternative battery types in various stages of development. These batteries currently represent an insignificant portion of the household battery market and were not the focus of this study. However, three secondary battery types, which are alternatives to the nickel-cadmium batteries, are worth mentioning and discussed below.

- *Sealed Lead Acid* - Lead acid batteries have been excluded from the scope of this study since they are typically used in automobiles, and the regulatory requirements and physical infrastructure to support recycling already exist. However, new small sealed lead acid batteries are appearing on the market as an alternative to nickel-cadmium batteries. Sealed lead acid batteries have greater power but a shorter life and higher cost than nickel-cadmium batteries. They are being introduced in some portable computers, camcorders, and portable cellular phones[12].

10 Balfour, October 1991
11 Say, 1986
12 Goldberg, 1991

- *Nickel-Metal Hydride* - Nickel-metal hydride batteries are secondary batteries with applications similar to nickel-cadmium. This battery type was developed in response to concerns regarding the health and environmental effects of cadmium. These cells 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 audio and video equipment[13].

- *Rechargeable alkaline manganese (RAM)* - RAM batteries are a new technological development in the secondary battery market. Applications of these batteries include high temperature uses and intermittent use requiring minimal discharge. These cells are expected to directly compete against the nickel-cadmium batteries, and eventually, the primary battery market[14].

One concern regarding new battery technologies is that materials in new battery types may create additional health and environmental concerns. Metal content limitations on the formulation of household batteries has the effect of encouraging the development of new battery designs. Policy makers should be cognizant that certain regulatory policies may result in exchanging one problem for another problem. For example, mercury that was present in many primary batteries to minimize hydrogen buildup has been reduced to 0.025 percent by weight. However, in these cases, the mercury is replaced by other substances that may cause as much, or greater, harm. In addition, the substitutes are not available for testing because of proprietorship.

13 Forker, Timothy and Sean Hecht, Environmental Action Coalition's Waste Household Battery Management Project, 1987-1991, Environmental Action Coalition, December 31, 1991

14 "RAM cells battle with Ni-Cads & primaries", Batteries International, January 1992, pp. 25-29

B. Uses and Applications of Household Batteries

There are dozens of battery uses in each household, including some where the presence of the battery may be overlooked by the consumer (e.g., power backup on digital clocks). Most wrist watches and many desk or wall clocks are battery powered. There are many portable entertainment devices, ranging from portable stereos, compact-disk players, and tape players, to toys like "Gameboy". Calculators are often battery powered; however, a trend is to replace some batteries with small solar cells for convenience. Cameras and camcorders are battery powered. Computers have memory backup batteries, and portable computers have batteries providing power as well. Household safety appliances, such as flashlights and smoke alarms, are battery powered. Home security and monitoring systems have battery backup. Cellular and cordless phones are battery powered. Small personal care products such as electric razors are usually battery powered, but the more energy intensive products, like hair dryers, are not. Portable power is provided by batteries for cordless vacuum cleaners, electric drills, soldering irons, and other tools. There are battery powered timers for the kitchen, toothbrushes for the bathroom, and clippers/trimmers for the yard. Batteries are in health-related products like hearing aids and pacemakers.

Exhibit II-3, on the following page, summarizes some of the typical uses of various types of household batteries. This list is not exhaustive but intended to illustrate the range and diversity of battery applications.

One study on household batteries[15] examined the growing trends in battery usage by tracking the number of products which use household batteries listed in the Sears' Christmas catalog. Between 1975 and 1988, the number of products using household batteries increased approximately five fold to 500 items. Various market surveys predict a continued increase in the demand and application of household batteries[16]. Many of the present uses for batteries were unheard of twenty or more years ago. The trends towards increasing productivity, convenience and leisure, expanding service and information-based industries, and an aging population all support the need for more batteries in the future.

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15 Carnegie Mellon University, Household Batteries: Is There A Need For Change in Regulation and Disposal Procedure?, Pittsburgh Pennsylvania, December 1989

16 Business Trends Analysts, The U.S. Battery Market: A Product-by-Product Marketing Analysis and Competitor Profile, 1990

Typical Applications For Household Batteries

Battery Type	Typical Applications
Primary Batteries	
Alkaline	Toys, games, clocks, electronic flashes, tape recorders, calculators, flashlights, radios, smoke alarms, cameras
Carbon-Zinc	Toys, games, flashlights, radios, tape recorders, video cameras, camcorders
Mercuric Oxide	Hearing aids, watches, calculators, medical devices
Silver Oxide	Watches, calculators, hearing aids, cameras
Zinc Air	Hearing aids, pagers
Lithium	Cameras, calculators, pacemakers, watches, computers, portable telephones
Secondary Batteries	
Nickel-Cadmium	Power hand tools, portable vacuums, computers, fire and burgular alarms, electric razors, cordless and celluar telephones, toys, games, video cameras, electric toothbrushes

Sources:

Goldberg, Terri L., et al., Source Reduction for Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives, prepared for the Northeast Waste Management Officials Association, May 1991

Balfour, Raymond I., personal communication on February 8, 1992

Business Trends Analysts, U.S. Battery Market: A Product-by-Product Marketing Analysis and Competitor Profile, 1990

New applications for batteries are emerging each year. The proliferation of imbedded microprocessors and computers in various appliances may require a "whole-house" of uninterruptible power supply or many smaller, dispersed battery power backups in the future.

C. Trends In The Use and Application of Household Batteries

Household batteries have become increasingly significant in the operation of numerous household items. As mentioned in the previous subsection, there has been tremendous growth in the number of consumer products which are battery operated, utilize batteries as backup power, or use rechargeable battery power. Accordingly, there are a number of significant trends which are observed and which affect the demand for household batteries. In this subsection, we review changes in market share, shifts in product mix, significant population and per capita changes, and changes in consumer composition.

1. Market Share Trends

During the past decade, the overall demand for household batteries has grown steadily. According to one market research firm[17], there were an estimated 1.3 billion battery-operated products in 1990, compared to 900 million in 1985. Due to the increasing number of battery applications and the widespread use of primary batteries, the household battery market remains strong and continued growth in most of these battery types is anticipated.

Within the household battery market, there is a trend toward shifting away from primary batteries to secondary, or rechargeable, batteries. During the 1980's, rechargeable batteries were not widely used as substitutes for primary batteries in many battery applications. In some applications, such as intermittent uses over an extended period of time, primary batteries are still preferable over secondary batteries because the longer shelf-life of primary batteries provides better assurance that battery power will be available when needed. In other applications where relatively frequent battery drain would limit the feasibility and convenience of a product, secondary batteries are preferred. Electric razors provide an example of a product where secondary batteries are preferred to primary batteries.

17 Business Trends Analysts, The U.S. Battery Market, 1990

In previous years, rechargeable batteries have required 12 to 14 hours to recharge[18]. Currently, new developments in nickel-cadmium batteries and battery chargers have resulted in a reduction in the recharging time to approximately one hour[19]. This provides greater convenience to the consumer and is expected to increase the substitution of primary batteries by secondary batteries, which will further increase nickel-cadmium battery sales.

In applications where battery substitution is possible, industry sources have estimated that a single rechargeable battery can replace between 200 and 300 primary batteries[20]. In theory, this level of substitution may be possible, but in reality, it is difficult to imagine many products, if any, that use batteries at this rate, consuming hundreds of units. It may be erroneous to assume that secondary batteries reduce the number of primary batteries used by such a large multiple. Given current trends, the market share of nickel-cadmium batteries is expected to continue to increase, growing from 10 percent in 1985, to 17 percent in the year 2000.

2. Product Mix Trends

In addition to market share shifts from primary batteries to secondary batteries, there also is a shift within the primary battery market segment. While the number of applications for household batteries is rising, the physical size of products requiring batteries is becoming smaller and lighter. This trend towards more compact product designs shifts the required battery size from the larger "C" and "D" cells to the smaller "AA", "AAA", and button cells.

Exhibit II-4, on the following page, illustrates the shift in the distribution of battery sales to smaller battery sizes between 1985 and 1990. In 1985, "C" and "D" battery sizes comprised 41 percent share of the market, whereas in 1990, these two sizes only comprised 31 percent. The area of greatest growth is anticipated in the "AA" battery size, with its market share growing from 40 percent in 1985 to 49 percent in 1990. These trends are expected to continue through the year 2000.

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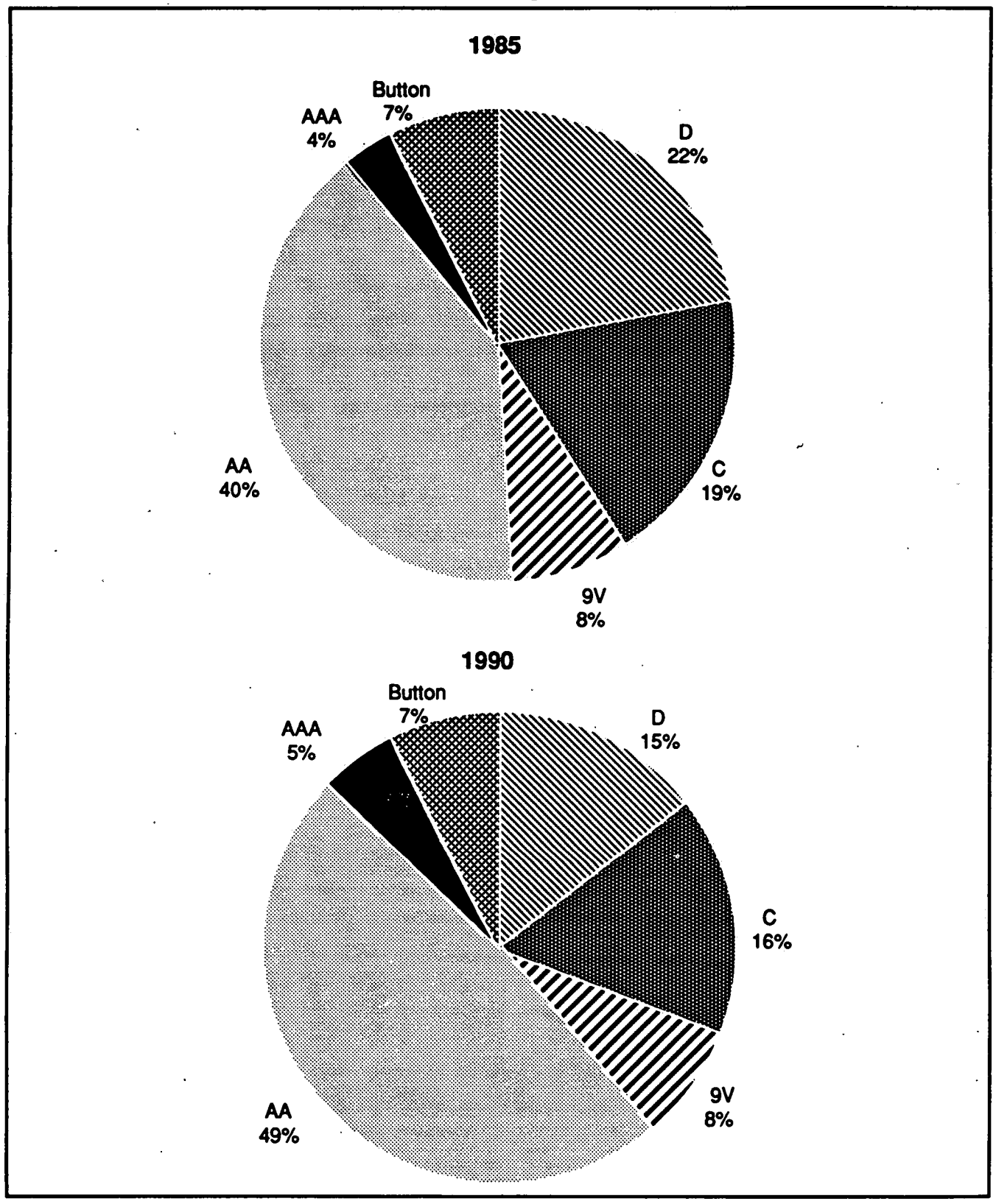
18 Business Trends Analysts, 1990

19 Tater, Todd, Portable Rechargeable Battery Association (PRBA), Materials Presented in a Meeting with CIWMB and Ernst & Young on January 31, 1992

20 Carnegie Mellon University, Household Batteries: Is there A Need For Change in Regulation and Disposal Procedure, December 1989

Size Distribution of Primary Household Batteries



Source:

Balfour, Raymond L., Materials Presented in Meeting with CIWMB and Ernst & Young on October 24, 1991

Another shift in product mix is expected to occur in the distribution of sales within the button cell category. Mecuric oxide batteries contain the largest quantity of mercury as a percentage of weight. Mercuric oxide batteries are increasingly being replaced by the zinc air and silver oxide button cells. In New Jersey, the state has passed a law banning the sale of mercuric oxide batteries by the year 1996. Recognizing concerns over mercuric oxide batteries, the National Electric Manufacturers Association (NEMA) anticipates that mercuric oxide batteries will be completely phased out of household applications throughout the United States prior to 1996. Since the phase-out of mercuric oxide button cells is only a possibility, this assumption is not explicitly included in the sales projections of this report.

3. Demographic Trends

Annual per capita consumption of household batteries is projected to increase from approximately 12 batteries per person in 1985, to 15 in 1990, and to nearly 23 by the year 2000. These values are consistent with those published in other reports[21]. This trend reflects the growing number of applications for household batteries, and their importance to consumers. Approximately 75 percent of the growth in household battery sales projected between 1985 and 2000 is a result of the increase in per capita consumption of household batteries and market share, product mix and consumer market trends. Furthermore, about 66 percent of the growth in per capita household battery consumption is in the "AA" and "AAA" sizes of alkaline batteries. Per capita use of nickel-cadmium batteries also are projected to increase nearly three-fold between 1985 and 2000.

Between 1985 and 2000, the average annual population growth rate in California is expected to be approximately double that of the United States average. As a result, household battery sales in California are projected to be a growing share of the total United States battery market. In 1985, California's population was 11.1 percent of the nation's population. This percentage increased to 12.0 percent in 1990, and by the year 2000, census projections indicate that California's population will be 12.6 percent of the total United States population. Population growth between 1985 and 2000 accounts for approximately 25 percent of the growth in household battery sales within California.

[21] Goldberg, 1991 and Carnegie Mellon, 1989

4. Consumer Market Trends

Another trend occurring in the demand for alkaline and carbon-zinc household batteries is the relatively large, and increasing number of non-residential users. In 1987, government, industrial, and other business-related users constituted 7 percent of alkaline battery sales and 24 percent of carbon-zinc battery sales[22]. This percentage is expected to increase to 8 percent for alkaline battery sales, and 32 percent for carbon-zinc battery sales by 1993. In 1987, the distribution of nickel-cadmium batteries purchased by residential and non-residential consumers was estimated to be 65 percent and 35 percent, respectively[23].

For the sales forecasts in this report, it was conservatively assumed, for the lack of any better information, that 8 percent of alkaline, 32 percent of carbon-zinc, and 35 percent of nickel-cadmium battery sales will be to non-residential consumers. This pattern is significant, since a relatively large number of both primary and secondary batteries are consumed and disposed by non-residential users.

22 Balfour, Raymond, Personal communication, February 1992
23 Tator, Todd, Personal communication, February 1992

D. Historical and Projected Sales of Household Batteries

This subsection combines the trends analyses discussed previously, along with sales data provided by Mr. Raymond Balfour, representing the National Electrical Manufacturers Association (NEMA), to derive California household battery projections through the year 2000.

Actual and estimated sales data for household batteries by type and size were provided by NEMA through the year 1994. For alkaline and carbon-zinc battery types, actual sales data is provided for the period 1985 through 1990, and estimated sales data for the period 1991 through 1994. For button cells and nickel-cadmium batteries, estimated annual sales is provided for the period 1985 through 1989. Estimates for the period 1990 through 1992 for button cells and nickel-cadmium batteries were obtained from NEWMOA[24], except for zinc air button cells (described below). For the remaining period through the year 2000, the following are the assumptions used to project battery sales:

- In the case of alkaline and carbon-zinc batteries, sales of each type and size of household battery is projected at the average growth rate estimated for the period 1991 through 1994.

- For button cells and nickel-cadmium batteries, sales of each type of battery is projected at the average growth rate estimated for the period 1989 through 1992.

- Following their introduction in the mid-1980's, zinc air button cells exhibited rapid sales growth, averaging over 30 percent per year. NEWMOA assumed a continued high growth rate of 25 percent from 1990 through 1992. We believe this rate of growth is too high relative to the overall button cell market; therefore, a more moderate rate of growth has been used for zinc air cells as indicated in **Table II-1**, on the next page. Zinc air cells are quickly replacing mercuric oxide cells for use in hearing aids[25]. The growth rates shown in Table II-1 are more consistent with trends in the substitution of zinc air cells for mercuric oxide cells and the growth in the use of hearing aids.

- Annual growth in the sale of nickel-cadmium batteries has not been projected by battery size. The reason for this is that nickel-cadmium batteries have a wide variety of different sizes, depending on the particular application (many more sizes than the standard D, C, AA,

24 Goldberg, Terri L., Source Reduction of Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives, prepared for the Northeast Waste Management Officials Association (NEWMOA), May 1991

25 Balfour, Raymond, Personal communication, February 4, 1992

AAA, and 9V sizes), and sales data are not available for the individual sizes.

Table II-1
Assumed Rate of Growth for
Zinc Air Button Batteries

Year	Annual Growth Rate
1990	15%
1991	10%
1992 through 2000	8%

Battery sales projections contained in this report should only be considered as order of magnitude approximations, and not as precise estimates. For purposes of this study, the general growth trends over time among and between various types and sizes of household batteries are more important than the absolute number projections themselves. We believe these trends are adequately portrayed in the data contained in this report.

As mentioned previously, the number of battery-operated products in use has increased from approximately 900 million in 1985 to 1.3 billion in 1990, an increase of 44 percent. During the same time period, U.S. sales of household batteries have increased from 2.4 billion to 3.1 billion, an increase of 29 percent. The increase in the number of battery operated products is greater than the increase in the projected sales of household batteries. Therefore, the ratio of the number of household batteries purchased to the number of battery-operated products is decreasing (from 2.67 in 1985 to 2.38 in 1990). This trend is expected to continue, and reflects the longer service life of batteries in many applications and the growing trend towards using rechargeable batteries in more consumer products.

Projected sales data are adjusted from national figures to represent those batteries purchased and used in California. This is accomplished by prorating national sales data for each year based on California population projections relative to the population of the United

States[26,27]. **Exhibit II-5**, on the following page, presents estimates for household battery sales, by type and size, in California for the period from 1985 through 2000. These data are graphically presented in a variety of forms on **Exhibits II-6 through II-8**, on pages II-20 through II-22. In **Table II-2**, below, changes in relative market share for each type of household battery is illustrated.

Table II-2
Estimated Market Share By Battery Type

Battery Type	1985	1992	2000
Primary Batteries			
Alkaline	49%	63%	68%
Carbon-Zinc	35	19	9
Mercuric Oxide Buttons	2	1	1
Silver Oxide Buttons	3	2	2
Zinc Air Buttons	1	2	3
Lithium Buttons[28]	0	0	0
Secondary Batteries			
Nickel-Cadmium	10	13	17
Total	100%	100%	100%

Several important observations are identified. Alkaline batteries are projected to continue to be the dominate type of household battery, as illustrated in Exhibit II-6, increasing both in absolute numbers and market share through the rest of the decade. This is an important trend since battery manufacturers have recently announced plans to produce alkaline batteries without the addition of mercury[29,30]. In addition, alkaline batteries typically last two to eight times longer than carbon-zinc batteries, resulting in fewer

26 California, Department of Finance, *California Statistical Abstract*, 1991
27 United States, Bureau of the Census, *Current Population Reports*, series P-25, No. 1053
28 Lithium button batteries were introduced in the mid-1980s. Their market share is projected to be negligible through the year 2000.
29 Panasonic News, *News Release: Panasonic Unveils New 99.999-Percent Mercury Fee Battery Line*, December 4, 1991
30 Rayovac Corporation, *News Release: Rayovac and Matsushita Sign Technology Agreement*, December 10, 1991

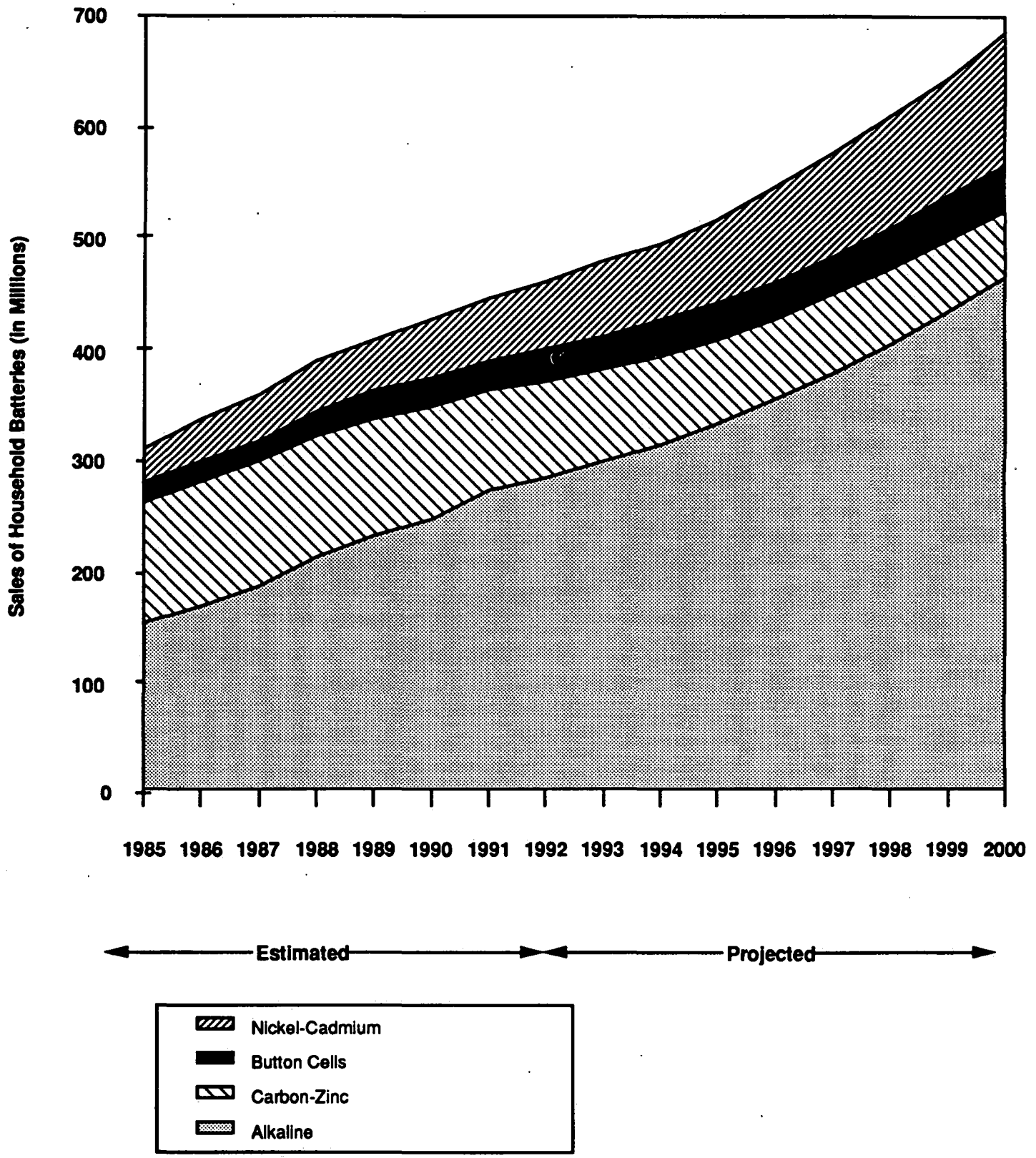
Annual Sales of Household Batteries in California
(Millions of Batteries)

Type/Size	Estimated								Projected							
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Alkaline																
D	32	33	31	35	36	37	41	39	39	39	40	41	41	42	43	44
C	26	29	32	34	34	37	35	37	37	36	37	38	38	39	40	40
AA	73	80	98	110	126	138	151	161	172	184	196	210	229	246	266	286
AAA	9	11	12	16	20	20	25	27	31	34	38	42	47	53	59	66
9V	12	14	15	17	17	17	19	20	21	21	22	24	25	26	27	29
Subtotal	152	167	188	212	233	249	271	284	300	314	333	355	380	406	435	465
Carbon-Zinc																
D	47	46	45	45	42	38	35	33	31	30	28	27	25	24	23	21
C	23	22	22	22	20	18	14	14	13	12	11	10	9	8	7	7
AA	31	37	35	36	34	36	34	33	31	30	29	28	27	27	26	25
9V	9	9	9	9	9	9	8	8	8	8	8	8	8	7	7	7
Subtotal	110	114	111	112	105	101	91	88	83	80	76	73	69	66	63	60
Button Cells																
Mercuric Oxide	7	7	6	6	6	6	5	5	5	5	4	4	4	4	4	4
Silver Oxide	9	9	9	9	10	10	11	11	11	11	12	12	13	13	13	13
Zinc Air	2	3	5	6	7	9	10	12	13	14	15	16	17	19	21	22
Lithium	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	3
Subtotal	18	19	20	21	24	26	27	29	30	31	32	34	36	38	40	42
Nickel-Cadmium All Sizes	32	35	39	43	47	51	57	60	66	71	77	83	90	99	107	117
TOTAL	312	335	358	388	409	427	446	451	479	496	518	545	575	609	645	684

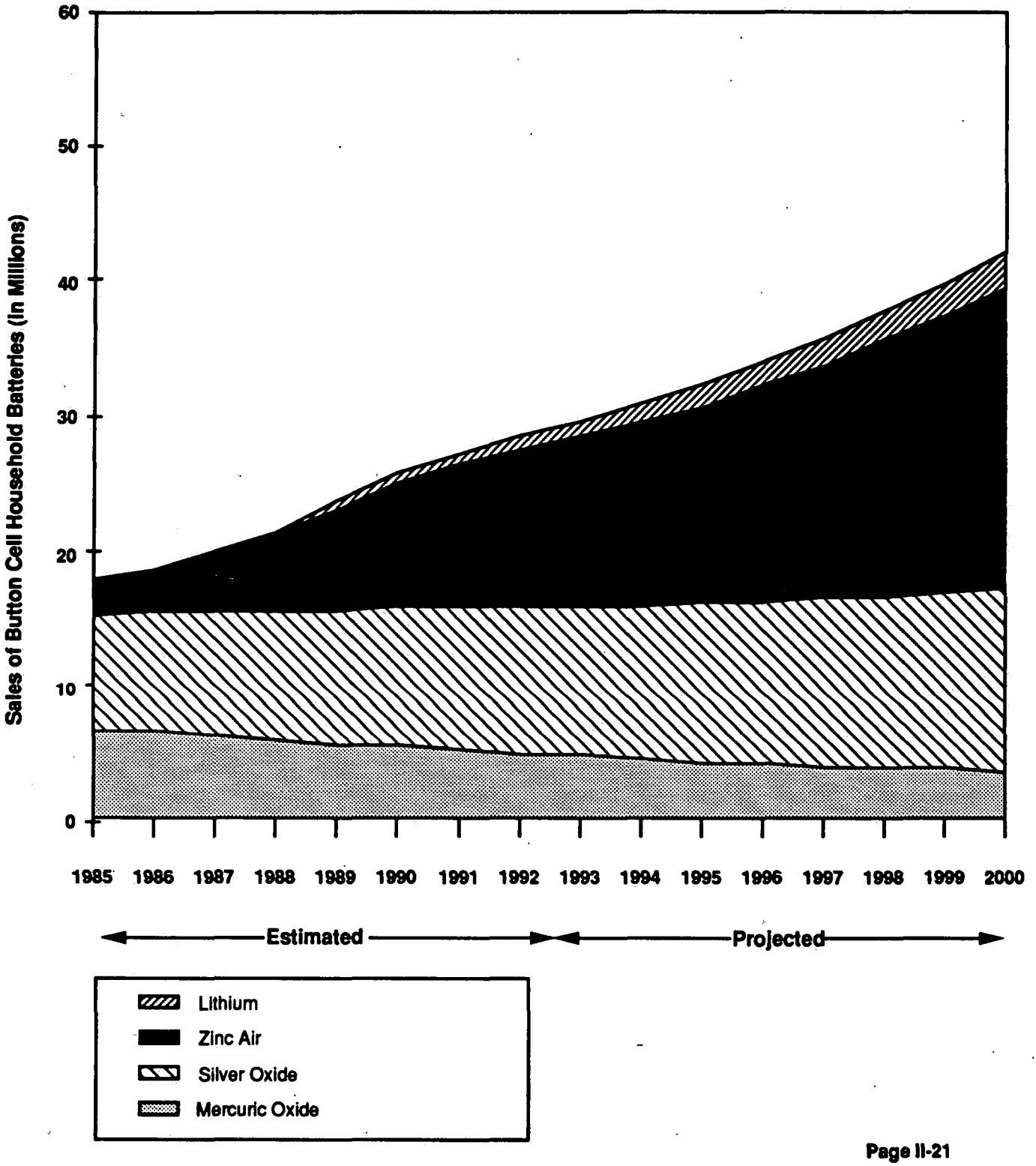
EXHIBIT II-5

EXHIBIT II-6

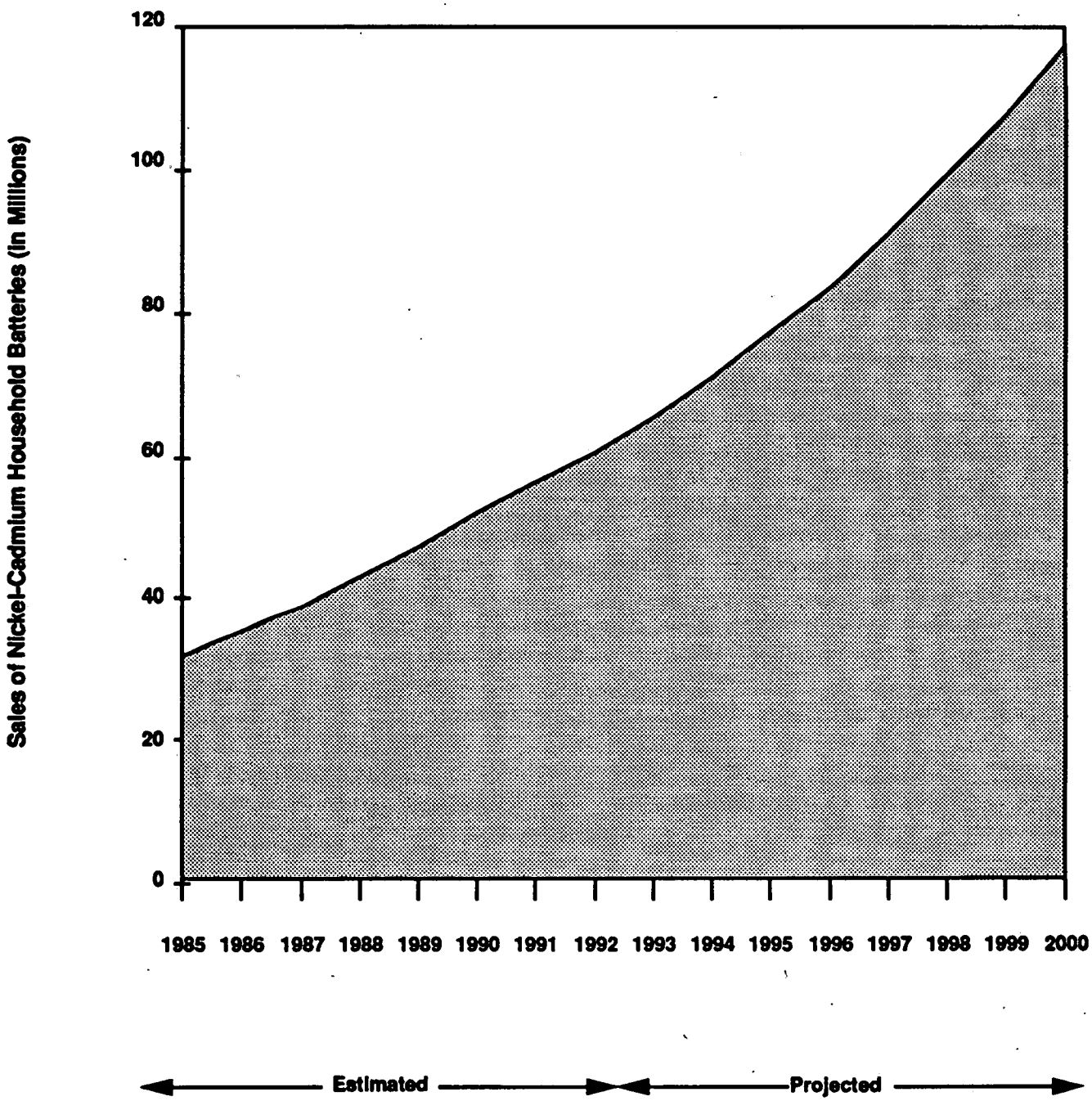
Sales of Household Batteries in California By Type



Sales of Button Cell Household Batteries in California By Type



Sales of Nickel-Cadmium Household Batteries in California By All Sizes



batteries used per application, and reducing the number of batteries in the waste stream. However, in some respects, the desire for longer service life may be counteracted by the trend for using smaller battery sizes. Smaller batteries have less total energy output, and, therefore, need to be replaced more frequently than larger size batteries of the same type.

Carbon-zinc batteries have been "mercury free" for a number of years. It is expected that within the next two years all the major battery manufacturers in the United States will be producing "mercury free" alkaline batteries as well[31]. This fact is significant since alkaline and carbon-zinc batteries represent over 80 percent of the household battery market.

Sales of nickel-cadmium batteries are projected to increase nearly four-fold between 1985 and 2000. Even with this rate of growth, nickel-cadmium's increase in market share is not dramatic because the entire household battery market is growing. In addition, one should keep in mind that in certain applications, nickel-cadmium batteries have the potential to replace a large number of primary batteries. Therefore, the increased use in portable power by consumers from secondary batteries is greater than battery sales data represent.

Exhibit II-7 illustrates trends in the button cell market. Total market share for all types of button cells, relative to other household batteries, is projected to remain constant; however, zinc air and lithium cells are increasing their share of the button cell market at the expense of mercuric oxide. One advantage of the zinc air cell is its service life which is about twice that of either mercuric oxide or silver oxide cells. Also, the zinc air cell is becoming the dominant battery type for use in hearing aids.

Similar to alkaline batteries, rechargeable nickel-cadmium battery sales are projected to realize significant growth, as shown in Exhibit II-8. Growth in the rechargeable battery market will be encouraged through the 1990's by the development of improved technologies in the batteries and chargers, which will allow nickel-cadmium batteries to be recharged in less than one hour[32]. This will increase convenience to the consumer and

31 Balfour, February 1992
32 Tater, January 1992

expand the applicability of rechargeable batteries. At this time, it is unclear how the nickel-metal hydride, small sealed lead-acid, and rechargeable alkaline manganese batteries may impact the secondary battery market. These batteries are outside the scope of this study; however, future developments for these batteries should be monitored closely.

III. Hazardous Nature of Household Batteries

III. HAZARDOUS NATURE OF HOUSEHOLD BATTERIES

This section of the report presents the metal contents of various household batteries, discusses the health and environmental impacts of the metals contained within batteries, and projects the amount of mercury and cadmium entering the California waste stream as a result of household battery disposal. Nearly all household batteries disposed in California become part of the municipal solid waste stream.

The California municipal solid waste which is not recycled is either landfilled, incinerated, or composted. There are only three municipal solid waste incinerators in California; therefore, only a small portion of waste is destined for these facilities. As a result of AB 939 and other state mandates regarding municipal solid waste disposal, more composting operations are appearing in California.

Since mercury and cadmium are metals of concern, and batteries contribute a substantial amount of each, trends in mercury and cadmium from household batteries in California's municipal solid waste are estimated in this section. Also, this section examines the total amount of mercury and cadmium consumed in the United States from all uses. From the data it is observed that primary household batteries are representing a decreasing portion of the mercury consumption, whereas secondary household batteries are representing an increasing portion of the cadmium consumption.

Zinc also is a metal of potential concern in California. However, neither the federal government nor any other state are known to have established a standard for zinc. Zinc is a naturally occurring metal found in soil, seawater, groundwater, plants, and animals. Zinc is an essential element, which is a constituent part of enzymes in all organisms. If humans do not receive a sufficient supply of zinc, deficiency diseases occur. Nothing is known concerning the chronic toxic effects of zinc on man when ingested.

Existing California Department of Toxic Substances Control regulations regard as toxic any waste containing a concentration of zinc and/or zinc compounds equal to, or exceeding 5,000 milligrams/kilogram. This regulation is not necessarily based on the direct protection of human health. For example, products containing zinc which are consumed by human beings (e.g., zinc mineral supplement tablets, zinc oxide skin creams, etc.) are viewed as beneficial uses, even though the same products would be considered hazardous

wastes when they are disposed. California's zinc regulation is apparently based on the belief that zinc poses a toxicity threat to aquatic life, and that zinc bioaccumulates in aquatic life. The State's "Statement of Reasons" for its zinc regulation which was prepared nearly ten years ago suggests that the standard was to protect the Fathead Minnow.

Household batteries contribute an insignificant amount of zinc to the waste stream in comparison to other sources. Because of this, and the above other reasons, less emphasis is placed on the projections of zinc in the California waste stream from household batteries, developed in this report section.

This section is organized under the following subsections:

- Contents of Household Batteries
- Toxicological Effects of Overexposure to Metals Contained in Household Batteries
- Hazardous Metals Loading From Disposal of Household Batteries
- Other Sources of Hazardous Metals in the Municipal Solid Waste Stream
- Classification of Household Batteries as Hazardous Waste.

A. Contents of Household Batteries

Major chemical ingredients in various household batteries are summarized in Exhibit II-2. Household batteries contain varying amounts of cadmium, lithium, manganese, mercury, nickel, silver, zinc, and other metals. **Exhibit III-1**, on the following page, provides the percent ranges of metals typically contained in household batteries. The exact composition of household batteries is proprietary knowledge of the battery manufacturer. In addition, the composition of some battery types has changed in recent years since manufacturers have worked to reduce the amount of mercury in household batteries. The battery industry has published or supplied data which lists metals generally contained in household batteries, either as a percent of battery weight, or as a weight range.

From the data presented in Exhibit III-1, it is clear that mercuric oxide batteries contain the greatest amount of mercury as a percent of weight, and nickel-cadmium batteries have the largest amount of cadmium. As we discuss in the next subsection, these two metals in household batteries are of primary concern since the household battery contributions of these metals to the municipal solid waste stream are more substantial.

Most primary batteries, with the exception of lithium, use zinc as the negative electrode (anode). Unfortunately, zinc has a natural tendency to react with other battery ingredients, generating hydrogen gas which may cause the battery to leak, and reduce the performance of the battery. Historically, battery manufacturers have overcome this undesirable reaction by including small amounts (1 to 3 percent by weight) of mercury on the surface of the zinc[33]. Several years ago, in response to environmental concerns, the battery industry began to explore other ways which would require less use of mercury[34] to control the behavior of the zinc . These efforts have focused primarily on alkaline and carbon-zinc battery types which represent the largest portion of battery sales.

33 United States, Environmental Protection Agency, Office of Research and Development, Achievements in Source Reduction and Recycling for Ten Industries in the United States, EPA/600/2-91/051, September 1991

34 Ibid

Metals in Household Batteries (Percent by Weight)

Battery Type	Cadmium	Lithium	Manganese	Mercury	Nickel	Silver	Zinc
Primary Batteries							
Alkaline	0.01		28-35	0.0001 - 1.0 a/			8 - 18
Carbon-Zinc	0.03		20-40	0.0001-.01			12 - 40
Mercuric Oxide				30 - 43			10 - 15
Silver Oxide				1		30 - 35	10 - 15
Zinc Air				2			35 - 40
Lithium		b/	b/				
Secondary Batteries							
Nickel-Cadmium	10 - 15				15 - 25		

a/ Mercury content in alkaline batteries has decreased from about 1 percent in the early 1980s to less than 0.025 percent currently. Several U.S. battery manufacturers have plans to begin producing *mercury free* alkaline batteries starting in 1992.

b/ There are numerous types of lithium batteries, each with different physical characteristics. Since these batteries represent a small portion of the overall household battery market they were not studied in detail for this report.

Sources:

Balfour, Raymond L., *Household and Other Batteries: Source Reduction and Recycling*, presented at the 10th Annual Resource Recovery Conference of the U.S. Conference of Mayors on behalf of the National Electrical Manufacturers Association and the Battery Products Alliance, July 12, 1991

Goldberg, Terri L., et al., Source Reduction for Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives, prepared for the Northeast Waste Management Officials Association, May 1991

Balfour, Raymond L., Materials Presented in Meeting with CIWMB and Ernst & Young on October 24, 1991, and personal communication on February 7, 1992

Legislation in several states, not including California, have set mercury content limits at 0.025 percent or 250 parts per million[35]. The battery industry has generally met this requirement, and recently, manufacturers have announced designs for alkaline and carbon-zinc batteries in which no mercury is added[36]. Manufacturers indicate that background levels of mercury of approximately 0.001 percent, or 10 parts per million, still will be present as impurities in other metals such as manganese[37].

Mercuric oxide batteries contain the highest level of mercury at approximately 30 to 43 percent by weight. A high level of mercury is required in this battery since mercury is used in the cathode material of the battery. Reducing the amount of mercury would proportionally reduce the energy content of the battery. The primary consumer application of mercuric oxide batteries are button cells used in hearing aids, watches, and calculators. Silver oxide, zinc air, and lithium batteries, which are manufactured as button cells, are substitutes for the mercuric oxide batteries. Silver oxide and zinc air battery types contain approximately 1 and 2 percent mercury, respectively, a substantial reduction over the mercuric oxide but still significantly greater than alkaline or carbon-zinc batteries. Lithium button batteries contain no added mercury.

Knowledge of battery contents of the various metals and the potential effects on health and the environment when landfilled or incinerated has led to legislated choices as to what battery consumers can purchase and use, and how batteries must be disposed. Appendix B, at the end of this report, summarizes key battery legislation in the United States, Europe, and Japan. Battery manufacturers have generally anticipated environmental concerns and modified their battery designs and materials in order to comply with legislation in different political jurisdictions, such as counties, states, and countries.

35 States that have enacted legislation limiting mercury content to 0.025 percent by weight for certain types of batteries include: Connecticut, Minnesota, New Jersey, Oregon, and Vermont. Michigan has proposed such legislation.

36 Rayovac Corporation, *News Release: Rayovac and Matsushita Sign Technology Agreement*, December 10, 1991

37 Panasonic Company, *News Release: Panasonic Unveils New 99.999-Percent Mercury-Free Battery Line*, December 4, 1991

B. Toxicological Effects of Overexposure to Metals Contained in Household Batteries

Specific metals, which are frequently contained in household batteries, have been identified as a potential risk to human health and the environment. The amount of these metals contained in household batteries does not present a risk, but the metals themselves may pose a risk under certain conditions and levels of exposure. These metals contained within batteries include cadmium, lithium, manganese, mercury, nickel, silver, and zinc[38]. Cadmium and mercury are the two metals of primary concern. Also, zinc, silver, and nickel are metals of concern in California. Zinc is common to almost all primary batteries.

This subsection describes the toxicological effects of overexposure to these metals in occupational settings. By presenting this information, it is not suggested that household battery use and disposal practices result in overexposure to these metals. The pathways and potential mechanisms for metals to escape into the environment , posing a potential hazard to human health, are discussed later in this report.

Effects on the body from exposure to certain metals can be either acute or chronic. In addition, the effects are related to the route through which the metal enters the body. Effects from inhalation often differ from those resulting from ingestion. The health effects of exposure to each of the metals are summarized below.

- *Cadmium* - The immediate health effects from cadmium exposure are the result of inhaling fumes or dust. Localized health effects caused by cadmium exposure include irritation to the respiratory tract and mucous membrane lining of the inner surface of the eyelid. A systematic effect of cadmium inhalation is severe pulmonary irritation. This is often accompanied by severe difficulty in breathing and general weakness. The most common result of acute systematic cadmium exposure is emphysema, but in some instances, death may occur. Chronic cadmium poisoning can be associated with both inhalation and ingestion, resulting in anemia, obstructive pulmonary disease, and chronic renal tubular diseases. Prolonged cadmium exposure has also been linked to prostrate and lung cancer in humans. In rodents, there is evidence that cadmium exposure can cause testicular necrosis, hypertension, and central nervous system damage. In 1990, the Occupational Safety and Health Administration (OSHA) determined that employees exposed to

38 Much of the information included in this subsection was obtained from Carnegie Mellon University, 1989 which summarized a number of occupational health studies and federal standards.

cadmium face a significant risk to their health at current permissible exposure limits and proposed rule changes to reduce that risk[39].

- *Mercury* - Mercury and its compounds may enter the body in a number of ways including inhalation, ingestion, and skin absorption. Mercury is an irritant to the skin and to the mucous membranes. It may also be a cause of conjunctivitis. Acute mercury poisoning may affect the lungs in the form of interstitial pneumonitis, bronchitis, and bronchiolitis with pulmonary edema. Delayed effects consist of inflammation of the kidneys and hepatitis. Chronic exposure to mercury produces four classical signs: gingivitis (inflammation of the gums), sialorrhea (excessive flow of saliva), increased irritability, and muscular tremors. Beyond these effects, renal failure may occur with prolonged exposure. Chronic exposure may affect the central nervous system resulting in personality changes, delirium, fatigue, memory loss, and hallucinations.

- *Zinc* - Exposure to zinc may be through inhalation of fumes or ingestion. Zinc chloride can cause dermatitis and chemical burns. Aqueous solutions of zinc are also extremely painful to the eyes, causing inflammation and swelling. Corneal ulceration may also follow exposure to the eyes. Acute exposure to high levels of zinc chloride results in severe irritation of the respiratory tract and is occasionally followed by acute pulmonary edema.

- *Silver* - The adverse health effects of silver and its compounds may be caused by prolonged exposure to fumes, as well as by ingestion or physical contact. Silver dust deposited in the lungs may also be regarded as a form of pneumonoconiosis. Although silver does not appear hazardous in its most common forms, certain silver compounds are highly corrosive to the skin, eyes, and intestinal tract. High levels of chronic exposure can cause argyria, a grayish discoloration of the skin. USEPA considers argyria a cosmetic effect since it does not impair bodily functions. Recognizing that silver does not pose a threat in drinking water, in January 1991, USEPA removed silver from primary drinking water standards[40].

- *Nickel* - Nickel exposure most commonly manifests itself locally in the form of skin sensitization which often results in chronic eczema or "Nickel Itch". Nickel exposure can also result in conjunctivitis and irritation of the mucous membrane of the respiratory tract which may take the form of pulmonary edema. Acute nickel poisoning manifests itself in forms similar to those of viral pneumonia, including chest pains, coughing, hypernea, and severe weakness. Epidemiological studies have shown an increased incidence of cancer among nickel refinery workers. The cancers most commonly reported are lung and nasal cancer.

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39 Federal Register, Vol. 55, No. 25, Tuesday February 6, 1990, Proposed Rules, Department of Labor, 29 CFR Part 1910, pg 4052

40 Federal Register, Vol. 56, No. 20, Wednesday, January 30, 1991, Rules and Regulations, Environmental Protection Agency, 40 CFR Parts 141, 142, 143, pg 3573

- *Lithium* - Acute exposure to lithium results in a condition referred to as lithium intoxication which typically lasts several days to two weeks. The systems affected by lithium intoxication are the central nervous system, the cardiovascular system, the renal system, and the gastrointestinal system. Chronic exposure to lithium can cause disruption in the renal tubular absorption of sodium, potassium, magnesium, and calcium. Lithium exposure can also result in nephrogenic diabetes insipidous and changes in thyroid function. Although lithium has many negative health effects, in controlled doses, its compounds are used in the treatment of chronic depression.

- *Manganese* - Manganese dust and fumes are minor irritants to the eyes and respiratory tract. Inhalation of manganese fumes may cause acute poisoning which manifests itself in an influenza-like illness referred to as metal fume fever. Chronic exposure to manganese, while not caustic, can irritate preexisting pulmonary conditions such as pneumonia, chronic bronchitis, and airway disability. Chronic exposure also may result in a psychiatric disorder characterized by irritability, difficulty in walking, speech disturbances, and compulsive behavior. Liver cirrhosis has been frequently observed among those exposed to manganese for extended periods of time.

Although all seven metals listed above pose certain health risks, mercury and cadmium have been the metals of primary concern with respect to household batteries[41,42,43]. The reason for this is that household batteries have historically been a major source of both mercury and cadmium in the waste stream. Nickel-cadmium batteries are the single largest source of cadmium in municipal solid waste, and primary household batteries, in general, have been a major source of mercury in municipal solid waste[44]. The amount of mercury and cadmium entering the California waste stream as a result of household battery disposal is discussed in the next subsection.

Within California, nickel, silver, and zinc also are regulated metals. The level of these metals may also cause some types of household batteries to be considered hazardous in California, even though they would not be hazardous due to mercury or cadmium. The level of zinc contributed by household batteries to the California waste stream is also discussed in the next subsection.

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41 United States, Office of Technology Assessment, Facing America's Trash: What Next for Municipal Solid Waste?, OTA-O-424, October 1989

42 Arnold, 1991

43 Reutlinger, Nancy, *Batteries in the Waste Stream: A Feasibility Study of Household Battery Recycling and Collection for the County of Santa Cruz*, County of Santa Cruz, Planning Department, July 20, 1990

44 United States, Office of Technology Assessment, October 1989

While exposure to the metals may have the consequences previously described, it is yet to be determined how the amount of metals contained in household batteries contribute to the level of these metals in the environment. A number of studies suggest that the disposal of household batteries in municipal solid waste may not pose a significant threat to human health or the environment when placed in properly operated landfills[45,46,47]. Concerns arise when household batteries are included in municipal solid waste destined for incinerators or compost operations[48]. In these instances, there is greater opportunity for the metals of concern to escape into the environment, either through incinerator emissions or elevated metal content in compost. The magnitude of the potential hazards associated with battery incineration or composting is yet unclear. The amount of metals added to the waste stream as a result of disposing household batteries is discussed further in the next subsection. The effects of household batteries in landfills, incinerators, and compost is further discussed in Section IV of this report.

45 United States, Environmental Protection Agency, Risk Reduction Engineering Laboratory, Pollution Prevention Research Program, Dry-Cell Battery Workshop, November 14, 1990

46 Jones, C. J., et al., *An Investigation of the Degradation of Some Dry Cell Batteries Under Domestic Waste Landfill Conditions*, in Journal of Hazardous Materials, 2 (1977-78), pg 259-289

47 Fochtman, Edward G. and William R. Hass, ITT Research Institute, *Relationship of Spent Dry Cell Batteries to the Heavy Metal Content of Solid Wastes*, presented at the Second National Conference on Water Use, Chicago, May 4-8, 1975

48 Arnold, 1991

C. Hazardous Metals Loading From Disposal of Household Batteries

Within California, most household batteries are disposed with municipal solid waste at sanitary landfills; however, city and county household hazardous waste collection programs are beginning to appear throughout California. Household batteries are typically included in lists of materials characterized as household hazardous waste[49]. Household hazardous waste programs are emerging as a result of household hazardous waste elements of AB 939, county integrated waste management plans[50]. Since mercury, cadmium, and zinc are hazardous metals and household batteries contain a large percentage, by weight, of one or more of these metals, the contributions of these metals by household batteries are discussed in this subsection.

To examine the effects of household batteries on the California waste stream, battery sales data is used to estimate the quantity of mercury, cadmium, and zinc added to municipal solid waste from household battery disposal. For analysis purposes, it is recognized that batteries are purchased by both residential and non-residential consumers, in the year following their manufacture. It is further assumed that primary batteries enter the waste stream a year after purchase, and secondary batteries enter the waste stream an average of 5 years after purchase[51].

Exhibit III-2, on the following page, indicates the average weight for the various types and sizes of household batteries. In general, the amount of mercury, cadmium, and zinc entering the California waste stream is estimated by multiplying battery sales estimates, contained in Exhibit II-5, by battery weights in Exhibit III-2, and by the percent of metal content for each battery type from Exhibit III-1.

49 California, Department of Health Services, Toxic Substances Control Program, "Hazardous Household Products: A Guide to the Disposal of Hazardous Household Products and the Use of Non-Hazardous Alternatives", information brochure, no date

50 Public Resource Code §41500 et seq.

51 These figures were obtained from Mr. Raymond Balfour of NEMA and Mr. Todd Tater of PRBA for primary and nickel-cadmium batteries, respectively. Other assumptions are possible but do not significantly alter the conclusions drawn from the analysis.

Weight of Household Batteries by Type and Size (In Grams)

Size	Alkaline	Carbon-Zinc a/	Mercuric Oxide	Silver Oxide	Zinc Air	Nickel-Cadmium b/
D	141.9	87.5	—	—	—	62.5
C	67.5	41.5	—	—	—	52.5
AA	22.9	15.4	—	—	—	22.5
AAA	11.6	—	—	—	—	11.0
9V	46.7	36.1	—	—	—	37.5
Button	—	—	1.57	0.92	1.56	—

a/ Average weight for "general purpose" and "heavy duty" carbon-zinc batteries
b/ Nickel-cadmium household batteries are manufactured in a variety of sizes other than the standard sizes shown. An average weight of 44.0 grams per nickel-cadmium battery was used in the analysis. This average weight was estimated from industry data.

Sources:

Goldberg, Terri L., Source Reduction of Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives, prepared for the Northeast Waste Management Officials' Association, May 1991

Carnegie Mellon University, Household Batteries: Is There A Need For Change in Regulation and Disposal Procedure?, December 1989

1. Mercury

Mercury content of alkaline cells has been reduced dramatically since the mid-1980's as a result of efforts by the battery industry to reformulate these batteries. Based on information provided by NEMA on battery sales and total mercury consumption for household battery manufacture, estimates for the average mercury content in alkaline batteries are calculated as shown below in **Table III-1**.

Table III-1
Mercury Content in Alkaline Batteries

Date of Manufacture	Mercury Content
1984	1.00%
1985	0.82%
1986	0.79%
1987	0.31%
1988	0.21%
1989	0.11%
1990	0.05%
1991 and 1992	0.02%
1993 through 2000	0.0001%

All of the four major U.S. battery manufacturers[52] were producing alkaline batteries with less than 0.025 percent mercury, which is the legislated limit in several states, (see Appendix B) by mid-1991. The average *actual* mercury content in alkaline batteries is reported to be about 0.020 percent[53]. Retail battery sales generally lag manufacture by approximately one year. Therefore, for 1992 and 1993, it is assumed that the average mercury content of alkaline batteries is 0.020 percent. In addition, the four major U.S. battery manufacturers are expected to start producing "mercury free" alkaline batteries by 1992 or 1993. Therefore, it is assumed that alkaline batteries manufactured

52 Eveready, Duracell, Rayovac, and Panasonic/Kodak
53 Balfour, 1992

from 1993 through 2000 will only contain 0.0001 percent mercury which represents the background level of mercury found in other metals.

Exhibit III-3, on the following page, summarizes the amount of mercury, in tons, which is estimated to enter the California waste stream as a result of household battery disposal. **Exhibit III-4**, on page III-15, graphically presents mercury data by battery type. This exhibit dramatically illustrates how the small amount of mercury historically included in alkaline batteries represented the majority of mercury from household batteries. This source of mercury in municipal solid waste should be practically eliminated within the next two years when battery manufacturers begin producing "mercury free" alkaline batteries.

Exhibit III-5, on page III-16, shows the amount of mercury contributed to the California waste stream from the disposal of consumer button cells. Mercuric oxide batteries contain over 30 percent mercury while silver oxide and zinc air batteries contain approximately 1 and 2 percent mercury, respectively. The substitution of silver oxide and zinc air batteries for mercuric oxide batteries results in a significant reduction in the amount of mercury in the waste stream. Zinc air batteries have approximately twice the life of silver oxide batteries. Even though they contain about twice the mercury, the amount of mercury contained in battery waste would be nearly equivalent (two silver oxide cells discarded for every one zinc oxide cell).

New Jersey has recently passed legislation calling for a ban on the sale of mercuric oxide button batteries by 1996. Anticipating that other states, or the federal government, may take similar actions, the battery industry is considering discontinuing the sales of mercuric oxide button batteries before 1996[54]. If this occurs in California, then up to 3 tons of additional mercury would be removed from the California waste stream each year.

2. Cadmium

Similar to the calculation of mercury in municipal solid waste from the disposal of household batteries, estimates of the amount of cadmium in the waste stream from the disposal of household batteries also are made. Similar procedures were followed to

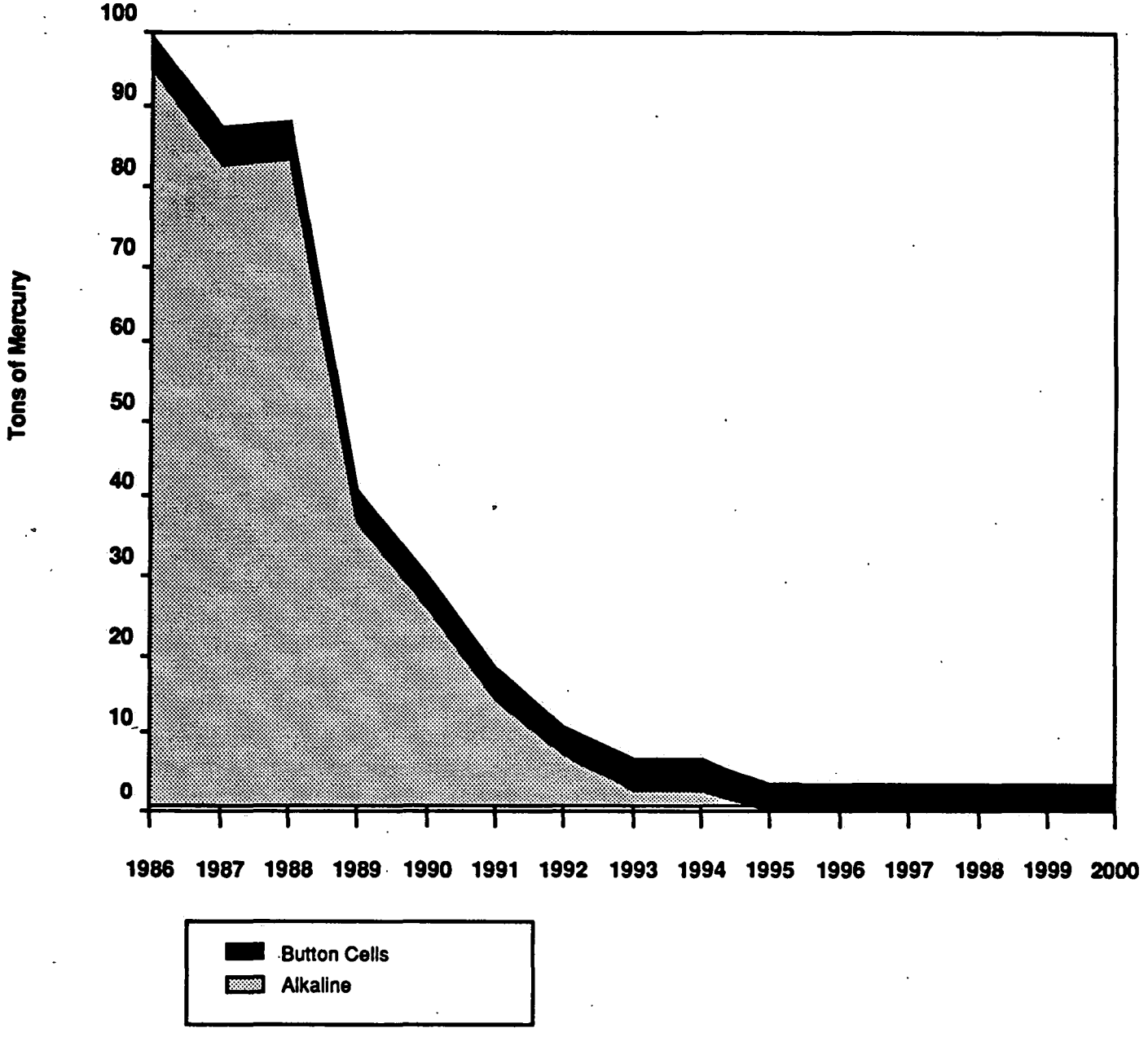
54 Balfour, February 1992

Mercury in the California Waste Stream From Household Batteries (In Tons)

Type/Size	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Alkaline															
D	49.8	41.7	38.2	16.8	11.8	6.3	3.2	1.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0
C	19.4	17.4	18.5	7.9	5.3	3.1	1.3	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0
AA	18.5	16.6	19.7	8.6	6.7	3.8	1.9	0.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0
AAA	1.1	1.2	1.2	0.6	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
9V	6.0	6.1	6.1	2.7	1.8	0.9	0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	94.8	83.0	83.7	36.6	26.1	14.4	7.1	2.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0
Carbon-Zinc															
D	0.5	0.4	0.4	0.4	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AA	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9V	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	0.6	0.6	0.6	0.6	0.6	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Button Cells															
Mercuric Oxide	4.3	4.2	4.1	3.8	3.7	3.6	3.4	3.3	3.2	3.0	2.9	2.8	2.6	2.5	2.4
Silver Oxide	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Zinc Air	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.7	0.8
Subtotal	4.5	4.4	4.3	4.1	4.0	4.0	3.9	3.8	3.7	3.6	3.5	3.4	3.3	3.3	3.3
TOTAL	99.9	88.0	88.6	41.3	30.7	19.0	11.1	6.7	6.6	3.6	3.5	3.4	3.3	3.3	3.3

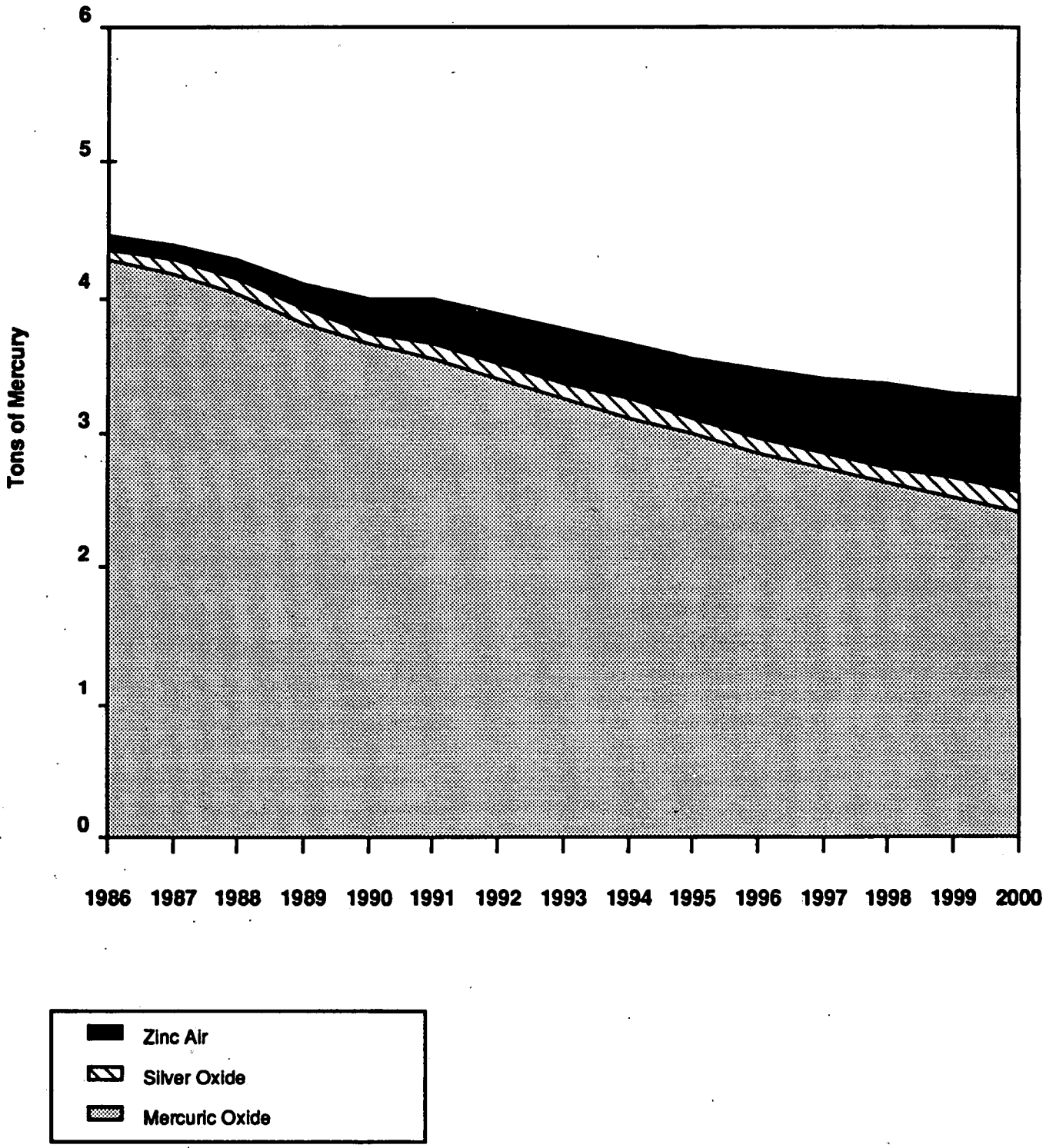
EXHIBIT III-3

Mercury in the California Waste Stream From the Disposal of Alkaline and Button Cell Household Batteries[a/]



a/ Carbon-zinc batteries contain a negligible amount of mercury and is not included in this exhibit.

Mercury in the California Waste Stream From the Disposal of Button Cell Household Batteries



estimate the amount of cadmium entering the waste stream. One important assumption which applies to the disposal of nickel-cadmium batteries is the difference in service life. Because they are rechargeable, nickel-cadmium batteries have an estimated service life of 3 to 7 years, with an average of 5 years[55]. For purposes of the calculations made in this study, a five year service life was assumed. Therefore, nickel-cadmium batteries were assumed disposed of five years after their purchase by consumers[56].

Exhibit III-6 on page III-18, and **Table III-2**, below, show the amount of cadmium, in tons, estimated to enter the California waste stream as a result of nickel-cadmium household battery disposal. Alkaline, carbon-zinc, and other primary batteries also contain trace amounts of cadmium as an impurity in zinc; however, the amounts are negligible, contributing less than 0.5 percent of the cadmium in municipal solid waste as compared to nickel-cadmium batteries.

Table III-2
Cadmium in the California Waste Stream
From Nickel-Cadmium Household Batteries

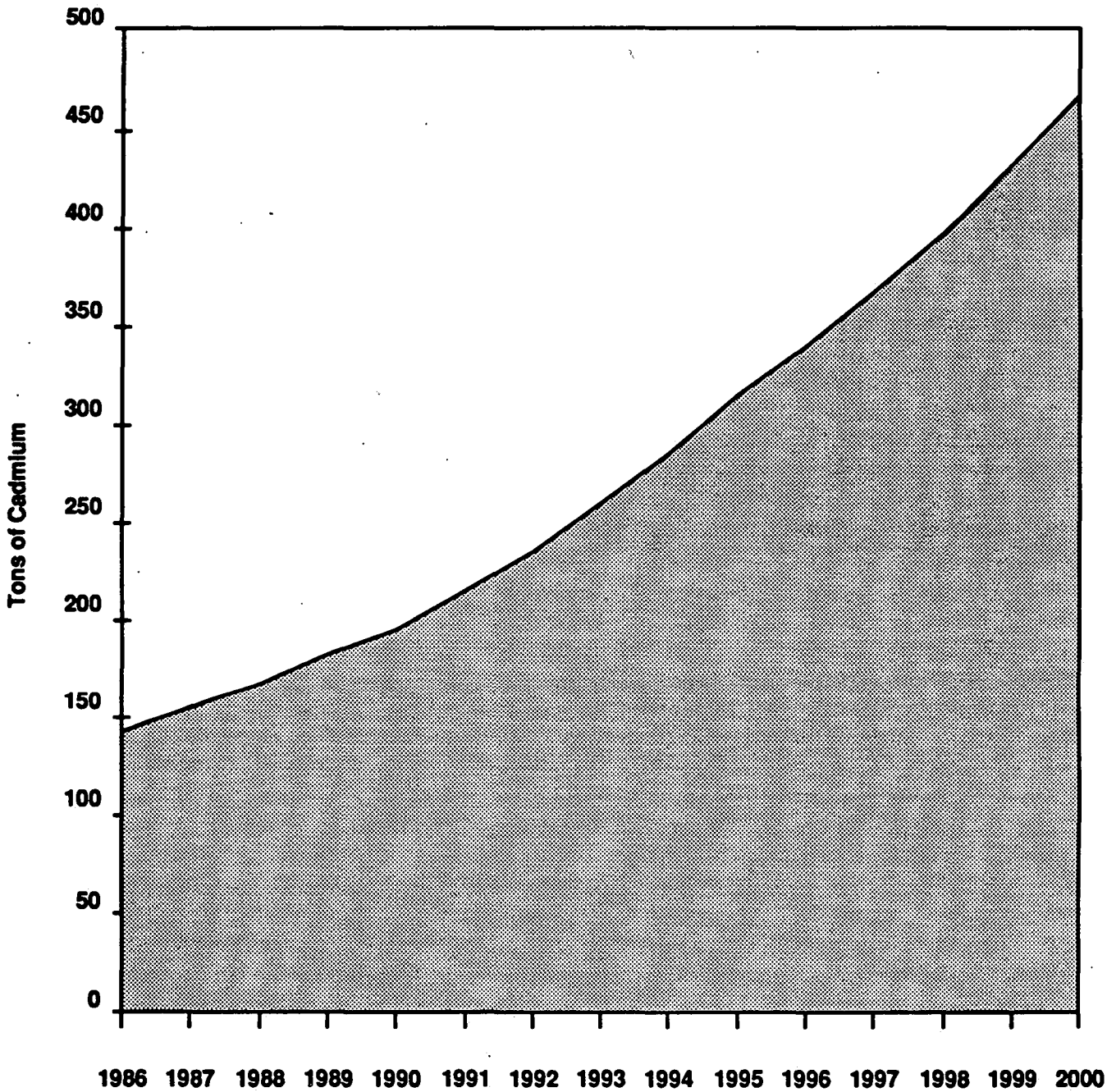
Year	Tons of Cadmium	Year	Tons of Cadmium
1986	143	1994	285
1987	155	1995	314
1988	168	1996	339
1989	181	1997	367
1990	196	1998	397
1991	215	1999	430
1992	236	2000	466
1993	259		

Similar to mercury in mercuric oxide batteries, cadmium is used as one of the electrodes in nickel-cadmium batteries. Therefore, a reduction in the amount of cadmium is

55 Tater, January 1992

56 Distributing nickel-cadmium battery disposal over a 3 to 7 year period after purchase (20 percent in each of five years) has minimal impact on the analysis.

Cadmium in the California Waste Stream From the Disposal of Nickel-Cadmium Household Batteries



not possible without proportionately affecting battery performance. For this reason, the amount of cadmium entering the waste stream from disposal of nickel-cadmium batteries will closely parallel the sales of this type of battery.

Approximately 80 percent of the nickel-cadmium household batteries sold are contained inside of consumer products. Frequently, these batteries are locked inside the products. The useful life of many of these products are designed to be about the same as the life of the battery. Battery and product are disposed at the same time, with the battery still inside the product.

3. Zinc

Estimates for zinc contributed to the waste stream from household batteries also are calculated. **Table III-3,** below, illustrates trends in zinc disposal resulting from primary batteries. Estimated zinc disposal in the California waste stream from household batteries assumes disposal for years 1992 and 2000 are based on sales in 1991 and 1999, respectively.

Table III-3
Zinc in the California Waste Stream
From Household Batteries

Primary Batteries	Tons in 1992	Tons in 2000
Alkaline		
D	839.8	876.4
C	336.6	382.1
AA	497.8	870.9
AAA	41.7	98.2
9V	124.5	183.4
Subtotal	1,840.4	2,411.0
Carbon-Zinc		
D	867.7	566.7
C	166.5	85.6
AA	150.9	114.8
9V	86.9	73.5
Subtotal	1,272.0	840.6
Button Cells		
Mercury Oxide	1.2	0.8
Silver Oxide	1.3	1.7
Zinc Air	6.8	13.2
Subtotal	9.3	15.7
Total	3,121.7	3,267.3

Although the total amount of zinc resulting from household batteries only increases 5 percent from 1992 to the year 2000, the portion contributed by alkaline batteries increases dramatically, by 31 percent for the same period. This is due to the shift of battery use to the smaller sizes and away from the carbon-zinc batteries. This increase of zinc contributed by alkaline batteries is offset by the decrease in contribution by carbon-zinc; therefore, zinc in the California waste stream grows at a fairly low rate overall.

Household batteries in California will contribute approximately 3,267 tons of zinc by the year 2000. However, the amount of zinc used in batteries, as compared to total zinc consumption, is extremely low. Household batteries are estimated to comprise approximately 2 percent of the total zinc contributed by all other uses[57].

Zinc is found in all sectors of the economy. The role of zinc is not obvious to the public because zinc tends to lose its identity in its end products. For example, zinc containing products are used for construction, transportation, electrical, machinery, and chemical purposes. This includes zinc coated galvanized steel sheet, fencing, storage tanks, fasteners, nails, and wire. Zinc anodes are used to protect ship hulls, offshore drilling rigs, and submerged and buried steel works, tanks, and pipes Zinc die-cast parts are used for handles, grilles, bezels, brackets, locks, hinges, gauges, pumps, mounts, and housings. Zinc dust has been used in primers and paints. Zinc has been used to protectively coat nuts, bolts, and small parts. Finally, rolled zinc is used by the U.S. Mint to produce pennies. All of the above consumptive uses of zinc are far more significant than the zinc that is contained in household batteries.

Since household batteries are estimated to comprise such a small percentage of total zinc contributed by all other uses, collection of household batteries will have little impact on reducing zinc levels in the California waste stream. (Also, California is the only state known to have established a standard for zinc, making alkaline and carbon-zinc batteries legally hazardous solely due to their zinc content.) Because of the above reasoning, the remainder of this report will continue to focus on mercury and cadmium as the two primary metals of concern.

57 Zinc Minerals Yearbook, 1989, p.10

4. Trends in Household Battery Metals Loading

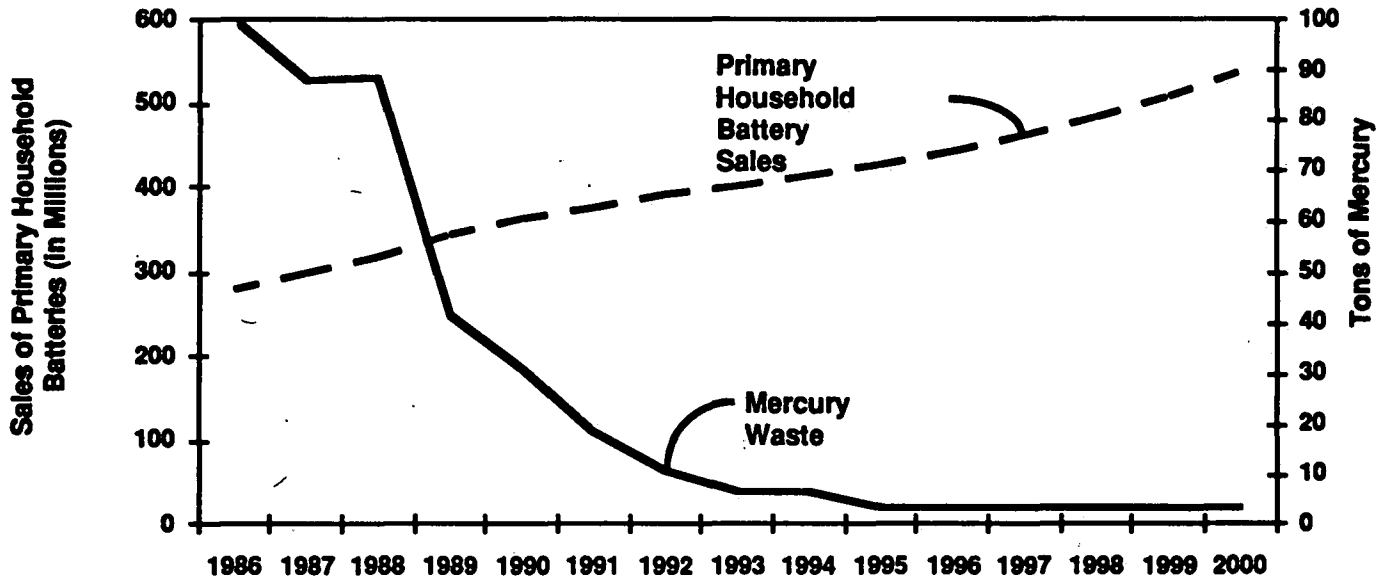
As a way of summarizing the information presented thus far in this section, **Exhibit III-7**, on the following page, illustrates both battery sales data and the amount of mercury and cadmium added to the California waste stream from household battery disposal.

For primary batteries, with mercury being the metal of concern, battery sales have continued to climb; however, changes in battery technology and the development of new battery types has resulted in the near elimination of mercury in household battery waste. From the mid-1980's to the year 2000, sales of primary batteries are projected to increase by more than 100 percent. During this same time, total mercury loading in municipal solid waste from household battery disposal is estimated to fall by more than 96 percent because of low, or no, mercury content household batteries. If mercuric oxide button cells are taken off the market by either manufacturers' initiative or legislative mandate, the remaining mercury from the disposal of household batteries in the year 2000 is estimated to be about 1 percent of the historical 1985 actual level. By the year 2000, with a total ban on mercuric oxide batteries, only one ton a year of mercury would be estimated to enter the California waste stream as a result of household battery disposal.

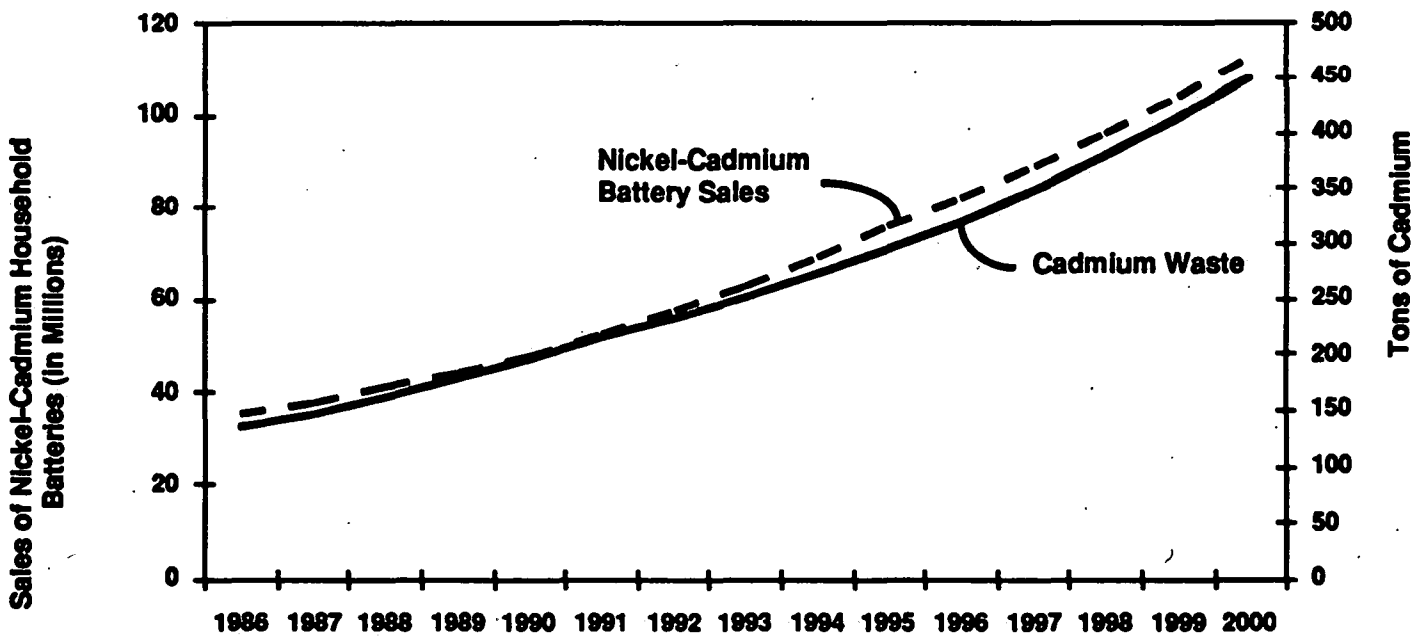
The secondary battery market, where cadmium is the metal of concern, shows a completely different situation. Exhibit III-7 exemplifies how cadmium loading in municipal solid waste will closely track nickel-cadmium sales. In order to break this trend, two approaches are possible and are as follows:

- *Decrease the Number of Nickel-Cadmium Batteries Sold* - Since the amount of cadmium in nickel-cadmium batteries cannot be reduced without affecting battery performance, reducing the amount of cadmium waste is not possible without reducing sales. Alternative secondary battery technologies, such as small sealed lead-acid or nickel-metal hydride batteries, may offer a future substitute for the nickel-cadmium batteries. These alternative types though may pose their own health and environmental risks.

Sales of Primary Household Batteries[a] and Mercury From Their Disposal in California



Sales of Nickel-Cadmium Batteries and Cadmium From Their Disposal in California



a/ With the exception of lithium batteries, all types of primary batteries included in this study have historically contained some amount of mercury.

- *Reduce the Disposal of Nickel-Cadmium Batteries as Waste By Increasing Reclamation of Cadmium* - Reclamation of cadmium is technologically feasible and in practice in Europe and Japan. However, the infrastructure and regulatory framework to efficiently support recycling of nickel-cadmium household batteries in the United States do not currently exist[58].

An important observation is that the amount of cadmium in a single nickel-cadmium battery is equivalent to the amount of mercury obtained from over 400 alkaline batteries. This is a significant factor when determining battery waste management practices if it is assumed that a pound of mercury is equally as toxic as a pound of cadmium. If it is hypothetically assumed that mercury is five times more hazardous than cadmium, pound for pound, the amount of cadmium in a single nickel-cadmium battery would still be the toxic equivalent to the amount of mercury obtained from 80 alkaline batteries.

58 Tater, January 1992

D. Other Sources of Hazardous Metals In The Municipal Solid Waste Stream

While this study focuses on the contribution of household batteries to toxic metals in municipal solid waste, toxic metals also enter the waste stream from other sources. In this subsection, we present data on the total amount of mercury and cadmium consumed in the United States, and identify other sources of mercury and cadmium in municipal solid waste. Although this is not a complete analysis of toxic metals in municipal solid waste, it helps to illustrate the magnitude of the contribution made by household batteries.

1. Mercury Consumption

Mercury is used for a variety of products and processes. The U.S. Bureau of Mines tracks the use of mercury by industry SIC codes[59]. **Exhibit III-8**, on the next page, summarizes the amount of mercury consumed by various industries. These data indicate that during the mid-1980's, all batteries represented over one-half of the mercury consumption in the United States. As a result of the battery industry's efforts to reduce the content of mercury in batteries, the proportion of mercury consumption attributable to all batteries has fallen to less than 15 percent in 1990. Household batteries in 1990 contributed approximately 8 percent to the total use of mercury. **Exhibit III-9**, on page III-26, graphically depicts the amount of mercury consumed by batteries and other uses. Total mercury used in household batteries in 1990 is approximately 92 percent less than the level in 1984. This reduction has occurred even with an increase in national sales of primary household batteries of approximately 30 percent during the same time period.

Many of the consumptive uses of mercury in Exhibit III-9 are industrial in nature. Industrial uses of mercury should not be contributing mercury to the municipal solid waste stream since industrial mercury waste is required to be handled as hazardous waste. Quantifying the amount of mercury contained in municipal solid waste from all sources is a difficult task, one beyond the scope of this study. We would expect that the total amount

59 United States, Department of Interior, Bureau of Mines, *Mineral Yearbook: Mercury 1988*, Annual Review, 1988

Use of Mercury in the United States
(In Tons)

Application	1984	1985	1986	1987	1988	1989	1990
Chemical and Allied Products:							
Chlorine and Caustic Soda Manufacture	279	259	285	343	490	420	272
Laboratory Uses	10	16	22	22	28	20	35
Paint	177	186	197	219	217	212	24
Electrical and Electronic Uses:							
Electrical Lighting	57	44	45	49	34	34	36
Wiring Devices and Switches	104	105	113	145	194	155	77
Household Batteries	778	696	694	297	225	131	62
Other Batteries	351	354	133	291	269	145	55
Instruments and Related Products:							
Measuring and Control Instruments	109	87	69	65	85	96	119
Dental Equipment and Supplies	54	55	57	61	58	43	48
Other Uses	159	94	135	102	156	79	64
TOTAL	2,077	1,894	1,750	1,594	1,755	1,334	794

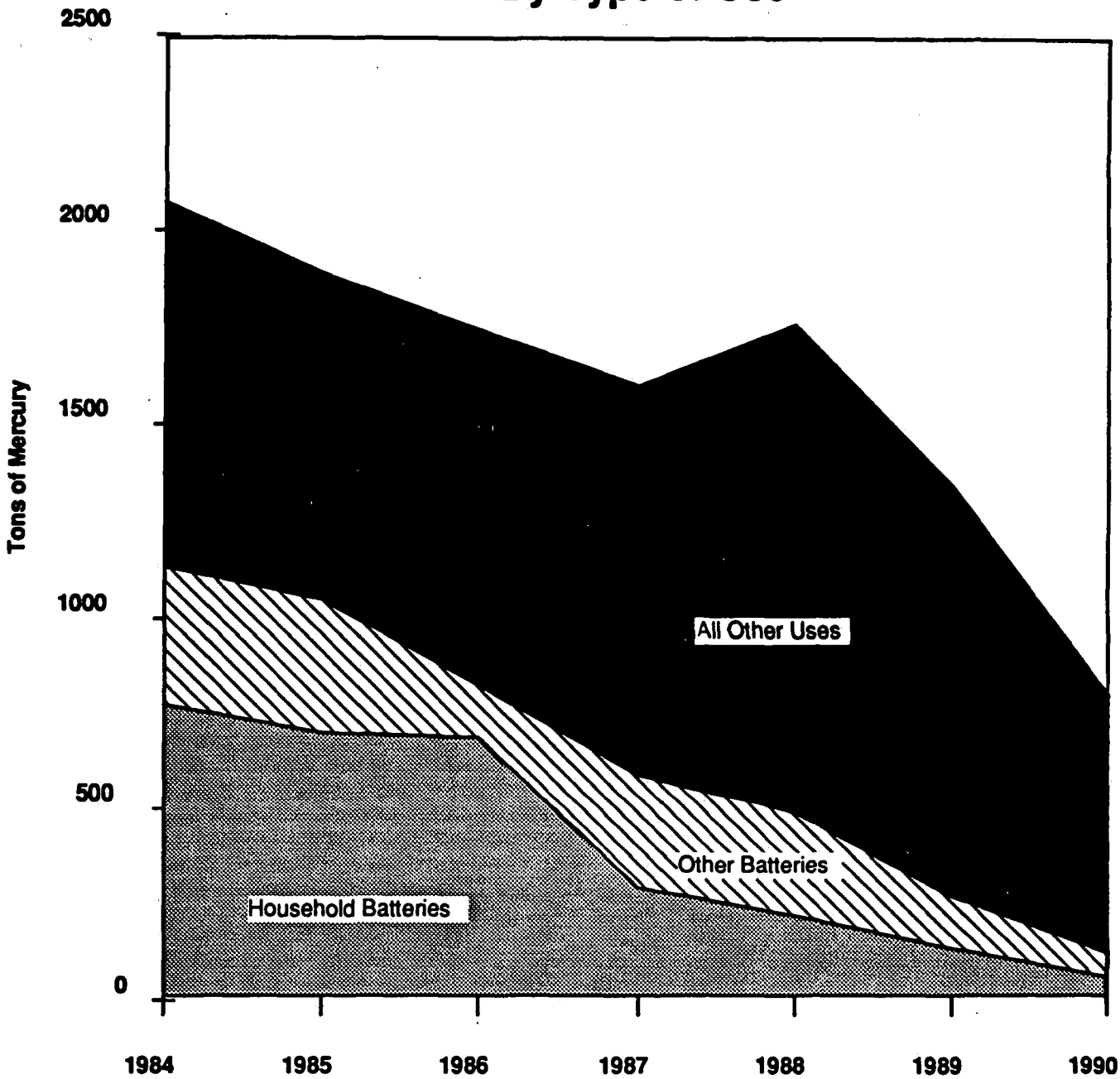
Sources:

United States, Department of Interior, Bureau of Mines, "Minerals Yearbook: Mercury 1988", Annual Review, 1988

Balfour, Raymond L., Material Presented in Meeting with CIWMB and Ernst & Young on October 24, 1991

"Today's Household Battery: Long on Life, Short on Mercury", USA Today, January 26, 1990

Mercury Consumption in the United States By Type of Use



Sources:

United States, Department of Interior, Bureau of Mines, "Minerals Yearbook: Mercury 1988" Annual Review, 1988

Balfour, Raymond L., Materials Presented in Meeting with CIWMB and Ernst & Young on October 24, 1991

Today's Household Battery: Long on Life, Short on Mercury, USA Today, January 26, 1990

of mercury from the disposal of household batteries as a portion of the total mercury found in municipal solid waste would be much greater than the 8 percent stated above. However, the exact proportion is unknown. Some other common mercury-containing products which frequently are discarded with other municipal solid waste include[60]:

- Fluorescent light bulbs
- Thermometers
- Mirrors
- Power control switches for lights and thermostats
- Paints.

Most municipal solid waste characterization studies classify waste by weight or volume within product or material categories (i.e., glass, newspaper, aluminum cans, plastic, etc.), not in terms of toxicity[61]. Such methods of characterizing waste are generally insufficient to quantifiably determine the amount of product specific metals that may be included in the waste stream.

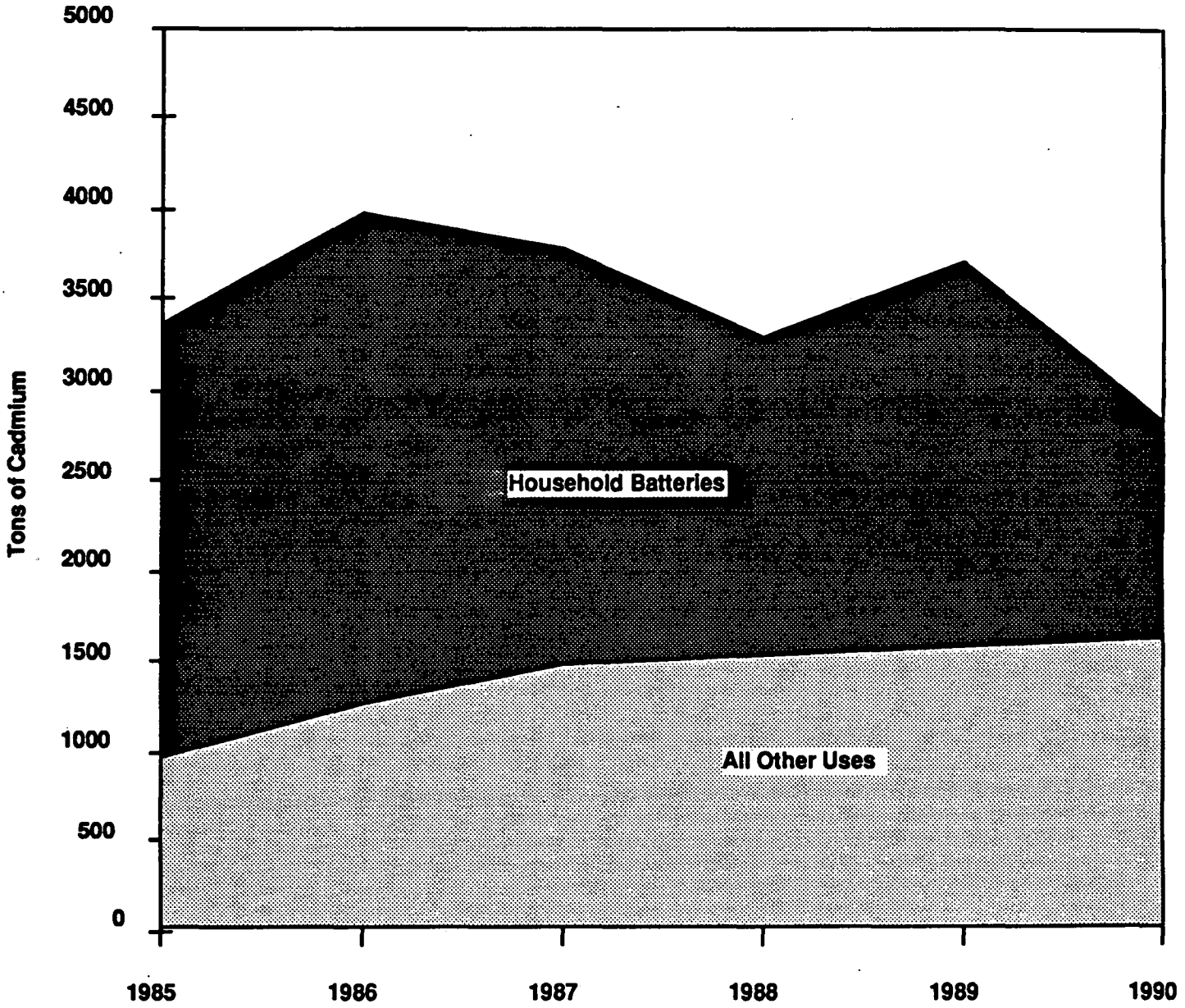
2. Cadmium Consumption

Exhibit III-10, on the following page, presents data on the total amount of cadmium consumed in the United States for household batteries and all other uses. The data indicates that nickel-cadmium batteries represent a growing use of this metal. Once again the situation concerning cadmium is different than that for mercury, whereas mercury use in batteries is a declining portion of total mercury use, the converse is true for cadmium. Therefore, to the extent that concerns presently exist regarding the health and environmental effects of cadmium disposal in municipal solid waste, nickel-cadmium batteries appear to be an appropriate target for that concern.

60 United States, Office of Technology Assessment, Facing America's Trash: What Next for Municipal Solid Waste?, OTA-O-424, Washington, D.C., October 1989

61 Ibid

Cadmium Consumption in the United States By Type of Use



Sources:

United States, Department of Interior, Bureau of Mines, "Minerals Yearbook: Cadmium 1988" Annual Review, 1988

United States, Department of Interior, Bureau of Mines, "Mineral Industry Survey: Cadmium in 1990", May 1991

United States, Environmental Protection Agency, Office of Solid Waste, Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000, January 1989

Cadmium is contained in other household products. For example, cadmium is found in:

- Metal coatings and platings
- Pigments used in plastics, paints, and inks
- Heat stabilizers used in plastics.

Nickel-cadmium batteries are estimated to be the largest source of cadmium in municipal solid waste, representing about 52 percent of the cadmium; plastics are estimated to contribute about 28 percent[62].

From a production standpoint, cadmium is different than other metals. Cadmium is almost always found in zinc ore reserves at a rate of approximately 0.36 percent of zinc[63]. Cadmium is not only a by-product of zinc production, it also must be removed as a purification process in the production of zinc[64]. In some cases, cadmium removal also is required in the production of lead and copper. Because of this relationship, as long as zinc and other non-ferrous metals are produced, cadmium will have to be produced. The production of cadmium is not demand-driven nor is it price dependent. When cadmium use decreases, cadmium prices fall; however, zinc producers will continue to produce cadmium even if they must dispose of the metal rather than sell it. World zinc consumption is expected to increase from 7.2 million tons in 1989 to 8.5 million tons in 2000, an increase of 18 percent[65]. Similar increases in total cadmium production also should be anticipated. This particular joint-product situation for cadmium may have implications for the economic feasibility of cadmium reclamation, as well as the price competitiveness of substitute battery types in the secondary battery market[66].

Nickel-cadmium batteries have become a major component of the cadmium market. In addition, nickel-cadmium batteries are finding a growing number of applications and increasingly are a battery of choice among consumers. These factors should be considered in the development of waste management strategies affecting nickel-cadmium batteries.

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62 Ibid

63 United States, Department of Interior, Bureau of Mines, *Mineral Industry Surveys: Cadmium in 1990*, May 1991

64 Derby, Dr. James V., *The Cadmium Situation From a Zinc-Cadmium Producer's Point of View*, in the proceedings of the Second International Seminar on Battery Waste Management, November 5-7, 1990

65 United States, Department of Interior, Bureau of Mines, *Minerals Yearbook: Zinc 1989*, April 1991

66 Derby, 1990

E. Classification Of Household Batteries As Hazardous Waste

Household batteries contain metals which are known to have adverse effects on human health and the environment. Mercury and cadmium are toxic metals of primary concern in household batteries. Household batteries may contribute more than 8 percent of the total mercury found in municipal solid waste, whereas household batteries may contribute more than fifty percent of the total cadmium found in municipal solid waste.

On the other hand, household batteries are estimated to comprise only approximately two percent of the total zinc contributed by all other uses. Again we would expect that the total amount of zinc from the disposal of household batteries, as a portion of the total zinc found in municipal solid waste, to be greater than the two percent stated above. However, the exact proportion is unknown. Though the focus of this report is still on mercury and cadmium as the two primary metals of concern, it should be noted that 3,267 tons of zinc are projected for the California waste stream in the year 2000 from the disposal of household batteries versus only 3.3 tons for mercury and 466 tons for cadmium, respectively.

Given society's concerns for public health and safety, and the protection of the environment, it is important to determine under what circumstances used household batteries constitute hazardous waste. If designated as a hazardous waste, it is then important to understand how state and federal regulations affect the collection, storage, transport, and disposal of household batteries.

In this subsection, we review test results used by the USEPA and the Waste Extraction Test used in California, to determine whether household battery wastes must be handled as hazardous wastes. Even though some of the component materials of household batteries are known to be hazardous, some household batteries may not be classified as hazardous for a variety of reasons. In general, federal and state laws regarding household hazardous wastes, particularly household batteries, are presently evolving and in some cases are somewhat difficult to interpret.

There currently appears to be ambiguity as to which types of batteries contain dangerous metals. Within California, nickel, silver, and zinc also are regulated metals. As a result, regulatory criteria for determining whether batteries are hazardous or not differs in

California than in other parts of the country. Furthermore, consumers may be receiving conflicting messages on the hazardous nature of household batteries. This is evident by a brochure published by the Toxic Substances Control Program, which states that primary household batteries should be replaced by the "non-hazardous alternative" of secondary batteries[67]. This contradicts the fact that nickel-cadmium rechargeable batteries contain high levels of cadmium, which is considered hazardous, and nickel-cadmium batteries contribute large amounts of cadmium to the municipal solid waste stream. Also, even though all household batteries are presently legally considered household hazardous waste in California, few consumers separate their household batteries for proper disposal.

1. Federal Definition of Hazardous Waste

Hazardous waste is defined by the federal government in the Resource Conservation and Recovery Act (RCRA) of 1976[68], and its subsequent amendments. In addition to defining hazardous waste through a variety of criteria, RCRA also establishes requirements for the collection, storage, transport, and disposal of hazardous waste.

Toxicity Characteristic Leaching Procedure

Effective September 1990, large quantity generators of hazardous waste were required by the USEPA to document that their hazardous waste has been evaluated for toxicity using the new Toxicity Characteristic Leaching Procedure (TCLP). Small quantity generators were required to meet the same requirements by March 1991. The TCLP is used by the USEPA to determine if certain metal- and pesticide-bearing waste must be managed as hazardous waste. The test simulates the acidic conditions in landfills that can potentially leach toxic metals and organics into groundwater.

The results of TCLP tests are useful in assessing the potential risks presented by household batteries in the waste stream. At this time, there is limited information on the performance of various types of household batteries in TCLP tests. The information we have obtained was provided by the Dry Battery Section of NEMA. This data is summarized in **Exhibit III-11**, on the following page, and indicates that these particular battery types tested are within USEPA limits. Mercuric oxide and nickel-cadmium batteries

67 California Department of Health Services, Toxic Substances Control Program, Hazardous Household Products, OPGL-90-04, Sacramento, California

68 Title 40, Code of Federal Regulations, Subtitle C, Chapter 1

Household Battery Toxicity Characteristic Leaching Procedure[a] Test Data

	Mercury (D009)	Cadmium (D006)
EPA Maximum	**0.2 mg/l**	**1.0 mg/l**
Rayovac		
Alkaline (0.1% Hg)	0.072	0.014
Carbon-Zinc ("No Mercury')	0.029	0.522
Zinc Air	0.020	
Silver Oxide	0.150	
Eveready		
Alkaline (Energizer)	<0.025	<0.01
Carbon-Zinc (General Purpose)	0.070	0.17
Carbon-Zinc (Super Heavy Duty)	<0.025	0.20

a/ As prescribed by USEPA TCLP SW846 test procedures.

Sources:

Letter from Raymond L. Balfour, Vice President, Rayovac Corporation to Paul Markowitz, Vermont Natural Resources Agency, September 18, 1991

Balfour, Raymond L., Material presented in Meeting with CIWMB and Ernst & Young on October 24, 1991

are not included on this exhibit. These battery types are generally acknowledged to fail TCLP tests for mercury and cadmium, respectively[69], and therefore are accepted as being hazardous.

From data in Exhibit III-11, it appears that most types of household batteries may not be considered hazardous based on the mercury and cadmium TCLP test data. For a complete analysis, every type and size of battery would have to be tested. In general, the responsibility for determining the hazardousness of a waste is with the generator of the waste. In the case of household batteries, the waste generator is most often a household, although, as discussed in the previous section, non-residential uses of household batteries is also common. Because it is impractical for households to determine the hazardousness of waste, RCRA includes specific provisions for hazardous waste generated by households.

Household Waste Exclusion and Small Quantity Generators

The RCRA states that *household waste*, including household waste that has been collected, transported, stored, treated, disposed, recovered, or reused, is not hazardous waste[70], and therefore, not regulated with other hazardous waste. The law was designed to escape the complexities of dealing with hazardous household wastes.

This leaves open the issue of household batteries which may be disposed of by businesses. For example, if a jewelry store replaces watch batteries as a service to customers, are these batteries considered hazardous waste? Batteries discarded by business, even though they may be the same type as those generated by households, are not necessarily considered hazardous waste. Under RCRA, businesses that generate less than 100 kilograms (220 pounds) of hazardous waste per month are allowed to deposit them in solid waste landfills or have them burned in municipal solid waste incinerators[71]. As a consequence of these exclusions, it may not always be clear whether waste generated from a specific business is classified as hazardous or non-hazardous.

69 Balfour, Raymond L., personal communication, February 4, 1992
70 Title 40, Code of Federal Regulations §261.4(b)(1)
71 Title 40, Code of Federal Regulations, §261.5

2. California Definition of Hazardous Waste

Within California, hazardous waste is defined in Health and Safety Code Sections 25117 et seq. and in Chapter 11, Division 4.5, Title 22, California Code of Regulations. The State's criteria for hazardous waste is more restrictive than federal requirements. For example, in addition to the TCLP test requirements, California also has requirements under a *Waste Extraction Test (WET)*, which is used to determine hazardousness of a waste[72]. **Table III-4**, below, lists the maximum permissible levels of toxic metals contained in batteries for the Waste Extraction Test.

Table III-4
Waste Extraction Test Threshold Limits

Substance	Soluble Threshold Limit Concentration (mg/l)	Total Threshold Limit Concentration (mg/kg)
Cadmium and cadmium compounds	1.0	100
Mercury and mercury compounds	0.2	20
Nickel and nickel compounds	20	2,000
Silver and silver compounds	5	500
Zinc and zinc compounds	250	5,000

While low-mercury alkaline and carbon-zinc household batteries pass TCLP tests, according to the California Department of Toxic Substances Control (DTSC), these batteries would fail Waste Extraction Test limits for zinc[73]. While data are not available on the performance of each battery type in Waste Extraction Tests, the DTSC considers all types of household batteries to be hazardous and, therefore, equally subject to hazardous waste regulation. (See letter response dated March 9, 1992, from the Department of Toxic Substances Control, Appendix D.)

72 Chapter 11, Division 4.5, Title 22, Code of California Regulations, §66261.24(a)(2)(A)

73 Personal communication with Robert McCormick, Department of Toxic Substances Control, with CIWMB and Ernst & Young, March 12, 1992

Some battery collection programs operating in the United States are presently reevaluating the need to collect alkaline and carbon-zinc batteries for hazardous waste disposal because the mercury has been nearly eliminated. This reevaluation also has been prompted by the high cost to dispose of household batteries in hazardous waste landfills. Under current state regulations in California, this course of action would not be possible.

In addition to the more stringent criteria for defining hazardous waste, California does not have the household waste exclusion from hazardous waste designation, nor are small quantity generators exempted from requirements of the regulations[74]. As a result, the same restrictions placed on hazardous waste generally also apply to household hazardous waste, including household batteries. However, there is a state transportation exemption which allows any person to transport hazardous waste to a permitted hazardous waste facility for transfer, treatment, recycling, or disposal, as long as the hazardous waste does not exceed 50 pounds or five gallons, without obtaining a manifest[75].

Household Hazardous Waste

Cities and counties throughout California have recently been required to prepare Household Hazardous Waste Elements (HHWE) which are to be included in county-wide integrated waste management plans [76]. The legal definition of household hazardous waste is broad. The USEPA defines *household hazardous waste* as:

> *Products discarded from residences which contain substances already regulated under RCRA as an industrial hazardous waste*[77].

In addition, the California legislation which requires the preparation of HHWEs generally defines household hazardous waste as:

> *Hazardous wastes, as defined in Section 25117 of the Health and Safety Code, which are generated by households... which should be separated from the solid waste stream*[78].

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74 Letter from Robert McCormick, Department of Toxic Substances Control, to James Gibson, Ernst & Young dated March 9, 1992 (see Appendix C)

75 Health and Safety Code §25163(c)

76 AB 2707 (Chapter 1406 of 1990 Statutes) added Chapter 3.5 to Part 2 of Division 30 of the Public Resources Code (PRC) commencing with §41500

77 United States, Environmental Protection Agency, Office of Solid Waste and Emergency Response, Survey of Household Hazardous Wastes and Related Collection Programs, EPA/530-SW-86-054, October 1986

78 Public Resource Code §41500

It is generally acknowledged that household hazardous waste includes used household batteries[79]. Consumers are being encouraged by the State to dispose of used household batteries with other household hazardous waste.

Disposal of Hazardous Waste in Sanitary Landfills

Over 86 percent of the municipal solid waste generated in California ends up in a sanitary (Class III) landfill. Within California, it is illegal for a landfill to accept hazardous wastes unless it has been approved for that particular waste[80]. Generally, landfill operators and/or waste haulers visually scan the contents of municipal solid waste for the presence of hazardous waste. When found, such hazardous waste is separated from the mixed municipal solid waste and either recycled or disposed as hazardous waste.

Household Battery Collection and Transport

In order to facilitate the collection and reclamation of household batteries, the State of California enacted the Management of Small Household Batteries Act of 1989 (SB 1594)[81]. The Act provides that any collection location or intermediate collection that receives, or any person that transports used household batteries, is exempt from the requirements regarding the receipt, storage, and transport of hazardous waste *if* the batteries are sent to a metal reclamation facility for the purpose of metal recovery.

Presently, there are limited options available for the recycling of used household batteries. Most existing household battery collection programs dispose of household batteries in a hazardous waste landfill. Therefore, the exemptions included in the Health and Safety Code would not apply to these efforts, and the collection, storage, and transport of the batteries would be subject to hazardous waste regulations.

As with most other household hazardous waste, household batteries which are accumulated through household hazardous waste collection programs must be handled, stored, transported, and disposed of as hazardous waste. Similarly, household batteries

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79 The California Department of Toxic Substances Control distributes information booklets which list batteries as a hazardous household waste and suggest that household batteries be disposed of through household hazardous waste collection events

80 Title 14, Code of California Regulations, §17742

81 Health and Safety Code §25216 et seq.

collected by businesses or other private parties also must comply with hazardous waste regulations applicable in California.

The specific requirements for handling hazardous waste are complex, and a detailed discussion is beyond the scope of this study. Regulations governing hazardous waste designation and disposal are included in Chapter 11, Division 4.5, Title 22 of the California Code of Regulations. Because of the complexity of these regulations, requirements to handle collected household batteries as hazardous waste may inhibit the establishment of household battery collection programs. For example, some battery manufacturers want to initiate nickel-cadmium battery collection programs, but have to contend with differing regulation interpretations on the part of hundreds of city and county local governments. Also, the fact that household batteries presently provide limited commercial opportunities for metals reclamation separates household batteries from other kinds of household hazardous waste that may be more recyclable.

IV. Household Battery Waste Management Practices and Economics

IV. HOUSEHOLD BATTERY WASTE MANAGEMENT PRACTICES AND ECONOMICS

This section of the report describes solid waste management practices in California and discusses the effects household batteries have on these practices. The discussion focuses on physical processes and battery pathways in the solid waste stream, and identifies potential risks posed by household batteries in municipal solid waste. In addition, this section describes processes and identifies risks associated with the collection, sorting, storage, and transfer of household batteries which have been separated for disposal as hazardous waste or for metal recovery.

This section is organized under the following subsections:

- Overview of Household Battery Disposal Pathways
- Household Battery Collection
- Disposal of Household Batteries As Municipal Solid Waste
- Disposal of Household Batteries As Hazardous Waste
- Reclamation of Metals From Household Batteries.

A. Overview of Household Battery Disposal Pathways

Currently, approximately 86 percent of California's municipal solid waste stream is landfilled, 12 percent recycled, and 2 percent composted or incinerated. AB 939, the Integrated Solid Waste Management Act of 1989, has changed the approach to solid waste management in California. This legislation mandates state and local governments to utilize a hierarchic approach to meet diversion from generation goals of (1) 25 percent by 1995 and (2) 50 percent by the year 2000. The hierarchy, in order of priority, includes:

- Source reduction and reuse
- Recycling and composting
- Transformation and landfilling.

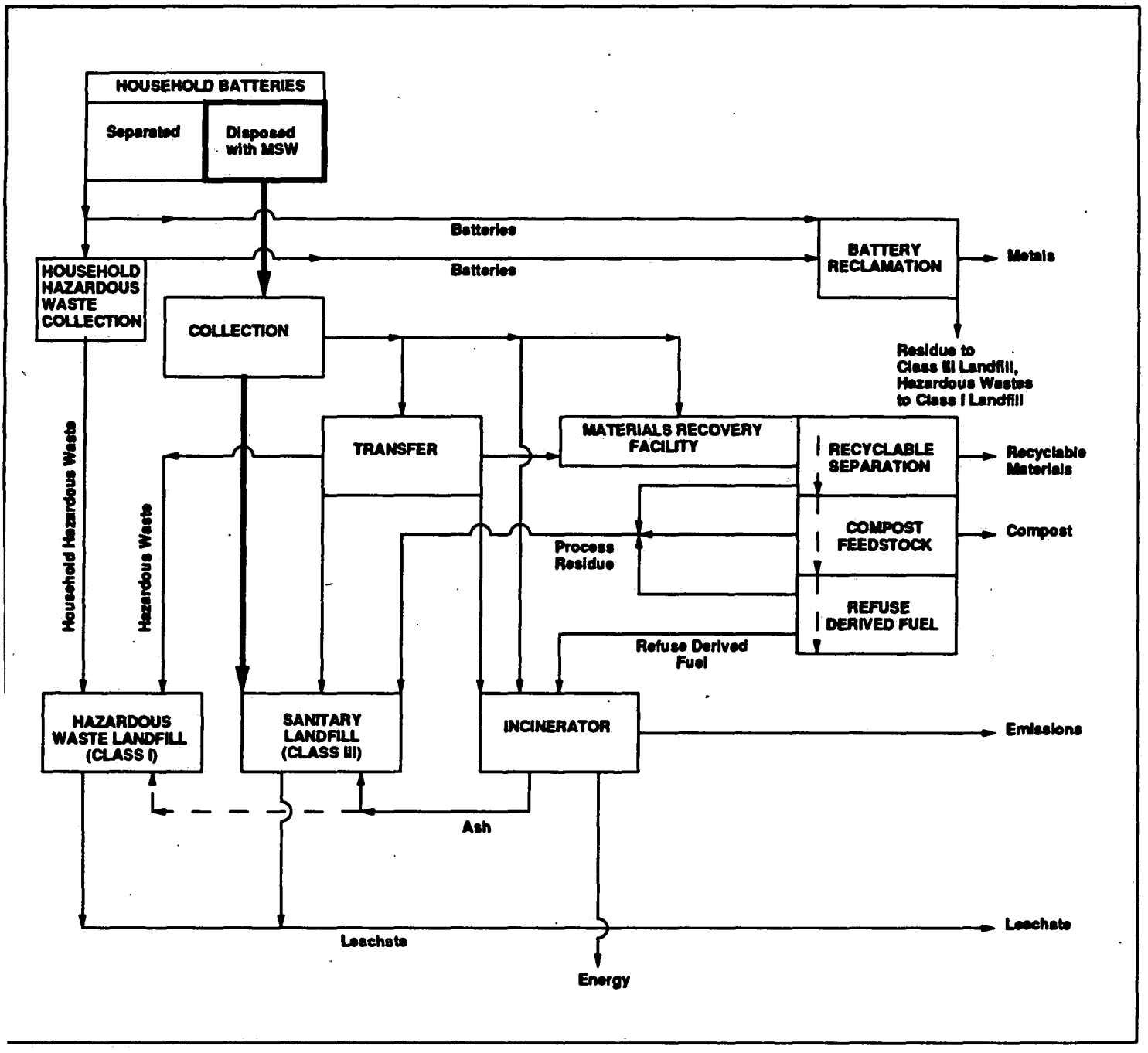
The hierarchy is consistent with the integrated approach adopted by the USEPA.

Household batteries make up only about 0.005 percent, by weight, of municipal solid waste[82]. Within California, household batteries are either disposed with other municipal solid waste, or segregated and brought to a household hazardous waste collection program. Unless there is a household battery reclamation program that recovers materials from batteries, most household battery collection programs take the used household batteries to a hazardous waste disposal facility.

Exhibit IV-1, on the following page, summarizes various pathways that household batteries can follow through the waste stream. The diagram also shows how metals in batteries may end up in the environment through landfill leachate, incinerator emissions, or metal content in compost product. The diagram does not follow batteries that are illegally discarded as litter.

82 Reutlinger, Nancy, and Dan de Grassi, *Household Battery Recycling: Numerous Obstacles, Few Solutions*, Resource Recovery, April, 1991

Household Battery Disposal Pathways



The solid waste management system is complex and household batteries in mixed municipal solid waste can travel many different pathways and be subjected to several different processes before their final disposal. This section examines principle routes which batteries may travel and different processes they can become subject to as part of the waste stream.

The risks from household batteries and the methodologies used to minimize risks are also discussed in this section. It should be noted that risks associated with household batteries in the waste stream are potential risks. Evidence of actual broad based impacts to human health and the environment from the disposal of household batteries in municipal solid waste has not been conclusively documented. Household batteries are assumed to pose risks to human health and the environment because they contain limited amounts of metal substances which are known to be toxic in threshold concentrations.

The majority of Exhibit IV-1 shows potential pathways for batteries disposed in mixed municipal solid waste. This includes the majority of all batteries that residents and businesses discard with other general refuse. Most municipal solid waste collected in California is destined for sanitary (Class III) landfills. The top and left portions of Exhibit IV-1 show pathways of household batteries which have been separately collected without first being discarded in municipal solid waste. Generally, separated batteries are subsequently disposed in a hazardous waste (Class I) landfill, or sent to a metal reclamation facility for recovery of metals.

With the enactment of AB 939, and subsequent amendments to the Integrated Solid Waste Management Act, there has been increased interest in the development and implementation of source reduction, curbside collection of recyclable materials, household hazardous waste collection, material recovery facilities, and composting facilities to meet the State mandated waste diversion from generation goals. As a result, the potential battery pathways in municipal solid waste have become more complex. Transfer stations, and transfer facilities with recyclable materials recovery capability, have become more common with the development of regional landfills. The closing of smaller landfills, due to the promulgation of new regulations that the landfills are not able to meet cost-effectively, also

has promoted the development of additional transfer stations. There are currently approximately 287 transfer stations in California[83].

A relatively new development in California's waste management strategy is materials recovery facilities. "Materials recovery facility" (or MRFs) is a general name applied to facilities designed to process mixed municipal solid waste to: 1) separate recyclable materials, 2) prepare compost feedstock, and/or 3) prepare refuse derived fuel for incineration. The actual number of currently existing *true* MRFs in California is unknown, but relatively small. An accurate count is difficult to make due to the broad potential definition of MRFs. For example, transfer stations which separate some recyclable materials may claim to be MRFs.

Collection of municipal solid waste and recyclable materials are provided either by municipal or county governments, or by private companies through a permit and/or franchise arrangement granted by the local jurisdiction. Most jurisdictions have mandatory collection, although some smaller jurisdictions do not have mandatory collection. Many larger jurisdictions are moving towards the use of automated collection vehicles and containers.

Household hazardous waste collection events, mobile hazardous waste facilities, and also permanent hazardous waste facilities are increasingly becoming part of the solid waste management system. It is generally estimated that household hazardous waste make up approximately 1 percent of municipal solid waste in California. The collection, transportation, packaging, and disposal of household hazardous waste accumulated by household hazardous waste programs can be the single most expensive element of municipal solid waste management practices. The next most expensive practice, a distant second, may be the collection of recyclable materials.

California presently only has three municipal solid waste mass burn incinerators in operation. These are as follows: the City of Commerce, Los Angeles County (360 tons per day), Stanislaus County (800 tpd), and Southeast Regional Recovery Facility (SERRF), City of Long Beach (1,150 tpd). AB 939 does not allow diversion credit for incineration until 1995, and even then, a jurisdiction may only get up to 10 percent

83 California Integrated Waste Management Board, MICROSWIS Database, Numerical List of Facilities in MICROSWIS, February 6, 1992

diversion credit for incineration. While additional incinerators have been proposed, it is uncertain how many facilities will actually be constructed in California's future.

California has about 41 existing composting facilities with the majority being "greenwaste only" composting facilities. With the passage of AB 939, another 210 composting projects of various types are presently planned.

B. Household Battery Collection

This subsection provides an overview of household battery collection program characteristics and strategies, including potential risks associated with collection of household batteries. Section V includes a discussion of the experiences of several existing household battery collection programs.

To prevent household batteries from entering the waste stream as municipal solid waste, a number of jurisdictions have established battery collection programs. There are a variety of methods used to collect household batteries, including collection with other household hazardous waste, curbside collection, and collection at retail outlets. In addition, the types of batteries collected vary between programs. Some programs collect all types of household batteries, while others only collect selected types such as button cells or nickel-cadmium batteries. A trend among some battery collection programs is to not collect alkaline or carbon-zinc batteries because of their low, and declining, mercury content.

As described in Section III of this report, nickel-cadmium batteries are a major source of cadmium in municipal solid waste. However, ni-cad batteries currently represent a disproportionately small share of the household batteries collected through battery collection programs. Data on one collection program determined that only one percent, by weight, of the collected batteries were nickel-cadmium[84]. This is in contrast to the current approximate 10 percent, and growing, market share of household batteries held by nickel-cadmium batteries. A high percentage of nickel-cadmium batteries are sold inside consumer products. Many of these batteries are sealed inside products and are not removable for proper disposal. As manufacturers redesign products to make batteries removeable (some states have passed legislation with this requirement, see Appendix B), it is reasonable to expect that more nickel-cadmium batteries will be collected in the future.

1. Household Battery Collection Methods

The collection of household batteries can be accomplished by one of, or a combination of, the following methods:

84 Tellis Institute Inc., A Cost Analysis of Municipal Waste Landfilling in California, prepared for the California Integrated Waste Management Board, April 1990

- *Household Hazardous Waste Collection* - The most prevalent method of collecting household batteries in California is through city or county sponsored household hazardous waste collection programs. Household hazardous waste can be collected either at permanent facilities, such as recycling centers or transfer stations, or at mobile and periodic collection events. Household batteries are collected along with other household hazardous wastes such as paints, used motor oil, herbicides and pesticides, and cleaning products. Typically, household batteries and other alkaline and corrosive products are packed together for disposal at a hazardous waste landfill.

- *Community Drop-Off Locations* - The collection of household batteries via community drop-off is accomplished by establishing a network of drop-off sites frequented by community residents. Ideal drop-off sites include fire stations, supermarkets, recycling centers, senior and community centers, libraries, and shopping malls. Drop-off locations, which commonly accept all types of batteries, are supplied with containers, signs, and informational material.

- *Curbside Collection* - The collection of household batteries at the curb is incorporated into the regular curbside pick-up of recyclable materials. Residents deposit used batteries in a special container, usually a plastic bag, and place it on top of their bin of other recyclable materials on designated pick-up days. Curbside programs most often target all battery types for collection. Most programs hand sort batteries by type for a combination of hazardous waste disposal and recycling.

- *Return-to-Retailer Drop-Off Locations* - These collection programs provide drop-off locations at major household battery distribution points. Depending on the type of retailer, return-to-retailer locations can either target specific household battery types, such as button cell batteries, or can collect all battery types. For example, retailers who specialize in cameras, watch repair, or hearing aids may collect only the button cell batteries since most button cell batteries are used by cameras, watches, and hearing aids. On the other hand, general merchandise stores which sell a variety of household batteries may collect all battery types. Return-to-retailer collection programs usually provide retailers with a collection bin, signs, and a window decal to foster public recognition. Retailers either market collected batteries directly for recycling, or are provided a pick-up service by the municipality or sponsoring organization.

- *Reverse Distribution* - Reverse distribution entails the collection of used batteries to retailers or product service centers which would be channeled back to product or battery manufacturers for proper disposal or reclamation. The Portable Rechargeable Battery Association (PRBA) and some individual product manufacturers are working in some states to implement reverse distribution collection schemes for nickel-cadmium household batteries. These efforts have been required under selected legislation in other states, however, some programs are proposed to be implemented nationwide.

In addition to these household battery collection methods, a relatively new area of battery collection is targeted collection of household type batteries from commercial and institutional sources such as hospitals, government agencies, industries, businesses, and military bases. For example, the New York City Police Department requires all department employees using communication devices with nickel-cadmium batteries to bring the batteries to a drop-off location when the batteries are discharged. These batteries are then shipped to France for recycling[85]. Non-household applications of household batteries are, in some instances, a significant portion of the household battery market, and may provide an opportunity for concentrated battery collection (e.g., nickel-cadmium).

2. Deposit Systems and Advanced Disposal Fees

In addition to the collection methods discussed above, deposit systems can theoretically provide additional incentives for consumers to properly dispose of household batteries, and advanced disposal fees may potentially help fund costs of disposal and/or reclamation. A brief description of each potential program is provided below.

- *Deposit or Redemption Systems* - Deposit or redemption systems can require distributors, retailers, and consumers to pay a fee on the purchase of a new product to be refunded when used items are returned for proper disposal. Deposit and redemption systems have been applied to plastic, glass, and aluminum beverage containers which are relatively high volume recyclable materials.

- *Advanced Disposal Fees* - Advanced disposal fees may be assessed on the consumer or producer, and can be collected in a manner similar to a sales tax. The fee is derived to cover waste disposal costs, management of hazardous wastes, and administration costs, plus any costs associated with implementation of the program. Advanced disposal fees may be most effective when the product category is broad, and the fee can be applied to the existing tax collection structure in order to achieve relatively low collection costs.

The deposit or redemption system is aimed at promoting the proper disposal of a specific waste product. While deposit and redemption systems have been suggested by some for household batteries, we are unaware of the existence of any such programs in the

85 Florida Department of Environmental Regulation, Solid Waste Section, *Battery Fact Sheet*, July 6, 1990

United States; however, several European countries have implemented deposit programs to achieve high collection rates for mercury and cadmium battery types [86].

The advanced disposal fee is a type of solid waste tax which can be applied on a product to cover its disposal and waste handling costs. Currently, there are no such programs applied to household batteries in the United States, but there are in Europe. For example, Norway assesses a tax of 30 to 45 cents per battery for batteries containing more than 0.025 percent of cadmium or mercury by weight.

In Switzerland, where thirty percent, or more, of spent household batteries are collected, a tax will be imposed on batteries introduced on the Swiss market in order to support financially the costs of recycling. This tax is approximately six percent of the battery cost. The tax will be set so as to cover the costs of battery reclamation using the new Sumitomo technology for reclaiming zinc and mercury from primary batteries. (The Sumitomo technology is explained on page IV-44 of the report.)

The results and the success of the European programs are unknown since they have only recently been implemented. One problem with deposit programs is the relatively weak incentive it provides to the consumer to properly discard a household battery. Effective implementation of deposit or advanced disposal fee systems is partly based on high volume, broad-based packaging, and the ease of administration[87]. The problem with applying similar programs to household batteries to successfully achieve recycling goals are as follows:

- Household batteries, particularly rechargeable batteries, have an extended service life, creating a lag between the time the deposit is paid and the time the refund is received
- A relatively small number of household batteries per consumer are discarded compared to say the volume of beverage containers (i.e. glass bottles or aluminum cans)
- Due to the relatively small number of batteries consumed and disposed, administrative costs for such a program could be prohibitive.

86 Forker, Timothy, *Strategic Approaches to the Used Household Battery Problem: A Report on European Experiences and Their Implications for Action in the United States*, Environmental Action Coalition, November 10, 1989

87 Montavon, Matthew, and Shinn, Paul L., *Taxing the Solid Waste Stream: Revenue Alternatives for State and Local Governments*, Government Research Center of the Government Finance Officers Association, April 1990

For these, and other, reasons, deposit or advanced disposal fee systems may not be considered practical to encourage proper household battery disposal.

3. Risks From Household Battery Collection, Storage, and Transfer

Collection, storage, and transfer of household batteries for recycling or disposal pose risks. The following risks may occur when a number of batteries are concentrated together:

- Ingestion by small children when batteries are collected and stored in the home
- Explosion and fire from improper storage of collected batteries
- Exposure to hazardous materials in batteries.

A discussion of each of these risks is provided below.

Ingestion Danger

Collection and storage of batteries at the household poses certain risks to small children. One of the risks is ingestion of the batteries and health effects associated with toxic components that are inside the various types of household batteries. A battery that is swallowed eventually may pass through the body.

One study on household batteries[88] compared ingestion data on penlight and flashlight dry cell, button-sized cells, coins, Christmas ornaments, and toys. The number of battery ingestions were found to be very small in comparison to the incidence of ingestions overall.

Nearly all cases of ingested batteries have had asymptomatic or non-harmful outcomes. The Carnegie Mellon study summarized the outcome characteristics for several years. The data showed that 0.1 percent resulted in a major (life threatening/life ending) outcome, 1.7 percent resulted in a moderate (self-limiting, longer lasting symptoms), 30.6 percent resulted in minor (self-limiting short-lived symptoms), and 67.6 percent resulted in no symptoms at all. Self-limiting means patients are fine; however, the patients place

88 Carnegie Mellon University, 1989

restrictions on themselves due to their own perceptions of their symptoms. Of all ingestions, battery-related ingestions represent only 0.3 percent.

The study did not find evidence indicating whether concentrating batteries in storage containers in the home for separate waste collection processes will increase ingestions. They did conclude that the number of ingestions could decrease due to the heightened awareness and precautionary storage methods that would occur if a storage program was begun.

Explosion and Fire Hazard

Hydrogen gas can be formed and released from batteries. Gas from batteries stored tightly in a drum will accumulate, and the batteries having residual voltage can cause a spark, potentially resulting in an explosion. Hydrogen gas is highly flammable and explosive and may be generated by reactions between chemicals found in all types of household batteries.

There have been four reports, only one documented case, of an explosion involving a large quantity of stored batteries[89]. The one incident occurred in 1985 when a sealed barrel of batteries exploded on a truck in route to a landfill. Analysis of the incident led to the conclusion that batteries, stored together in a 55 gallon drum, continued to discharge electricity. The electrical discharge produced hydrogen gas which accumulated in the tightly sealed drum. A spark, originating either from an external source, or the batteries themselves, set off the explosion.

Batteries that are not completely discharged may short circuit when in contact with other materials. Heat may be given off sufficient enough to start a fire. Elevated temperatures, electrical sparks, or even static electricity may cause ignition of the hydrogen gas. The accumulation of hydrogen gas can be avoided if batteries are stored in ventilated containers and/or not allowed to make physical contact.

89 VanMaele, Lori, *Household Battery Collection and Storage*, Prepared by the Science and Technology Division of the Legislative Services Bureau for the Michigan Legislature, March 1990

Exposure to Hazardous Materials in Batteries

The strong bases which are the electrolyte solutions in batteries are caustic and corrosive. Direct contact with human skin or mucous membranes can cause chemical burns. In addition, strong basic solutions contribute to battery corrosion and leakage, and reaction to form hydrogen gas. Although mercury and cadmium compounds do not burn skin, they are very toxic when ingested or absorbed. Other methods of improving battery performance without the use of mercury are now being implemented to reduce the use of mercury.

In general, the collection, storage, and transfer of household batteries may present some risks, as described above. However, these risks can largely be eliminated through relatively simple and pragmatic precautionary measures such as storing collected batteries in well ventilated containers, lab-packing batteries for transportation and disposal, and using extra care when handling corroded or damaged batteries.

4. Sorting Household Batteries

Most battery collection programs collect all types of household batteries, although a recent trend is not to collect alkaline and carbon-zinc batteries. For the few types of batteries in which metal reclamation is an option, it is first necessary to separate out household batteries by type. Separation may even be necessary for lithium batteries prior to disposal in a hazardous waste landfill since these batteries should be deactivated to prevent subsequent reaction of the lithium metal. In most instances, household batteries are collected together and then separated by type. Occasionally, button cells will be separated from the larger cylindrical and prismatic batteries during collection.

Separation of household batteries by type is usually performed manually. While some battery types are easily recognizable, button cells tend to have no labelling with the exception of engraved or stamped codes. Battery collection personnel need to be trained to recognize the various types of batteries. Limited research has been conducted to develop automated processes for separating the various types of household batteries. However, more work is required to develop practical techniques of separation[90].

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90 Bruis, W. H. J., *Sorting of Mixed Batteries By Eddy Current and X-Ray Image Analysis Methods*, Nickel-Cadmium Battery Update 90. Report on Seminar, September 1990, Cadmium Association, November, 1990

Battery collection programs which accept all types of household batteries have found that approximately 90 percent of collected batteries are alkaline and carbon-zinc types. There are no reclamation processes available to recover metals from these battery types. In addition, low mercury content alkaline and carbon-zinc batteries have been shown to pass USEPA Toxicity Characteristic Leaching Procedure (TCLP) tests and therefore may not be hazardous according to this test. Again, the California Department of Toxic Substances Control would still consider these primary battery types to be classified as hazardous household waste due to their failing the Waste Extraction Text threshold limits for zinc. The collection of all these primary battery types may significantly add to the cost of separating and reclaiming the minority of household batteries which contain significant amounts of mercury and cadmium.

5. Household Battery Collection Costs

Costs associated with collection of household batteries depends on the method(s) of collection utilized. Collection costs may include staffing, public education and materials, collection containers, packing equipment and supplies, collection and storage space, and other operating and administrative costs. Another major cost component is the cost for transportation and disposal of household batteries.

Section V of this report includes a discussion of several battery collection programs operating throughout the United States. Cost information on these programs is limited, and generally not provided in sufficient detail to allow detailed analysis. Total program costs, including transportation and disposal costs for used household batteries has ranged from $1,840 to $4,840 per ton of batteries collected. In general, the costs to transport and dispose of household batteries has accounted for approximately 30 to 40 percent of the total program cost.

For cities and counties planning to implement battery collection programs, it may be important to make a distinction between collection costs (including collection facilities, education programs, staffing, and operational and administrative costs), and transportation and disposal costs. The former category will likely be a relatively fixed cost with only slight variation depending on the volume of batteries collected; transportation and disposal costs, on the other hand, will vary directly with the amount of batteries collected.

C. Disposal of Household Batteries as Municipal Solid Waste

Waste management practices for municipal solid waste includes collection, transfer, materials recovery, composting, and disposal in landfills or incinerators. Each of these processes are discussed in this subsection as they may relate to household batteries in the municipal solid waste stream.

1. Collection and Transfer

Once collected, household batteries disposed with municipal solid waste are generally transported to a sanitary landfill or to a transfer station for subsequent transport to a landfill. No transfer stations are known to remove household batteries; however, if hazardous materials are spotted in the mixed waste they may be separated for proper disposal.

There are several types of transfer stations which consolidate loads from packer vehicles and self haul loads into specialized transfer trailers for a more efficient trip to the disposal facility. Transfer facilities using trackloaders can potentially crush household batteries against the concrete floor. Facilities using wheeloaders may not face the same risk because the wheeloaders do not normally ride on a layer of solid waste as do the trackloaders.

Some transfer stations may remove recyclable materials which are spotted in scavenging operations. The majority of transfer stations that scavenge for recyclable materials do not scavenge through mixed residential waste. Scavenging is normally done through commercial and industrial sector loads for high grade papers, cardboard, wood, and sometimes metal.

Within California, it is illegal for sanitary landfills to accept hazardous wastes unless the site has been approved for the particular waste involved[91]. Many load check programs provide a visual scan of municipal solid waste at transfer stations or as the waste enters the landfill. When spotted, hazardous waste, such as automotive lead-acid batteries, are removed from the waste stream. Because of their small size and relatively small

91 Title 14, California Code of Regulations, §17742

numbers, load check programs do not inspect for household batteries. Consequently, household batteries disposed in municipal solid waste are not separated prior to disposal. Hazardous materials removed at transfer stations or through load check programs are normally sent to a Class I hazardous waste facility, or recycled, if recycling opportunities exist.

2. Materials Recovery Facilities (MRF)

Material recovery facilities are a relatively new component of municipal solid waste management. Currently, there are relatively few materials recovery facilities in California handling a small percent of the municipal solid waste. Many more materials recovery facilities have been proposed and should be anticipated as municipalities work to meet diversion goals specified in AB 939.

Recyclable materials and hazardous wastes, including most household batteries, could be removed from mixed municipal solid waste through a materials recovery facility. Materials recovery facilities are essentially a waste processing facility that can serve a number of purposes including one or more of the following:

- Recover recyclable materials
- Produce a compost feedstock
- Produce a variety of refuse derived fuels (RDF).

Materials recovery facilities can process mixed residential, commercial, and/or industrial waste streams, or wholly source-separated commingled recyclable materials.

An *intermediate processing center* (IPC) is a name sometimes given to a materials recovery facility that only processes the source separated recyclable portion of a waste stream. Depending upon the product the materials recovery facility processes, other names given to materials recovery facilities include *compost feedstock preparation facility, refuse derived fuel (RDF) facility, alcohol feedstock preparation facility, mixed waste processing facility, and/or automated recyclable scavenging facility.*

Household batteries entering a materials recovery facility with a mixed municipal waste stream, where recyclable materials are hand sorted and/or removed by automated

process equipment, can travel many different paths. The potential pathways, separation efficiencies, and ultimate disposition of household batteries depend upon the number, type, and sequence of intermediate processes.

The non-recyclable component of the municipal solid waste stream is called *process residue*. Process residue is disposed in a sanitary landfill. If the materials recovery facility also prepares a compost feedstock or refuse derived fuel from the mixed municipal waste stream, household batteries, under most current process designs, would likely be separated and disposed in a Class III landfill along with the process residue (non-product fraction).

Current materials recovery facilities which are designed to produce fuel and compost feedstock do not remove household batteries as a homogeneous product. Household batteries are usually commingled with the *inerts* or *heavies* fraction of the process residue. If screening equipment is used to produce compost feedstock, the household batteries tend to aggregate in the *undersize* fraction (also a process residue).

The pathway traveled by household batteries depends on the system process design used to separate and produce desired products. The predominate processing technologies commonly utilized to separate recyclable materials, produce compost feedstock, or produce refuse derived fuel from mixed residential, commercial, and/or industrial waste are described below.

Manual Sorting Systems (Hand Sorting)

The predominant method of removing recyclable materials from municipal solid waste is a *positive sort*. In a positive sort, the item (e.g., aluminum can) targeted for separation is *removed* from the waste stream in the sorting process. In a *negative sort*, the material that is targeted for separation is left in the process stream and the remaining material is removed. For hand sorting operations that recover recyclable materials and process mixed residential waste, both the recyclable materials and hazardous materials are normally removed by the positive sorting method.

Most manual systems use some form of mechanical equipment for bulk materials handling and product packaging. Most materials recovery facilities include a combination of mechanical and manual systems. Even the most rudimentary hand sorting systems will utilize a magnetic separator for removal of ferrous materials.

One very serious risk associated with hand sorting recyclable materials and household hazardous waste from the mixed municipal solid waste stream is the existence of hypodermic needles in the waste stream, particularly in mixed residential waste. The primary risk to the hand sorters who are removing recyclable materials and household hazardous materials is getting stuck and being exposed to hepatitis rather than being exposed to household batteries. There also is a concern of exposure to AIDS from hand sorting, although little is known about the ability of the AIDS virus to survive in municipal solid waste. Most operators of mixed waste facilities consider the risk from hepatitis far more serious than any risk from exposure to household batteries.

Technical issues and policy decisions on manual separation need to be assessed to determine whether the efficiencies derived from hand sorting for household batteries are justified in light of potential hazards to workers. Mechanical processes exist that could remove most household batteries, along with other process residue, from the mixed waste stream. Mechanical processes would add to the capital cost (fixed costs) and to the annual operational and maintenance costs (variable costs) of the facility. Methodologies that have been recommended to minimize risk of exposure to hazardous materials include eliminating hand sorting for both recyclable materials and hazardous materials and automating a materials recovery process with a series of magnetic separators, screening, and/or air density separation equipment.

Mechanical Unit Process Systems

Mechanical unit process systems can be categorized into functional groups which the solid waste processing industry recognize. Many types of process equipment can have an impact on batteries while processing a mixed waste stream, while other types of processing equipment will have no effect on batteries in the waste stream. **Exhibit IV-2,** on the following page, lists the main unit functions and associated process equipment for mechanical processes.

Materials recovery facilities utilize a number of unit process operations commonly used to separate recyclable materials, prepare a refuse derived fuel, or prepare compost feedstock. Some of these processes can be used to sort and separate household batteries. Unit processes for materials recovery facilities are normally designed to provide *progressive fractionation* of the waste stream to recover recyclable materials, or produce a

Mechanical Process System Design
Functional Requirements and Associated Process Units

Functional Element	Process Equipment
Receiving and Storage	Pit and Crane Tipping Floor and Loader
Bulk Material Handling	Conveyors Rubber Belt Pocket Belt Apron Conveyors Drag Flight Vibrating Conveyors Screw Conveyors Pneumatic Conveyors
Open Bags and Liberate Contents, Size Reduction Prior to Mechanical Separation	High Speed Shredder Low Speed Shredder Flail Mill Trommel
Size Separation	Trommel Screen Disc Screen Vibrating Screen
Extract Ferrous Metal	Magnetic Separators
Density Separation (Heavies/Lights)	Air Classifier Air Knife Air Table/Stoner
Separation By Shapes or Ballistic Characteristics	Friction Belts Bounce and Adherence
Separation By Electromagnetic Characteristics	Metal Detector Eddy Current Separator
Secondary Size Reduction to Facilitate Processing	Grinding/Milling Machines Secondary/Tertiary Shredders
Product Packaging	Balers Metal Nuggetizers Non-Ferrous Biscuiting RDF Densification Pelletizers Cubers Bisquitters

Source:
Rhys, H. , Rhys and Associates, personal communication with E. Tseng, February 1992

refuse derived fuel or a compost feedstock. Progressive fractionation refers to the successive application of unit process operations to split a heterogeneous waste stream into several well defined homogeneous waste streams.

An example of progressive fractionation is taking a heterogeneous waste stream, consisting of paper and ferrous metals, and passing it under a magnetic separator. The heterogeneous waste stream is split into two homogeneous waste streams by the magnet. The magnet removes the ferrous material putting it into one stream, and the nonmagnetic paper material continues as the other fractionated waste stream.

Most of the higher grade refuse derived fuels and compost feedstocks use a progressive fractionation design, utilizing a combination of magnets, sizing screens, and air density separators to remove the inorganic fraction of the waste stream. The inorganic portion of the waste stream consists of glass, rocks, bricks, metals, and items such as household batteries.

Shredders and flail mills have the greatest probability of breaking open battery casings when struck by the hammer or flail. This would be particularly true with high speed shredders. Other unit processes and equipment may not have a high physical impact on the batteries, but each unit process will govern which subsequent fractionated waste stream the household batteries will be concentrated. Bulk handling conveyer equipment merely transport materials and do not process the material.

From a process standpoint, increased heavy metal exposure from smashed batteries would be higher for facilities that used high impact and/or high energy size reduction equipment, such as a high speed horizontal shaft hammermill or shredder, as compared to a facility that used a slow speed, lower energy/impact size reduction equipment, such as a slow speed shear shredder. Household batteries which have been crushed, shredded, or otherwise damaged may present a greater opportunity for metals to escape into the environment when landfilled or composted.

The determinate factors that govern which fraction of the waste stream batteries will culminate in depends on the unit process sequencing and subsequent recombination of fractionated process streams and outputs. Three physical properties of household batteries, density, size, and magnetic property, control process fractionation.

Only some batteries can be removed by magnets because only some household batteries are magnetic. The properties of density and size can be used to concentrate batteries into a residue waste stream so that they will not be included in the compost feedstock or refuse derived fuel. Household batteries tend to be concentrated in the *undersize* fraction when a sizing screen (4 inches or larger) is used in the mechanized process stream. Household batteries also tend to be classified into the *heavies* fraction by air density process equipment. **Table IV-1**, below, shows the density of some typical household batteries. The density of all household batteries is greater than 2.5 grams per cubic centimeter, the density of glass. As a result, household batteries tend to be separated into the *heavies* fraction of the waste stream, along with glass, rocks, and ceramic pieces.

Table IV-1
Household Battery Density Characteristics

Battery Type	Size	Density (g/cm^3)
Alkaline	D	2.60
	C	2.60
	AA	2.93
Mercuric Oxide	Button	4.27
Silver Oxide	Button	5.48
Nickel-Cadmium	C	2.86
	AA	3.08
	AAA	2.92

The concern of the existence of a shredder in process design must be examined in relationship to the shredder location in the process train and the function design of the shredder. As an example, if there is sorting of the waste stream and the batteries are removed prior to the waste stream being shredded, the concern would be lower than if the waste stream was first processed through the shredder before removing the batteries.

Through the proper sequencing of unit processes in a materials recovery facility, it may be possible to process municipal solid waste to separate most household batteries from waste destined for composting or incineration. Household batteries collected with other

process residue would then be disposed of in a sanitary landfill. Disposing of household batteries in landfills may be preferable to incineration or composting, since both of these operations create a greater potential for metals to escape into the environment.

3. Landfills

Sanitary landfills have traditionally been defined as an engineered method of disposing solid wastes on land in a manner that protects the environment by spreading the waste in thin layers, compacting it to the smallest possible volume, and covering it with soil by the end of each working day[92]. Following burial and compaction, the organic portion of the waste material is degraded by soil micro-organisms into more stable compounds.

Landfill technology has advanced significantly in the past 10 to 15 years. Older landfills were often uncontrolled *open dumps* with few pollution controls. Open dumping frequently resulted in unsanitary conditions, methane explosions, and releases of hazardous substances to surface and ground water and the atmosphere. Old landfills comprise as much as 22 percent of the sites on the Superfund National Priorities List established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)[93].

Modern landfills, by contrast, are required to include a variety of pollution control features such as synthetic or clay liners, leachate collection and treatment systems, and methane gas collection systems designed to minimize and detect releases of potentially problematic substances[94]. In 1984, the first of a series of amendments to State regulations took effect which govern land disposal of municipal solid waste[95]. Currently, there are approximately 370 active landfills in the State. As of 1990, only three landfills have received permits under the new regulations. These landfills have a combined capacity of 1,330 tons per day, less than 2 percent of the municipal solid waste generated in the State[96]. Currently, an additional 24 sanitary landfills are proposed with permits pending[97].

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92 Robinson, William D., The Solid Waste Handbook: A Practical Guide

93 Office of Technology Assessment, 1989

94 Ibid

95 Title 23, California Code of Regulations, Chapter 3

96 Tellus Institute, A Cost Analysis of Municipal Waste Landfilling in California, prepared for the California Integrated Waste Management Board, April 1990

97 MICROSWIS, February 1992

Landfill Decomposition Processes

Biological and chemical degradation of solid wastes in landfills occur in three distinct decomposition phases. In the first stage, the degradable organic fraction reacts with the oxygen trapped during the landfilling process to form carbon dioxide and water. This is accompanied by heat and growth of the degrading organisms. Part of the carbon dioxide can dissolve within the water to form a weak acid that can dissolve other minerals.

After the oxygen is fully consumed, the second stage of decomposition begins. In the second stage where anaerobic degradation occurs, the large organic molecules present in food, paper, and similar wastes are broken down into simpler molecules, including hydrogen, ammonia, carbon dioxide, and inorganic acids. Carbon dioxide levels can reach as high as 50 to 90 percent of the gas generated. Facultative organisms that survive in both oxygen and non-oxygen environments account for the degradation of most of the organic solid wastes in the landfill, and also produce water soluble organic acids from the hydrolysis of complex organic solid wastes.

In the third decomposition stage, which is also anaerobic, methane-forming micro-organisms utilize the carbon dioxide, hydrogen, and organic acids to form methane gas and other products. During the third stage, about one-half of the gas produced is carbon dioxide and the other one-half is methane. Total methane production depends on waste composition and the growth conditions for the bacteria inside the landfill.

In addition to the biological decomposition processes, chemical processes also occur. For example, ferrous and other metals may be oxidized. Battery casings may rust and degrade to varying degrees depending on surrounding conditions. Acidic liquid waste products of micro-organisms can increase chemical activity within a landfill. Inorganic materials such as metals can change under chemical reactions and may become associated with the liquid or water phase. Since municipal solid waste usually forms a very heterogeneous mass of size and composition, and other factors are complex, variable, and difficult to assess, it is difficult to predict accurately all the biological and chemical activity that occurs within a landfill.

The migration of metals in unlined landfills will be affected by the soil type and the hydrology of the area. An acidic environment is likely to produce a higher concentration of metals in leachate. A high rate of flushing may dilute the metal concentrations and/or

increase the flow of metals into leachate[98]. The State of Vermont, in preparing a waste battery management plan, found that recent investigations and reports are inconclusive regarding the environmental impact of disposing batteries in landfills. It is generally believed that certain metals, such as mercury, would be bound in soil and not released rapidly from landfills, although long-term impacts are difficult to predict[99].

Modern Landfills

Modern landfill practices have vastly improved to minimize the amount of degradation and control the escape of substances from the landfill. Greater compaction has been achieved which result in less trapped oxygen in the landfill. This limits the first aerobic stage of decomposition. Air does not penetrate a well-compacted landfill to any extent.

Newer landfills with liners and leachate collection systems contain the municipal solid waste in daily cells. Modern landfills which claim to compact the materials to over 1,200 pounds per cubic yard are so densely compacted to save space that conditions remain essentially anaerobic once the limited amount of trapped oxygen is consumed. Surface runoff control designed for modern landfills and daily cover over the disposal cells minimize the amount of moisture entering a landfill. The modern design and operational procedures have made the landfills into more of an entombment rather than a controlled bio-reactor for anaerobic decomposition.

Modern landfills that have gas collection systems installed remove much of the moisture from the landfill in the form of water vapor. The moisture is collected along with the gas. The condensed waste water can be treated and discharged into sewers, or hauled off site for treatment as a hazardous waste. The removal of moisture through the landfill gas collection system also can retard decomposition in the landfill.

Household Batteries in Landfills

Household batteries in modern, highly compacted, and relatively moisture-free landfills do not degrade as much as they would in the older landfills where the batteries are

98 Vermont, Agency of Natural Resources, *Vermont Waste Battery Management Plan*, Final Draft, November 12, 1991

99 Ibid

subjected to the by-products of intense chemical and biological decomposition of the organic fraction. Unless a landfill is going to be mined or exhumed for remediation purposes, the landfill is presently the final destination of household batteries in the solid waste system. Should heavy metals be leached from batteries, modern landfills have leachate collection systems which are designed to remove and treat the leachate.

Household batteries in older unlined landfills without leachate collection systems may pose a potential risk to the environment. The battery industry has indicated that there is no known instance in which the disposal of household batteries has been shown to have caused any environmental harm or threat to human health. Battery manufacturers have pointed to a number of studies conducted during the 1970's and 1980's which generally concluded that there are no environmental or health reasons for removing batteries out of the household waste stream[100].

Concerns regarding toxic metals in municipal solid waste have identified mercury, lead, and cadmium as the primary metals of concern. However, the state of knowledge about potentially toxic substances in municipal solid waste is uncertain. Little is known about the distribution of toxic substances in various products, what exposures during or after disposal are sufficient to cause problems, and what relative risks these substances pose when landfilled[101].

4. Incineration

There are only three waste-to-energy incinerators operating in California, and one of these in the City of Commerce primarily processes commercial and industrial waste. Waste incinerators in California are mass burn (RDF-1) facilities which incinerate waste with minimal pre-processing.

Fuel Processing

Municipal solid waste can be processed into many different forms, so the energy value may be realized and emission quality controlled. Each type of refuse derived fuel (RDF) subjects the waste stream to different processes that will create or reduce risks from

100 National Electrical Manufacturers Association, Written Statement of the National Electrical Manufacturers Association and the Battery Products Alliance Concerning Household Battery Disposal, no date

101 Office of Technology Assessment, 1989

household batteries. **Exhibit IV-3**, on the following page, shows the different solid waste fuel classifications used by the American Society of Testing Methods (ASTM) and used by the solid waste industry.

Currently, there are no processed fuel incineration facilities in California. If RDF facilities are built, the battery pathway would be dependent upon the process design. If household batteries are part of the non-fuel process residue, they would likely end up in a Class III sanitary landfill. Because no unit process is 100 percent efficient, even a processed RDF stream may have a small amount of household batteries in its fuel stream which could potentially end up in a RDF incinerator. If household batteries are not separated into the non-fuel stream, they will be incinerated. This is the fate of household batteries in municipal solid waste destined for California's existing mass burn incinerators.

In 1984, research groups of the Tokyo Metropolitan Government reported results of a study on mercury emissions from urban incinerators and mercury concentrations in ambient air[102]. The groups' reports showed that while levels of mercury in the ambient air were below the World Health Organization standard, a very strong correlation exists between the level of mercury emissions from municipal incinerators and the number of household batteries put into incinerators. A similar correlation between mercury emissions and the number of household batteries in municipal incinerators has been established in Sweden.

The Japanese and Swedish studies indicate that lower emissions of metals in air, and lower concentrations of these metals in the residues from incineration facilities can be achieved by removing household batteries from the waste stream prior to incineration.

Table IV-2, on page IV-28, compares the total measured heavy metals in as-received municipal solid waste to the amount of heavy metals in processed fuel after heavy metals removal by the National Recovery Technologies (NRT) process. The NRT technology is an enhanced fuel process which creates a fuel rated between RDF-2

102 *Household Batteries: Management or Neglect?*, A Staff Report to the Chairman of the New York Legislative Commission on Solid Waste Management, Albany, New York, September 1988

Refuse Derived Fuel (RDF) Classifications

Classifications	Description
ASTM Classification	
RDF-1	Municipal solid waste used as fuel in as-discarded form, "Mass Burn Fuel"
RDF-2	Municipal solid waste processed to a coarse particle size with or without ferrous metal separation, "C-RDF (Coarse or Crude RDF)"
RDF-3	Municipal solid waste processed to 95 percent by weight to less than 2 inches and from which most metals, glass, and other inorganics have been removed, "F-RDF (Fluff or Utility Grade RDF)", also called "Mixed MSW Compost Feedstock"
RDF-4	Municipal solid waste processed into a powdered form, 95 percent by weight minus 10-mesh screen, and from which most metals, glass, and other inorganics have been removed, "P-RDF (Powder RDF)"
RDF-5	Municipal solid waste that has been processed and densified into pellets, cubes, or briquettes, can be used as compost bulking agent, "D-RDF (Densified RDF)"
RDF-6	Municipal solid waste processed into a liquid fuel, "Liquid Synfuel" or "Biofuel"
RDF-7	Municipal solid waste processed into a gaseous fuel, product of bio/pyro-synthesis, "Syngas" or "Gaseous Synfuel"
Non-ASTM Classification	
PEF	Municipal solid waste processed into a fuel without shredding, (ferrous removal and minimal screening to remove undersize), "Processed Enhanced Fuel" or "Modified Mass Burn"
W-RDF	Fibrous de-watered pulp with most of the non-combustibles removed

Source:

Summarized from UCLA Municipal Solid Waste Management Technology Course Materials, E Tseng and Associates

and RDF-3. Table IV-2 compares the impact of fuel processing on cadmium and mercury levels in the waste. Solid waste was processed by the NRT technology and then incinerated at different locations. Minimal PEF (between RDF-2 and RDF-3, but without shredding) processing can significantly reduce the total measured heavy metals in the as-received municipal solid waste.

Table IV-2
Total Measured Heavy Metals in Processed and Unprocessed Waste
(Pounds Per 1,000 Tons)

Toxic Metal	Nashville	Salem
As-Received MSW (Mass Burn)		
Cadmium	16.2	9.5
Mercury	12.2	9.5
NRT Processed to Remove Heavy Metals (PEF)		
Cadmium	5.3	1.5
Mercury	8.6	0.024

Table IV-3, on the following page, summarizes the impact of removing heavy metals by processing the municipal solid waste on *unabated* stack emissions at two waste-to-energy facilities. The incineration of processed fuel is compared to the incineration of as-received (RDF-1) mass burn fuel where there is no separation of heavy metals.

Table IV-3
Heavy Metals in Unabated Stack Emissions
(Pounds of Pollutant Per 1,000 Tons)

Toxic Metal	Nashville	Salem
Incineration of As-Received MSW (RDF-1)		
Cadmium	15.1	5.5
Mercury	12.2	0.032
Incineration of NRT Processed Fuel (PEF)		
Cadmium	8.5	4.5
Mercury	3.6	0.008

The above data indicate that the amount of cadmium and mercury is significantly reduced in stack emissions when the municipal solid waste is processed removing magnetic material and some inerts. In addition, data on fly ash from Minnesota incinerators show higher levels of cadmium from mass burn facilities than RDF facilities[103]. Since most household batteries can be removed from the waste stream by relatively simple processing in a materials recovery facility, the risk tradeoff centers around whether household batteries that are removed and disposed of in a sanitary landfill pose a greater or lesser risk than when the batteries are incinerated, with metals ending up in ash and emissions.

Incinerator Ash and Emissions Control

Metals are not destroyed by combustion but are altered into different forms, depending on the metal. Metals that have a high boiling point and do not volatilize easily are likely to become incorporated into bottom ash. Metals with lower boiling points are more likely to become entrained in the flue gas and, depending on temperatures and pollution control equipment, to be captured in fly ash or emitted into the environment. Most heavy metals, including mercury and cadmium, are volatilized in elemental form during incineration. Volatilized metals are entrained in the flue gases, and as the gases cool, the metals condense either onto fly ash particles or into a homogeneous material. Mercury is an exception among the heavy metals. Mercury is often present in flue gases in

103 Arnold, 1991

the form of mercury chloride. Mercury chloride has a lower condensation point than elemental mercury and other metals, so the gases have to be cooled to a greater extent before mercury chloride will condense onto fly ash particles[104].

The disposition of metals in bottom ash, fly ash, and incinerator emissions is dependent on the specific characteristics of the incinerator, processed fuel, and emissions control equipment. Existing pollution control equipment can be effective at removing particulates and gases that contain metals originally found in household batteries. Current dry and semi-dry air pollution control systems can collect 95 percent or more of the metals found in municipal solid waste, except for mercury. A dry scrubber plus baghouse can achieve 75 to 85 percent mercury control, and a dry scrubber plus electrostatic precipitator can achieve 35 to 45 percent mercury control[105]. The choice of the most effective mercury control technology is still a controversial subject.

In December 1989, the USEPA published proposed regulations for municipal waste combustors which included a requirement that all dry cell batteries be kept out of incinerators. The proposal was based on concern about mercury. In its final rules published in February 1991, the USEPA confirmed that it had decided *not* to require mandatory programs for separation of household batteries in the municipal waste combustor standards. The USEPA noted, however, that communities who want to remove specific mercury-containing materials from the waste stream may want to target mercuric oxide batteries[106].

Ash from incinerators in the United States typically are 15 to 30 percent by weight and 5 to 15 percent by volume of the original municipal solid waste. Most of the volatile metals, including mercury and cadmium, tend to be more concentrated in the fly ash. According to the USEPA, about 36 percent of all ash goes to monofills, 17 percent is co-disposed with municipal solid waste, and the fate of the remainder is unknown[107]. In general, incinerator ash that is non-hazardous will end up in a Class III sanitary landfill. Incinerator ash that tests hazardous will end up in a Class I hazardous waste landfill or may be treated and disposed in a Class II monofill.

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104 Office of Technology Assessment, 1989

105 Arnold, Karen, Household Battery Recycling and Disposal Study, Minnesota Pollution Control Agency, June, 1991

106 Balfour, 1991

107 Office of Technology Assessment, 1989

5. Compost Operations

Table IV-4, below, shows the status of existing and proposed composting projects in California as of December 1991[108].

Table IV-4
Existing and Planned Composting Projects in California

Facility Type	Existing	Planned
Green Waste Composting	38	165
Co-Composting	3	7
Mixed Waste Composting	0	38

The three types of composting facilities are briefly described below.

- *Green Waste Composting* - Green waste composting involves composting of yard trimmings, grass, and leaves. Although there may be some minor contamination from residential refuse, the majority of the feedstock consists of yardwaste. Size reduction by grinding or shredding for the purpose of obtaining a more uniform handling and improved feedstock material is usually the only mechanical processing before the actual composting process begins.

  Green waste only composting projects do not, under normal circumstances, have risks from household batteries unless the greenwaste compost feedstock was contaminated by batteries that were included in the separately collected green waste materials. Reducing contamination in separately collected green waste could be improved with the implementation of adequate enforcement and education programs.

- *Co-Composting* - Co-composting involves the use of sewage sludge or animal manure with either yardwaste and/or mixed municipal solid waste. California law defines co-composting as mixing the two streams at approximately 80 percent municipal solid waste and 20 percent wastewater treatment plant sludge or septage. The sludge is a source of high nitrogen content and the municipal solid waste is a source of carbonaceous or bulking material for the sludge. Most co-compost facilities will process the waste stream to remove some portion of materials that are not wanted for composting before the sewage sludge or manure is added.

108 Finch, Michael, Oral Presentation at CIWMB Compost Workshop, December 17, 1991

- *Mixed Municipal Waste Composting* - Mixed municipal waste composting utilizes the mixed residential, commercial, and industrial waste streams as compost feedstock after undergoing a series of mechanical/manual processing steps for the purpose of size reduction and recovery of recyclable materials. Mixed municipal waste compost facilities are sometimes referred to as municipal solid waste compost facilities. There are no current municipal solid waste composting facilities in California, but the process is used in other states and in other countries. There are currently 38 planned mixed municipal solid waste composting facilities in California.

  Some mixed waste compost facilities are designed as part of an integrated materials recovery facility. In these facilities, only a fraction of the organic waste materials are used for the production of a compost feedstock and the majority of the organic material such as paper and plastic are processed into a refuse derived fuel. For this type of facility, the compost feedstock would only be a secondary product.

The presence of household batteries in compost material presents some potential concerns. The potential risks from household batteries in the composting programs result from:

- Mechanical/manual processing for preparation of compost feedstock
- Final compost quality.

The potential risks presented by household batteries in municipal solid waste destined for mixed composting are the same as those risks described in the previous pages regarding mechanical processes utilized in materials recovery facilities. Some of the mechanical separation processes may result in crushed or shredded batteries which increases the potential for the escape of metals from the battery container.

The composting facilities that use both hand sorting and mechanical sorting in their process do not have a battery problem. However, if only a hand sort is performed, household batteries, particularly button batteries, could contribute to metal contamination in the finished compost (button batteries have the highest level of mercury as a percent of weight).

Heavy metals composition in final compost product may affect allowable end-use of the product. The State of Vermont's proposed compost rules restrict the uses of municipal solid waste compost which exceed specific metals content. Some compost product cannot

be applied on land used for food for direct human consumption. Under the proposed Vermont Solid Waste Management Division Rules, composting operations would be required to sort and separate out unregulated hazardous waste from exempt small quantity generators and households prior to treatment. The level of presorting would be equivalent to a system that includes bag opening, magnetic separation, handpicking, and mechanical screening. This type of operation should be adequate to capture larger batteries (hand sorting) and the small button batteries (magnetic separation).

In Minnesota, where there are five municipal solid waste composting operations, most of the large batteries (9 volt, AA, C, and D cells) are removed by handsorting, and button batteries are generally captured through mechanical separation, usually a magnetic system. A study completed by the Minnesota Pollution Control Agency[109] noted that in order to reduce the concentrations of metals in finished compost, most facilities sort the municipal solid waste before it is composted. This is accomplished by hand sorting, mechanical sorting, or a combination of both.

Metal contamination may result from smashed batteries when its contents are mixed with the municipal solid waste. The metal contamination would also be enhanced if the batteries were not removed prior to the composting process because the heavy metals may be leached by the composting process itself.

During the initial stages of composting, decomposing organic material experiences a slight drop in the pH due to the formation of organic acids. The organic acids potentially could leach some of the heavy metals out of the household batteries, especially if the batteries have been shredded. Usually acidic conditions are only temporary as the decay process progresses. The propensity for leaching of heavy metals by the organic acids formed during the composting process may be of greater concern particularly when composting large quantities of acid-producing materials such as pine needles. Neutralizing agents such as lime may be necessary to prevent the decay process from being disrupted by too much acid. The adding of lime to balance the pH would also help minimize the leaching of metals.

In order to minimize risks of affecting final compost quality, household batteries could be removed before mixed waste feedstock starts the composting process. Compost

109 Arnold, 1991

feedstock process designers estimate that over 90 percent of the household batteries can be mechanically removed by incorporating the use of sizing screens, followed by magnetic separators, and then followed by some type of air density system. Mechanical processes are recommended over positive sorting by hand to remove household batteries because of the inherent risks and inefficiencies of hand sorting.

6. Municipal Solid Waste Disposal Costs

The cost to dispose municipal solid waste is highly dependent on the method of disposal and the level of treatment or processing performed on the waste between collection and disposal. In general, within California, the combined total cost to collect, transport, and dispose of municipal solid waste in a sanitary landfill is less than $100 per ton. Landfill disposal costs alone range from $6 to $65 per ton according to a study prepared for the CIWMB in 1990[110]. Because nearly 90 percent of California's solid waste is disposed in landfills, landfill disposal costs are the standard against which the economics of alternative waste management strategies may be measured.

Costs for incinerating municipal solid waste in mass burn facilities are generally higher than landfill disposal costs. This is partially due to high ash disposal and air emission control costs. Costs for composting mixed municipal solid waste in California are not known since no such facilities currently exist in the State.

110 Tellus Institute, April 1990

D. Disposal of Household Batteries as Hazardous Waste

In general, two disposal options are available for the disposal of collected household batteries. These are: 1) disposal in a hazardous waste (Class I) landfill, and 2) reclamation of mercury, silver, or other metals. Of these two disposal options, the majority of collected batteries are currently disposed in a hazardous waste landfill. Presently, the only household batteries for which metal recovery is possible in the United States are mercuric oxide, silver oxide, and nickel-cadmium batteries. These batteries comprise a small percentage of the household battery market and household battery waste stream. Approximately 90 percent of the household batteries collected in one program are alkaline or carbon-zinc which have no recycling value[111]. In California, where household batteries are most often collected at household hazardous waste events, batteries are commonly packed with other alkalies and corrosives and sent to a hazardous waste landfill.

1. Hazardous Waste Landfills

Alkaline, carbon-zinc, lithium, and zinc air batteries are almost always disposed in a hazardous waste landfill. This is true even if the batteries are first sent to a metal reclamation facility. In addition, mixed household batteries are frequently disposed in hazardous waste landfills even though some battery types are recyclable. Mixed or sorted batteries are *lab-packed*, possibly with other household hazardous wastes, into drums with an absorbent filler before being transported to a secure landfill.

Lab-packing is the process of safely packing many smaller containers of hazardous waste into a larger container, usually a 30- or 55-gallon steel, plastic-lined drum. All wastes in a drum must be of the same hazard class, and the smaller containers are separated and protected by sufficient vermiculite to absorb the liquid wastes in the drum.

To dispose of wastes in a hazardous waste landfill, the waste generator (e.g., a household hazardous waste collection program) must document the type, quantity, and nature of the waste to be disposed. Hazardous waste must be properly handled and transported in accordance with specific regulatory requirements. This usually involves

111 Du Bois, Annette, and Jessie Lang, *Household Batteries: Drop-Off and Curbside Collection*, Resource Recovery, February, 1992

manifesting shipments to provide clear documentation that wastes are properly transported and disposed.

2. Hazardous Waste Disposal Costs

Hazardous waste landfilling of household batteries is an expensive disposal option. The City and County of San Francisco reports that it costs approximately $250 to send a 55-gallon drum (approximately 200 pounds of batteries) of used batteries to Kettleman Hills Hazardous Waste Landfill. This cost includes labor, transportation, drum, and packing material, and translates into a disposal cost of approximately $1.25 per pound ($2,500 per ton) of batteries. There is an additional $400 per year for a "profiling fee"[112]. which is required for the costs of documenting the type, nature, and source of the hazardous waste involved.

Section V of this report describes several battery collection programs in California and throughout the United States. These descriptions include data on the costs of operating collection programs, including disposal costs, to the extent that data are available. From the limited data available, it appears that hazardous waste disposal costs in California are significantly higher than in other states. This may be partially due to the fact that California presently only has one Class I hazardous waste facility. The presence of only one facility increases transportation costs and in addition some waste is exported out of the state. The costs for disposing of household batteries as hazardous waste in other states has been reported to range from about $600 to $1,000 per ton of batteries, including transportation costs. For purposes of this study, it is assumed that the cost of disposing of household batteries as hazardous waste in California will range from $2,000 to $2,500 per ton, including transportation.

As household hazardous waste programs in California become operational, cities and counties will develop more accurate cost figures for the disposal of household batteries and other household hazardous wastes.

112 Whatkins, Tom and Paula Kehoe, personal communications with Gainer & Associates, February, 1992

E. Reclamation of Metals From Household Batteries

The term *battery recycling* is a misnomer. Collected batteries are not directly remanufactured into new batteries or other products. Battery recycling refers to metal reclamation processes which entail the extraction of one or more of the metals contained in the batteries. Some types of primary batteries are processed to recover mercury or silver. In the United States, nickel-cadmium batteries are processed primarily to recover nickel. Processes exist in Europe and Japan which also focus on cadmium recovery from nickel-cadmium batteries. Although zinc is a major component of most primary batteries, zinc recovery is generally not economically feasible, although battery reclamation processes which include zinc recovery have been proposed. Zinc can be produced much cheaper from mines around the world than it can be from battery reclamation. Also, cadmium is produced directly or indirectly from zinc production. As a precious metal, recovery of silver from silver oxide button cells can be profitable. One metal processor pays for silver oxide button cells based on the spot price of silver[113], thus, demonstrating a market for used silver oxide batteries.

This subsection focuses on the potential reclamation of household batteries with attention focused on mercury and cadmium recovery since these are the metals of primary concern. The processes and technologies used to reclaim metals from household batteries are complex, and it is not the intent of this study to evaluate technical merits of the various processes. The following pages describe options available to operators of household battery collection programs for recovering mercury and cadmium from household batteries. The options are few, and in some instances, processors have been responsible for creating additional environmental problems.

1. Current Household Battery Reclamation Opportunities

The following is a summary of the current status for recycling different battery types in the United States.

- *Alkaline, Carbon-Zinc, Zinc Air* - There are no reclamation facilities for either alkaline, carbon-zinc, or zinc air batteries. Currently, all alkaline, carbon-zinc, and zinc air household batteries diverted by

113 Gainer & Associates, February 1992

collection programs are sent to a hazardous waste landfill, either directly or by metal processors. Low mercury content in these battery types generally make them unsuitable for mercury recovery.

- *Mercuric Oxide, Silver Oxide* - Of the button cell batteries, only silver and mercuric oxide batteries are able to be reprocessed. Mercury Refining Company (MERECO) is the only facility in the United States that will reprocess both mercuric oxide and silver oxide button cells. Currently, they are charging $1.50 per pound for mercuric oxide batteries and pay 1.05 times the "spot" silver price for silver oxide batteries.

- *Lithium* - Lithium batteries are not recyclable. There are a few firms that accept lithium batteries for deactivation. The cost to send lithium batteries to these firms range between $4.00 and $15.00 per pound. After deactivation, they are sent to a secure hazardous waste landfill. Deactivation is a process to completely discharge the battery and prevent subsequent reaction of the lithium metal.

- *Nickel-Cadmium* - There are several domestic companies that will handle consumer nickel-cadmium batteries. Generally, handling means remarketing the acquired batteries to overseas metal processors. International Metals Reclamation Company, Inc. (INMETCO) is the only processor of nickel-cadmium batteries in the United States, although their processes focus primarily on nickel recovery for the production of stainless steel and other alloys.

Exhibit IV-4, on the following page, profiles metal processing and reclamation facilities for waste household batteries. This list was originally produced by the Environmental Action Coalition in New York City[114] and updated for this report. The Environmental Action Coalition warns: "...there is evidence that several companies reclaiming battery metals are doing so in a manner that may not be safe for their employees and the environment." Inclusion of any company in this exhibit should not be construed as an endorsement of that firm's services or practices. Any household battery collection program should thoroughly investigate potential battery processors before sending any materials to them. Some specific examples of organizations involved in the reclamation of metals from household batteries in the United States are described on the following pages.

114 Forker, Timothy, 1991

Household Battery Metal Reclamation Facilities

Company	Household Battery Services
BDT 4255 Research Parkway Clarence, New York 14031 (716) 634-6794	Accepts alkaline and lithium batteries; charges $4 to $15 per pound; crush, "neutralize", and dispose as hazardous waste
International Metals Reclamation Company, Inc. (INMETCO) P.O. box 720, Rt. 488 Ellswood, Pennsylvania 16117 (412) 758-5515	Accepts consumer nickel-cadmium batteries; charges $0.23 per pound, no minimum charge; processed for nickel on site, reprocessed for cadmium by another company
Kinsbursky Brothers Supply 1314 N. Lemon Street Anaheim, California 92801 (714) 738-8516	Accepts consumer nickel-cadmium batteries; charges $0.60 per pound, minimum charge $500 (833 pounds); brokered to domestic and international processing plants
Mercury Refining Company, Inc. (MERECO) 790 Watervliet-Shaker Road Latham, New York 12110 (518) 785-1703, (800) 833-3505	Accepts all household batteries; charges $1.50 per pound for mercuric oxide, pays 1.05 times spot silver price for silver oxide, charges $0.65 per pound for nickel-cadmium, charges $0.38 per pound for alkaline and carbon-zinc, charges $6.00 per pound for lithium; mercuric oxide and silver oxide processed on site, nickel-cadmium sent to another facility for processing, alkaline and carbon-zinc sent to a secure landfill, lithium deactivated and sent to a secure landfill
NIFE Industrial Blvd., P.O. Box 7366 Greenville, North Carolina 27835 (919) 830-1600	Accepts consumer nickel-cadmium batteries; charges $0.70 per pound, minimum charge $75; sent to NIFE plant in Sweden for reclamation
Universal Metals and Ores Mt. Vernon, New York (914) 664-0200	Not accepting any household batteries at this time due to problems with USEPA RCRA regulations; may accept consumer nickel-cadmium batteries in the future; batteries brokered to French, Korean, and Japanese processing plants

Sources:

Forker, Timothy and Sean Hecht, Environmental Action Coalition's Waste Household Battery Management Project, 1987-1991, Environmental Action Coalition, December 31, 1991

Gainer & Associates, February 1992

Mercury Refining Company, Inc. (MERECO)
Latham, New York

MERECO has been involved in metals recovery from mercuric oxide and silver oxide button cell batteries for over thirty-five years. Using a unique process developed by MERECO, all mercury and silver oxide batteries are processed for mercury recovery. The silver oxide cells are then further processed for separation and recovery of silver. Both mercury and silver are purified and sold in markets for these materials.

MERECO accepts all types of household batteries; however, only the mercuric oxide and silver oxide cells are processed to reclaim metals. Due to the small amounts of mercury contained in alkaline and carbon-zinc batteries, MERECO arranges to have these batteries disposed in a hazardous waste landfill. Lithium batteries also are disposed in a secure landfill, however, prior to disposal, lithium batteries are deactivated to prevent reaction of the lithium metal. Nickel-cadmium batteries are accepted by MERECO. These batteries are sent to another facility for processing.

MERECO had serious mercury contamination problems in the past and was listed as a superfund site by the USEPA in the early 1980s. The company remediated the contaminated site to the satisfaction of the USEPA. MERECO is currently upgrading its facility to address additional problems with its mercury reclamation process[115].

International Metals Reclamation Company, Inc. (INMETCO)
Ellswood City, Pennsylvania

INMETCO is an industrial nickel-cadmium processor that accepts consumer size nickel-cadmium batteries for metal recovery. It is reported to be the only processor of consumer-size nickel-cadmium batteries in the United States. In 1990, INMETCO recycled approximately 150 tons of nickel-cadmium and nickel-iron batteries. In 1991, this amount increased significantly to about 500 tons[116].

INMETCO utilizes a pyrometallurgical (thermal) reclamation process for processing a variety of industrial wastes including plating sludges, nickel and chrome containing

115 Reutlinger, Nancy, and Dan de Grassi, April, 1991
116 *INMETCO Newsletter*, Winter 1992

solutions, spent catalysts, and nickel-iron and nickel-cadmium batteries[117]. The process involves: 1) feed preparation, 2) reduction, 3) smelting, and 4) casting. INMETCO reports that typically 98 percent recovery of the nickel from waste feedstocks such as nickel-iron and nickel-cadmium batteries is achieved. The nickel that is reclaimed becomes a component in metal pigs which typically contain 8 percent nickel, 13 percent chrome, and the balance primarily iron. The pigs are sold to stainless steel producers to produce *type 304* stainless steel (18 percent chrome, 8 percent nickel, balance iron).

Gaseous effluent from a rotary hearth furnace contains significant quantities of zinc, lead, and cadmium. A wet gas scrubbing system treats the gas effluent producing an alkaline filter cake containing these three metals. In addition, a standard baghouse system attached to an electric furnace collects remaining zinc, lead, and cadmium. The scrubber filter cake and baghouse dust are further processed by another company (Zinc Corporation of America) who is a producer of zinc. The scrubber filter cake and baghouse dust are further processed to recover zinc, lead, and cadmium. Because this second metal processor must be involved to recover the cadmium, some organizations believe other recycling technologies, such as those utilized in Europe and Japan which were developed specifically for nickel-cadmium batteries, may be better suited for nickel-cadmium batteries.

NIFE
Greenville, North Carolina

NIFE has obtained a hazardous waste permit to receive, store, and handle nickel-cadmium, nickel-iron, and zinc air batteries at its North Carolina facility. Most of the batteries received by NIFE are industrial type batteries. NIFE is prohibited from receiving or processing batteries containing mercury. Batteries are not processed in the United States by NIFE but sent to the SAB NIFE facility in Sweden where the batteries are dismantled, recycled, or disposed. NIFE claims that the hazardous waste is recycled or rendered non-hazardous. SAB NIFE is one of two well-established companies specializing in recycling nickel-cadmium batteries[118]. SAB NIFE also is a manufacturer of nickel-cadmium batteries.

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117 Schweers, M. E., et al., *A Pyrometallurgical Process for Recycling Cadmium Containing Batteries*, International Metals Reclamation Company, Inc., 1991

118 Hiscock, S. A., *Nickel-Cadmium Battery Collection and Recycling in Europe*, presented at the Nickel-Cadmium Battery Update in Brussels, sponsored by the Cadmium Association, September 1990

Environmental Pacific Corporation
Lake Oswego, Oregon

One company has claimed that it recycles all types of batteries, including alkaline and carbon-zinc batteries[119]. Environmental Pacific began operations in 1985 by handling used carbon-zinc batteries from railroad signals and U.S. Coast Guard signal buoys. They also have collected consumer batteries from local governments and other battery collection programs. The actual fate of household batteries acquired by Environmental Pacific is uncertain. In addition, the firm has had a number of environmental and safety problems. Most recently, in January 1991, the Oregon Department of Environmental Quality fined Environmental Pacific over $28,000 for incidents which include:

- Shipping hazardous waste to an unregistered facility by an unauthorized transporter
- Shipping hazardous waste without a hazardous waste manifest
- Storing hazardous waste in excess of allowable quantities.

Environmental Pacific has sent shipments of waste to foreign countries for disposal. Shipments to China and the Philippines were rejected by those countries in 1987 because the shipments violated environmental protection regulations[120].

Some of the battery collection program managers contacted during this study indicated that they have avoided sending collected household batteries to Environmental Pacific because of their past problems and the uncertainty surrounding how the batteries would ultimately be disposed[121]. This particular example illustrates some of the uncertainty that battery collection programs are confronted with in seeking appropriate ways to dispose of collected batteries. Given the liability issues present in the disposal of hazardous waste, any household battery reclamation facility utilized by a collection program should be thoroughly investigated.

119 Watson, Tom, *The Unsavory Side of Battery Recycling*, Resource Recovery, April 1991
120 Forker, 1991
121 Watson, 1991

2. The Future of Household Battery Reclamation

In addition to the metal processors described above, a number of new technologies are emerging which may increase opportunities for battery reclamation. Hydrometallurgical processes have been developed on pilot scales for reclaiming metals from batteries. While these new technologies are being taught by their supporters, commercial, full-scale facilities have yet to be proven. Emerging technologies in battery reclamation are summarized below.

Recytec
Cedar Knolls, New Jersey

Recytec was established in October 1987 in Switzerland and has offices in Germany, New Jersey, and Maryland. The company was formed to develop and commercialize patented technologies in the field of metal wastes, including recycling of materials in household batteries[122]. The process is reported to not require the sorting of batteries. A 100 kg per day research and development unit is in operation in Switzerland. A 250 ton per year commercial facility and a 500 ton per year commercial facility are proposed in Germany and Switzerland, respectively. Recytec is marketing its processes in the United States and seeking a guaranteed supply of batteries to sustain a 500 ton per year facility. The Recytec battery process is a thermo-mechanical-electrochemical process with the following advantages[123]:

- Does not produce any secondary waste due to closed loop water and acid circuits
- Quality of the products is constant and controllable
- Process recycles up to 95 percent of the inputs that enter the system.

Products from the process include mercury, iron, zinc and cadmium, nickel, silver, and other materials. Only 5 percent of the material becomes secondary waste.

122 *Recytec: Household Battery Recycling Process*, presented at the Municipal Waste Combustors Meeting on Precombustion Control of Mercury Emissions From Batteries sponsored by the USEPA, February 8, 1990

123 Fiala-Goldiger, Jan, et al., *The Status of Battery Recycling in Switzerland*, presented at the Second International Seminar on Battery Waste Management, November 7, 1990

Sumitomo Heavy Industries
Japan

Niihama Technical Research Laboratories of Sumitomo Heavy Industries, Ltd. (SHI) has researched and developed a new process for treatment of used dry batteries (household batteries) based on a wholly integrated pyrometallurgical process. This process favors urban plant-sites because of the enclosed nature of the process, inexpensive treatment cost, and low energy consumption using combustible material in used batteries as fuel and reductant[124].

SHI has had a working pilot plant operating successfully in Japan since 1985, and has progressively advanced the technology. The technology has recently been selected for the development of a commercial facility in Switzerland. BATREC AG of Switzerland was founded in 1989 with the goal to develop an environmentally safe solution to the disposal of consumer batteries. In May 1991, BATREC AG received a permit for a 2,000 ton per year battery reclamation facility using the Sumitomo technology[125].

The SHI treatment technology is based on a thermal process in which the organic materials are burned and the different metals are separated through their different physical properties. The reclamation process accepts a mixed stream of household batteries which are primarily comprised of alkaline and carbon-zinc battery types. Primary products of the process are a ferro-manganese alloy (which includes iron, manganese, and small amounts of nickel and copper), zinc (which includes small amounts of lead and cadmium), and mercury. SHI is exploring opportunities to construct a similar commercial facility in the United States.

TNO
The Netherlands

The process developed by TNO for recovery of metals from nickel-cadmium batteries is largely based on hydrometallurgical principles (i.e., the metals are dissolved in an aqueous solution and subsequently separated from each other and processed into high

124 Sumitomo Heavy Industries, *New Technology for Treatment of Used Dry Batteries*, Revision 6, June 14, 1991

125 Burri, Roger, et al., *Approval Procedure for a Commercial Battery Recycling Plant in Switzerland*, Proceedings of the Third International Seminar on Battery Waste Management, Deerfield Beach Florida, November 4-6, 1991

quality product materials)[126]. Existing commercial facilities for processing nickel-cadmium batteries rely on pyrometallurgical (thermal) principles in which cadmium is evaporated and recovered by condensation. An advantage of the TNO process is that no off-gases are produced. Additionally, thermal processes can form emissions of toxic organic substances such as dioxins. The hydrometallurgical process, however, creates liquid waste which must be treated to remove any remaining heavy metals.

The process developed by TNO for recovery of metals from used nickel-cadmium batteries shows promising technological characteristics. However, the economics of the process are still unclear, although a full scale commercial unit for processing spent nickel-cadmium batteries could be established in Europe in 1992.

3. Household Battery Reclamation Costs

The cost to reclaim metals from used household batteries varies by type of battery and the reclamation process used. Other costs which must be considered in the reclamation of household batteries include battery separation by type and transportation. The major metal processors in the United States for the reclamation of metals from used household batteries are located in New York (MERECO) and Pennsylvania (INMETCO). Therefore, battery transportation costs are presently a significant consideration for California battery collection programs.

Table IV-5, on the next page, summarizes the amount charged by metal processors in the United States to reclaim or otherwise dispose of the various types of household batteries. Transportation costs from California for packages weighing less than 70 pounds add $0.44 to $0.75 per pound ($880 to $1,500 per ton), depending on the size of the shipment. In addition, reclamation facilities usually require that batteries are separated by type in order to be accepted. This creates yet another cost for a battery collection program.

126 van Deelen, C. L. and J. van Erkel, *Recovery of Metals From Spent Nickel-Cadmium Batteries*, presented at the Nickel-Cadmium Battery Update in Brussels, sponsored by the Cadmium Association, September 1990

Table IV-5
Cost to Dispose of Household Batteries
At Metal Reclamation Facilities[a]

Battery Type	$/lb	$/ton	Method of Disposition
Alkaline	$0.38	$760	Hazardous Landfill
Carbon-Zinc	$0.38	$760	Hazardous Landfill
Mercuric Oxide	$1.50	$3,000	Reclaim Mercury
Silver Oxide	b/	b/	Reclaim Silver and Mercury
Zinc Air	$0.38	$760	Hazardous Landfill
Lithium	$4 to $15	$8,000 to $30,000	De-Activate then Hazardous Landfill
Nickel-Cadmium	$0.23 to $0.70	$460 to $1,400	Reclaim nickel and cadmium, or send to Europe or Japan

a/ Excludes transportation costs, see text.
b/ Processor pays 1.05 times the spot price of silver for silver oxide button cells.

V. Existing Household Battery Waste Management Programs

V. EXISTING HOUSEHOLD BATTERY WASTE MANAGEMENT PROGRAMS

This section describes household battery collection programs currently operating in California, and elsewhere in the United States. The material is presented through a selection of case studies on existing collection programs. Topics covered include the various collection methods to divert household batteries from the waste stream, disposal mechanisms used for collected batteries, reclamation potential for collected household batteries, household battery source reduction education efforts, and total costs of operating battery collection programs, including disposal and/or reclamation costs.

Within California, household batteries are primarily collected through household hazardous waste programs established by cities and counties. Recent legislation in California has required cities and counties to develop household hazardous waste plans as an element of their broader integrated waste management plans. This section begins with a discussion of household hazardous waste programs in California, then examines specific battery collection efforts, both within and outside of California. The programs which are implemented outside of California are selected as case studies because they have been established for several years, and provide insight into collection, reclamation, and disposal issues, and problems not yet experienced in California.

This section is organized into the following subsections:

- Household Hazardous Waste Management Programs in California
- Case Studies of Household Battery Waste Management Programs
- Effectiveness of Household Battery Collection, Disposal, and Reclamation.

A. Household Hazardous Waste Management Programs in California

In 1989, the California Legislature passed the Integrated Waste Management Act, commonly referred to as AB 939. This landmark legislation requires cities and counties to implement source reduction and recycling programs which will reduce solid waste disposal 25 percent by 1995 and 50 percent by the year 2000. The passage of AB 939 represents a sweeping change in California waste management practices. As a result, the management of solid waste has changed focus from waste landfilling to source reduction, recycling, and composting.

Household hazardous waste programs also are a growing component of California's waste management strategy. AB 939 addresses the reduction of solid waste entering the State's landfills and requires, among other things, that cities and counties develop a Source Reduction and Recycling Element (SRRE). The SRREs are required to provide strategies that will divert solid waste from landfills.

Although household hazardous waste is a small percentage of the total waste stream because of the significance of household hazardous waste, amendments to the Integrated Waste Management Act, included in AB 2707 (which passed in 1990), elevated the household hazardous waste component to a separate Household Hazardous Waste Element (HHWE). Other recent legislation has allowed *small quantity commercial sources* to participate in household hazardous waste programs (AB 2641), and has encouraged the collection of *recyclable* household hazardous wastes (AB 2597). The significance of each of these Acts is briefly summarized below:

- *Amendments to the Integrated Waste Management Act (AB 2707)* - AB 2707 requires each city and county to prepare, adopt, and submit to the CIWMB, by July 1, 1991, a HHWE which identifies a program for the safe collection, recycling, treatment, and disposal of hazardous wastes generated by households within their jurisdiction. To gain approval of the HHWE from the CIWMB, the city or county must demonstrate that:

  - Feasible methods will be used to properly reduce, collect, recycle, treat, and dispose of household hazardous waste

  - Reasonable expenditures will be devoted to the safe reduction, collection, recycling, treatment, and disposal of household hazardous waste

- Reasonable efforts will be made to inform the public and encourage public participation in the household hazardous waste program

- The program is available for use by all households within the jurisdiction of the city or county and provides a safe alternative to properly dispose of household hazardous waste.

- *Small Quantity Commercial Sources of Hazardous Waste (AB 2641)* - This Act allows any city or county which operates a household hazardous waste program to allow small quantity commercial sources to participate in the program under certain conditions. For purposes of this Act, small quantity commercial source means a business which generates less than 100 kilograms (220 pounds) of hazardous waste per month. Businesses may be charged for this service. Specified exemptions from taxes, reporting requirements, and liability provided for household hazardous waste programs are extended for programs accepting hazardous waste from small quantity generators.

  This Act effectively broadens the number of potential participants in household hazardous waste programs to include businesses which generate small quantities of hazardous waste. Typically, this would include similar *household* type items which are also used in a business environment, such as household batteries.

- *Household Hazardous Waste Recycling (AB 2597)* - AB 2597 facilitated the collection of recyclable household hazardous waste by eliminating the need for Department of Toxic Substances Control permits for household hazardous waste collection programs that target specific categories of recyclable household hazardous waste. These categories include:

  - Water-based latex paint

  - Used motor oil

  - Used antifreeze

  - Spent lead-acid automotive batteries

  - Small household batteries.

  Common household hazardous waste management practices described in the HHWEs are special household hazardous waste events. For example, one Saturday per month the municipality may have either a toxics disposal day or a recycle day. At these event days, the municipality accepts household hazardous waste for proper disposal or recycling. In order to qualify for the permit exemptions, no other household hazardous waste may be received and handled other than those listed above, and all recyclable household hazardous waste collected must be transported to a recycling facility. Because of these requirements, separate household hazardous waste events and facilities may be required for

the collection of recyclable and non-recyclable household hazardous wastes.

HHWEs which have been submitted for approval, currently, are undergoing review by the CIWMB. A review of these plans indicates that many of the proposed household hazardous waste programs plan to accept household batteries for disposal along with other household hazardous waste. In addition, it is common for the HHWE to include plans for recycling: 1) latex paints 2) motor oil, 3) lead-acid batteries, and 4) antifreeze. Very few of the programs include plans for collecting household batteries for recycling, in contrast with disposal. The reason most often stated for not collecting household batteries for recycling is that *there is no proven and available recycling technology for the majority of household batteries*. In addition, concerns have been raised to whether the collection of household batteries which are not recycled would jeopardize the status of a hazardous waste recycling program due to requirements of AB 2597.

As household hazardous waste collection programs around the state are organized and implemented, communities will gain experience in various collection, disposal, and recycling options for the various types of household hazardous wastes. The development of household battery collection and disposal or reclamation will depend upon: 1) the perceived health and environmental risk associated with each battery type, 2) the availability of suitable reclamation options, and 3) the relative costs of battery disposal and/or reclamation.

B. Case Studies of Household Battery Waste Management Programs

This subsection describes several of the household battery collection programs located in California and throughout the United States. Programs outside of California were selected since they have been in existence longer than programs in California. These programs have evolved over the last few years as experience has been gained. Valuable lessons learned from these programs are beneficial to those wishing to establish household battery collection programs in California. As described in the previous subsection, within California, household batteries are generally collected with other household hazardous waste for disposal. Finally, the end of this subsection includes a discussion of efforts by product and battery manufacturers to develop battery collection and reclamation programs for nickel-cadmium batteries.

1. Household Battery Collection Programs Within California

The scope of California's household battery waste management efforts has been limited to their acceptance at household hazardous waste collection events and permanent collection facilities. San Francisco is in the planning process of implementing a collection program that will accept button cell and nickel-cadmium batteries at their permanent household hazardous waste facility. In addition, two counties, the County of Stanislaus and the County of Santa Cruz, have performed feasibility studies of household battery collection and recycling. Collection programs recommended by these studies have not yet been implemented.

Exhibit V-1, on the following page, and the selection of case studies that follow below, describe the present status of household battery collection within California. These case studies are not intended to be an exhaustive summary of household battery collection programs in the State, but are representative of the current status of activities. Because household battery collection programs are mostly in developmental stages, there is limited information on program effectiveness or costs.

EXHBIT V-1

Household Battery Collection Programs in California

Collection Program	Types of Batteries Collected	Collection Methods	Battery Disposal Methods
City and County of San Francisco	All Types	Permanent HHW Collection Facilities, Batteries Sorted by Type	Hazardous Waste Landfill, Mercury Refining Co.
Stanislaus County	All Types	Community Drop-Off	Unknown
Santa Cruz County	All Types	Permanent HHW Collection Facility	Hazardous Waste Landfill
Los Angeles County	All Types	Community Drop-Off, Batteries Bulked with Other Alkalies/Corrosives for Disposal	Hazardous Waste Landfill/Incinerator

City and County of San Francisco[127,128]

The City and County of San Francisco, which handles its solid waste through landfilling and resource recovery, has a permanent household hazardous waste facility operated by Sanitary Fill Company. This facility has been in operation for four years and accepts household hazardous waste three days a week, Thursdays through Saturdays. The program is funded through residential solid waste service fees.

Prior to August 1991, household batteries were excluded from the list of materials accepted at the facility. Due to heightened awareness of the potential environmental and health hazards associated with household hazardous wastes, there has been an increasing demand from residents for information on, and services for, proper household battery disposal. Public interest, coupled with San Francisco's own awareness of the potential impacts of batteries in the waste stream, prompted San Francisco to begin accepting household batteries at the household hazardous waste facility on an *informal* basis only. Education and public information concerning the battery program is disseminated only on request.

During the first six months of the informal program, 600 pounds of mixed household batteries were collected. Of this amount, over 90 percent were alkaline and carbon-zinc, and the remaining were a mix of button cell and nickel-cadmium batteries. The alkaline and carbon-zinc batteries are disposed at Kettleman Hills Hazardous Waste Landfill and the remaining mix of batteries are awaiting shipment to Mercury Refining Company.

Of the programs surveyed for this study, the City and County of San Francisco is the only program that distributes information to residents addressing household battery waste reduction. Produced by San Francisco's Solid Waste Management Program, the Battery Fact Sheet dedicates a significant portion of the two-page handout to source reduction. The household battery fact sheet includes an explanation of problems associated with batteries, their harmful components, and a menu of battery substitutes and better management practices to reduce battery purchases. This battery fact sheet also directs

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127 Whatkins, Tom, Sanitary Fill Company and Maria Trapalis-Baird, San Francisco Solid Waste Management Program, personal communications with Gainer & Associates, January/February, 1992

128 *Hazardous Waste News/Household Battery Fact Sheet*, produced by the San Francisco Solid Waste Management Program

residents to dispose of household batteries in their household garbage because of the difficulties surrounding battery recycling.

San Francisco's Solid Waste Management Program is actively planning to *formally* include household batteries into their household hazardous waste collection program. They will be limiting the collection service to only button cell and nickel-cadmium batteries, which will be sent to MERECO for reclamation and disposal. The decision to limit collection to these types of household batteries was based on the following factors:

- Reclamation options
- Program cost-effectiveness
- Current transition to low-mercury alkaline batteries.

It is anticipated that the program will begin in the Spring of 1992. Public education to support the new battery collection program will include the updating and distribution of their battery fact sheet, press releases, and garbage bill inserts.

Stanislaus County[129,130]

Stanislaus County, which has a population of 350,000, is one of only three California jurisdictions with a waste-to-energy facility. The facility operates under a permit issued by the USEPA which directed Ogden Martin, the incinerator operator, in cooperation with Stanislaus County and the City of Modesto, to perform a study of consumer dry cell batteries and develop a plan for their separation from the waste stream.

The study, completed in August 1990, consisted, in part, of a waste stream characterization analysis which revealed that, out of a four ton sample, there were 21 alkaline and carbon-zinc batteries and no button cell batteries. Based on this and other information, predictions were made that: 1) button cell battery collection programs must exist already, and 2) to reduce mercury emissions, all batteries would have to be targeted for diversion. These predictions were altered when the County surveyed local battery

129 County of Stanislaus, Household Batteries in the Waste Stream. A Study of Their Current Status and Proposed Program for Separation. Stanislaus County. Final Report, August 13, 1990

130 Aggers, Jami, Senior Environmental Health Specialist, Stanislaus County Solid Waste Management Division, Department of Environmental Resources, personal communication with Gainer & Associates, February 1992

retailers and found that, out of the 30 retailers and service locations for watch, photographic, and hearing aid products, only half were collecting used batteries when they were exchanged for new ones.

The household battery study concluded with a two year plan of action for battery collection. Under the plan, the first year would consist of targeted diversion from the remaining 15 retailers and service locations, and drop-off collection of button cell batteries at all major retailers of general household batteries. In the second year, the collection of button cell batteries would be incorporated into the household hazardous waste program, which includes both one day *round-up* events and a permanent, staffed drop-off location. Battery collection would be specifically addressed in public education regarding the household hazardous waste program.

After these first two programs are on-line, another waste analysis would be performed to evaluate the success of household battery diversion. If a significant reduction is realized, the program would continue without modification, with program emphasis on public education. If a net reduction of batteries in municipal solid waste is not realized, the program would be expanded to include the collection of all household batteries, and consideration given to collecting household batteries through curbside collection programs.

Since this study's release, no action has been taken to implement the proposed programs due to the lack of a response from the USEPA. Currently, all household batteries are accepted at household hazardous waste "round-up" events and will be accepted at the permanent and mobile facilities which are planned to start in 1992.

Santa Cruz County[131,132]

In July 1990, the County of Santa Cruz Planning Department released a household battery study, performed by a student intern. The study recommended a household battery collection program and implementation plan for the County. This five phase collection program targeted all household batteries as well as dry cell battery collection from the commercial sector. The five phases are as follows:

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131 Reutlinger, Nancy, *Batteries in the Waste Stream, A Feasibility Study of Household Battery Recycling and Collection for the County of Santa Cruz*, prepared for the County Planning Department, Resources Section, July 20, 1990

132 de Grassi, Dan, Program Coordinator, Integrated Waste Management Planning Program, personal communication with Gainer & Associates, February, 1992

- Phase 1: Return-to-retailer collection for button cell batteries
- Phase 2: Drop-off at hazardous waste depots for all battery types
- Phase 3: Return-to-retailer collection for all battery types
- Phase 4: Commercial/business battery collection and recycling
- Phase 5: Curbside collection of all battery types.

None of these five program phases have been implemented to date because they were contingent upon finding suitable disposal and reclamation facilities for the collected batteries. MERECO, the only mercury reclamation facility which accepts all types of household batteries, was found to have serious site, emissions, and run-off contamination problems, and was deemed an unacceptable option until their refining site and operation meets USEPA standards. Hazardous waste landfilling was also deemed a prohibitively expensive disposal option if large quantities of batteries are collected. As a result, separate household battery collection mechanisms were not established in the County; however, household batteries are accepted through household hazardous waste collection activities.

The battery study prepared for the County reported on an informal survey of electronic and jewelry stores and hearing aid centers in Santa Cruz County to inquire about their battery disposal practices. The survey revealed that several of these stores were currently diverting their button cell batteries to one reclamation source or another. When these sources were investigated, some proved to be either out of business or only interested in silver recovery in the silver oxide button cell batteries.

The County of Santa Cruz currently accepts household batteries at their permanent household hazardous waste facility. Household batteries are packed with alkalies and corrosives, and sent to a hazardous waste landfill. No data are available on the amount of household batteries collected.

Los Angeles County[133]

Los Angeles County, which supports a population of approximately nine million, has two cities, the City of Long Beach and the City of Commerce, that use waste-to-energy

133 Reilly, Joe, Los Angeles County Sanitation District, personal communication with Gainer & Associates, February 1992

technology as a solid waste management tool. Neither city has a household battery collection program, but participate in Los Angeles County's household hazardous waste collection program which accepts all household batteries at their collection events. To date, the County has had thirteen collection events since the program's start in 1988, servicing 20,000 residents thus far. There has been one collection event in the City of Long Beach, which collected household hazardous waste from approximately 3,100 vehicles. The majority of the City of Commerce is commercially zoned. Consequently, a household hazardous waste collection event has not been held in that city; however, they have been held in closely surrounding cities.

Information on the amount or types of household batteries diverted is unavailable. Collected household batteries are lab-packed with other alkalies and corrosives for hazardous waste disposal. Household hazardous waste collected by Los Angeles County is either recycled or sent to a hazardous waste landfill. A permanent household hazardous waste collection program has recently commenced with the goal of conducting 24 to 48 collection events per year, spatially distributed among all cities in Los Angeles County.

2. Household Battery Collection Programs Outside California

There are a variety of battery collection programs in place throughout the United States. The majority of programs were initiated in conjunction with, or subsequent to, the start of waste-to-energy incinerator facilities in order to stay within USEPA mercury emission standards. Cadmium also has been a concern in incinerator emissions. **Exhibit V-2**, on the following page, and the case studies that follow below, represent a cross-section of established household battery collection programs in the United States.

Household Battery Collection Programs Outside California

Collection Program	Start Up Date	Types of Batteries Collected	Collection Methods	Battery Disposal Methods
Hennepin County, Minnesota	Nov. 1990	All Types	Community Drop-Off, Curbside, Return-to-Retailer	Hazardous Waste Landfill, Mercury Refining Co., Inmetco, Local Smelter
County and City of Spokane, Washington	Sept. 1990	All Types	Curbside, Return-to-Retailer	Hazardous Waste Landfill, Mercury Refining Co.
Whatcom County and City of Bellingham, Washington	Sept. 1988	All Types	Return-to-Retailer	Hazardous Waste Landfill, Mercury Refining Co.
New Hampshire/ Vermont Solid Waste Project	May 1987	All Types	Community Drop-Off, Return-to-Retailer	Hazardous Waste Landfill
Environmental Action Coalition, New York City	1987	Mercuric Oxide, Silver Oxide Nickel-Cadmium	Community Drop-Off, Return-to-Retailer	Mercury Refining Co.
Greene County and City of Springfiled, Missouri	1987	Button Cells	Return-to-Retailer	Each Retailer Responsible for Collection/Disposal

EXHIBIT V-2

Hennepin County, Department of Environmental Management
Hennepin County, Minnesota[134,135]

Hennepin County (population 1 million) began county-wide collection of household batteries in November 1990 in order to reduce the amount of heavy metals entering the municipal waste stream. Solid waste management in Hennepin County consists of a mass-burn incinerator, two refuse derived fuel facilities, resource recovery, and yard waste composting. Collection of household batteries is one component in their comprehensive household battery program which also includes: 1) a periodic chemical analysis of the household battery waste stream, 2) a survey of the transition to low mercury content batteries in the Hennepin County marketplace, and 3) legislative efforts to affect the manufacturing and collection of household batteries.

Hennepin County residents can participate in the household battery program through community drop-off, curbside collection, and return-to-retailer programs. The City of Minneapolis offers curbside collection for all types of household batteries along with the pick-up of recyclable materials. In addition, the City has several community drop-off locations which also accept all types of household batteries. These drop-off sites are located at fire stations, municipal buildings, and at some drug store chains. In suburban and rural Hennepin County, residents can bring their household batteries to any of sixty locations including drug stores, shopping malls, and Hennepin County Libraries.

In addition to the mixed battery program, button cell batteries are specifically targeted for collection through a return-to-retailer drop-off program that targets locations where there is a frequent "change-out" of these types of batteries. Examples of these locations are camera shops, hearing aid stores, audiologists, and nursing homes. There is currently a network of 500 drop-off locations of this type.

Hennepin County employs two social service organizations to collect batteries from the drop-off locations and sort them. People Unlimited, a private non-profit organization that employs economically disadvantaged persons in need of establishing a positive work history, collect the batteries from the drop-off sites and bring them for sorting to Hennepin County's Vocational Services Program, a social services agency for mentally ill adults.

134 Oyass, Mark J., et al., *Hennepin County Household Battery Program Report and Recommendations*, prepared for the Department of Environmental Management, October, 1991

135 Lofrano-Zaske, Cheryl, Environmental Scientist, Hennepin County Department of Environmental Management, personal communication with Gainer & Associates, February, 1992

Batteries are sorted into several categories according to physical type and chemical content including button cell, alkaline, carbon-zinc, nickel-cadmium, lithium, small lead acid, and other mercuric oxide (9 volt) batteries. The batteries are disposed in the following manner:

- Alkaline and carbon-zinc are sent to a hazardous waste landfill
- Button cell batteries and other mercuric oxide batteries are sent to Mercury Refining Company (MERECO)
- Nickel-cadmium batteries are sent to International Metals Reclamation Company, Inc. (INMETCO)
- Small lead-acid batteries are sent to a local smelter.

Table V-1, below, shows the amount of batteries collected during the first year of the program. Data are not available on the amount of small lead-acid batteries collected. The cost of the battery collection program is estimated to be $1.26 per pound ($2,520 per ton). This estimate does not include the cost of education and public information efforts.

Table V-1
Hennepin County Household Battery Collection
(November 1990 Through October 1991)

Battery Type	Amount (lbs)	Percent
Alkaline	71,327	58.2%
Carbon-Zinc	42,416	34.6
Nickel-Cadmium	8,689	7.1
Mercuric Oxide	150	0.1
Total	122,582	100.0%

With the exception of expanding the button cell and mixed battery drop-off programs, the current collection program will continue unchanged through 1993. During this time, grab samples of the collected batteries will continue to be analyzed for mercury content, particularly the mercury content of alkaline batteries. It is expected that by 1993 all of the alkaline batteries tested will pass the Minnesota legislated requirement of a maximum

mercury content of 0.025 percent by weight. If this proves correct, the County will reevaluate the program to assess the need to collect alkaline batteries.

An enhanced public education campaign to promote the proper use and disposal of batteries will complement the current program. Some of the problems that have been identified with consumer use of batteries relate to alkaline and nickel-cadmium batteries, which represent 65 percent of the collected batteries. Alkaline batteries are being discarded before they are fully discharged because of the tendency to throw away all of the batteries when emptying a radio or tape recorder, when only two or three (out of the six or eight required) are drained. Nickel-cadmium batteries are often misused also, ending up in the trash or collection bin far sooner than their designed life span due to incorrect recharging practices.

Hennepin County has contacted the Portable Rechargeable Battery Association to discuss how the organization intends to meet the requirements of new Minnesota legislation which restricts rechargeable batteries from entering the landfill and mandates that manufacturers begin pilot collection programs to recover these batteries. In addition, Hennepin County is evaluating the feasibility of accepting dry cell batteries from *small quantity generators* if inclusion of these types of generators into a household battery collection program is approved by the State and County.

Spokane Regional Solid Waste Disposal Project
County and City of Spokane, Washington[136]

The Spokane Regional Solid Waste Disposal Project established a County-wide household battery collection program in September, 1990. The program employs both curbside collection and a network of drop-off locations in an effort to divert batteries from the waste stream due to the waste-to-energy incinerator that began operating in September, 1991.

Of the 150,105 households in Spokane County, 93,000 (62 percent) have curbside collection of household batteries. The curbside program, which originally serviced only the City of Spokane, expanded in the fall of 1991 to include its urban unincorporated areas. Residents are asked to seal their discharged batteries in a plastic bag (such as an old bread

136 Lang, Jessie, et al., *Spokane City/County Household Battery Collection Program 1991*, November 5, 1991

bag), and place the bag on top of their bin of regular recyclable materials. Collection drivers place the bag of batteries in a plastic bin inside their truck and deposit the accumulated batteries in a central storage facility at the end of each week.

A network of return-to-retailer drop-off locations is intended to service the remaining 57,000 homes in the County that do not receive curbside service, as well as supplement the curbside collection program in the urban areas. The return-to-retailer drop-off program started with cooperation from four major retail chain stores and quickly grew from 50 drop-off locations to 80 locations in the first year of the program. The program's mascot is a brightly colored character called *Battery Man*. Residents can easily identify a drop-off location by the yellow and black Battery Man poster or window decal. The collection system consists of a small counter-top collection box (purchased from MERECO) for residents to deposit their discharged batteries, and a 4 gallon plastic storage bucket that stays behind the service counter, accessible only to store employees. Both the counter-top box and the plastic storage bucket are divided into two compartments to separate button cell batteries from the other batteries. Retail stores call the Spokane Regional Solid Waste Disposal Project for battery pick-up when the plastic storage container is full.

Once batteries reach the central storage facility, a person specially trained and equipped with gloves and dust mask sort batteries into button cell and non-button cell categories. They also sort out miscellaneous batteries not included in the program, such as small lead acid batteries. Non-button cell type batteries, which compose over 99 percent, by weight, of the total batteries collected, are packed in a plastic lined metal drum and shipped to a hazardous waste landfill. The button cell batteries are further sorted to separate the recoverable (silver and mercuric oxide) from the non-recyclable types (zinc-air and lithium). The reclaimable types, which consisted of 200 pounds in the first year, are shipped to MERECO for reclamation of mercury and silver. The non-recyclable button cell batteries are shipped to a hazardous waste landfill. Hazardous waste landfill disposal costs are approximately $89 per drum (approximately 300 pounds of batteries[137]), or $593 per ton.

137 The amount of batteries contained in disposal drums varied from 200 pounds to 650 pounds depending on the collection program interviewed. The variations are due to different drum sizes used (ranging from 19 to 55 gallons), and varying practices for packing drums prior to disposal.

In the first year of the program, 15 tons of batteries were collected, 80 percent from the curbside program and 20 percent from the return-to-retailer drop-off locations. It is expected that the recent expansion of the curbside program will bring in an additional 200 to 300 pounds of household batteries per week (5 to 8 tons per year). The cost of the program in the first year was $58,900, which included $26,656 in one-time implementation costs. Annual operating costs are currently expected to be $42,359, which includes the cost of the additional time required by the curbside collection drivers. At a diversion rate of 23 tons per year, this translates into a total ongoing operating cost of $0.92 per pound ($1,840 per ton) of batteries diverted. In addition, it is acknowledged that program costs will depend on the amount of batteries collected, and may be as much as $3,000 per ton.

City of Bellingham and Recomp of Washington, Inc.
Whatcom County, Washington[138]

The City of Bellingham and Recomp of Washington, Inc. (Recomp) are co-sponsors of the household battery collection program that services all of Whatcom County (population 130,000). Recomp operates the solid waste processing facility that processes approximately 250 tons per day of municipal solid waste through recycling, solid waste composting, and waste-to-energy incineration. The incinerator has been in operation since 1974, and a materials recovery facility and composting program have been initiated in 1991. The household battery collection program began in September 1988 to reduce the amount of heavy metals entering the waste stream and focus public attention on the issue of household hazardous waste.

The collection program consists of sixty return-to-retailer and community drop-off locations. The return-to-retailer drop-off locations consist of stores that sell or repair watches, cameras, calculators, and hearing aids. Forty retailers collect batteries from the general public. The remaining twenty collect batteries in-house only and from employees. The community drop-off sites are located at recycling centers, senior citizen centers, and city and county government offices.

Each site is provided with a plastic bucket for battery storage and a supply of promotional flyers. During the first seven months, the program only targeted button cell and nickel-cadmium batteries but, subsequently, began accepting all types of batteries

138 Muecci, Lisa, Recomp of Washington, Inc., personal communications with Gainer & Associates, January/February, 1992

because of the public's inability to distinguish between recyclable and non-recyclable batteries. The batteries are centrally collected on an on-call basis by a Recomp staff person.

Once the batteries are collected from the drop-off sites, a Recomp staff person sorts them into two general categories: 1) alkaline and carbon-zinc, and 2) nickel-cadmium, silver oxide and mercuric oxide buttons, and lithium. The alkaline and carbon-zinc batteries are sent to a hazardous waste landfill in Oregon, and the nickel-cadmium, silver and mercuric oxide button cells, and lithium batteries are sent to MERECO. MERECO reclaims the mercury and silver from mercuric oxide and silver oxide batteries, deactivates the lithium batteries, and sends the nickel-cadmium batteries to another reclamation facility for processing. Between September 1988 and November 1991, the program collected thirty-two 55-gallon drums of non-recyclable batteries, and four 55-gallon drums of recyclable batteries. The program currently collects about 800 pounds of batteries per month.

The total annual operating cost of the battery collection program is approximately $23,250, or about $2.42 per pound ($4,840 per ton) of batteries diverted. This covers the salary of a part-time staff person, shipping and storage materials, and disposal costs. The City of Bellingham covers the disposal cost of sending the non-recyclable batteries to the hazardous waste landfill, and the rest of the program is funded from tipping fees. An initial $3,000 was spent for developing and purchasing promotional materials and collection containers.

Recomp and the City of Bellingham intend to continue the household battery collection program, as is, for the next three to five years. At that time, the program will be reviewed to determine whether it is still necessary to accept alkaline and carbon-zinc batteries.

New Hampshire/Vermont Solid Waste Project[139,140]

The New Hampshire/Vermont Solid Waste Project, a consortium of twenty-nine small rural municipalities in two states, implemented a mixed household battery collection

139 Hirth, Carl, *NH/VT Solid Waste Project, Household Battery Program*, Claremont, New Hampshire, December 1991

140 Hirth, Carl, Solid Waste Planner, NH/VT Solid Waste Project, personal communication with Gainer & Associates, February 1992

program in 1987. The program, servicing a population of 72,000, began simultaneously with the start-up of a 200 ton per day waste-to-energy incinerator servicing the residential and commercial waste stream of the project area. The goals of the program were *to reduce concentrated sources of heavy metal in the waste stream and return to industry those batteries which could be recycled.*

The battery collection program has both return-to-retailer and community drop-off sites. Community drop-off sites are located at transfer stations, recycling centers, and government offices. Drop-off sites are supplied with a 5-quart metal bucket, adorned with the project's logo, which sits adjacent to their battery collection display. Retailers play a significant role in the program by encouraging customers to return their discharged batteries. Household batteries are collected by a staff person or a municipal work crew, who collects the batteries every six months and on a per call basis, and transports them to one of two centralized storage facilities. When a significant amount of batteries have accumulated, they are sent, unsorted, to a hazardous waste landfill in South Carolina. At the program's inception, it was intended that silver and mercuric oxide type batteries would be sorted and sent to MERECO, but this was later canceled due to the lack of staff and appropriate facilities for battery sorting.

From May 1987 through December 1991, the project diverted over 13 tons of mixed batteries. The largest quantities of batteries are collected from municipal transfer stations and recycling centers. During this time, the diversion rate has risen from approximately 8 percent in 1987, and 1988 to 18 percent in 1991, based on an industry estimate of the annual per capita consumption rate of 8 batteries, or about one pound. No data are available on the diversion rate of specific types of batteries due to the program's current practice of hazardous waste landfilling of mixed batteries.

The cost of the program has been kept to a minimum, with disposal as the largest single expense, at approximately $300 per 55-gallon drum or $923 per ton (the NH/VT Project reports that a 55 gallon drum will hold approximately 650 pounds of batteries). Collection equipment, drums and packing material, and public education cost approximately $6,000 per year. Based on current battery diversions, total program costs are about $1.54 per pound ($3,080 per ton) of batteries collected.

Environmental Action Coalition
New York City, New York[141,142]

Since 1987, Environmental Action Coalition (EAC) has extensively researched the effects of household batteries in the waste stream and provided a variety of household battery collection services for New York City residents. Motivated by the potential health and environmental impacts caused by these batteries, EAC set up a test program to collect and recycle button cell batteries from retail stores. Funding for this pilot program was provided by the New York State Environmental Facilities Corporation.

During the six month pilot program, EAC set up 180 return-to-retailer drop-off sites in stores that sold button cell battery-powered items such as watches, hearing aids, and cameras. Stores were provided counter-top collection boxes, signs, window stickers, and customer information on proper battery disposal. When the collection boxes filled, stores were instructed to either call EAC for pick-up service, ship the batteries to EAC post-paid, or ship the batteries directly to MERECO. The pilot program netted approximately 75 pounds of batteries, delivered to MERECO by EAC, plus an undetermined additional quantity that was directly mailed to MERECO by retailers. Because of the revenue received from the sale of silver oxide batteries, some retailers were motivated to directly mail their collected batteries.

EAC also experimented with providing battery collection service to residents living in high-rise apartment buildings to determine the battery diversion rate possible from this type of program. Over a period of twelve months, this service collected mixed batteries from three buildings, totaling 1,300 units. The mixed batteries were sent to MERECO, where the silver and mercuric oxide button cell batteries were sorted for refining, and the rest were sent to a hazardous waste landfill. The year-long collection service from apartment buildings diverted approximately 1,000 pounds of mixed batteries. EAC was forced to discontinue this service due to the expense of sending the non-recyclable batteries to a hazardous waste landfill.

As the result of a grant received from the USEPA, EAC expanded its return-to-retailer program in 1990, to further encourage the recycling of button cell and rechargeable

141 Forker, Timothy and Hecht, Sean, Environmental Action Coalition's Waste Household Battery Management Project, 1987-1991, December, 1991

142 Forker, Timothy, personal communication with Gainer & Associates, February, 1992

household batteries. This grant also allowed them to continue to research battery markets, legislation and public policy, and to study national and European battery management programs.

With this program expansion, EAC honed the focus of their household battery collection program primarily to capture nickel-cadmium batteries, and silver and mercuric oxide button cell batteries. To do this, EAC established drop-off sites at areas having a high replacement rate of these batteries, primarily retailers and users, such as hearing aid and camera stores, audiologists, and doctors working with the hearing impaired. They also set up drop-off locations at schools, non-profit organizations, and at two *environmentally friendly* retail stores.

Household Hazardous Waste Project
Green County and City of Springfield, Missouri[143]

Now affiliated with the University of Missouri Extension Service, the Household Hazardous Waste Project began as a grassroot coalition concerned with the environmental and health impacts of household hazardous waste. The coalition was composed, in part, of representatives from the Springfield Public Works Department, the American Red Cross, Green County Department of Health, the County of Green/City of Springfield Watershed Committee, and the League of Women Voters. The purpose of the Household Hazardous Waste Project was to formulate a plan of action to reduce the amount of household hazardous waste entering the waste stream. Funding for implementation came from the State's Environmental Improvement and Energy Resources Authority.

The Household Hazardous Waste Project addressed household batteries in the same manner as other household hazardous waste. Businesses which would accept household hazardous waste from the public for recycling and safe disposal were systematically identified. Participating businesses were wholly responsible for the collection and disposal of the household hazardous waste. Starting in Green County in 1987, the Household Hazardous Waste Project identified approximately twenty retailers, mostly jewelers and hearing aid stores, who were willing to collect and dispose of button cell batteries. Some retail stores, which had been offering this service previously, were disposing their batteries through a collection program supported by the American Watchmakers Institute. Local

143 Steinwachs, Marie, Associate Director, Household Hazardous Waste Project, personal communications with Gainer & Associates, January/February 1992

Soroptimist Clubs also had been involved with battery recycling as a fund raising activity from the sale of used silver oxide batteries. Retailers not previously accepting button cell batteries were supplied with information on disposal and recycling options.

With the collected information, the Household Hazardous Waste Project published a *Household Hazardous Waste Resource List* to disseminate information to county residents. In 1988, the program expanded to provide information to residents in twenty-three counties in Southwest Missouri. The Household Hazardous Waste Project discontinued updating the counties' lists in 1989, but a handful of counties have continued maintaining the list on their own. No data on the amount of batteries diverted has been collected.

The Springfield Regional Waste District is in the start-up phase of implementing a municipal waste composting system. It is the Household Hazardous Waste Project's intention to have the diversion of household batteries specifically addressed as a condition of this waste management system.

3. Industry Sponsored Household Battery Collection and Recycling

Some states, such as Minnesota and New Jersey, have recently passed legislation which requires either product manufacturers or battery manufacturers to develop and implement plans for the collection and recycling of nickel-cadmium and mercuric oxide household batteries. These industries are now just working to meet requirements of the new laws. However, some of these efforts are worth noting.

Compaq Computer Corporation
Houston, Texas[144,145]

In January 1992, Compaq Computer implemented the computer industry's first nationwide PC battery pack recycling program. The program is offered to all Compaq Computer customers. Under the program, depleted nickel-cadmium batteries contained in laptop and notebook computers are sent to INMETCO for reclamation.

144 Compaq Computer Corporation, *News Release: Compaq Announces Battery Recycling Program for COMPAQ Laptop and Notebook PC Users*, January 27, 1992

145 Rosenberg, Walt, Compaq Computer Corporation, personal communication with Ernst & Young, February, 1992

To participate in the program, Compaq customers call a toll-free hotline and receive a pre-addressed, postage-paid battery mailer which is directly mailed to INMETCO with the used computer battery pack. For each Compaq battery pack received, Compaq will be charged a fee for reclamation of the battery pack. Compaq plans to notif. all Compaq consumers of the disposal/recycling procedures which will accommodate all Compaq battery packs sold in the United States.

Portable Rechargeable Battery Association (PRBA)
Atlanta, Georgia[146,147]

In response to recent legislation in Minnesota and New Jersey, five manufacturers of rechargeable household batteries formed the Portable Rechargeable Battery Association (PRBA) to respond to specific requirements which mandate that rechargeable battery manufacturers and battery product manufacturers develop and adopt battery collection and management plans. The mission of the PRBA is *to represent the interests of manufacturers, distributors, assemblers, users, suppliers, and sellers of small sealed rechargeable batteries and battery operated products.*

The PRBA is currently working to develop and implement nickel-cadmium household battery collection and reclamation programs in the United States. The approach the association is taking involves a reverse distribution network whereby used nickel-cadmium batteries would be returned to original equipment manufacturers, certain retailers, and service centers. Collected nickel-cadmium batteries would be transported to manufacturers' regional warehouses until a sufficient quantity is accumulated to ship containerized batteries to reclamation facilities in Japan or Europe. The PRBA also is supporting efforts to develop additional reclamation facilities in the United States. The PRBA's efforts to implement collection programs have been delayed by the lengthy RCRA permit process and the classification of nickel-cadmium batteries as hazardous waste.

146 Tater, Todd,, representing the Portable Rechargeable Battery Association, Materials presented in meeting with CIWMB and Ernst & Young, January 31, 1992

147 Portable Rechargeable Battery Association, *Briefing on Implementation of Ni-Cd Collection-Reclamation Programs*, August 15, 1991

C. Effectiveness of Household Battery Collection, Disposal, and Reclamation

In this subsection, we review the success and effectiveness of the programs described previously.

1. Diversion Rates of Household Battery Collection Programs

Most household battery collection programs do not keep accurate records on the amount of batteries diverted from their community's waste stream. Of the programs that have kept track of the amount of batteries collected, overall diversion rates range between 7 and 18 percent. This diversion rate is defined as the percentage of discarded household batteries which are diverted from the municipal solid waste stream through collection efforts. **Table V-2**, below, presents the estimated overall diversion rates and total annual operating costs of several surveyed programs. These programs were described earlier in this section.

Table V-2
Effectiveness of Household Battery Collection Programs

Collection Program	Diversion Rate[a]	Program Cost
Hennepin County, Minnesota	12%	$1.26/lb[b] ($2,520/ton)
County and City of Spokane, Washington	18%[c] 7%	$0.92/lb ($1,840/ton)
City of Bellingham and Whatcom County, Washington	7%	$2.42/lb ($4,840/ton)
New Hampshire/Vermont Solid Waste Project	18%	$1.54/lb ($3,080/ton)

a/ Estimates based on a per capita annual disposal rate of one pound (approximately 8 batteries)
b/ Does not include public education costs
c/ Curbside and return-to-retailer diversion rates, respectively. These rates are not additive since the two programs are implemented in different parts of the County

Diversion rates for curbside collection are usually higher than diversion rates for return-to-retailer and community drop-off collection. For example, in Spokane County, the portion of the County served by the curbside program saw an 18 percent diversion rate, while the area covered by their return-to-retailer programs achieved a diversion rate of approximately 7 percent.

In addition, it should be noted that the return-to-retailer and community drop off battery collection program operated by the New Hampshire/Vermont Solid Waste Project, which began in 1987, claims a diversion rate of 18 percent. The diversion rate of this program, which started two to three years earlier than the other programs, is substantially higher than other drop-off programs. This seems to indicate that higher diversion rates can be achieved over time.

Of the several household battery collection programs surveyed, the cost of these battery management programs ranges from $0.92 to $2.42 per pound ($1,840 to $4,840 per ton) of batteries diverted. These costs reflect both collection and disposal and/or reclamation. At $0.92 per pound, the collection program in Spokane, Washington is the most cost-effective collection program reviewed. This may be attributable to the relatively low cost ($593 per ton) for disposing of the batteries in a hazardous waste landfill.

2. Factors Influencing Collection Program Effectiveness

Significant factors influencing the future of household battery waste management programs are:

- Changes in the chemical content of household batteries
- Existence of suitable household battery reclamation opportunities
- High cost of disposal.

With present manufacturing trends to reduce or eliminate mercury content in alkaline batteries, coupled with the high cost to dispose of household batteries in a hazardous waste landfill, many collection programs are reevaluating the viability of collecting all types of household batteries. In the next few years, high mercury content alkaline batteries will be *flushed* through the market and waste stream, leaving only button cells and nickel-cadmium batteries as the batteries of primary environmental concern. At

this point, many household battery collection programs may opt to discontinue collection of alkaline and carbon-zinc batteries. This could reduce program operating and disposal costs since these batteries typically represent from 85 to over 90 percent of the waste household batteries collected.

The decision on what type of household batteries to collect may affect the decision on how best to collect batteries. Return-to-retailer collection may be better suited for button cell and nickel-cadmium batteries where consumers are looking for a specific type and size of replacement battery. It should be noted, though, that with the narrowing of battery types collected, there also would be greater need to educate the public on differentiating battery types. This could be accomplished with a battery labelling system which would help consumers sort their batteries after use. Another alternative would be to label batteries with a magnetic strip during the manufacturing process which could greatly facilitate the battery separation process at a materials recovery facility.

Although mercury reduction in batteries is welcomed by household battery collection programs, the high cost of recycling or disposing of nickel-cadmium and button cell batteries remains a financial burden. With limited options available for battery recycling, the cost to recycle most types of batteries may be greater than disposal as hazardous waste[148]. A part of the cost differential is due to the cost of separating batteries by the various types prior to processing (this must either be performed as batteries are collected or prior to the reclamation process). This cost differential may be reduced in the future as methods for separating collected batteries are improved, or reclamation processes are adopted which do not require the separation of batteries by type. Facilities are not presently commercially operational; however, processes and technologies to accomplish these objectives are being developed.

The concept of household battery recycling is becoming increasingly popular, however, some practical issues have received less attention. This section has shown how opportunities for recycling, or reclaiming metals from used household batteries, are quite limited. While battery collection programs are being developed and supported in the United States, similar efforts to facilitate the establishment of additional reclamation facilities are needed. Reclamation technologies that currently exist in Europe and Japan could be

148 Wallis, George and S. P. Wolsky, *Options for Household Battery Waste Management*, Proceeding of the Second International Seminar on Battery Waste Management, November 5-7, 1990

implemented in the United States; however, lengthy permit processes and adverse public response to siting these facilities (NIMBY syndrome) have stymied these efforts[149].

Dedicated battery reclamation facilities may require a high volume of used batteries in order to be economically viable. To obtain the necessary volume it may be necessary to increase collection efforts. Until such time as adequate facilities are developed to efficiently, effectively, and safely dispose of waste batteries through appropriate reclamation processes, battery collection programs may continue to be confronted with costly battery disposal options.

149 Ibid

VI. Summary of Study Findings and Recommended Household Battery Waste Management Strategies

VI. SUMMARY OF STUDY FINDINGS AND RECOMMENDED HOUSEHOLD BATTERY WASTE MANAGEMENT STRATEGIES

This section of the report summarizes study findings and presents recommendations regarding the management of used household batteries in California. In developing the recommendations, consideration was given to existing waste management practices and regulations. This includes current development of local household hazardous waste programs and recent developments in household battery management in other states.

In determining appropriate strategies for the management of household battery waste, a number of important issues need to be addressed concerning: 1) designation of the various types of household batteries as hazardous waste, 2) requirements for the collection, storage, transportation, and disposition of hazardous waste within California, and 3) obligations of cities and counties to establish household hazardous waste collection and disposal programs. Each type of household battery can present different issues and problems regarding their disposal, and may involve different technological, economic, and legal issues.

Actual health and environmental impacts from the disposal of household batteries are not well known. Mercury and cadmium are metals of primary concern in municipal solid waste. Historically, household batteries have contained significant levels of mercury and cadmium. However, mercury may be less of a concern than in the past, owing to the efforts of the battery industry in nearly eliminating mercury from the most common types of household batteries. Cadmium, on the other hand, is a growing concern since nickel-cadmium batteries represent a growing share of the household battery market, and nickel-cadmium batteries represent the single largest source of cadmium in municipal solid waste.

This section of the report is organized under the following subsections:

- Household Batteries of Concern in the Waste Stream
- Household Battery Disposal Practices
- Metals Reclamation From Household Batteries
- Economics of Household Battery Collection and Disposal

- Legal and Regulatory Issues Involving Household Batteries
- Summary of Household Battery Legislation in the United States
- Key Household Battery Policy Issues for California
- Recommended Household Battery Waste Management Strategies.

A. Household Batteries of Concern in the Waste Stream

There are several types of batteries which fall under the general category of *household battery*. Each battery type is comprised of different kinds and amounts of metals and other materials. In addition, the various types of batteries have found different applications due to their operating characteristics, size, and cost.

The portable power offered by household batteries has become an increasingly important component of everyday life. Sales estimates indicate that per capita consumption of household batteries has risen from 12 batteries per year in 1985 to 16 batteries per year in 1992. Per capita annual sales are projected to increase to nearly 23 batteries by the year 2000.

Trends in the use and application of household batteries vary by the various types and sizes of batteries. Some significant trends in battery sales include the following:

- Sales of household batteries are projected to increase nearly 50 percent in California between 1992 and the year 2000. Major factors in this increase include a large increase in per capita consumption and changes in market share, product mix, and consumer market trends
- Alkaline batteries will continue to be the dominant type of household battery, accounting for 68 percent of the household batteries sold in the year 2000
- Nickel-cadmium batteries are expected to receive an increasing share of the household battery market, accounting for 17 percent of the market by the year 2000.

Exhibit VI-1, on the following page, lists the common types of household batteries and summarizes information regarding projected California battery sales, metals of concern, and the amount of metals entering the waste stream from the disposal of household batteries in California. The USEPA has identified mercury and cadmium as the metals of primary concern in municipal solid waste. Small amounts of mercury historically have been included in most types of primary batteries. Mercury is a major component of mercuric oxide batteries since the mercury serves as one of the electrodes in the cell.

Summary of Household Batteries of Concern in California

Battery Type	Battery Sales in California (Millions) 1992	2000	Metal of Concern	Metal Content (Percent)	Amount of Metal in California Municipal Solid Waste (Tons/Yr) 1992	2000	Potential For Metal Reclamation
Primary Batteries							
Alkaline	284	465	Mercury	0.025% and decreasing	7.1	0.0	Reclamation Not Available
Carbon-Zinc	88	60	Mercury	0.0001%	0.1	0.0	Reclamation Not Available
Mercuric Oxide	5	4	Mercury	30% to 43%	3.4	2.4	Mercury Reclaimable (MERECO)
Silver Oxide	11	13	Mercury	1%	0.1	0.1	Silver Reclaimable (MERECO)
Zinc Air	12	22	Mercury	2%	0.4	0.8	Reclamation Not Available
Lithium	1	3	Lithium	Varies	a/	a/	Reclamation Not Available
Secondary Batteries							
Nickel-Cadmium	60	117	Cadmium	10% to 15%	236	466	Nickel Reclaimable, Secondary Process Required for Cadmium (INMETCO)

a/ Insufficient data are available for a detailed analysis of lithium batteries. Lithium and other new battery technologies may warrant special study if their use increases significantly.

Cadmium is a major component of nickel-cadmium batteries, also functioning as one of the electrodes. Because each battery type includes varying amounts of mercury and cadmium, each battery type may have a different impact in the waste stream.

Alkaline and carbon-zinc batteries presently represent approximately 80 percent of the household battery market. In recent years, battery manufacturers have all but eliminated mercury from these types of batteries. Currently, carbon-zinc batteries generally do not contain any added mercury. In December 1991, two of the four major battery manufacturers in the United States announced plans to begin production of *mercury free* alkaline batteries in 1992. Other battery manufacturers are expected to follow this lead. If this development occurs as anticipated, then the contribution of mercury to the waste stream from alkaline and carbon-zinc batteries will be virtually eliminated in the next few years.

There are several types of button cell batteries. While each type has slightly different characteristics, they are generally used for hearing aids, watches, cameras, and calculators. Historically, mercuric oxide has been the most common type of button cell. However, silver oxide, zinc air, and lithium batteries each offer some characteristics superior to mercuric oxide and have steadily increased their market share over mercuric oxide batteries. This is a beneficial trend since mercuric oxide cells contain significantly greater amounts of mercury than the other types of button cells. The availability of substitute battery technologies has contributed to the decline of mercury in the waste stream contributed from mercuric oxide batteries.

The focus of efforts to further reduce mercury in the waste stream should be placed on removing mercuric oxide batteries from the waste stream. This could be accomplished through both reducing the use of these batteries and through collection of button cells. Two states have legislated a ban on mercuric oxide button cells. In addition, battery manufacturers have indicated that mercuric oxide button cells may be taken off the market within the next few years, with or without a legislated ban.

Examination of the metals loading to the waste stream from household batteries indicates that by the year 2000 there will be over 100 times as much cadmium in municipal solid waste from household batteries as there will be mercury. Cadmium is one of the electrodes in nickel-cadmium batteries and the cadmium content cannot be reduced without changing the battery's performance. For purposes of relative comparison, the amount of

cadmium in a single nickel-cadmium battery is roughly equivalent to the amount of mercury in over 400 low-mercury (0.025 percent) alkaline batteries of the same size.

Nickel-cadmium batteries should be targeted for diversion from the municipal solid waste stream and disposed as hazardous waste or reclaimed for the following reasons:

- Nickel-cadmium battery usage is growing significantly
- The amount of cadmium in nickel-cadmium batteries cannot be reduced without affecting battery performance
- Alternative battery technologies presently are not sufficiently developed to provide a suitable substitute for nickel-cadmium batteries for most applications.

Many consumers may not recognize how many batteries they use during everyday activities. It is estimated that approximately 80 percent of the nickel-cadmium batteries are sealed inside consumer products. In many cases, consumers may not even realize that their products contain a nickel-cadmium battery.

B. Household Battery Disposal Practices

In general, household batteries can be disposed by consumers in one of two ways. Household batteries can be disposed with other refuse in municipal solid waste, or they can be separated and collected for metals reclamation or disposal as hazardous waste.

1. Household Batteries in Municipal Solid Waste

Approximately 86 percent of the municipal solid waste in California is landfilled, 12 percent is recycled, and the remaining 2 percent is incinerated or composted. Household batteries comprise an estimated 0.005 percent, by weight, of municipal solid waste. Therefore, disposal issues surrounding household batteries are not related to the space occupied by batteries in landfills. Concern exists regarding the potential health and environmental effects of metals contained in household batteries after they are disposed.

Once household batteries enter the waste stream in mixed municipal solid waste, they can travel many different pathways before reaching a final destination. The potential pathways may include transfer stations or materials recovery facilities prior to final disposition in a landfill, incinerator, or compost. Intermediate processes to separate and refine municipal solid waste may have an impact on the final disposition of household batteries. A materials recovery facility which prepares compost feedstock or a refuse derived fuel could be designed to separate out household batteries with other process residue. It is presently not practical to separate batteries from general municipal solid waste as a homogeneous waste stream, although in theory this could be accomplished. (It is possible to separate battery types, once battery wastes are sorted together.) Batteries separated from the waste stream with other process residue would end up in a sanitary landfill.

The effects of household batteries in landfills is uncertain. Recent studies and reports about the environmental impact of household batteries in landfills are inconclusive. Given the inconclusive nature of research in this area, we have accepted USEPA's position that mercury and cadmium are of primary concern in municipal solid waste.

Household batteries may present a greater concern if they are present in incinerators or compost. In either of these situations, the metals in batteries have a greater potential to escape into the environment. In the case of incinerators, stack emissions may include

sufficient levels of mercury or cadmium to be of concern. In addition, incinerator ash disposed in landfills contains more concentrated materials from which metals may be leached. Studies have shown that modest processing of municipal solid waste prior to incineration (RDF-2 to RDF-3) can significantly reduce the metals loading of the waste stream entering the incinerator. In addition, emissions control equipment can be effective in controlling emissions. Nevertheless, if new or existing incinerators in California wish to limit the amount of metals incinerated, then battery collection programs may be further justified.

In the case of compost, the presence of household batteries, particularly if they have been crushed or shredded by process equipment, may contribute to the metal content of compost product. Metal content in compost may limit its uses, and provide a pathway for the metals back into the environment. Similar to the preparation of refuse derived fuel, compost feedstock could be rid of most household batteries through the design of intermediate feedstock preparation processes. In this regard, materials recovery facilities could help to minimize the potential impacts of household batteries in the compost municipal solid waste stream.

2. Household Battery Collection

In California, the primary collection vehicle for household batteries not disposed in municipal solid waste is household hazardous waste collection programs sponsored by cities and counties. Collection programs operating outside of California have demonstrated that return-to-retailer and curbside collection of household batteries may also be effective collection mechanisms. In communities with a mass burn incinerator, or compost operations for mixed municipal solid waste, collection programs which include participation by retail establishments or inclusion of household batteries in curbside collection may provide additional convenience to the consumer for proper battery disposal.

Increasingly, household battery collection programs are reconsidering the need to collect and dispose of alkaline and carbon-zinc batteries. The mercury content in these types of household batteries has been virtually eliminated. In addition, alkaline and carbon-zinc batteries often represent approximately 90 percent of the collected batteries. This significantly increases the complexity of separating batteries by type if reclamation is a collection objective. Some battery collection programs surveyed during this study are considering limiting, or have limited, the types of batteries collected to only button cells and

rechargeable nickel-cadmium batteries. Under current regulation in California, this would not be an alternative for city and county hazardous waste collection programs because all household batteries types are considered hazardous.

Battery and product manufacturers have begun to develop programs for the collection of nickel-cadmium batteries. Manufacturers generally are motivated in this regard by legislation in other states.

3. Household Battery Hazardous Waste Disposal

Collected household batteries must be handled and disposed along with other hazardous waste, unless they are reclaimed. Reclamation technologies are not commercially available for alkaline, carbon-zinc, zinc air, and lithium batteries. These battery types represent about 84 percent of the household batteries currently sold in California. In addition, other recyclable types of household batteries are frequently disposed as hazardous waste due to high cost and other concerns regarding the limited options for battery reclamation.

Household batteries destined for hazardous waste landfills are generally lab-packed with other household hazardous wastes. Lab-packing is the process of safely packing many smaller containers of hazardous waste into a larger container, usually a 30- or 55-gallon steel, plastic lined drum. Hazardous waste must be properly stored, packed, transported, and disposed in accordance with applicable state and federal requirements. This usually involves the permitting of facilities and manifesting of shipments.

C. Metals Reclamation from Household Batteries

In the United States, there are limited opportunities for the reclamation of metals from household batteries. Only two facilities are known to reclaim metals from household batteries in the United States.

- *Mercury Refining Company (MERECO)* - MERECO, located in New York, reclaims mercury from mercuric oxide batteries and silver and mercury from silver oxide batteries. Other batteries types are accepted by MERECO; however, they are either disposed as hazardous waste or sold to other processors.

- *International Metals Reclamation Company (INMETCO)* - INMETCO, located in Pennsylvania, is an industrial waste metal processor which accepts used consumer nickel-cadmium batteries for metal recovery. INMETCO's process focuses on the recovery of nickel for the production of stainless steel. Waste products containing cadmium are shipped to a second metal processor for cadmium recovery.

Mercuric oxide, silver oxide, and nickel-cadmium batteries currently represent only 16 percent of the household battery market in California. All other batteries must be disposed as hazardous waste.

Other metal reclamation processes exist in Europe and Japan which are designed specifically for recovery of nickel and cadmium from nickel-cadmium batteries. While some people believe similar facilities should be sited in the United States it is unknown whether this will occur. Problems inhibiting the construction of this type of facility in the United States include:

- Complex and lengthy permit requirements
- The NIMBY (Not-In-My-Back-Yard) syndrome
- Economic viability and the need for a large steady supply of batteries.

In addition, new battery reclamation technologies have been proposed for reclamation of nickel-cadmium batteries, and also mixed batteries. The latter technology would reclaim a ferro-manganese alloy, zinc, and mercury from all types of household batteries. These new technologies are still in the developmental stages and have not been proven in large-scale commercial facilities.

The outlook for battery reclamation in the United States is unknown, but appears limited. If nickel-cadmium batteries are targeted for large-scale collection, as is occurring in a few other states, then the need for additional reclamation facilities should be examined further.

D. Economics of Household Battery Collection and Disposal

The costs of collection and disposal of household batteries as hazardous waste may presently cost on the order of up to $4,000 a ton in California. This includes approximately $2,000 a ton for collection, and $2,000 a ton for disposal. The cost per ton to collect and reclaim the applicable metal from household batteries is generally equal to, or greater than, this $4,000 per ton.

The development and implementation of household battery collection and disposal programs in California can create an additional financial burden on local governments. For a community of 100,000 people with a household diversion rate of only 10 percent, the annual costs for collection and disposal of just household batteries as hazardous waste could equal $20,000, or more.

For the most part, the cost to dispose household batteries as a hazardous waste will be the same for each type of battery. The exception to this may be lithium batteries. Because of the potential for lithium in its metallic state to react violently with water, some battery collection program operators report that these cells should be deactivated prior to disposal. Reported costs for deactivating lithium batteries range from $4 to $15 per pound, or $8,000 to $30,000 per ton of batteries.

Since the amount of mercury and cadmium is the concern of household batteries, it is illustrative to examine costs for diverting these metals from the waste stream through battery collection and disposal. Each battery type contains varying amounts of mercury and cadmium. **Table VI-1**, on the following page, shows the approximate cost incurred of removing a single pound of mercury, from primary battery types, and cadmium, from nickel-cadmium batteries. These costs are achieved by diverting each battery type from the waste stream and disposing of them as hazardous waste.

Table VI-1
Cost of Diverting Metals From Municipal Solid Waste Through the Collection and Disposal of Household Batteries

Battery Type	Metal of Concern	Metal Content	Cost of Metal Diversion[a] ($/lb of metal)
Alkaline	Mercury	0.025%	$8,000
Carbon-Zinc	Mercury	0.0001%	$2,000,000
Mercuric Oxide	Mercury	37%	$5
Silver Oxide	Mercury	1%	$200
Zinc Air	Mercury	2%	$100
Nickel-Cadmium	Cadmium	12.5%	$16

a/ Assumes $4,000 per ton household battery hazardous waste collection and disposal costs.

The data presented in Table VI-1 indicate that, from a cost-effectiveness standpoint, household battery collection efforts should focus on button cell and nickel-cadmium batteries. The data also support the direction that many existing battery collection programs are taking which is not to accept alkaline and carbon-zinc batteries in their programs.

The data in Table VI-1 do not include costs for reclaiming metals from batteries. Mercuric oxide, silver oxide, and nickel-cadmium batteries can be reclaimed. The cost to reclaim mercury from mercuric oxide batteries is higher than the cost of household battery hazardous waste disposal. Silver oxide batteries command a payment price from metal processors due to the value of silver as a precious metal. Finally, the costs to reclaim nickel-cadmium batteries is comparable to the cost of hazardous waste disposal.

Table VI-2, on the following page, shows the number of batteries required to be diverted for each pound of the applicable hazardous material avoided. These data indicate that it would require over nine million carbon-zinc batteries to be collected in order to divert a pound of mercury from the municipal solid waste stream. It also is interesting to note that both alkaline and silver oxide batteries need approximately 40,000 batteries to be collected to divert a pound of mercury from the municipal solid waste stream, even though it is much

cheaper to dispose of the silver oxide batteries because of their lesser weight. Table VI-2 shows that a relatively small number of mercuric oxide and nickel-cadmium batteries must be collected in order to divert a pound of hazardous metals in the municipal solid waste stream.

Table VI-2
Number of Batteries Collected For Each Pound of Hazardous Material Diverted

Battery Type	Metal of Concern	Metal Content	Average Weight Per Battery[a] (Grams)	Required Number of Batteries Diverted (Batteries/ Pound of Metal)
Alkaline	Mercury	0.025%	46	39,391
Carbon-Zinc	Mercury	0.0001%	49	9,244,897
Mercuric Oxide	Mercury	37%	2	612
Silver Oxide	Mercury	1%	1	45,300
Zinc Air	Mercury	2%	2	11,325
Nickel-Cadmium	Cadmium	12.5%	44	82

a/ 453 grams per pound Avoirdupois Weight.

Given (1) the current financial pressures on local governments, (2) the costs of collecting and disposing each type of battery, (3) the varying metal content levels for each type of household battery, (4) the need for a cost-effective and pragmatic approach in the management of battery waste, and (5) the evidence that nickel-cadmium batteries may pose a relatively larger potential risk to health and the environment, an appropriate battery management strategy may require targeted efforts directed primarily at nickel-cadmium batteries.

E. Legal and Regulatory Issues Involving Household Batteries

The federal and State of California classifications of household batteries as hazardous waste are quite dissimilar. Also, the State of California's approach to managing household hazardous waste, by placing the burden on local governments for collection and disposal, may be missing opportunities to both focus requirements on manufacturers and target certain types of household batteries.

1. Federal Versus California Classification of Household Batteries as Hazardous Waste

The USEPA determines whether toxic materials are hazardous based on Toxicity Characteristic Leaching Procedure (TCLP) tests. Mercuric oxide and nickel-cadmium batteries fail TCLP tests for mercury and cadmium, respectively, and therefore generally are considered hazardous. Based on data available for this study, other types of household batteries such as certain manufacturer's alkaline and carbon zinc batteries have been shown to pass TCLP tests for mercury and cadmium.

At the federal level, wastes generated by households are excluded from hazardous waste designation[150]. As a result, the disposal of mercuric oxide and nickel-cadmium batteries, and other household hazardous waste, are not regulated under federal regulations. In addition, small quantity commercial generators of hazardous waste, which generate less than 100 kilograms (220 pounds) per month, are conditionally exempt from many of the hazardous waste regulations in RCRA[151].

Regulations within California, however, are more stringent than at the federal level. California hazardous waste control laws and regulations do not include the household waste exclusion or the small quantity generator conditional exemptions. Therefore, in California, all wastes determined to be hazardous must be handled and disposed in accordance with the State's hazardous waste laws and regulations.

California requirements on the collection, storage, handling, transportation, and disposal of household batteries are the same as they are for other hazardous waste. There

150 Title 40, Code of Federal Regulations, §261.4(b)(1)
151 Title 40, Code of Federal Regulations, §261.5

is a transportation exemption which allows households to transport their household hazardous waste to a collection facility without a manifest. This exemption applies for any person transporting hazardous waste to a permitted hazardous waste facility for transfer, treatment, recycling, or disposal, which does not exceed five gallons or 50 pounds[152].

Furthermore, California's definition of hazardous waste is broader than the USEPA's. In addition to the TCLP criteria, California regulations include criteria for toxicity using the Waste Extraction Test (WET). This test which establishes standards for mercury and cadmium includes criteria for silver, nickel, and zinc. Based on these additional standards, the Department of Toxic Substances Control (DTSC) considers all types of household batteries to be hazardous because of zinc contained in most types of primary batteries. Only in California are alkaline and carbon-zinc batteries legally considered hazardous since no other states are known to have established a standard for zinc.

2. California Management of Household Battery Hazardous Waste

The approach adopted by California for managing the disposal of household generated hazardous waste is the development of household hazardous waste collection programs operated at the city and county level. Cities and counties have been required by State legislation to plan and implement collection programs for household hazardous waste[153], including household batteries. Household hazardous waste programs are being established to assist the general public, and possibly many businesses, to properly dispose of hazardous waste. Many of these programs currently are in the early stages of development by cities and counties.

Typically, cities and counties are either establishing permanent hazardous waste collection facilities or conducting periodic household hazardous waste collection events. To facilitate the development of these programs, the State has passed legislation which eases some of the regulatory and permit requirements. One Act[154] allows any city or county which operates a household hazardous waste program to accept hazardous waste from small quantity (less than 220 pounds) commercial sources, and exempts the program

152 Health and Safety Code §25163(c)
153 AB 2707, Chapter 1406 of 1990 Statutes
154 AB 2641, Chapter 1266 of 1990 Statutes

from specified taxes, reporting requirements, and liability. Another Act[155] facilitates the collection of certain recyclable hazardous wastes, including household batteries, by eliminating the need for permits for programs which collect only specified recyclable hazardous wastes. Although this legislation includes household batteries, most recyclable household hazardous waste collection programs do not accept household batteries because of the limited opportunities for reclamation.

While the State is working to establish an infrastructure for the collection of household hazardous waste through cities and county sponsored programs, collection programs sponsored by retailers, manufacturers, and other private organizations are required to adhere to the regulatory requirements for collecting, storing, treating, transporting, and disposing of hazardous waste. With respect to household batteries, the State has attempted to facilitate household battery reclamation by providing limited exclusions and exemptions from hazardous waste laws if batteries are reclaimed[156]. Once again, however, the limited opportunities for battery reclamation have restricted the usefulness of this legislation.

155 AB 2597, Chapter 1265 of 1990 Statutes
156 Health and Safety Code, §25216 et seq.

F. Summary of Household Battery Legislation in the United States

A number of other states have studied issues surrounding the collection and disposal of household batteries. Some states have passed legislation with provisions ranging from placing limits on mercury content to requiring manufacturers to establish battery collection and reclamation programs. Additional states are considering legislation on household batteries, and it is anticipated that battery legislation will be introduced in the United States Congress by New Jersey Senator Frank Lautenberg in the Spring of 1992. This legislation is expected to closely mirror legislation already enacted in the State of New Jersey.

Exhibit VI-2, on the following page, summarizes the provisions of the more significant household battery legislation enacted by several states. Legislation in each state has generally included provisions on battery content limitations, battery product labelling, removability of batteries from products, and mechanisms for the collection and disposal of specific battery types. Appendix B of this report includes a summary of proposed and enacted legislation in the United States, and also describes some battery management activities in Europe and Japan.

Review of the legislation in other states indicates a relatively consistent trend among states in three distinct areas. These are: 1) continued reduction in mercury content, 2) requirements for product design and labelling, and 3) development of collection and disposal mechanisms. Trends in each of these areas is briefly described below.

- *Mercury Content* - Battery manufacturers have been successful at reducing the amount of mercury used in the production of household batteries by over 90 percent since 1984. The reduced reliance on mercury has resulted largely from the reformulation of alkaline batteries. To assure that batteries sold in their state contain low levels of mercury, several states have established mercury content limits on alkaline and carbon-zinc batteries, and in some cases, have banned the sale of mercuric oxide button batteries. While battery manufacturers have purportedly voluntarily reduced their use of mercury, the legislation serves to provide manufacturers with an incentive for continued progress. Battery manufacturers have indicated that batteries manufactured to meet the requirements of one state are also produced and sold in other states. However, there is nothing that requires this to occur.

Summary of Household Battery Legislation in the United States

Provision in Legislation	Effective Date				
	Conn.	Minn.	New Jersey	Oregon	Vermont
Content Limitations					
Alkaline - 0.025% mercury	Jan-92	Feb-92	Jan-92	Jan-92	Feb-92
- 0.0001% mercury	—	Jan-96	Jan-96	—	—
Carbon-Zinc - 0.0001% mercury	Jan-93	—	Jan-92	—	—
Button Cells - 25 mg mercury	—	Feb-93	—	—	—
Product Bans					
Mercuric Oxide Button Cells	—	Feb-92	Jan-92 f/	—	—
Any Batteries Containing Mercury	—	—	—	—	Jan-96
Product Labelling					
Batteries Labelled to Identify Type	—	Jul-93 d/	Jul-93	—	Jul-93 d/
Batteries Labelled Regarding Proper Disposal	—	Jul-93	Jul-93	—	Jul-93
Products/Packaging Labelled To Identify Battery Type	Jul-93	Jul-93	Jul-93	—	Jul-93
Products/Packaging Labelled Regarding Proper Battery Disposal	Jul-93	Jul-93	Jul-93	—	Jul-93
Batteries Removeable From Products					
Rechargeable Batteries Easily Removeable From Products	Jul-93	Jul-93	Jul-93	Jul-93	Jul-93
Collection Program Responsibility					
State and/or Local Government	Jul-93 b/	—	—	—	—
Battery or Product Manufacturers	—	Apr-92 e/	Jan-92 g/	—	—
Retailers	Jan-92	—	Jan-92	—	—
Household Battery Disposal					
Not Allowed in Municipal Solid Waste	Jan-92 a/	Aug-91 b/	Apr-92 c/	—	Jul-92 b/

a/ Mercuric oxide batteries
b/ Rechargeable batteries
c/ Mercuric oxide and nickel-cadmium batteries
d/ Button cells by an earlier date
e/ Pilot program required by April 1992
f/ Hearing aid batteries exempt until January 1994
g/ Submit plans to State

In general, carbon-zinc are now being produced without the addition of mercury (less than 0.0001 percent mercury). Alkaline batteries can meet the 0.025 percent requirement, and within a couple of years, they also will be produced with no mercury added.

Minnesota and New Jersey have banned the sale of mercuric oxide button batteries (New Jersey has exempted those batteries used in hearing aids until January 1994). The battery industry has indicated that mercuric oxide batteries may be removed from the market in the United States prior to 1996, with or without legislation, due to the increased use of substitute battery types.

- *Product Design and Labelling* - With most of the attention on household batteries shifting to the cadmium in nickel-cadmium batteries, several states have recognized that batteries must be accessible from products before they can be effectively collected for proper disposal or reclamation. Therefore, several states are mandating that rechargeable batteries, or battery packs, be removable from products by the consumer. A uniform target date for meeting this requirement of July 1993 has been established by all states with such legislation.

  Complementing battery removability are requirements for the labelling (of both batteries and battery-operated products) of the type of battery and the need for proper disposal procedures. This is being accomplished through uniform symbols on products and packaging, and in some cases, written instructions. Labelling also serves to help educate consumers on the various types of household batteries and varying requirements for disposal.

- *Collection and Disposal Mechanisms* - The most complicated and controversial aspect of present battery waste management trends is the establishment of an infrastructure to collect and dispose of household batteries. States have experimented with a variety of techniques including voluntary programs for the collection of household batteries. Because of the limited options available for battery reclamation, most collected batteries are disposed as hazardous waste. Both reclamation and hazardous waste disposal are costly to collection program operators.

  In addition, a few states have made it illegal to dispose mercuric oxide and/or rechargeable household batteries in municipal solid waste. Other batteries are either considered non-hazardous or determined to pose a relatively small risk relative to costs of disposal.

  Throughout California, cities and counties are currently in the process of establishing household hazardous waste collection programs. Household batteries can be collected through these programs. Other states have implemented collection programs at the local government level; however, interest is growing in requiring product or battery manufacturers to take responsibility for the collection and disposal of used rechargeable batteries.

> What is consistent among states working to establish collection and disposal mechanisms is that no state has found an ideal solution to the many complex problems involved.

In considering appropriate household battery waste management strategies for California, it is important to understand what has occurred in other states. For example, battery content limits and product design requirements require extensive lead time and impose significant cost on manufacturers. Target dates for provisions required in legislation have been established in consultation with manufacturers so that deadlines are achievable and reasonable. In addition, labelling requirements need to be consistent in each state since manufacturers may have little control over where products are ultimately sold.

G. Key Household Battery Policy Issues for California

Current laws and regulations in California designate all household batteries as hazardous waste, subject to proper handling and disposal. Because of the large number of household batteries which are used by both businesses and households in everyday applications, it may be impractical, ineffective, and very costly to manage all household batteries as currently dictated by California requirements.

A more pragmatic and cost-effective approach to battery management would target those household batteries which present the most significant risk to human health and the environment. This study, and other studies conducted throughout the country, have found that nickel-cadmium batteries currently pose the greatest risks due to their high levels of cadmium. While mercuric oxide button cells, and to a lesser extent other button cells, also should be cause for concern due to their mercury levels, alkaline and carbon-zinc battery types are starting to be recognized as a *relatively* small risk when present in the municipal solid waste stream.

Although alkaline and carbon-zinc batteries present a relatively small risk, under current California regulations, they are required to be handled as hazardous waste. This places increased burdens on cities and counties in managing household hazardous waste.

In confronting the household battery issue, the State needs to explicitly consider the following key policy issues:

- Should all household batteries be targeted as household hazardous waste? Should new low, or no, mercury content alkaline and carbon-zinc primary batteries be granted a waiver from their California classification as hazardous waste due to the unique consideration of zinc as a toxic substance?

- Who should be responsible for collection and disposal of household hazardous batteries, such as button cell and nickel-cadmium batteries? Should local governments be responsible through special event days and/or curbside collection programs, or should retailers and battery and product manufacturers be more responsible for collection and disposal?

- What are the true total costs of hazardous household battery collection and disposal programs? Who should bear these costs, and how should hazardous household battery programs be funded?

- Should communities with active incineration and compost projects have special requirements for collection and disposal of all household batteries, versus a community which relies primarily on landfilling?

- Should local governments be allowed to accept hazardous household batteries from commercial sources with exempted regulatory requirements concerning amounts and liability? Should local governments be able to collect and transport hazardous household batteries exempt from certain regulatory requirements regardless of the recyclable nature of household batteries?

- Should the State encourage the location of battery reclamation facilities in California for button cell and nickel-cadmium batteries, or even primary battery types such as alkaline batteries? Is the technology for reclamation environmentally sound and do the economics of reclamation justify such a facility without a tax subsidy?

- Should the State encourage or provide incentives to manufacturers to commercially develop new battery technologies such as nickel-metal hydride batteries and rechargeable alkaline manganese batteries as a replacement for existing nickel-cadmium secondary household hazardous batteries?

The above key questions represent some of the many diverse policy issues concerning the management of household batteries as either non-hazardous, or hazardous, waste. This study provides insight into most of the above key questions, but does not attempt to answer all of the above complex outstanding policy issues. The recommendations in the next subsection do address those policy issues which we believe are conservatively justifiable at this time. Those policy issues which are not addressed as a result of this report should be considered for future policy evaluation.

H. Recommended Household Battery Waste Management Strategies

As a result of the research and findings of this report, we present the following recommendations for further consideration by the State. Some of these recommendations will require new legislation and regulations, and some recommendations may require modifications to existing State regulations. Finally, the recommendations will require a more active future role on the part of state agencies to assist in the management of hazardous household batteries. Below are presented the five major recommendations of this report.

1. Develop Specific Legislation for Household Battery Regulation

It is recommended that California develop broad based legislation for regulation of household batteries. This kind of legislation is similar to what is already occurring in other states. Recommended legislative general provisions include (1) mercury content limitations, (2) standardized product labelling requirements, (3) a targeted battery product ban, and (4) specifications that batteries be removable from products. Specific provisions for recommended household battery legislation are shown in **Table VI-3**, on the next page.

Table VI-3
Recommended Household Battery Legislation

Battery Type	General Provision	Specific Provision
Alkaline	Mercury Content Limitation	Limit mercury content in alkaline batteries to 0.025 percent, by weight, by July 1993
Alkaline	Mercury Content Limitation	Limit mercury content in alkaline batteries to 0.0001 percent, by weight, by January 1996
Carbon Zinc	Mercury Content Limitation	Limit mercury content in carbon-zinc batteries to 0.0001 percent, by weight, by July 1993
All Button Cells	Product Labelling	Require button cell batteries and packaging to identify the type of battery and need for proper disposal by July 1993
Mercuric Oxide	Product Ban	Ban sale of mercuric oxide button cell batteries by January 1996
Nickel-Cadmium	Product Labelling	Require nickel-cadmium batteries and packaging to identify the type of battery and need for proper disposal by July 1993
Nickel-Cadmium	Product Labelling	Require battery-operated products using nickel-cadmium batteries and packaging to identify battery type used and the need for proper disposal by July 1993
Nickel-Cadmium	Batteries Removable from Products	Require that all battery-operated products using nickel-cadmium batteries to be manufactured so that the batteries are easily removeable by the consumer

2. Facilitate Dialogue With the Department of Toxic Substances Control and the Battery Industry Regarding California's Hazardous Waste Regulations as Applied to Zinc in Household Batteries

Only in California are alkaline and carbon-zinc batteries legally considered hazardous waste due to zinc content, since no other states are known to have established a standard for zinc. Also, household batteries contribute an insignificant amount of zinc in

comparison to other contributed sources. In light of these, and other, reasons, the battery industry believes that household batteries should be exempt from the California Waste Extraction Test for zinc. This would allow low-mercury, and mercury free, alkaline and carbon zinc batteries to be classified as non-hazardous waste.

The California Integrated Waste Management Board needs to facilitate discussions with the Battery Industry and the Department of Toxic Substances Control concerning this issue. The battery industry may want to present documentation and evidence to the Department of Toxic Substances Control concerning the hazardous nature of zinc in household batteries. The battery industry may argue to modify existing California regulations to provide a zinc toxic substance exemption specifically for household batteries.

If the battery industry is successful in obtaining a zinc exemption from the Department of Toxic Substances Control, this reclassification of alkaline and carbon zinc household batteries would greatly increase the cost-effectiveness of household battery collection and disposal programs. The overwhelming proportion of household batteries collected by household battery waste management programs could potentially be alkaline and carbon-zinc batteries which have no present value for reclamation, and which may need not be considered legally hazardous.

3. Review and Revise Existing California Regulations Which Affect Household Batteries

In addition to more stringent criteria for defining hazardous wastes, California does not have the federal household waste exclusion from hazardous waste designation. Also, in California small quantity generators are not exempted from requirements of the regulations. As a result, the same restrictions placed on hazardous wastes generally also apply to household batteries in California. However, there is a state transportation exemption for small quantity battery transport and an exemption on transport requirements if the batteries are sent to a metal reclamation facility.

All of the above California regulations should be reviewed by the State with regard to household batteries to determine if there should be some additional special waivers for household batteries. Existing state hazardous waste regulations should not act as an impediment to local governments and private businesses who need to collect, store, and transport household batteries for proper hazardous waste disposal.

Existing regulations may need to be able to allow a broadening in the number of participants in household hazardous waste programs to include more businesses and manufacturers. Also, local governments should not be constrained to having separate hazardous household battery waste events just because there may be no proven and available recycling technology for the majority of household batteries.

4. Develop and Implement a Statewide Education Program for Hazardous Household Batteries

Any household battery which is designated as household hazardous waste should be separated from the municipal solid waste stream. A large number of California consumers do not realize that household batteries are presently considered hazardous waste. Because consumers do not generally know this, the effectiveness of household hazardous waste collection programs are seriously undermined. The public's willingness to separate out batteries depends on the perceived health and environmental risks associated with each battery type.

The State of California presently considers all household batteries as legally hazardous. On the other hand, the Department of Toxic Substances Control currently publishes a brochure which states that primary household batteries should be replaced by the "non-hazardous alternative" of secondary batteries. As the result of some confusion on the hazardous nature of household batteries, consumers may be receiving conflicting signals.

The State should develop and implement a statewide education program on the various types of household batteries, and the special requirements for disposal. The education program should include the following areas:

- Description of the various types of household batteries
- The varying contribution of toxic metals in different battery types
- Proper disposal of button cells and nickel-cadmium batteries.

The State needs to help relay a consistent message to California consumers regarding the collection and disposal of household batteries. If consumers are advised to collect certain household batteries, there needs to be provided a proper form of disposal.

Consumers should not be advised to collect any household batteries which are not considered hazardous waste. It should also be noted that with any narrowing of hazardous battery designations, there will be a greater need to educate the public on differing battery types. This can only be accomplished with a standardized consumer product labelling system.

5. Further Develop Hazardous Household Battery Collection and Disposal Strategies

Existing household hazardous waste programs sponsored by city and county governments should be the present primary mechanism for hazardous household battery collection. These battery collection programs should focus on the required collection and hazardous disposal of nickel-cadmium and button cell batteries. However, if additional battery collection efforts are considered necessary (for example if a community has an incineration or compost operation) then collection programs should extend to retail outlets and curbside collection programs. As the State develops regulations for expanded compost operations as part of AB 939 diversion requirements, it should give special consideration to the treatment of household batteries.

The ultimate decision on what type of household batteries to collect may affect decisions on how best to collect batteries. Return to retailer collection may be highly suited for button cell batteries and even nickel-cadmium batteries where consumers are looking for a specific type and size replacement battery.

Consideration should be given to identifying ways to facilitate the collection and disposal or reclamation of nickel-cadmium batteries, particularly for applicable product manufacturers and battery manufacturers. The State may ultimately want to encourage that battery collection programs be set up by manufacturers.

Appendices

Appendix A

Bibliography

APPENDIX A

BIBLIOGRAPHY

This appendix summarizes much of the recent literature on the household batteries, their disposal, and potential recyclability. The bibliography is annotated with a brief description of each article, report, or document as it may relate to this study for the CIWMB. The bibliography includes literature prepared by officials of industry groups, government agencies, and academic and private researchers, as well as other studies.

The bibliography is separated into three sections:

- Adverse Effects of Metals Contained in Household Batteries
- Market and Product Trends
- Potential for Collection and Reclamation Programs.

A. Adverse Effects of Metals Contained in Household Batteries

1. Balfour, Raymond L., Letter to Paul Markowitz, Chief, State of Vermont, Agency of Natural Resources, Department of Environmental Conservation, Recycling and Resource Recovery, Solid Waste Management Division, September 18, 1991

TCLP data is provided for alkaline and zinc carbon batteries. The products pass the TCLP tests for mercury and cadmium. Manufacturers and distributors of the larger (not consumer button cell) mercuric oxide batteries are listed. Alexander Manufacturing Company is the only company that manufactures these batteries in the United States.

2. Balfour, Raymond L., Letter to Paul Markowitz, Chief, State of Vermont, Agency of Natural Resources, Department of Environmental Conservation, Recycling and Resource Recovery, Solid Waste Management Division, September 23, 1991

Summary of statements by the U.S. EPA appearing in the Federal Register concerning silver. The EPA recognizes that silver does not pose a threat to human health in drinking water.

3. California Integrated Waste Management Board, *A Cost Analysis of Municipal Waste Landfilling in California,* Tellis Institute Inc., Boston, Massachusetts, April 1990

A study which reviews solid waste management planning, site-specific cost information, and a comparison of tipping fees versus comprehensive costs.

4. Douglas, John, *Mercury in the Environment*, EPRI Journal, December 1991, pp. 4-11

The story discusses the high levels of mercury found in the remote lakes of Northeastern and North Central United States which has affected the local food chains. Research has proceeded to find ways of detoxifying mercury through enhancement of natural demethylation by bacteria already present in the lakes.

5. *Environmentally Relevant Effects of the Substances Present in Primary Batteries when Disposed of in Dumps and Incinerators for Domestic Waste and in Composting Systems*, University of Germany, Stuttgart, Germany, October 1990

The reduced concentrations of mercury in primary batteries means that batteries will no longer be the principal source of mercury emissions. According to the current state of

knowledge, no disadvantageous or toxic effects from zinc or manganese are of concern.

6. Federal Register, Vol. 52, No. 130, Wednesday, July 8, 1987, Proposed Rules, pg. 25720-25734, U.S. EPA, Drinking Water; Proposed Substitution of Contaminants and Proposed List of Additional Substances Which May Require Regulation Under the Safe Drinking Water Act

The Agency is proposing to remove zinc and silver from the list of 83 contaminants. Available data indicate that zinc in drinking water does not pose a public health risk, and that the potential effects of human exposure to silver via drinking water are not considered adverse.

7. Federal Register, Vol. 52, No. 131, Thursday, July 9, 1987, Rules and Regulations, pg. 25942-25953, U.S. EPA, List (Phase 1) of Hazardous Constituents for Ground-Water Monitoring; Final Rule

The U.S. EPA earlier proposed a list of constituents that require ground-water monitoring. The list of analyses is contained in Appendix IX. Some constituents that are generally non-toxic have been deleted from Appendix IX. These constituents include manganese.

8. Federal Register, Vol. 55, No. 25, Tuesday, February 6, 1990, Department of Labor, Occupational Safety and Health Administration, Occupational Exposure to Cadmium; Proposed Rule

OSHA has determined that employees exposed to cadmium face a significant risk to their health at the current permissible exposure limits.

9. Federal Register, Vol. 56, No. 20, Wednesday, January 30, 1991, Rules and Regulations

The U.S. EPA considers that the only known effect of silver in drinking water, argyria, is a cosmetic effect rather than a health effect.

10. Fochtman, Edward G. and Willard R. Haas, *Relationship of Spent Dry Batteries to the Heavy Metal Content of Solid Wastes*, ITT Research Institute, presented at Second National Conference on Water Use, May, 1975, pages 312-318

Disposal methods of used batteries and transport of the heavy metals through the environment were examined. Based on groundwater samples taken in 1971 and 1972, it appears that metals will not travel far from well-placed and operated landfills. Based on EPA regulations published in

1973, it appears that incineration of solid waste will not cause ambient air concentrations of mercury which would be hazardous to public health.

11. Gray, Jerry, *Florio Signs Regulations On Batteries*, New York Times, January 21, 1992

Article announces the Governor's signing of New Jersey legislation requiring battery manufacturers to virtually eliminate mercury from dry cells by the end of 1995 and to establish collection programs for used batteries. The law also requires rechargeable consumer products to be redesigned by July 1, 1993 to allow for battery removal.

12. Kinman, Riley N. and Dave Nutini, *Hazardous Household Waste in the Sanitary Landfill*, presented at the Fourth Annual Conference on Solid Waste Management and Materials Policy, January, 1988

Household hazardous waste is perceived to have a detrimental effect in sanitary landfills, but the exact impacts are not known. The study indicates that the small quantity of hazardous material in municipal solid waste has little effect on the leachate or gas emitted from sanitary landfills. Collection programs may not be necessary where the hazardous materials are placed in a well-designed and operated sanitary landfill.

13. Lewis, Richard J. Sr, Hazardous Chemicals Desk Reference, Second Edition, Van Nostrand Reinhold, New York, 1991

Descriptions of hazardous chemicals and their impacts on human health and safety.

14. National Electrical Manufacturers Association (NEMA), Written Statement of the National Electrical Manufacturers Association and the Battery Products Alliance Concerning Household Battery Disposal, no date

Proposals to collect and recycle batteries should clearly distinguish between lead-acid automobile batteries and household batteries. On an annual basis, in the late 1980's, about 260,000 tons of lead will enter the waste stream from those automobile batteries that are not recycled, compared to 131 tons of mercury and 1,800 tons of cadmium. Studies conducted by governments, universities, and consultants have found no environmental or health reasons to take household batteries out of the household waste stream.

15. New York State Legislative Commission on Solid Waste Management, *Household Batteries: Management or Neglect?*, Prepared by Randall D. Coburn, September, 1988

Separating out components of solid waste containing heavy metals is becoming important due to concerns about air emissions and ash residues from incinerators. The New York State Department of Health is in the process of developing risk assessments for indirect exposure to toxic metals through air emissions.

16. Sumitomo Heavy Industrials, Ltd., *New Technology for Treatment of Used Dry Batteries*, Revision 6, June 14, 1991

This paper discusses the new process for treatment of used dry batteries based on a wholly integrated pyrometallurgical concept.

17. United States, Environmental Protection Agency, Office of Solid Waste, Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, January 1989

Report describes products which contain lead or cadmium in municipal solid waste, including batteries. The report projects the use of cadmium in consumer batteries will increase by approximately 135 percent between 1985 and the year 2000. Cadmium from these batteries is estimated to be approximately 76 percent, by weight, of the total cadmium in products in MSW in 1995 and 2000.

18. United States, Environmental Protection Agency, Solid Waste and Emergency Response, Decision-Makers Guide to Solid Waste Management, EPA/530-SW-89-072, November 1989

The disposal of household hazardous waste is unregulated in most states. Quantifying the risks from improper disposal is difficult, because it is almost impossible to determine the quantity or the composition of household hazardous waste.

19. van Deelem, C. L., *Recovery of Metals from Waste Streams by Hydrometallurgical Processes*, Waste Reduction and Recovery Case Studies, TNO Netherlands Organization for Applied Scientific Research, Apeldoorn, Netherlands

The paper presents a processing route to remove heavy metals from a number of waste streams and recover individual metal components as saleable products. The process is based on hydro-metallurgical principles and applied to both solid and liquid waste streams.

20. Vermont, Agency of Natural Resources, Department of Environmental Conservation, Solid Waste Management Division, Final Draft of the Vermont Waste Battery Management Plan, November 1991

The Agency created a waste battery management plan. The report includes an assessment and determination of environmental harm and health risks from particular battery types, and contains a dry cell battery implementation plan. Mercuric oxide and nickel cadmium batteries, regardless of method of disposal, and alkaline batteries, if disposed of through incineration, are determined to be harmful.

B. Market and Product Trends

21. Brooks, Clyde S., Metal Recovery From Industrial Waste, Lewis Publishers, Inc., 1991

Technical handbook for the recovery of valuable nonferrous metals from industrial waste. Principal incentives for recovery are reduction in the volume and toxicity of the waste effluents, the recovery of valuable metals, and the reduction of disposal costs. This handbook describes disposal alternatives and the current status of recycling technologies.

22. Business Trends Analysts, The U.S. Battery Market: A Product-by-Product Marketing Analysis and Competitor Profile, 1990

This market research report provides a wide range of information on the battery industry, the market for primary and storage batteries, analysis of end use markets, structure of the battery industry in the United States, imports and exports of batteries, and the Japanese battery market.

23. Cadmium Association, London, and Cadmium Council, New York, *Technical Notes on Cadmium - Cadmium in Batteries*, 1979

The properties of nickel-cadmium batteries are compared with other rechargeable battery systems, such as lead-acid. Construction types and performance characteristics of different nickel-cadmium cells are described.

24. California, Department of Conservation, Division of Recycling *Biannual Report of Redemption and Recycling Rates: January 1, 1991-June 30, 1991*, 1991

This report contains data on the numbers of aluminum, glass, plastic, and steel containers sold and recycled in California.

25. Derby, Dr. James V., Zinc Corporation of America, *The Cadmium Situation From a Zinc-Cadmium Producer's Point of View*, Proceedings of the Second International Seminar on Battery Waste Management, November 1990

This paper describes the relationship between zinc and cadmium production. Cadmium is a by-product of zinc refining. The incentives and factors influencing recycling of materials such as lead, aluminum, and other metals can not be applied to cadmium. Cadmium must be produced and disposed whether or not it is used in batteries or other applications.

26. *Five Battery Makers from Japan, US and Europe Establishing Storage Battery Recycling Association in the US*, Comline Daily News: Chemicals and Materials, November 20, 1991

Article announces the formation of a battery recycling association to facilitate recycling of consumer-use batteries. The association is called the Portable Rechargeable Battery Association.

27. Guillaume, Martial, *The Computer/Telephone Explosion*, Batteries International, January 1991, pp. 24-25

The article discusses future market increases for nickel-cadmium batteries in lap-top and cellular phone markets.

28. *Germany Leads the Way On Reducing Waste*, Business Europe, February 9, 1987

This article describes goals of Germany's Environment Ministry regarding batteries. Battery manufacturers are being asked to make proposals on ways of reducing mercury content in alkaline manganese batteries and also to improve labelling to facilitate separation of different types of batteries when discarded. The Environment Ministry intends to require consumers to return batteries and include a refundable deposit system.

29. Goldberg, Terri L., *Source Reduction of Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives*, Northeast Waste Management Officials' Association (NEWMOA), May 1991

Several policy options are presented for reducing the toxicity of batteries through source reduction, the EPA's preferred method of waste management. A materials use policy would phase-out high toxicity metals such as mercury and cadmium, and encourage the development and use of non-toxic metals.

30. *Hazardous Household Products: A Guide to the Disposal of Hazardous Household Products and the Use of Non-Hazardous Alternatives*, Information Booklet prepared by the California Department of Health Services, Toxic Substances Control Program

This booklet was developed by the California Department of Health Services to encourage Californians to protect their health and the environment by reducing, reusing, and recycling household hazardous products. The booklet lists commonly used products, suggests effective alternatives, and provides guidelines for safe handling and proper disposal.

31. Holusha, John, *All About Batteries: Keeping a Gadget Mad Nation Charged Up -- and Safe*, New York Times, September 22, 1991

Americans now consume 2.7 billion household batteries a year. Most end up as trash in landfills and incinerators. The battery market is estimated to be growing 4 to 5 percent per year. This article discusses the differences between various types of household batteries, market trends, and disposal practices. The article also provides a comparison of the cost and waste generated associated with using either primary or secondary household batteries.

32. Iida, Takatoshi, *Metal Recycling From Used Ni-Cd Batteries*, Toho Zinc Company, Ltd., Japan

This article describes the recycling process for spent nickel-cadmium batteries used by Toho Zinc Co, Ltd. in Japan. The recycling process recovers both cadmium and nickel.

33. *Japan Storage Battery Association Promoting NiCd Battery Recycling*, Comline Daily News: Chemicals and Materials, October 24, 1991

Japan's storage battery industry has initiated a nationwide campaign to promote the recycling of nickel-cadmium batteries. The year-long campaign is aimed at working out future plans for launching extensive recycling projects.

34. Linden, D., Handbook of Batteries and Fuel Cells, McGraw Hill Book Company, New York, 1984

Basic reference text on batteries, battery technology, market developments, battery chemistry, and battery materials.

35. Margolies, Michael, *Recycling Lead Acid and NiCd Batteries: A View From Within*, Proceedings of the Second International Seminar on Battery Waste Management, November 5-7, 1990

Environmental policy plays a crucial role for the recycling industry. Recycling batteries is not just the responsibility of recyclers, but the responsibility of the metals industry, manufacturers, distributors, retailers, government agencies, and consumers. While many communities have started collecting household batteries for the purpose of recycling, clearly there has yet to be established in the United States the technology necessary to facilitate collection and recycling programs.

36. Matsuoka, Toshio, *Sumitomo Used Dry Battery Recycling Process*, Proceedings of the Second International Seminar on Battery Waste Management, November 5-7, 1990

This paper describes Sumitomo's process for recycling used dry batteries (primary batteries) to reclaim mercury, zinc, and ferro-manganese alloy. Sumitomo has had a demonstration project in Japan and has been working to install a commercial facility in Switzerland.

37. National Electrical Manufacturers Association, presentation by Raymond L. Balfour to Ernst & Young and CIWMB staff, October 24, 1991

Fact sheets on metallic content by weight of household battery types, sales by type, mercury consumption by industry, mercury consumption in mercuric oxide batteries, and TCLP data for mercury by type.

38. Onuska, J.C. Jr., Hanewald, R.H., Schweers, M.E., *A Pyrometallurgical Process for Reclaiming and Recycling Nickel-Cadmium Containing Batteries*, Prepared for the Third International Seminar for Battery Waste Management, Deerfield, Florida, November, 1991

The pyrometallurgical reclamation process created by INMETCO is reviewed. This process includes the reclamation of cadmium.

39. Panasonic News, *Panasonic Unveils new 99.999-Percent Mercury-Free Battery Line*, News Release

Panasonic announced the introduction of a new line of batteries which are 99.999 percent mercury free. The new alkaline, heavy-duty, and general-purpose cells will provide the same level of performance as their predecessors. The 0.001 percent mercury content is due to traces of mercury naturally occurring in other materials.

40. Rayovac Corporation, *Rayovac and Matsushita Sign Technology Agreement*, News Release, December 10, 1991

Rayovac and Matsushita Battery Industrial Co., Ltd. announced a technology agreement that will allow Rayovac to produce alkaline batteries with a no mercury added formula. Rayovac plans to incorporate the technology in its U.S. based alkaline battery production. Matsushita-made batteries incorporating this technology will be available in the U.S. and Japan in January 1992.

41. Say, M. G., editor, Electrical Engineer's Reference Book, Butterworths, London, Chapter 15, Cells and Batteries, 1986

The "redox" chemical reactions that produce electrical energy within battery cells, and the buildup of gaseous hydrogen as a result of these reactions, are explained. The construction and performance of cells using different combinations of metals are described.

42. Shapiro, Eben, *New Life for Rechargeable Battery*, New York Times, February 15, 1991

Several companies are offering new lines of rechargeable batteries. Consumers are buying 25 percent more rechargeables each year. The main advantage of rechargeables compared with alkaline batteries is economic. Rechargeables cost more to buy initially, and are less convenient to use; however, they are less costly over the life of the battery. It is not clear which battery type is better for the environment.

43. Stammbach, Nyon; Roller, Michael, *Status of the World's First Commercial Battery Process for Unsorted Household Batteries: The Recymet Plant for Hazardous Waste in Aclens, Switzerland*, Prepared for the Third International Seminar for Battery Waste Management, Deerfield, Florida, November 1991

The paper gives a technological update of the battery recycling process in Aclens, including the safety and environmental aspects. Also, the battery recycling market is addressed and the cost burdens associated with it.

44. *Today's Household Battery: Long on Life, Short on Mercury*, USA Today, January 26, 1990

This news article presents data prepared by the National Electrical Manufacturers Association on reductions in the use of mercury in consumer batteries. It also describes industry efforts to eliminate the use of mercury altogether in some types of batteries.

45. United States, Department of Interior, Bureau of Mines, *Annual Report: Lithium 1990*, Annual Review, July 1991

Almost all major battery manufacturers marketed some type of lithium battery, and research and development continues for further applications of lithium batteries in substitution for alkaline batteries. Lithium batteries represent a growth area for lithium consumption, but sales have not increased as rapidly as originally expected. Lithium batteries offer improved performance over alkaline batteries at a slightly

higher cost. Uses include watches, microcomputers, cameras, and more recently, small appliances, electronic games, and toys.

46. United States, Department of Interior, Bureau of Mines, *Mineral Industry Surveys - Cadmium in 1990*, Annual Review, May 1991

Domestic production of cadmium metal in 1990 increased about 8 percent. Estimated consumption for cadmium in 1990 was as follows: batteries, 40%; coating and plating, 25%; pigments, 13%; plastic and synthetic products, 12%; and alloys and other, 10%.

47. United States, Department of Interior, Bureau of Mines, *Minerals Yearbook: Cadmium 1988*, Annual Review, 1988

This annual review reports on the production and consumption of cadmium from 1984 through 1988. The report also discusses developments in the European Community to tighten controls on the disposal of batteries containing more than 0.025 percent cadmium by weight.

48. United States, Department of Interior, Bureau of Mines, *Minerals Yearbook: Mercury 1988*, Annual Review, 1988

This annual review reports that consumption of mercury for batteries fell for the fourth straight year, and that batteries showed the largest drop in mercury use. Mercury consumption for battery manufacture fell from 29,700 flasks (1 flask equals 76 pounds) in 1984 to 12,987 flasks in 1988.

49. United States, Department of Interior, Bureau of Mines, *Minerals Yearbook: Silver 1989*, Annual Review, October 1990

This annual report provides a summary of the production and consumption of silver in the United States and throughout the world. Silver is used to produce batteries with a high energy output per unit size and weight. Because of their high cost and relatively short life use of silver batteries has generally been confined to military applications. However, silver button cells are growing in use for applications such as calculators and hearing aids..

50. United States, Department of Interior, Bureau of Mines, *Minerals Yearbook: Zinc 1989*, Annual Review, April 1991

This annual report provides a summary of the production and consumption of zinc in the United States and throughout the world. Zinc is a major component of most types of

primary household batteries. In addition, cadmium production is a function of zinc demand since cadmium is a by-product of zinc production and purification.

51. United States, Environmental Protection Agency, Office of Research and Development, Achievements in Source Reduction and Recycling for Ten Industries in the United States, EPA/600/2-91/051, September 1991

This report documents a sample collection of source reduction and recycling case studies which were presented to the U.S. EPA as success stories. Included is a discussion of the U.S. dry cell battery manufacturing industry's efforts to reduce the toxicity in dry cell batteries through product substitution.

52. van Deelen, C. L. and J. van Erkel, *Recovery of Metals From Spent Nickel-Cadmium Batteries*, Presented at the Nickel-Cadmium Battery Update Seminar in Brussels, Sponsored by the Cadmium Association, September 1990

This article describes a hydrometallurgical process for reclaiming nickel and cadmium from used household batteries. The process has been developed on a pilot scale, and a full scale facility is proposed. The hydrometallurgical process offers some advantages and disadvantages over the more common pyrometallurgical processes currently used in Europe.

C. Potential for Collection and Recycling Programs

53. Abbotts, John, *Disposable Consumer Items: The Overlooked Mercury Pollution Problem*, 1981

A large percentage of the mercury lost to the environment comes from used household batteries. Properly managed landfills might adequately contain mercury, but the EPA estimates that 90 percent of hazardous wastes are improperly disposed. A recycling system based on deposits and returnable batteries could reduce both the environmental problems associated with mercury and the dependence on imported mercury.

54. A. D. Little, Inc., Marketing Development Strategies for Recyclable Materials - Batteries, Waste Paper, Plastics, Ferrous Auto Scrap, Tires, Prepared for the New Jersey Department of Environmental Protection, July 1989

This study reports that at the present time, there is no industry in the United States established to recycle consumer batteries. In addition, there is no reprocessing of used battery materials by the battery industry. There are, however, secondary markets for some of the materials contained in batteries, including mercury, zinc, nickel, and cadmium. Implementation of recycling appears to be a matter of economics.

55. Arnold, Karen, et al., Household Batteries in Minnesota: Interim Report of the Household Battery Recycling and Disposal Study, Minnesota Pollution Control Agency, March 1990

Minnesota incinerates over 50 percent of its solid waste. Current technology is not effective in managing mercury emissions because mercury has a low vapor pressure. Most composting operations have developed methods for removal of batteries. The mercury limit for Class I unrestricted compost is 5 parts per million.

56. Arnold, Karen, Household Battery Recycling and Disposal Study, Minnesota Pollution Control Agency, June 1991

Household batteries are the dominant source of mercury and cadmium in incinerators, landfills, and composting operations. Minnesota has investigated several options to ensure that mercury and cadmium are managed properly. These options include legislation to enact content limitations on mercury, simplify rules concerning household hazardous

waste collection programs, and implement collection programs for nickel-cadmium batteries. A pilot program to collect button batteries and test collection methods was implemented in six communities. Participation in the program was related to convenience and publicity.

57. Balfour, Raymond L., *Household and Other Batteries: Source Reduction and Recycling*, Presented at the Tenth Annual Resource Recovery Conference of the U.S. Conference of Mayors, on behalf of the Dry Battery Section, National Electrical Manufacturers Association and the Battery Products Alliance, Washington, D. C., July 12, 1991

Concerns about household batteries are based on the toxicity of the metal content, not on the cubic volume in solid waste. Battery manufacturers are reducing the quantities of these toxic metals. Battery recycling should be limited to mercuric oxide and nickel cadmium batteries where source reduction is not possible or is limited.

58. Balfour, Raymond L. and Anderson, Timothy J., *Source Reduction and Waste Minimization at Rayovac Corporation*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 1991

The paper highlights the progress and changes made by Rayovac in response to the source reduction and waste minimization trends.

59. Bender, Michael, *Vermont's Battery Law and the Development of a State Used Battery Management Plan* , Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 1991

The paper discusses the new battery law and requirements implemented in the State of Vermont.

60. Brown, Vence & Associates, *City and County of San Francisco: Household Hazardous Waste Element*, Preliminary Draft, October 1991

The Element develops short-term and medium-term goals for managing household hazardous materials. In addition, recycling and collection programs are expanded and efforts increased to ensure proper management and disposal of household hazardous wastes.

61. Burri, Roger; Antensen, Adrien; Rosatzin, Martin; Stolz, Peter, *Approval Procedure for a Commercial Battery Recycling Plant in Switzerland*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 1991

The approval procedure for a commercial consumer battery recycling plant in Switzerland is described. Key problems and corresponding solutions are discussed in this paper.

62. Cadmium Association, London, *Nickel-Cadmium Battery Update 90 - Report on Seminar*, Proceedings of seminar held in Brussels on September 18, 1990

Nickel-cadmium batteries are firmly established in the marketplace for rechargeable power sources. The publication includes fifteen papers presented at the seminar and reports on discussions. Topics included the commitment of both the battery and metal industries to the safe use and disposal of their products.

63. California Department of Conservation, Division of Recycling, *Redemption & Recycling Rates,* Biannual Report, January 1, 1991- June 30, 1991

The Report provides recycling and redemption rates for various recyclable materials in the State of California.

64. California Integrated Waste Management Board, *The Hazards of Household Wastes*, Pamphlet

The pamphlet describes household products which are hazardous. It provides information on how to properly discard household hazardous waste and how to avoid using dangerous chemicals.

65. Carnegie-Mellon University, Department of Engineering and Public Policy, School of Urban and Public Affairs, and Department of Social and Decision Sciences, Household Batteries: Is There a Need for Change in Regulation and Disposal Procedure?, December 1989

The goal of the project was to assess if there is a problem with household batteries and the current methods of disposal. The report examines the main technical, economic, and political issues regarding disposal of household batteries. The report includes sections on forecasting the future demand for batteries, and total industry metal requirements in the production of batteries. A risk assessment model was developed based on exposure rates to metals contained in batteries. Structural, chemical, and electrical laboratory tests were performed to supplement current information available regarding the risk associated with disposal of household batteries. Recommendations include encouraging the source reduction of heavy metals by the battery industry, and prohibiting the incineration of batteries.

66. Clover, Charles and Greg Neale, *Green Dustbin May Lay Waste to £2.5 Billion Bill*, The Sunday Telegraph, November 19, 1989

Article describes the start of a curbside collection program in Sheffield, England. Approximately 10,000 households received collection bins with divided compartments for bottles, glass, steel, aluminum, newspapers and magazines, plastics, and household batteries. Long term goals of the Environmental Secretary include recycling 50 percent of all reusable domestic rubbish.

67. Compaq Computer Corporation, *News Release: Compaq Announces Battery Recycling Program For COMPAQ Laptop and Notebook PC Users*, January 27, 1992

Compaq Computer Corp. launched the personal computer industry's first nationwide PC battery pack recycling program. The program begins immediately and is offered free to all Compaq customers. The company will work with users to help them safely recycle rechargeable nickel-cadmium batteries used in COMPAQ laptop and notebook personal computers. Compaq will arrange to have used batteries mailed directly to a nickel-cadmium recycler; the recycler will then charge Compaq for processing the batteries.

68. David, Jacques, *Economical Approach to the Processing of Nickel-Cadmium Accumulators*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 1991

The presentation materials review the different types of nickel-cadmium accumulators, examine their principal uses, and discuss the problems associated with accumulators collected through specialist channels.

69. Du Bois, Annette and Jessie Lang, *Household Batteries: Drop-Off and Curbside Collection*, Resource Recycling, February 1992

Household battery collection programs are easily implemented and popular with the public. They are also expensive, due to high disposal costs and the lack of recycling alternatives.

70. EBA Wastetechnologies, *City of Concord: Household Hazardous Waste Element*, Preliminary Draft, June 1991

The Element develops goals and objectives, discusses recycling and collection alternatives, evaluates public education programs, and provides a program implementation

schedule for household hazardous wastes in the City of Concord.

71. Eloy, Robert, *Battery Waste Management Legislation in the European Communities: A Point of View of a Nickel-Cadmium Manufacturer*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 5, 1991

The paper reviews the various European Community Directives which affect battery manufacturers and the disposal of used batteries. The legislation has created a challenge for the nickel-cadmium manufacturers; however, they remain confident in their product.

72. England, Norm, *Portable Rechargeable Battery Association's Response to Environmental Concerns*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 4, 1991

The paper reviews the association's long range goals to develop environmentally acceptable options for the collection and reclamation of batteries and battery products.

73. Europile, *Implementation of the EC Battery Directive: The Basis for Collection & Recycling Schemes*, Batteries & the Environment, Association of European Primary Battery Manufacturers, Bern, Switzerland, April 1991

The paper discusses the directive passed by the European Community on batteries and accumulators containing dangerous substances. The directive limits mercury content levels in alkaline manganese batteries and requires mercuric oxide, nickel cadmium, and lead acid batteries to be collected separately and recycled.

74. Federal Register, December 20, 1989, Proposed Regulations, and Federal Register, Vol. 58, No. 28, Rules and Regulations, February 11, 1991

The U.S. EPA finds that it has not been shown that battery separation programs have a sufficiently significant effect on mercury emissions. The Agency has decided not to require mandatory programs for separation of household batteries in the final municipal waste combustors (MWC) standards.

75. Fiala-Goldriger, Dr. Jan, et al., *The Status of Battery Recycling in Switzerland*, Presented at the Second International Seminar on Battery Waste Management, Deerfield Beach, Florida, November 7, 1990

This article describes battery consumption and disposal practices in Switzerland, and describes the technical aspects of recycling technologies used by Recytec, S.A. The

recycling process described does not require pre-sorting of batteries. The process can accept any type of household battery or battery mix.

76. Florida Department of Environmental Regulation, Solid Waste Section, *Batteries Fact Sheet*, July 6, 1990

This paper describes some of the environmental problems, waste management issues, and collection and recycling efforts involving household batteries.

77. Forker, Timothy, and Sean Hecht, Environmental Action Coalition's Waste Battery Management Project, 1987-1991, Environmental Action Coalition, Inc. New York, December 31, 1991

This report describes the Environmental Action Coalition's waste battery management project activities from 1987 through 1991. The report explains the reasons why EAC undertook the project, how the project has been supported, the scope of work for the project , and conclusions drawn from experiences to date.

78. Forker, Timothy, *Strategic Approaches to the Used Household Battery Problem: A Report on European Experiences and Their Implications for Action in the United States*, Environmental Action Coalition, New York, November 1989.

This paper summarizes European approaches and experiences in managing household batteries in municipal waste, including content limitations, collection programs, and disposal and recycling.

79. Fricke, Jürgen, *Recycling of Batteries: The View of the European Battery Industry*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 1991

The paper discusses the basic conditions for recycling and problems associated with the recycling processes. The association supports recycling of specific batteries and does not for batteries which have not been proven to have an ecological advantage in comparison to disposal.

80. Hennepin County, Office of Planning and Development, *An Assessment of Current Retail Sales in Hennepin County of Alkaline Batteries Meeting Reduced Mercury Standards*, Prepared for the Hennepin County Bureau of Public Services, July 9, 1991

This report assesses the percentage of current retail alkaline battery sales in Hennepin County that meet the low mercury content standard. The displayed battery stock of four major battery sizes

(AA, C, D, and 9 Volt) were inspected in a random sample of 100 retail outlets in the county.

81. Hiscock, S. A., *Nickel-Cadmium Battery Collection and Recycling in Europe*, Presented at the Nickel-Cadmium Battery Update Seminar in Brussels, Sponsored by the Cadmium Association, September 1990

This paper briefly reviews some of the different approaches being made by national authorities, regional and local authorities, battery and equipment manufacturers, recyclers, and cadmium producers for collecting and recycling small, consumer size nickel-cadmium batteries in Europe.

82. Johnson, Randy, Hennepin County Commissioner, *Hennepin County's Approach to Household Batteries*, Presentation to U.S. EPA Dry-Cell Battery Workshop, November 1990

A household battery collection program was initiated together with plans to build and operate a waste-to-energy combustion plant. In 1989, drop-off and curbside pilot collection programs were started. Early in 1990, the program was redirected towards mercuric oxide cells only. Later in 1990, the curbside program was reinstated, despite questions about disposal methods and whether the mercury content is sufficient to justify collection. Hennepin County will be operating the largest and most expensive household battery collection program in the United States.

83. Johnson, Randy and Carl Hirth, *Myths and Realities: Collecting Household Batteries*, Waste Age, June 1990

Concern about alkaline batteries as the major source of mercury in the waste stream is misplaced. Local officials should focus their collection efforts on those types of batteries that still contain large quantities of mercury and cadmium and can be recycled.

84. Kehoe, Paula, City and County of San Francisco, Office of Chief Administrative Officer, Solid Waste Management Program, *Battery Reclamation Technologies*, Presented at Northern California Household Hazardous Waste Information Exchange, December 1990

The City and County of San Francisco is planning a household battery collection program. Only silver oxide and mercuric oxide batteries can be recycled in the United States. A facility in France will recycle nickel-cadmium batteries.

85. Kertese, Tibor, *Battery Collection in Swedish Municipals*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 1991

The paper discusses the Swedish model of the voluntary collection program for batteries. The program instituted limits on mercury levels in batteries and implemented information campaigns to achieve high collection results.

86. Levy, Steven J., U.S. EPA, Office of Solid Waste, *European Battery Management Practices*, Presented to OAQPS meeting on Precombustion Control of Mercury Emissions From Batteries, February 8, 1990

This paper summarizes waste management practices throughout Europe concerning the disposal of household batteries. Collection programs are prevalent, and batteries containing more than 0.025 percent of mercury or cadmium are typically handled as hazardous waste or recycled. Only silver and cadmium from batteries are recycled.

87. NH/VT Solid Waste Project, *Household Battery Program Packet*, Claremont, New Hampshire, December 1991

The packet contains articles on the NH/VT Solid Waste Project, a Bibliography of General, Waste-to-Energy, and Landfill Studies, and miscellaneous presentation papers. It includes material presented at the NHRRA Conference regarding recommendations on implementing household battery collection programs.

88. Oyaas, Mark J. and Associates, *Hennepin County Household Battery Program Report and Recommendations*, Prepared for the Department of Environmental Management, Hennepin County, Minnesota, October 1991

This report contains results of chemical analyses of heavy metals from batteries entering the waste stream, and a survey of mercury levels in batteries available in the retail marketplace. The report also summarizes current law regulating batteries and a brief narrative of the costs and logistics of collection and sorting.

89. *Portable Rechargeable Battery Association Focuses Efforts*, Cordless Power News, January 1992, pp. 6-7

The immediate focus of the Portable Rechargeable Battery Association is to develop a program of action for the recycling of batteries and battery-operated products which will allow the continued sale of those products.

90. Radian Corporation, Dry-Cell Battery Workshop, Compilation of materials prepared for the USEPA Risk Reduction Engineering Laboratory Pollution Prevention Research Program, Cincinnati, Ohio, November 14, 1990

The Pollution Prevention Research Branch of the USEPA held a workshop on Dry Cell Batteries. The goal of the workshop was to identify pollution prevention research needs in the dry cell battery industry.

91. Reutlinger, Nancy, *Batteries in the Waste Stream: A Feasibility Study of Household Battery Recycling and Collection for the County of Santa Cruz*, Internship Project, County of Santa Cruz, California, Planning Department, Resources Section, July 1990

The study addressed the economic and technological feasibility of battery recycling. A five-part battery recycling program was designed for the County, for use if obstacles concerning safety of the recycling process are overcome. A mixed battery collection program should be implemented. The collected batteries would be disposed at hazardous waste landfills to satisfy California solid waste regulations prohibiting the disposal of household hazardous waste in municipal landfills.

92. Reutlinger, Nancy and Dan de Grassi, *Household Battery Recycling: Numerous Obstacles, Few Solutions*, Resource Recycling, April 1991, pages 24-29

Household batteries may be considered hazardous waste under California hazardous waste criteria due to their heavy metal content. Unless the technology is available for economical and environmentally sound recycling, collectors of household batteries may end up with a costly disposal problem. A question exists whether manufacturers or municipalities should be responsible for disposal.

93. R. W. Beck and Associates, *Household Hazardous Waste Element for the Unincorporated Area of Sacramento County*, Prepared for the Sacramento County Solid Waste Management Division, Sacramento, California, September 1991

The Element establishes household hazardous waste management objectives, identifies improved management systems, and establishes a program implementation schedule for the unincorporated area of Sacramento County. The new planning requirements for household hazardous wastes is in response to Assembly Bill 939, modified by Assembly Bill 2707, which requires all California counties and cities to improve management of household hazardous wastes.

94. *San Francisco's Permanent Program*, Household Hazardous Management News, Quarterly Newsletter of the Waste Watch Center, Vol. 1, No. 2, Andover Massachusetts, Summer, 1989

Description of San Francisco's Household Hazardous Waste Collection Facility. The facility currently landfills only 1.7 percent of the waste received. The rest of the materials, mostly paint, are either burned as supplemental fuel or recycled. The program is funded by a five cents per month increase in refuse collection fees.

95. Second International Seminar on Battery Waste Management, Proceedings of the Three Day Seminar and Workshop held in Deerfield, Florida, November 5-7, 1990

These proceedings include papers presented during the seminar. Topics include the regulatory environment, current and developing battery technologies, battery waste management practices, and battery collection programs.

96. Shiley, R.H., Gates Energy Products, Inc., *Recycling Small Sealed Nickel Cadmium Batteries*, April 1991

Battery industry supports collection and recycling of nickel cadmium batteries, and redesign of consumer products for easy removal of rechargeable battery packs. Technology for recycling exists, but all reclamation facilities are outside of the United States. Investment in recycling facilities in the United States will be difficult due to permitting process, proposed OSHA cadmium standards, and long range plans of industry to supplant nickel cadmium batteries with a replacement technology.

97. Spokane Regional Solid Waste Disposal Project (SRSWDP), *Household Battery Collection Project*, November 1991

The Spokane area mixed household battery collection program is designed to divert heavy metals from the new 800 tons per day waste-to-energy plant processing all of the municipal solid waste in Spokane County. About 20 percent of the collected batteries are from the drop-off collection system and 80 percent are from curbside recycling.

98. *Solving the Problem of Recycling Batteries; Water Pollution By Farms*, Economist Publications: Country Report, July 12, 1989

Article describes efforts to operate a pilot recycling plant for used batteries in Zurich, Switzerland. Under Swiss regulations, used dry batteries may not be disposed with normal household refuse; however, there are not satisfactory battery disposal facilities in Switzerland.

99. Stanislaus County, Department of Environmental Resources, *Household Batteries in the Waste Stream: A Study of Their Current Status and Proposed Program for Separation*, Final Report, Prepared for the USEPA, August 13, 1990

This report was prepared by Stanislaus County under provisions of its permit to operate the facility issued by USEPA. The study included assessing the practicality of recovering batteries from the waste stream, identifying the most effective mechanisms for removing batteries from the waste stream, and seeking to identify the mercury content of various types of household batteries.

100. State of Michigan, Legislative Service Bureau, Science and Technology Division, *Household Battery Collection and Storage*, Briefing Paper, March 1990

This paper provides information on options for collection and storage of used household batteries. The Science & Technology Division contacted two battery manufacturers, battery processors, and two battery collection programs for information on their experiences with large-quantity battery storage.

101. State of Michigan, Legislative Service Bureau, Science and Technology Division, *Removing Household Batteries from the Waste Stream: Problems and Opportunities*, Briefing Paper, January 1990

This paper describes household battery collection programs aimed at reducing the amount of batteries entering solid waste landfills and incinerators. Special concerns have been identified regarding the handling and storage of household batteries and limited opportunities for recycling of metals contained in household batteries. The paper concludes that most batteries currently collected are either stockpiled or disposed as hazardous waste.

102. State of Michigan, Report of the Joint Legislative Committee on Batteries, December 1990

There has been greater use of incinerators for solid waste reduction and greater concerns over hazardous substances in solid waste. The state initiated a deposit and return system for lead-acid batteries, and created the Joint Legislative Committee concerned with the management of all batteries, regardless of type. The Committee reviewed the framework in the model legislation presented by the household battery industry. Proposed legislation by the Committee includes an eventual ban on nickel-cadmium batteries and required recycling of alkaline and zinc carbon batteries.

103. State of Wisconsin, *Household Batteries Waste Management Study*, Final Report, Prepared by Gershan, Brickner, & Gratton, Inc., February 28, 1992

This document was prepared in response to Wisconsin Act 335. It reviews the current types of household batteries purchased and discarded in the State of Wisconsin, projects future battery composition and disposal rates, discusses the potential for environmental impacts, evaluates current capacity for recycling or reprocessing household batteries in the U.S. and overseas, and recommends legislation to address future handling of household batteries in the State.

104. Sumitomo Heavy Industries, Ltd., *New Technology for Treatment of Used Dry Batteries*, Revision 6, June 14, 1991

The paper describes a completely new process for treatment of used dry batteries (primary) based on an integrated pyrometallurgical concept. This process favors urban plant sites because of the enclosed nature of the process, inexpensive treatment cost, and low energy consumption.

105. Taylor, Kevin, David J. Hurd, and Brian Rohan, *Recycling in the 1980s: Batteries Not Included*, Resource Recovery, May/June 1988

Household batteries are one category of potential hazards in solid waste for which recycling seems the only prudent solution. Factors that must be considered before recycling can occur include markets for the materials, environmental effects of processing, quantity of materials, and convenience. One issue was whether batteries collected would be considered non-hazardous or hazardous waste.

106. Thermal Reduction Company, Inc., *Household Battery Recycling Project*, Ferndale, Washington, June 1989

Thermal Reduction Company is a waste-to-energy facility that incinerates all of the waste of the City of Bellingham, Washington. The program began as a button cell battery recycling project and now includes all types of household batteries. Retail outlets serve as drop-off locations, and the eventual goal of the project is to be included as part of the City's curbside recycling service. The project summary includes potential recycling revenues and retail outlet program costs.

107. United States, Environmental Protection Agency, Municipal Solid Waste Task Force, The Solid Waste Dilemma: An Agenda for Action, February 1989

This report presents the goals and recommendations for action by the EPA, state and local government, industry, and private citizens concerning solid waste management. A key element of integrated waste management is the hierarchy, which favors source reduction to decrease the volume and toxicity of waste, and recycling and composting to manage waste. Integrated waste management should be implemented at the local level.

108. United States, Environmental Protection Agency, Office of Solid Waste and Emergency Response, Survey of Household Hazardous Wastes and Related Collection Programs, EPA/530-SW-86-038, October 1986

This report defines household hazardous wastes as products discarded from residences which contain substances regulated under RCRA as industrial hazardous waste. The report also summarizes household hazardous waste collection efforts in the United States.

109. United States, Environmental Protection Agency, Risk Reduction Engineering Laboratory, Pollution Prevention Research Program, Dry-Cell Battery Workshop, Cincinnati, Ohio, November 1990

The workshop materials include an executive summary, presentations, and discussion of collection programs and battery types to be targeted for collection and recycling, recycling technologies, and the economics of recycling.

110. United States Congress, Office of Technology Assessment, Facing America's Trash: What Next for Municipal Solid Waste?

Collection and recycling programs for household batteries in Europe and Japan are described. Battery management programs include source reduction and content limitations. In Germany, a voluntary agreement between the government and industry was reached in 1987 to limit mercury content.

111. Vandenbosch, Mary, et al., Household Battery Report, Minnesota Office of Waste Management, December 1991

The Office of Waste Management (OWM) describes OWM activities to support collection programs and makes recommendations for legislation. OWM activities include working with household hazardous waste facilities to accept used batteries, and exploring market development projects which are eligible for the recyclable materials grant and loan program. Legislation could include designating one state

agency to investigate compliance, and requiring labels on the battery instead of the package.

112. Ventura County, *Household Hazardous Waste Element: Unincorporated Ventura County*, November 1991

This report presents the policies and programs to safely reduce, collect, treat, and dispose of household hazardous wastes within unincorporated areas of Ventura County.

113. Waffen, Tom and Lillian Dean, *Household Battery Collection, Recycling, and Disposal Pilot Program*, Southeastern Oakland County Resource Recovery Authority, Royal Oak, Michigan, November 1991

This report identifies reasons for household battery recycling, summarizes approaches to collection, disposal, and recycling used in the pilot project, and evaluates the success of various collection methods. A waste-to-energy facility is planned for operations starting in 1992.

114. Wallis, George, and S. P. Wolsky, *Options for Household Battery Waste Management*, Proceedings of the Second International Seminar on Battery Waste Management, November 5-7, 1990

This paper discusses the future trends in the disposal of household batteries in the United States. The trends are deduced from a consideration of regulatory activities and from a review of prevalent attitudes towards battery wastes. The paper discusses regulations, collection and disposal, and recycling.

115. Waste Management of North America, *Pilot Program - Household Dry Cell Battery Collection*, Prepared for the Third International Seminar on Battery Waste Management, Deerfield, Florida, November 1991

This paper reviews three methods of battery collection methods: curbside, retail drop-off centers, and recycling drop-off centers. Two pilot programs were implemented by the Waste Management of North America, and the results are reviewed.

116. Watson, Tom, *The Unsavory Side of Battery Recycling*, Resource Recycling, April 1991

The article looks at the effects of laws that try to encourage recycling by allowing exemptions from hazardous waste regulations. A battery recycling company in Oregon has had several violations of the hazardous waste handling and storage regulations.

117. Woods, Randy, *New Burden on Buttons*, Waste Age's Recycling Times, Vol. 2, No. 12, June 5, 1990

While the battery industry has made tremendous strides to reduce mercury levels in alkaline batteries, some recyclers are saying the onus for hazardous waste reduction should not be shifted to recycling the more toxic mercuric oxide batteries.

Appendix B

Local, State, Federal and International Legislation

APPENDIX B

LOCAL, STATE, FEDERAL AND INTERNATIONAL LEGISLATION

This appendix summarizes legislation that has been proposed or enacted at various levels of government. This includes legislation at the local, state, and federal levels in the United States, and in Japan and several European countries. Several local programs to collect and process household batteries have been initiated in the United States. Most of these programs have not required specific authorization, such as city council resolutions or ordinances. However, several have been mandated at the local level by state legislation.

The local, state, federal, and international legislation reviewed for the study includes legislation proposed or enacted by the following jurisdictions:

State

- California
- Connecticut
- Maine
- Maryland
- Michigan
- Minnesota
- New Jersey
- Oregon
- Rhode Island
- Vermont

Federal

- United States

Local

- Minneapolis
- San Francisco

International

- Austria
- Britain
- Denmark
- European Community
- Germany
- Japan
- Sweden
- Switzerland.

The discussion of legislation is organized by types of waste management approaches which have been proposed or initiated to identify and manage the potential hazards from used household batteries. Industry officials also have drafted model

legislation to guide the management and disposal of batteries. In general, waste management approaches to household batteries have included a wide variety of practices, many of which are described throughout this report. This appendix describes legislative efforts to manage household battery waste and disposal under the following headings:

- Source Reduction in the United States
  - Content Limitations
  - Product Bans
- Waste Management Practices in the United States
  - Household Hazardous Waste Programs
  - Household Battery Waste Management Plans
  - Education Programs and Labelling Requirements
  - Collection and Processing Programs
  - Recycling Programs
  - Studies in Progress
- Source Reduction and Waste Management in Europe and Japan
- Model Legislation for Household Batteries.

Exhibit B-1, following this page, is a one-page summary of legislation which identifies the types of provisions in legislation. Following Exhibit B-1, is a discussion of proposed and enacted legislation pertaining to each of the waste management approaches listed above. **Exhibit B-2**, beginning on page B-12, is a comprehensive summary of legislation by jurisdiction, this summary includes reference to bill number, effective date of provisions, description of major provisions in the legislation, affected entities, status concerning introduction or enactment, and contact agency.

Summary of Household Battery Legislation

Jurisdiction	Reference	Status		Requirements							
		Enacted	Proposed	Study	Labelling Requirements	Education Program	Management Plan	Disposal Restrictions	Content Limitation	Recycling Program	Collection Program
California	SB 1594	●								●	●
	AB 3530*		●		●		●				●
	SB 1813	●		●							
	AB 3530	●		●							
	SB 1143*		●			●	●				●
Connecticut	89-377	●							●		
	91-385	●			●				●	●	●
Maine	LD 1278		●		●						●
Maryland	89-820	●									●
Michigan	90-20	●		●							
	Study		●					●	●	●	
Minnesota	90-409	●						●	●		●
	89-1	●								●	●
New Jersey	SB 3157	●		●	●	●	●	●	●	●	●
New York	S. 4275-A		●		●		●		●		
	A. 7029-A		●		●		●		●		
Oregon	HB 3361	●			●				●	●	
	89-833	●				●					
Rhode Island	N/A		●		●			●	●	●	●
Vermont	91-124	●		●	●	●	●		●	●	●
	Study		●								
	87-78	●					●	●		●	●
	87-246	●					●	●		●	●
	89-218	●					●	●		●	●
City of Minneapolis	Ordinance	●				●		●			
City of San Francisco	Resolution	●								●	●
United States	N/A		●		●	●	●	●	●	●	●
	HR 3735		●	●							

*Bill as originally proposed.

A. Source Reduction in the United States

Mercury and cadmium have been identified by the USEPA and several state environmental agencies as the metals contained in household batteries that may pose potential hazards to human health and the environment[157,158,159]. Several jurisdictions have proposed or enacted source reduction requirements aimed at these metals. Where it is technically feasible, source reduction has been implemented through limitations on the percentage content by weight of mercury. Where substitute battery types currently exist or are expected to be developed, product bans have been proposed for specific battery types. Many of the content limitation provisions are to take effect in 1992, with other provisions on content limitations and product bans to be phased in over several years.

1. Content Limitations

Mercury in alkaline and carbon-zinc batteries is an additive used to control the buildup of hydrogen gas within the battery. Several jurisdictions have proposed or passed legislation aimed at limiting the mercury content in these batteries. In general, current legislation limits the mercury content of alkaline batteries to 0.025 percent (250 parts per million) by weight. These provisions are to be effective in 1992 in Connecticut, Michigan, Minnesota, New Jersey, Oregon, and Vermont. Similar legislation is scheduled to be introduced in Congress this year by Senator Lautenberg of New Jersey. The four major battery manufacturers in the United States have redesigned their products and have met these goals since mid-1991[160].

Limitations on mercury content as low as one part per million by weight (0.0001 percent), for both alkaline batteries and carbon-zinc batteries, also have been proposed. These provisions will become effective within the next few years. One part per million by weight is considered to be the background level of mercury. This limit essentially legislates that mercury will not be added to these types of household batteries during manufacture. With the exception of Eveready's heavy duty line of carbon-zinc batteries, major

157 United States, Office of Technology Assessment, Facing America's Trash: What Next for Municipal Solid Waste, OTA-O-424, October 1989

158 Arnold, Karen, Household Battery Recycling and Disposal Study, Minnesota Pollution Control Agency, June 1991

159 State of Michigan, Report of the Joint Legislative Committee on Batteries, December 1990

160 Balfour, October 1991

manufacturers of carbon-zinc batteries in the United States claim to have met this requirement since 1990. Eveready plans to begin producing "mercury free" heavy duty carbon-zinc batteries in the spring of 1992[161]. In addition, two battery manufacturers have announced plans to begin production of "mercury free" alkaline batteries in 1992[162].

2. Product Bans

Product bans have been aimed primarily at mercuric oxide button cells. These cells typically contain from 30 to 43 percent mercury by weight, and reduction of the mercury content within the cell is not feasible because mercury is one of the electrodes. Silver oxide and zinc air button cells, with about 1 and 2 percent mercury content by weight, respectively, are substitutes for mercuric oxide cells. Complete product bans of mercuric oxide batteries, where enacted, will be phased in over several years.

New Jersey legislation to ban mercuric oxide batteries was vetoed on a conditional basis by the Governor. It is expected that mercuric oxide hearing aid batteries will be exempt from the product ban because some hearing aid devices only accept mercuric oxide cells. The exemption will last three years, after which a total product ban on mercuric oxide cells will be effective. Bans on the sale of mercuric oxide cells have been proposed by special study committees in Michigan and Vermont. Michigan also proposed the ban of silver oxide and lithium batteries by January 1, 1992, and nickel-cadmium batteries by January 1, 1995. These proposals have not been enacted.

161 Balfour, February 1992

162 Rayovac Corporation, December 1991 and Panasonic Company, December 1991

B. Waste Management Practices in the United States

Where content limitations are not technically feasible, states have enacted or proposed a wide range of approaches to prevent or reduce toxic metals contained in household batteries from entering into the solid waste stream. Waste management practices differ in terms of (1) placement of responsibility on consumers, retailers, manufacturers, or public agencies, (2) types of household batteries which are targeted for management, (3) degree of compliance required or incentives offered, and (4) intensity of management practices.

1. Household Hazardous Waste Programs

Several jurisdictions have implemented the collection and recycling or disposal of household hazardous waste. Used household batteries are included as a component of household hazardous waste. The most comprehensive management approach is to prepare a household hazardous waste management plan. Plans typically include methods to reduce generation of hazardous material, and to separate, collect, and recycle materials such as household batteries, paints, and unregulated household hazardous wastes. Two pieces of legislation in California were passed to manage household hazardous waste. AB 2707[163] requires that agencies develop household hazardous waste management plans which include source reduction, public education, and regional interagency approaches. AB 939[164] requires a 50 percent reduction in the amount of solid waste generated over the next decade, including the proper disposal of household hazardous waste. Provisions of both AB 939 and AB 2707 specify the responsibilities of local governments in California to develop and implement integrated waste management practices.

In 1990, the California Legislature passed legislation to assist in efforts of local governments and other agencies in providing safe disposal methods for household hazardous waste and providing public information on the proper disposal of hazardous substances commonly found in and around homes. SB 937[165] requires that the Board implement a public information program and prepare guidelines for local agencies to follow

163 Chapter 1406 of 1990 Statutes
164 Chapter 1095 of 1989 Statutes
165 Chapter 35 of 1990 Statutes

in planning and implementing household hazardous waste collection, recycling, and disposal programs.

In Maryland, each county is required to prepare and submit an assessment of the feasibility of establishing a household hazardous waste collection program. Assessments are to include an estimate of the cost of one household hazardous waste collection day every year and the feasibility of establishing regional household hazardous waste collection by county. In Vermont, this approach is to be implemented at the state level.

A statewide household hazardous waste public information program has been implemented in Oregon. The education program includes the following information:

- Alternatives to disposal of household hazardous waste at solid waste disposal sites
- Methods of reusing or recycling household hazardous waste
- Alternatives to the use of products that lead to the generation of household hazardous waste.

Collection programs may involve one-day collection events or permanent collection facilities. Periodic household hazardous waste collection events have been implemented in Oregon. Pilot project collection events will include the recycling of used household batteries, where feasible. A permanent collection facility for household hazardous waste has been constructed in San Francisco. Almost all collected materials are either processed or recycled with only 2 percent of materials disposed in hazardous waste landfills. It is anticipated that rechargeable batteries and button cells also will be recycled as part of this program.

In California, proposed legislation, SB 1143 would have established a fee on the first sale of a potentially environmentally hazardous product, based on 2 percent of the sales price. The bill would have required that 50 percent of the fee revenues be deposited in the Hazardous Waste Control Account, to be available for expenditure for educational, regulatory, and remedial programs. The other 50 percent would have been allocated to cities and counties to implement the household hazardous waste collection and education programs mandated by AB 2707 and AB 939. SB 1143 was substantially revised in January 1992, removing all references to fees. Action on this bill is still pending in the California Legislature.

2. Battery Waste Management Plans

Waste management plans have been proposed, or are required, which target used household batteries rather than household hazardous waste in general. Responsibility for collection and disposal is placed on either manufacturers or local government agencies. Financial mechanisms, such as return deposits or grants, have been proposed to defray program costs and provide incentives to participate.

When the responsibility for waste management is that of the manufacturers, written battery management plans have been required to include provisions for the collection, transportation, and recycling or disposal of targeted batteries, such as rechargeable batteries or mercuric oxide cells. The plans designate the collection system to be utilized, consumer education programs, an industry-wide uniform coding system, and the funding source or mechanism to defray the cost of the plan. Regulatory authorities also have been given emergency powers to require manufacturers to develop management plans for other types of household batteries. Legislation placing the responsibility on manufacturers has been passed in New Jersey and will be introduced into the United States Congress by Senator Frank Lautenberg of New Jersey.

When the responsibility for waste management lies with a government agency, management plans also include collection, transportation, and processing or recycling provisions. Vermont law authorized the development of a statewide used battery management plan. The plan includes a comprehensive system for collection and disposal of batteries determined to be harmful. The plan also considers incentives to encourage consumer participation, such as return deposits. Minnesota law established a grant program to help counties plan and implement household battery collection, processing, and disposal projects. The bill also establishes guidelines for collection and transportation systems, dissemination of educational materials regarding environmentally sound battery management, and development of markets for materials recovered from batteries.

3. Education Programs and Labelling Requirements

To encourage and enable participation in voluntary programs, several jurisdictions have passed legislation on education programs aimed at the general public, and labelling requirements to be placed on individual batteries and battery packaging.

For rechargeable batteries, labelling and information on proper disposal methods have been legislated in several states. In Oregon, the batteries must be labelled with the recycling symbol and the symbol "Cd" for the metal cadmium. Other jurisdictions which have passed labelling requirements on rechargeable batteries include New Jersey and Connecticut, and is scheduled to be proposed in the United States Senate. In Minneapolis, retailers are responsible for disseminating information. A city ordinance requires that retailers must post notices on the proper disposal methods of used household batteries.

4. Collection and Processing Programs

Several jurisdictions have required the implementation of collection and processing programs for household batteries. Legislation provisions requiring the proper disposal and processing of the collected batteries have not been specific in describing processing options such as recycling. In general, collection programs are aimed at mercuric oxide batteries and rechargeable batteries. These battery types contain the highest percentage by weight of toxic metals, and substitute battery types are still in the development stage.

Where specific battery types are targeted for collection, the legislation emphasizes the responsibilities of the manufacturers. These responsibilities include designation of collection systems and processors, designation of funding sources and mechanisms to defray the costs of the programs, consumer education, and industry-wide uniform codes to identify specific battery types.

Nearly 80 percent of nickel-cadmium batteries are used as components of consumer products, where the batteries have been included as an integral component of the product. To facilitate separation and collection of these batteries, several states have passed legislation requiring that all rechargeable batteries be easily removeable from consumer products. The responsibility for collection of rechargeable batteries depends on the jurisdiction. Minnesota law requires that manufacturers implement pilot programs and then, within two years, permanent programs to collect rechargeable batteries. The goal of the pilot program is to gather sufficient statewide data for the design and implementation of the permanent program. The goal of the permanent program is to collect 90 percent of waste rechargeable batteries. Connecticut law requires that municipalities have the responsibility for recycling nickel-cadmium batteries through local or regional processing centers. New Jersey law requires that retailers shall accept rechargeable batteries from consumers. Legislation on the design of consumer products has been passed in Oregon,

and proposed for the states of Michigan and Vermont, and at the federal level for the United States.

Mercuric oxide batteries also have been targeted for collection and processing. Because of the specialized uses of these cells, responsibility for collection and processing has been placed on distributors and manufacturers, rather than municipalities. In New Jersey, mercuric oxide hearing aid batteries were exempt from mercury content limitations and banning, if the used batteries are collected by hearing aid distributors. Government, medical, commercial, and industrial generators of large quantities of mercuric oxide cells also are required to provide on-site collection and source separation. In Minnesota, government and other large generators are prohibited from disposing used mercuric oxide cells in the mixed solid waste stream, but manufacturers are responsible for collection and processing.

5. Recycling Programs

A critical component of household battery waste management programs is the establishment of technically, institutionally, and economically feasible recycling programs for those batteries identified as recyclable. Current legislation on household batteries leave the issue of recycling unanswered. Several states currently require the collection of various types of household batteries, as discussed above. However, ultimate disposal of the batteries is frequently left to some future determination or additional study. For example, in Minnesota, the Office of Waste Management was directed to investigate options and develop guidelines for collection and disposal of household batteries[166]. As a result of its study, the Minnesota Office of Waste Management recommendations for the recycling market included that the Office *work with industry to explore and solicit possible household battery market development projects*[167]. Clearly, the opportunities for recycling household batteries remain limited and uncertain.

6. Studies in Progress

Several jurisdictions have passed legislation authorizing studies, as interim measures to frame possible future actions. The main unresolved issues concern: 1) the

166 Minnesota Act 89-1, Article 20

167 Vandenbosch, Mary, et al., *Household Battery Report*, prepared for the Legislative Commission on Waste Management by the Minnesota Office of Waste Management, December 1991

extent to which battery types other than mercuric oxide and nickel-cadmium cells may pose potential health hazards, 2) the extent to which recycling is technically or economically feasible, 3) the potential hazards which may be present in the recycling process, and 4) the development of comprehensive funding mechanisms which both defray costs of collection and provide incentives for consumer participation. The studies also incorporate technical and scientific perspectives in the evaluation of the potential adverse effects on human health and the environment, and involve cooperation with battery and consumer product manufacturers, wholesalers, and retailers who will be responsible for developing management plans. Studies have been authorized in California, Minnesota, Vermont, and Michigan. This report is the product of legislated authorization to study household batteries in California.

Detailed Summary of Household Battery Legislation

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of California	SB 1594 (1989)	Enacted	Jan-1-90	**Hazardous Waste Exemption** Collection locations and transportation of household batteries are exempt from hazardous waste requirements for receiving, storage, and transportation, if the batteries are to be recycled.	• Solid waste facilities • Hazardous waste facilities
State of California	AB 3530 (1990)	Proposed (subsequently amended, see below)	-----	**Deposit and Refund Value** Would require consumers to pay dealer a ten cent deposit upon purchase of household batteries. Would require dealers to accept used batteries and pay a ten cent refund value for household batteries. The deposit and refund value is to be increased by five cents every two years until the redemption rate is 80 percent.	• CIWMB • Consumers • Retailers • Battery distributors • Battery manufacturers
State of California	SB 1813 (1990) AB 3530 (1990)	Enacted	Jan-1-91	**Study of Disposal and Collection Program** Requires study on the disposal and potential recyclability of used household batteries.	• CIWMB
State of California	SB 1143 (1991)	Proposed (subsequently amended, see below)	-----	**Hazardous Products Fee** Requires a fee of 2 percent of the sales price, with 50 percent of revenues for education and remedial programs, and 50 percent to implement household hazardous waste collection programs.	• CIWMB • State Board of Equalization • Dept. of Health Services • Cities • Counties • Consumers
State of California	SB 1143 (1992)	Proposed	-----	**Household Hazardous Waste Facility** Establishes criteria by which a hazardous waste facilities permit is not required for a household hazardous waste collection facility. To be exempt from permit requirements, such a facility would be required to accept nickel-cadmium, alkaline, carbon-zinc, and other small batteries.	• Household hazardous waste collection facilities • Cities • Counties

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of Connecticut	Public Act 90-248 89-385	Enacted	Jul-1-93	**Product Design, Labelling, and Recycling Program** • Nickel-cadmium batteries in consumer products must be easily removeable, and packages must be labeled requiring proper disposal. Municipalities must recycle nickel-cadmium batteries through processing centers.	• Battery manufacturers • Manufacturers of consumer products • Municipalities
State of Connecticut	Public Act 91-377	Enacted	Jan-1-92 Jan-1-92 Jan-1-93	**Content Limitation** • Used mercuric oxide cells are considered hazardous waste. Retailers will be required to accept used cells from consumers. • Limit on mercury content in alkaline batteries of 0.025 percent (250 parts per million) by weight. • Limit on mercury content in zinc-carbon batteries of one part per million by weight.	• Battery manufacturers • Retailers
State of Maine	L.D. 1278 (1991)	Proposed	Feb-1-92 Aug-1-93 Feb-1-94	**Battery Refund Program** This bill would: • Establish a household battery collection program by instituting a 10¢ deposit system on all household batteries sold in the state. • Prohibit incineration of household batteries • Ban sale of products from which batteries cannot be removed and replaced by the consumer. • Require all State agencies to purchase, to the maximum extent possible, rechargeable household batteries rather than non-rechargeable batteries.	• Consumers • Retailers • Distributors • Manufacturers • Importers • Incinerator operators • State agencies

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of Maryland	Public Act 89-820	Enacted	Jul-1-89	**Household Hazardous Waste Collection Program** Each county is to assess by January 1, 1990 the feasibility of establishing a household hazardous waste collection program, including one collection day per year.	• Counties
State of Michigan	Public Act 90-20	Enacted	Apr-1-90	**Recycling Program and Deposit System** • Authorizes the study of disposal and recycling options, and possible deposit system, for nickel-cadmium and mercury batteries. • Report due December 31, 1990 from joint legislative committee (see below).	N/A
State of Michigan Joint Legislative Committee on Batteries	Report of the Committee	Proposed		**Management and Disposal of Household Batteries**	• Battery manufacturers • Manufacturers of consumer products
			Jan-1-92	• Nickel-cadmium batteries are to be banned from disposal in solid waste landfills and incinerators immediately and to be banned from sale by January 1, 1995	
			Jan-1-92	• Mercuric oxide, silver oxide, and lithium batteries are to be banned from disposal in solid waste landfills and incinerators immediately and are to be banned from sale by January 1, 1992	
			Jan-1-92	• Alkaline and carbon-zinc batteries are required to limit mercury content to 0.025 percent by weight by January 1, 1992.	
			Jan-1-95	• Recycling of alkaline and carbon-zinc batteries to be required by January 1, 1995.	
			Jan-1-95	• Batteries are to be removeable from products and devices	

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of Minnesota	Act 90-409	Enacted		**Content Limitation and Product Design**	• Government agencies • Industrial facilities • Commercial facilities • Medical facilities • Battery manufacturers • Manufacturers of consumer products
			Aug-1-90	• Prohibits disposal of mercuric oxide, silver oxide, and nickel-cadmium batteries used by government agencies and medical facilities. Manufacturers are responsible for collection and processing.	
			Jan-1-92	• Limit of 25 mg. of mercury in alkaline button cells.	
			Feb-1-92	• Limit of 0.025 percent by weight mercury in alkaline batteries.	
			Apr-15-92	• Manufacturers are to implement pilot programs for the collection and management of rechargeable batteries.	
			Jul-1-93	• Removeable nickel-cadmium battery packs.	
			Apr-15-94	• Manufacturers are to implement permanent programs for the collection of rechargeable batteries. The program goal is to collect 90 percent of waste rechargeable batteries.	
State of Minnesota	Act 89-1 Article 20	Enacted	N/A	**Collection and Recycling Program** • Office of Waste Management is to investigate options and develop guidelines for collection and disposal. • Report is available as of December, 1991.	• Office of Waste Management

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of New Jersey	SB 3157 (1991)	Passed state legislature Amended by Governor		**Dry Cell Battery Management Act** (as amended by Governor)	• Battery manufacturers • Manufacturers of consumer products • State solid waste management agencies • Retailers • Government Agencies
			Jan-1-92	Mercury content limitation of 0.025 percent by weight (250 parts per million) for alkaline batteries.	
			Jan-1-92	Mercury content limitation of 25 mg. from button alkaline batteries.	
			Jan-1-92	Mercury content limitation of 0.025 percent by weight (250 parts per million) for mercuric oxide batteries.	
			Jul-1-92	Mercury content limitation of 0.0001 percent by weight (one part per million) for zinc carbon batteries.	
			Jul-1-93	Rechargeable batteries must be removeable from consumer products, labeled, and include information on proper disposal.	
			Jan-1-94	Two year exemption for mercuric oxide hearing aid batteries expires.	
			Jan-1-96	Mercury content limitation of 0.0001 percent by weight (one part per million) for alkaline batteries.	
				Retailers are to accept used rechargeable batteries from consumers.	
				Government agencies, hospitals, and commercial and industrial establishments that generate at least 220 pounds per month are to provide on-site collection and source separation of mercuric oxide and rechargeable batteries.	
				Manufacturers are to prepare and submit written battery management plans for the disposal of mercuric oxide or rechargeable batteries, including designation of the collection system, funding source or mechanism, consumer education, and an industry-wide uniform coding system.	
				The State Department of Environmental Protection may issue emergency orders to manufacturers of other dry cell batteries, directing suspension of sale or requiring battery management plans.	

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of New York	S. 4275-A A. 7029-A	Proposed		**Content Limitation and Product Design**	
			Jan-1-92	• Limit of 0.025 percent by weight in alkaline batteries	• Battery Manufacturers
			Jan-1-92	• Limit of 25 mg of mercury in alkaline button cells	• Manufacturers of consumer products
			Jan-1-93	• Prepare a study on the feasibility of requiring the elimination of mercury from alkaline batteries and a schedule for the collection, recycling, and disposal of mercuric oxide, silver oxide, nickel-cadmium, and small lead-acid batteries.	• State agencies
			Jul-1-93	• Limit of 0.0001 percent by weight in carbon-zinc batteries	
			Jul-1-93	• Nickel-cadmium and small lead-acid batteries or battery packs must be easily removeable from consumer products	
			Jul-1-93	• Rechargeable batteries must by clearly marked to identify its chemical content	
State of Oregon	AB 3361 (1991)	Enacted		**Content Limitation and Product Design**	
			Jan-1-92	• Limit of 0.025 percent by weight mercury in alkaline batteries.	• Battery manufacturers
			Jan-1-92	• Limit of 25 mg. mercury in alkaline button cells.	• Manufacturers of consumer products
			Jul-1-93	• Removeable nickel-cadmium battery packs.	
State of Oregon	Act 89-833	Enacted	Jul-1-90	**Household Hazardous Waste Management** Implements a statewide household hazardous waste public education program. Conduct a pilot project to operate periodic household hazardous waste collection events. Collection of household batteries included in one-day events. Contractors are to sort and recycle batteries.	• State Department of Environmental Quality

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of Rhode Island	N/A	Proposed		**Battery Content, Product Design, and Recycling**	• Consumers • Battery manufacturers • Consumer product manufacturers • Retailers • Distributors • Dept. of Environmental Management
			Jan-1-92	• Limit to 0.025 percent by weight the mercury content of alkaline batteries	
			Jan-1-93	• Prohibit sale of mercuric oxide button batteries	
			Jan-1-94	• Prohibit disposal of nickel-cadmium, mercuric oxide, or lead-acid batteries, or consumer products containing nickel-cadmium or lead acid batteries, in municipal or commercial solid waste.	
			Jan-1-94	• Nickel-cadmium and lead-acid batteries contained in consumer products must be easily removeable by the consumer and labeled to indicate: 1) the battery is recyclable and not to be disposed of in municipal solid waste, and 2) the type of electrode used in the battery.	
			Jan-1-94	• Nickel-cadmium and lead-acid batteries must be labeled to indicate: 1) the battery is recyclable and not to be disposed of in municipal solid waste, and 2) the type of electrode used in the battery	
			Jan-1-94	• The Department of Environmental Management shall develop regulations for a battery recycling program for mercuric oxide, nickel-cadmium, and lead-acid batteries. Collection is to be at the point of sale.	
State of Vermont	Bills 87-78 87-246 89-218	Enacted	Jul-1-91	**Hazardous Waste Management Collection and Recycling Program** Hazardous waste management plan should be published and include a statewide strategy to reduce, remove, separate, collect, and recycle materials, including disposable batteries based on volume of waste, sources of waste, current disposal methods, cost to recycle, and potential markets.	• State agencies

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
State of Vermont	Bill 91-124	Enacted		**Battery Content, Product Design, and Recycling**	
			Jul-1-91	• Landfill prohibition for waste mercuric oxide, silver oxide, nickel-cadmium, and sealed lead-acid batteries from certain nonconsumer users. • Manufacturers are required to ensure a collection system, inform purchasers of landfill prohibition, and include cost collection in the sales transaction.	• Consumers • Battery manufacturers • Consumer product manufacturers • Retailers • Distributors • Agency of Natural Resources
			Jan-1-92	• All button cell batteries must be labelled by type. • Manufacturers are not allowed to distribute or sell for retail an alkaline battery that contains more than .3% mercury or a button cell which contains more than .025% mercury.	
			Feb-1-92	• Manufacturers are not allowed to distribute or sell any alkaline battery with more than .025% of mercury.	
			Jul-1-92	• Nickel-cadmium and other rechargeable batteries are banned from landfill disposal where there is an onging collection program.	
			Jan-1-93	• Button cell batteries containing 25 milligrams or more of mercury are banned from being sold in Vermont. • Unless proven unfeasible, all mercuric oxides, silver oxides, nickel-cadmium, and sealed lead-acid batteries are prohibited from landfill disposal.	
			Jul-1-93	• Nickel-Cadmium batteries must be easily removeable and labelled as to the proper disposal of the battery.	
			Jan-1-96	• All batteries with mercury are prohibited from retail sale.	
State of Vermont Agency of Natural Resources	Waste Battery Management Plan	Proposed		**Waste Battery Management Plan** Agency determined that mercuric oxide and nickel-cadmium batteries, regardless of disposal, and alkaline batteries, when incinerated, may cause harm to health and the environment based on quantities of mercury and cadmium contributed to the solid waste stream. Recommendations include:	• Battery manufacturers • Incinerator operators
			Jul-1-92 Jan-1-93	• Prohibit sale of mercuric oxide batteries by July, 1992. Nickel-cadmium batteries are to be diverted from disposal through targeted collection programs. • Alkaline batteries are to be removed from waste streams destined for incineration by January 1, 1993.	

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
City of Minneapolis	Title 8 Chapter 152	Enacted	Sep-14-90	**Disposal and Education Program** Retailers must post notice on proper disposal of batteries.	• Retailers
City of San Francisco	Resolution 226-87-3	Enacted	Dec-14-87	**Household Hazardous Waste Collection Program** Established household hazardous waste collection program and permanent collection facility. Proposal to recycle rechargeable batteries and button cells is part of the program.	• City of San Francisco

Detailed Summary of Household Battery Legislation (Continued)

Jurisdiction	Reference	Status	Effective	Description	Affected Entities and Agencies
United States Senate	N/A	Proposed by Sen. Lautenberg To be introduced in 1992	Jan-1-93 Jan-1-96 Jan-1-92 Jan-1-96 Jan-1-93	**Battery Recycling and Disposal Act of 1991** • Mercury content limitation of 0.025 percent by weight (250 parts per million) for alkaline batteries. • Mercury content limitation of 0.0001 percent by weight (one part per million) for alkaline batteries. • Mercury content limitation of 0.0001 percent by weight (one part per million) for zinc carbon batteries. • Mercury content limitation of 0.025 percent by weight (250 parts per million) for mercuric oxide batteries. • Rechargeable batteries must be removeable from consumer products, labeled, and include information on proper disposal. • Manufacturers are to prepare and submit written battery management plan for the collection, transportation, and recycling or disposal of mercuric oxide or rechargeable batteries. Plans are to include description of the collection system, funding source, consumer education, and industry-wide uniform codes. Combustion is prohibited as a means of disposal. • The U.S. EPA may issue emergency orders to manufacturers of other dry cell batteries, directing suspension of sale or requiring battery management plans.	• Battery manufacturers • Manufacturers of consumer products • State solid waste management agencies
United States House	HR 3735 (1989) Sec. 2010	Proposed	N/A	**Study of Disposal and Collection Program** The U.S. EPA shall conduct a study of: • Effects of used batteries on landfills and incinerators • Potential recyclability of used household batteries.	• U.S. EPA

C. Source Reduction and Waste Management Practices in Europe and Japan

European countries have been at the forefront of establishing legislation on household batteries. Typically, legislation has been aimed at reducing mercury and/or cadmium content levels in batteries which has led to voluntary agreements with manufacturers regarding product labelling and collection programs. Educational programs, such as those found in Japan, are increasing public awareness in the recyclability of household batteries and have resulted in high return rates. Collection and processing programs have been in effect for over five years in both Switzerland and Sweden, achieving collection rates as high as 60 percent in Sweden. Although battery collection programs were implemented in the late 1980's, only a few countries have facilities to recycle the batteries.

1. Germany

The Federal Parliament of the Federal Republic of Germany passed a second amendment to the Refuse Disposal Law on January 15, 1982. This amendment issued the Sewage Sludge Discharge Implementation Order, effective April 1, 1983, and placed limitations on lead, cadmium, chromium, copper, nickel, mercury, and zinc in sewage sludge[168].

In 1986, Article 14 of the Refuse Disposal Law was amended to set specific waste reduction goals. This change allowed the Environment Minister of Germany to issue environmental-related orders. The Minister requested battery manufacturers to cooperate in reducing heavy metals in household waste by voluntarily reducing the mercury content in batteries and by improving product markings to facilitate separating certain types of discarded batteries[169]. In September, 1988, voluntary agreements with battery manufacturers were established to limit mercury levels and require recycling labels on dry cell batteries. Batteries with mercury content levels exceeding 0.1 percent of weight had to

168 Tabasaran and Partners, Compiled for the Fachverband Batterien, Hanover, Environmentally Relevant Effects of the Substances Present in Primary Batteries when Disposed of in Dumps and Incinerators for Domestic Waste and in Composting Systems, October, 1990

169 Business International, Business Europe, *Germany Leads the Way on Reducing Waste*, February 9, 1987

be marked effective April, 1989 and are to be returned to dealers. Also, the battery manufacturers have agreed to reduce mercury contents to 0.1 percent of weight.

Depending on the success of these voluntary agreements, the Environment Agency will make customer return of such batteries mandatory and will require the manufacturers to supply the necessary facilities. If attempts to recycle by these measures do not achieve high return rates, the Government intends to implement a refundable deposit on batteries[170].

2. Austria

With the passing of the Austrian Standard, S2022, limiting mercury and zinc contents, Austria has also established voluntary industrial agreements which limit the quantities of mercury and zinc in household products[171]. All household hazardous wastes, including batteries, are actively separated from the municipal solid waste since 50 percent of the waste is composted and sold for agricultural use. To assist in the collection of dry cell batteries prior to entering the household hazardous waste stream, Austria also plans to implement a labelling and deposit system on household batteries to achieve a higher return rate.

3. Switzerland

Used dry cell batteries, under Swiss regulations, are prohibited from being placed in household refuse. Since 1983, battery suppliers have been required to accept used batteries. In addition, the Government has established a comprehensive battery collection program with both retail and public collection containers. In 1990, collection of used household batteries in Switzerland was about 35 percent of total batteries consumed for that year. The problem Switzerland faces is the lack of recycling capabilities within the country. A group consisting of private firms, individuals, and public authorities have established a battery recycling company in Zurich to recycle used Swiss batteries which formerly had been sent to Germany[172].

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170 Business International, 1987

171 Tabasaran and Partners, 1990

172 Economist Publications Ltd., Country Report, *Solving the Problems of Recycling Batteries; Water Pollution by Farms* , July 12, 1989

In addition to the collection programs, Switzerland also has passed strict product labelling legislation, requiring mercury or cadmium contents of over 0.025 percent in batteries to be marked with labels indicating that the product is environmentally hazardous. Also, nickel-cadmium batteries will have a deposit system in place and must be removeable from rechargeable household appliances and tools[173].

4. Sweden

As typical with the Scandanavian countries, Sweden passed strict content limitation restrictions in the early 1980's. The Swedish Government requires batteries with mercury and cadmium levels greater than 0.025 percent to be labelled as hazardous and bans such batteries from entering municipal solid waste landfills. Also, the Government has placed levies equal to 15 to 20 percent of the battery price on the manufacturers. These revenues are then used to fund the recycling program.

Since 1987, Sweden has enacted an extensive household battery collection program and currently retrieves 60 percent of all disposed batteries[174]. The program uses a combination of curbside, retail outlet, and public collection boxes. The batteries are then manually sorted by type and disposed accordingly. The nickel-cadmium batteries are sent to a recycling facility while other batteries are stored.

5. Denmark

Under the Danish Recovery Act, there are strict labelling requirements on batteries. Household batteries with mercury and cadmium contents greater than 0.025 percent are to be labelled hazardous, and all batteries are to be labelled recyclable. In addition, rechargeable products with built-in batteries will be labelled. If passed, this legislation will implement a rebate system which will be equal to 10 percent of the purchase price and will help achieve a 95 percent return rate of used nickel-cadmium batteries[175].

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173 Goldberg, 1991

174 Levy, Stephen J., United States, Environmental Protection Agency, Office of Solid Waste, European Battery Management Practices, Presented to OAQPS, Precombustion Control of Mercury Emissions from Batteries Meeting, February, 8, 1990

175 Ibid

6. Britain

The Environment Minister of Britain launched a pilot collection program in 1989 which was established to help meet the goal of recycling 50 percent of usable household rubbish by the year 2000[176]. This program provided 10,000 households in Sheffield with a box container, which has partitions for various recyclable household products, including batteries, and will be collected as frequently as twice a week. Curbside collection programs such as this pilot program are deemed necessary in order for Britain to increase its recycling rate from 1.5 percent to over 30 percent.

7. European Community

In March 1991, the Council of Ministers "Environment" formally adopted the EC Directive Number 91/157 relating to batteries containing certain hazardous substances (mercury, cadmium, and lead)[177]. The main provisions of the proposal are: 1) a ban on alkaline batteries with a mercury content more than 0.025 percent, and 2) labelling of batteries containing, by weight, more than 25 mg mercury (except alkaline batteries), 0.025 percent cadmium, or 0.4 percent of lead. Mercuric oxide, nickel-cadmium and lead acid batteries are to be collected separately from municipal solid waste for recycling or other special disposal[178].

The directive illustrates the basic principles by which the EC Commission has established its strategy for waste management. In ranking order, these are:

- Prevention
- Recycling and reuse
- Optimization of final disposal.

Similar to the United States, under the European Community Directive, batteries that contain appreciable amounts of mercury, cadmium, or lead are considered to be

176 Clover, Charles, Sunday Telegraph, *Green Dustbin May Lay Waste to L2.5b Bill*, November, 19, 1989

177 *European Community Waste Management and Its Applications to Used Batteries*, Proceedings of the Second International Seminar on Battery Waste Management, November, 5-7, 1990

178 Europile, *Implementation of the EC Battery Directive: The Basis for Collection & Recyling Schemes*, Batteries and the Environment, Association of European Primary Battery Manufacturers, Bern, Switzerland, April 1991

hazardous wastes. However, the European approach differs significantly from that of the United States in at least two respects[179]:

- In the United States, consumer wastes are explicitly excluded from the provisions of RCRA. However, in Europe, the EC Directive very definitely includes consumer wastes. In order to control the disposal of consumer wastes, methods for separate collection must be established.

- In the United States, the criterion for whether batteries are a hazardous waste is the leachability of the toxic metal contents (TCLP test). In Europe, the hazardousness of batteries is determined by the concentration of toxic metals in each product (e.g., alkaline batteries with more than 0.025 percent mercury).

These differences have implications on the approaches taken for managing household battery waste disposal.

8. Japan

In Japan, battery recycling programs have been in existence for over five years. Most municipalities collect batteries although the collection method varies among communities. Most retrieve used batteries through monthly household hazardous waste collection days where batteries are placed in marked bags, separate from other recyclable items[180]. Other collection programs include quarterly pick-up days and public drop-off containers. Recovery rates for household batteries in Japan average about 20 percent.

The Japan Storage Battery Association has started a one year nationwide recycling program, which began in October, 1991, targeting nickel-cadmium batteries. This campaign has published and distributed literature promoting the collection and recycling of nickel-cadmium batteries. The Association hopes it will increase the recovery rates of these batteries from 13 to 20-30 percent[181,182]. The program calls for manufacturers to voluntarily collect the used batteries from local customers. This campaign is a pilot program which will determine the future for other such recycling projects.

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179 Ibid

180 Levy, 1990

181 COMLINE News Service, COMLINE Daily News Chemicals and Materials, *Japan Storage Battery Association Promoting NiCd Battery Recycling*, October, 24, 1991

182 COMLINE News Service, COMLINE Daily News Chemicals and Materials, *Japan: Recycling Campaign*, November 22, 1991

It should be noted that in Japan more than 300 municipal corporations are undertaking separate collection for used batteries apart from general garbage. This is in spite of a report issued in 1985 by the Ministry of Health and Welfare which is generally thought to declare the safety of used household batteries.

D. Model Legislation for Household Batteries

Model legislation for household batteries has been proposed by the Dry Battery Section of the National Electrical Manufacturers Association (NEMA) and the Battery Product Alliance (BPA). The model legislation is shown in **Exhibit B-3**, following this page.

The model legislation would have manufacturers responsible for technical approaches to waste battery management, such as limitations on mercury content, consumer product redesign for easy separation of batteries, and product labelling. The legislation would not commit the battery industry to technical approaches that may not be feasible, such as development of new battery types. Municipalities would be responsible for programmatic approaches that require public participation. In some cases, the provisions of the model legislation have been incorporated into the enacted legislation detailed above. The model legislation includes the following provisions:

- *Source Reduction.* Mandate mercury content limitations of 0.025 percent by weight in alkaline manganese batteries. Work towards mercury-free alkaline and zinc carbon batteries
- *Education Programs and Labelling Requirements.* Label nickel-cadmium and small sealed lead batteries, the consumer product, and the package with the chemical symbol "Cd" or "Pb", and the recycling symbol, and include instructions on the proper disposal of such batteries
- *Collection and Processing Programs.* Require easy removal of nickel-cadmium and small sealed lead batteries from consumer products. Require municipalities to establish a local collection and processing system for nickel-cadmium, small sealed lead, and mercuric oxide batteries.

Model Legislation For Household Batteries

Proposed by the Dry Battery Section
of the National Electrical Manufacturers Association
and the Batteries Products Alliance

Be it enacted by the State of _____:

SECTION 1. "FINDINGS AND PURPOSE"

A. FINDINGS

1) Batteries have come to play an important role in the advancement of social, medical, and economic concerns.

2) It is important to advance environmental interests without unnecessary interference with, or complications of, local, interstate, and international commerce to the detriment of our state's economy.

3) It is important to provide clear, safe, and practical guidelines to our state's citizen's, businesses and governmental bodies.

4) There are inherent differences in batteries and products using batteries with respect to their composition, distribution, and application.

5) It is the public interest to recycle certain types of batteries and , on balance, not in the public interest to recycle other types of batteries.

B. PURPOSES

1) To require the mercury content in alkaline manganese batteries to be reduced to a level so that batteries at or below the level may be disposed in solid waste, and so that batteries above the level may not be sold in this state.

2) Require the mercury content in zinc carbon batteries be reduced to a level of no more than one part per million, so that batteries at or below that level may be disposed in solid waste and batteries above that level may not be sold in this state.

3) To provide for the management of small sealed lead, nickel cadmium, and mercuric oxide batteries that might pose environmental or health problems if the batteries were disposed of in the solid waste stream.

4) To maximize consumer acceptance and convenience in accomplishing important objectives of environmental protection.

5) To minimize unnecessary administrative expenses to the state and avoid undue burdens on the state's consumers, retailers, manufacturers, and suppliers.

Model Legislation For Household Batteries
(Continued)

SECTION 2. "DEFINITIONS"

A. "BATTERY"

A battery consists of one or more cells, each cell consisting of a positive electrode, a negative electrode, and an electrolyte.

B. "ALKALINE MANGANESE BATTERY"

An alkaline manganese battery is a battery consisting of manganese dioxide positive electrode material, zinc negative electrode material, and an alkaline electrolyte.

C. "ZINC CARBON BATTERY"

A zinc carbon battery is a battery consisting of manganese dioxide positive electrode material, zinc negative electrode materials, and an electrolyte consisting of a solution of zinc chloride and /or ammonium chloride.

D. "MERCURIC OXIDE BATTERY"

A mercuric oxide battery is a battery consisting of mercuric oxide positive electrode material and zinc negative electrode material.

E. "NICKEL CADMIUM BATTERY"

A nickel cadmium battery is a battery consisting of nickel positive electrode material and cadmium negative electrode material.

F. "SMALL LEAD BATTERY"

A small lead battery is a battery consisting of nickel positive electrode material and cadmium negative electrode material.

G. "BATTERY PACK"

A battery pack consists of one or more batteries enclosed in a housing.

H. "CONSUMER PRODUCT"

A consumer product is any product which is sold primarily for personal, family or household use, and which is normally sold through consumer retail distribution.

I. "NONCONSUMER PRODUCT"

A nonconsumer product is a product which is not a consumer product.

J. "DISTRIBUTOR"

A distributor is a seller of batteries.

Model Legislation For Household Batteries
(Continued)

K. "RECYCLE"

Recycle is the term used to describe the collection and transportation of certain batteries and the reclamation of materials from certain batteries.

L. "EASILY REMOVED"

Easily removed refers to a battery or battery pack which is either detachable or readily removed by the consumer from a consumer product with the use of common household tools (e.g., flat bladed or phillips head screwdriver) and which can be removed by the consumer without cutting or desoldering any wires.

SECTION 3. "MERCURY CONTENTS IN ALKALINE MANGANESE BATTERIES"

A. Except for Subdivision B of this section, no person may sell or offer for sale in this state an alkaline manganese battery manufactured on or after January 1, 1992, which battery contains more than 0.025 percent mercury by weight of the battery.

B. For alkaline manganese batteries having sizes and shapes resembling buttons or coins, the limitation on mercury content shall be 25 milligrams of mercury/battery.

C. After January 1, 1996, a manufacturers may not sell, distribute, or offer for sale in this state an alkaline manganese battery (except an alkaline manganese button cell) that contains mercury, unless the Commissioner of the (appropriate regulatory agency) grants an exemption pursuant to paragraph D of this section.

D. On application by a manufacturer, the Commissioner of the (appropriate state regulatory agency) may exempt a manufacturer from the requirements of paragraph C if the manufacturer demonstrates that"

1) Since the effective date of this law, the manufacturer has worked in good faith to develop mercury-free alkaline manganese batteries with respect to safety, leakage, capacity, rate capability and shelf life, which are as good as alkaline manganese batteries containing no more than 0.025 percent mercury produced by that manufacturer on January 1, 1992; and,

2) If granted that exemption, the manufacturer will continue to work in good faith to achieve the goals described in subparagraph (1) of this paragraph D.

An exemption granted by the Commissioner of the (appropriate state regulatory agency) under this paragraph D must be limited to a maximum of two years and may be renewed.

Model Legislation For Household Batteries
(Continued)

SECTION 4. "MERCURY CONTENT IN ZINC CARBON BATTERIES"

A manufacturer may not sell, distribute or offer for sale in this state a zinc carbon battery that contains a mercury concentration level of more than one part per million (0.0001%) by weight for batteries manufactured on or after January 1, 1993.

SECTION 5. "PRODUCT REQUIREMENTS FOR NICKEL CADMIUM AND SMALL LEAD BATTERIES"

A. No distributor may sell or offer for sale in this state any consumer product or nonconsumer product manufactured on or after July 1, 1993, which product contains a nickel cadmium or small lead battery or a battery pack containing a nickel cadmium or small lead battery, unless:

1) In the case of consumer products, the battery can be easily removed by the consumer, or is contained in a battery pack that is separate from the product and can be easily removed from the product.

2) In the case of nonconsumer products, the battery can be removed or is contained in a battery pack that is separate from the product.

3) The product, the battery itself, and the package containing a consumer product are labeled in a manner to meet the requirements of the International Standards Organization (ISO 7000-1135) recycling symbol with the chemical composition "Cd" for nickel cadmium, or "Pb" for small lead batteries included as part of the recycling symbol.

4) The instruction manual, if any, for the product includes information explaining the recycling symbol and methods to assure proper disposal of the batteries or battery packs.

B. The commissioner or (appropriate state regulatory agency) may authorize the sale of a consumer product or a nonconsumer product which does not comply with subdivision A of this section if the commissioner determines that:

1) The product was available for sale on or before the effective date of this act, and the product cannot reasonably be redesigned and manufactured by July 1, 1993: or,

2) Design of the product to comply with subdivision A would result in significant danger to public health and safety.

Model Legislation For Household Batteries
(Continued)

SECTION 6. "MUNICIPAL RESPONSIBILITY FOR RECYCLING MERCURIC OXIDE BATTERIES, CONSUMER SMALL LEAD BATTERIES, AND CONSUMER SMALL NICKEL CADMIUM BATTERIES"

A. Each municipality in this state shall be responsible for establishing a local collection and processing system, or participating in a regional processing center, for recycling the following batteries by the following dates:

1) For mercuric oxide batteries, (date)

2) For nickel cadmium and small lead batteries used in household and consumer products, July 1, 1993.

B. In the case of batteries or battery packs included in the Section 6, no person may dispose of the battery or battery pack except as part of the collection system established under Section 6A above.

SECTION 7. "RESTRICTIONS ON DISPOSAL OF NONCONSUMER SMALL LEAD BATTERIES AND NONCONSUMER SMALL NICKEL CADMIUM BATTERIES"

A. In the case of nonconsumer small lead batteries and nonconsumer small nickel cadmium batteries, none of which are include in Section 6 of the Act, no person may place such batteries or battery packs in mixed municipal solid waste. The following methods are acceptable for recycling said batteries:

1) The user or distributor may contract with the local municipal collector or authorized scrap dealer or transporter to collect, transport, and recycle such batteries or battery packs; and/or,

2) The user of distributor may contract with an authorized scrap dealer or transporter to collect, transport, and recycle such batteries or battery packs; and/or,

3) The user may contact the distributor of such batteries or battery packs who must accept batteries or battery packs for recycling up to the number of batteries or battery packs of the same type and brand which that distributor has sold. The distributor may contact the next level of distribution in like manner until the batteries or battery packs are returned to the manufacturer for recycling.

4) Paragraphs 1), 2), and 3) of this subdivision A shall not be interpreted to exclude other recycling methods.

SECTION 8. "PENALTIES AND EXEMPTIONS"

A. A person who fails to comply with Section 3, 4, 5, or 7 of this act shall be liable to the state for a civil penalty in an amount not to exceed $100 for each day the noncompliance continues following receipt of notice of the noncompliance from the state.

Model Legislation For Household Batteries
(Continued)

B. A person who complies with the requirements of Section 7 is not liable for improper disposal by any other person.

C. Batteries which are recycled in accordance with Sections 6 or 7 of this act, as applicable, shall be exempt from this state's hazardous waste regulations.

SECTION 9. "APPLICATION"

Notwithstanding any provisions of this Act, no actions or activities prohibited or regulated by this Act shall be affected by this Act if they occur prior to the effective date, and any products manufactured prior to the effective date shall not be subject to the Act.

Appendix C

Legislation Authorizing the Household Battery Study

APPENDIX C

LEGISLATION AUTHORIZING THE HOUSEHOLD BATTERY STUDY

This appendix presents the two state bills, Senate Bill (SB) 1813 and Assembly Bill (AB) 3530 which authorized this study. SB 1813, approved September 10, 1990, authorizes the CIWMB to conduct a study on the disposal and recyclability of household batteries. AB 3530, which passed on September 30, 1990, also requires the CIWMB to conduct a similar household battery study.

Senate Bill No. 1813

CHAPTER 711

An act to amend the heading of Chapter 8 (commencing with Section 42440) of Part 6 of, to add an article heading immediately preceding Section 42440 of, and to add Article 2 (commencing with Section 42450) to Chapter 8 of Part 6 of, Division 30 of, the Public Resources Code, relating to solid waste.

[Approved by Governor September 10, 1990. Filed with Secretary of State September 12, 1990.]

LEGISLATIVE COUNSEL'S DIGEST

SB 1813, McCorquodale. Household batteries: study.

Existing law does not expressly authorize the California Integrated Waste Management Board to study the disposal and means of promoting the recycling of batteries typically generated as household waste.

This bill would authorize the board to conduct a study on the disposal and recyclability of batteries typically generated as household waste, as specified. The bill would make a statement of legislative findings.

The people of the State of California do enact as follows:

SECTION 1. The Legislature finds and declares that it is desirable to study the recyclability of household batteries and the effect of household batteries on solid waste landfills and transformation facilities. Household batteries include batteries from hearing aids, cameras, watches, computers, calculators, flashlights, lanterns, standby and emergency lighting, portable radio and television sets, meters, toys, clocks, and other batteries typically generated as household waste.

SEC. 2. The heading of Chapter 8 (commencing with Section 42440) of Part 6 of Division 30 of the Public Resources Code is amended to read:

CHAPTER 8. RECYCLED BATTERY PROGRAMS

SEC. 3. An article heading is added immediately preceding Section 42440 of the Public Resources Code, to read:

Article 1. Lead-Acid Battery Program

SEC. 4. Article 2 (commencing with Section 42450) is added to Chapter 8 of Part 6 of Division 30 of the Public Resources Code, to read:

Article 2. Household Battery Program

42450. (a) The board may conduct a study on the disposal and recyclability of household batteries, taking into account any studies completed or underway elsewhere, including, but not limited to, any studies by the Environmental Protection Agency. The board may participate in the study.

(b) The study may include, but is not limited to, all of the following:

(1) The effect of used household batteries on solid waste landfills and transformation facilities, including any threats to human health or environment.

(2) The recyclability of used household batteries, including, but not limited to, the following topics:

(A) Applicable recycling technologies and their effectiveness.

(B) Collection systems.

(C) Possible adverse effects on human health or the environment resulting from exposure to household batteries at all stages of the recycling process.

(D) Costs and revenues associated with recycling, including avoided disposal costs.

(E) Development of markets for products derived from recycled household batteries.

(c) For the purposes of this section, "household batteries" means batteries made of mercury, alkaline, carbon-zinc, nickel-cadmium, and other batteries typically generated as household waste, including, but not limited to, batteries used in hearing aids, cameras, watches, computers, calculators, flashlights, lanterns, standby and emergency lighting, portable radio and television sets, meters, toys, and clocks, but excluding lead-acid batteries as defined in Section 42440.

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Assembly Bill No. 3530

CHAPTER 1631

An act to add Division 12.2 (commencing with Section 15000) to the Public Resources Code, relating to batteries, and making an appropriation therefor.

[Approved by Governor September 30, 1990. Filed with Secretary of State September 30, 1990.]

LEGISLATIVE COUNSEL'S DIGEST

AB 3530, Margolin. Household batteries.

Existing law does not require the California Integrated Waste Management Board to study the disposal and recyclability of household batteries.

This bill would require the board to conduct a study of specified contents on the disposal and potential recyclability of household batteries, as defined. The bill would require the board to submit a report describing the results of the study and its recommendations, as specified, to the Legislature on or before March 1, 1992. The bill would also require the board to include prescribed information based on the study in a specified report to the Legislature on March 31, 1993.

The bill would appropriate $150,000 from the Integrated Waste Management Account in the Integrated Waste Management Fund to the board for the purposes of conducting the study and making the report.

Appropriation: yes.

The people of the State of California do enact as follows:

SECTION 1. Division 12.2 (commencing with Section 15000) is added to the Public Resources Code, to read:

DIVISION 12.2. HOUSEHOLD BATTERIES

CHAPTER 1. DEFINITIONS

15000. "Board" means the California Integrated Waste Management Board.

15001. "Consumer" means every person who, for his or her use, purchases a household battery from a dealer.

15002. "Dealer" means a person in this state who sells or offers for sale household batteries to consumers.

15003. "Distributor" means every person who sells or offers for sale household batteries to a dealer in this state, including any manufacturer who engages in these sales. "Distributor" includes, but

is not limited to, any person who imports household batteries from outside this state for sale to dealers or consumers in this state.

15005. "Household battery" means primary or secondary batteries, including nickel-cadmium, alkaline, carbon-zinc, mercury, and other batteries generated as non-RCRA hazardous waste similar in size to those typically generated as household waste. "Household battery" does not include lead-acid batteries. For purposes of this section, "non-RCRA hazardous waste" has the meaning as defined in Section 25117.9 of the Health and Safety Code.

15007. "Manufacturer" means any person who produces or manufactures household batteries.

15009. "Recycling center" means an operation which is certified by the department pursuant to Section 14538.

CHAPTER 2. STUDY ON HOUSEHOLD BATTERIES

15010. The board shall conduct a study on the disposal and potential recyclability of household batteries. In conducting the study, the board shall consult with other appropriate agencies and shall take into account any studies that have already been conducted on those batteries and their relation to solid waste.

15011. The study shall include, but is not limited to, all of the following:

(a) The effects of used household batteries on municipal solid waste landfills and incinerators, including any threats to human health or the environment.

(b) The potential recyclability of used household batteries, including, but not limited to, the following:

(1) Recycling technologies that could be used.

(2) The potential effectiveness of those technologies in recovering reusable materials from household batteries.

(3) Existing and potential collection systems for household batteries, including all of the following:

(A) Voluntary collection systems, using existing recycling centers and other mechanisms.

(B) Inclusion in the California Beverage Container Recycling and Litter Reduction Act.

(C) A deposit system which requires distributors to pay to the manufacturer a refundable deposit on purchase, dealers to pay to the distributor a refundable deposit on purchase, consumers to pay to the dealer a refundable deposit on purchase, and each deposit to be refunded on return of the household battery.

(D) The collection systems described in subparagraphs (A) to (C), inclusive, in conjunction with collection of other household hazardous wastes.

(4) The potential adverse effects on human health or the environment resulting from exposure to household batteries at all phases of the recycling process, including collection, storage,

transportation, and reclamation of reusable materials.

(5) The costs of recycling household batteries, including avoided disposal costs.

15012. On or before March 1, 1992, the board shall submit to the Legislature a report describing the results of the study conducted under this chapter, together with recommendations on whether there is a need for legislation, regulation, or further study relating to the disposal or recyclability of used household batteries. The board shall also include a section on these subjects in the report submitted pursuant to Section 42950 on March 31, 1993.

SEC. 2. The sum of one hundred fifty thousand dollars ($150,000) is hereby appropriated from the Integrated Waste Management Account to the California Integrated Waste Management Board for the purposes of conducting the study and making the report required by Section 1.

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Appendix D

Letters Requesting Information for the Household Battery Study and State Response Letter

APPENDIX D

LETTERS REQUESTING INFORMATION FOR THE HOUSEHOLD BATTERY STUDY AND STATE RESPONSE LETTER

This appendix includes a copy of the letter sent to the California Department of Toxic Substances Control, requesting information on household battery characterization in relation to hazardous waste.

Also included is the response letter from the Department of Toxic Substances Control. The letter from the Department addresses several key issues regarding household batteries such as the classification of hazardous waste, regulations governing disposal practices, and restrictions on collecting, handling, storing, transporting, and disposing batteries.

This third letter included in the appendix is a copy of a letter sent by the California Integrated Waste Management Board which requests information on household batteries and battery waste management practices . This letter was distributed to eighty-six different battery manufacturers, product manufacturers, environmental groups, and other interested parties who are listed following the letter.

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January 22, 1992

Mr. Robert McCormick
Senior Hazardous Materials Specialist
Advanced Technology Division
California Department of Toxic Substances Control
P.O. Box 806
Sacramento, California 95812-0806

Classification of Household Batteries as Hazardous Waste

Dear Mr. McCormick:

Ernst & Young is currently conducting a study for the California Integrated Waste Management Board (CIWMB) concerning the disposal and recyclability of used household batteries. This study is being conducted to meet requirements of Assembly Bill 3530, passed in September 1990, and will result in a report to be submitted to the State Legislature. In brief, this study will review:

- The effects of used household batteries on municipal solid waste landfills, incinerators, and compost operations, including any threats to human health or the environment

- The potential recyclability of used household batteries, including recycling technologies, the potential effectiveness of those technologies, and existing and potential collection programs for used household batteries

- The potential adverse effects on human health or the environment resulting from exposure to household batteries at all phases of the recycling process, including collection, storage, transportation, and reclamation of reusable materials.

In conducting this study for the CIWMB we have recognized a number of significant issues related to the hazardousness of household batteries. In addition, the existing legal and regulatory framework may encourage or impede efforts to recycle, or provide other special handling and disposition of used household batteries.

The purpose of this letter is to seek clarification and a greater understanding of some of these issues. Below we have summarized some pertinent information on household batteries. Following this background material, we pose a number of specific questions related to household batteries.

Background on Household Batteries

For purposes of our study, household batteries are defined to include primary or secondary batteries, including alkaline, carbon-zinc, mercuric oxide, silver oxide, zinc air, lithium, and nickel-cadmium batteries. Household batteries do not include lead-acid batteries, such as those used in automobiles. Household batteries do include those batteries typically used for hearing aids, cameras, watches, toys, computers, calculators, flashlights, lanterns, tools, portable radios and television sets, hand held vacuums, clocks, and many other consumer and household items. Household batteries generally fall into one of two categories:

- *Primary Batteries* - Primary batteries are non-rechargeable batteries constructed so that only one continuous or intermittent discharge is obtained. Alkaline, carbon-zinc, mercuric oxide, silver oxide, zinc air, and lithium batteries are primary batteries

- *Secondary Batteries* - Secondary batteries are rechargeable, that is they can be recharged following partial or complete discharge by reversing the flow of electrical current. Secondary batteries can be reused hundreds of times. Nickel-cadmium batteries are secondary batteries.

Exhibit 1, attached, provides a summary of the various types, sizes, and quantities of household batteries. Exhibit 1 also lists the materials used for anodes, cathodes, and electrolyte for each type of battery. Batteries also can be made with different materials, however, other combinations presently do not represent a significant share of the market. Household batteries may contain a variety of metals including cadmium, lead, lithium, manganese, mercury, nickel, silver, and zinc. All of these metals have been identified to present potential health risks to humans. Mercury and cadmium are the metal of greatest concern in household batteries[1].

The exact composition of household batteries is the proprietary knowledge of each battery manufacturer. In addition, the composition of some battery types has changed in recent years as manufacturers have worked to reduce the amount of mercury in household batteries. The battery industry has published or supplied data which lists the metals contained in household batteries, either as a percent of battery weight, or as a weight range. **Exhibit 2**, attached, summarizes estimates of the percent of various types of metals contained in the different types of household batteries.

Most primary battery systems (with the exception of lithium batteries) use zinc as the negative electrode (anode). Unfortunately, zinc has a natural tendency to react with other battery ingredients, generating hydrogen gas which may cause the battery to leak and which reduces the performance of the batteries. Historically, battery manufacturers have

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[1] United States, Environmental Protection Agency, Office of Technology Assessment, Facing America's Trash: What Next for Municipal Solid Waste?, OTA-O-424, October 1989.

overcome this undesirable behavior by including small amounts of mercury (1 to 3 percent by weight) on the surface of the zinc[2]. Several years ago, in response to environmental concerns, the battery industry began to explore other ways to control the behavior of the zinc, ways which would require less use of mercury[3]. These efforts have focused primarily on alkaline and carbon-zinc battery types which represent the largest portion of battery sales.

Legislation in a few states (not including California) have set mercury limits at 0.025 percent (250 ppm)[4]. The battery industry has generally met this requirement, and recently manufacturers have announced designs for alkaline and carbon-zinc batteries in which no mercury is added[5]. Manufacturers indicate that background levels of mercury of approximately 0.001 percent (10 ppm) still will be present as impurities in other metals such as zinc[6].

Mercuric oxide batteries contain the highest level of mercury at approximately 30 to 43 percent. A high level of mercury is required in this battery type since mercury is used in the cathode material of the battery Reducing the amount of mercury would proportionally reduce the energy content of the battery[7]. The primary consumer application of mercuric oxide batteries is with button cells used in hearing aides, watches, and similar applications. Silver oxide, zinc air, and lithium batteries are manufactured as button cells and are substitutes for the mercuric oxide batteries. Silver oxide and zinc air battery types contain 1 to 2 percent mercury, a substantial reduction over the mercuric oxide, but still significantly greater that alkaline or carbon-zinc batteries. Lithium button batteries contain no added mercury.

Nickel-cadmium batteries, the most common type of secondary household battery, contain no added mercury. The metal of concern in nickel-cadmium type batteries is cadmium which makes up about 10 to 15 percent of the battery. Since cadmium is an electrode material in nickel-cadmium batteries, its use can not be reduced without proportionally reducing the energy content of the batteries[8]. Nickel-cadmium batteries are

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2 United State, Environmental Protection Agency, Office of Research and Development, Achievements in Source Reduction and Recycling for Ten Industries in the United States, EPA/600/2-91/051, September 1991

3 Ibid

4 States that have enacted legislation limiting mercury content to 0.025 percent by weight for certain types of batteries include: Connecticut, Minnesota, New Jersey, Oregon, and Vermont. Michigan has proposed such legislation

5 Rayovac Corporation, *News Release: Rayovac and Matsushita Sign Technology Agreement*, December 10, 1991

6 Panasonic Company, *News Release: Panasonic Unveils New 99.999-Percent Mercury-Free Battery Line*, December 4, 1991

7 Balfour, Raymond L., *Household and Other Batteries: Source Reduction and Recycling*, presented at the 10th Annual Resource Recovery conference of the U.S. Conference of Mayors on behalf of the National Electrical Manufacturers Association and the Battery Products Alliance, Washington, D.C., July 12, 1991

8 Ibid

growing in use and popularity among consumers and manufacturers of consumer products. Since a single nickel-cadmium battery can replace hundreds of primary batteries, the volume of waste is reduced. It is estimated that 80 to 85 percent of the household nickel-cadmium batteries sold are sealed inside consumer products[9]. In many cases, consumers may not be aware that products contain batteries, either at time of purchase or during disposal.

At this time, there is limited information on the performance of various types of household batteries in Toxicity Characteristic Leaching Procedure (TCLP) tests. The information we do have was provided by Mr. Ray Balfour, Vice President for Rayovac, and representative for the Dry Battery Section of the National Electrical Manufacturers Association (NEMA). These data are summarized in **Exhibit 3**, attached. The battery types tested are within EPA limits, however, neither mercuric oxide or nickel-cadmium batteries are included in the data.

A number of studies suggest that the disposal of household batteries in municipal solid waste may not pose a significant threat to human health or the environment when placed in properly operated and maintained landfills[10,11,12]. Concerns arise when household batteries are included in municipal solid waste destined for incinerators or compost operations[13]. In these instances, there is greater opportunity for the metals of concern to escape into the environment. The magnitude of the potential hazards associated with battery incineration or composting are as yet unclear. One waste characterization study conducted on municipal solid waste found that household batteries represent only 0.07 percent, by weight, of the waste stream[14]. A separate study determined that household batteries represented only 0.01 percent of the volume of municipal solid waste[15]. By contrast, other waste characterization studies have found that all household hazardous waste represents between 0.2 and 1.0 percent, by weight, of the total municipal solid waste[16].

A number of collection programs have been established across the country and in other countries for household batteries. Mercuric oxide and silver oxide batteries contain

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9 Balfour, Raymond L., material presented in meeting to CIWMB and Ernst & Young on October 24, 1991

10 United States, Environmental Protection Agency, Risk Reduction Engineering Laboratory, Pollution Prevention Research Program, Dry-Cell battery Workshop, November 14, 1990

11 Jones, C. J., et al., *An Investigation of the Degradation of Some Dry Cell Batteries Under Domestic Waste Landfill Conditions*, in Journal of Hazardous Materials, 2(1977-78), pg 259-289

12 Fochtman, Edward G. and Willard R. Haas, IIT Research Institute, *Relationship of Spent Dry Batteries to the Heavy Metal Content of Solid Wastes*, presented at the Second National Conference on Water Use, Chicago, May 4-8, 1975

13 Minnesota Pollution Control Agency, Household Battery Recycling and Disposal Study, June 1991

14 U.S. EPA, 1990

15 Ibid

16 U.S. EPA, 1989

sufficient levels of mercury and silver, respectively, to make them economical to recycle[17]. These battery types also represent a small portion of the total number of household batteries. Nickel-cadmium household batteries are recycled in Europe and Japan for their cadmium, however, no such facilities to recycle cadmium from used household batteries exist in the United States[18]. Household batteries collected in some programs are destined for hazardous waste landfills or to storage for possible future recycling[19].

Collection and storage of household batteries present additional problems. When batteries discharge, a small amount of hydrogen is produced. The hydrogen is vented off the battery and does not cause any concern in normal battery operation. However, the aggregation of large quantities of batteries in a barrel or other container, result in batteries being in physical and electrical contact with one another. As a consequence, they may continue to discharge, generating both heat and hydrogen gas in the process and creating dangers of fire and explosion if not properly ventilated[20]. Lithium batteries may pose a new problem in disposal. Lithium compounds present in lithium batteries are highly reactive in water.

Questions Related to Household Batteries

Given the above background information on household batteries, we have formulated a number of questions regarding household battery characterization and disposal alternatives. Given the Department's responsibilities for regulating hazardous waste in the State, we would appreciate some clarification on these important issues. Our questions are as follows:

1) Under what conditions would each type of household battery (alkaline, carbon-zinc, mercuric oxide, silver oxide, zinc air, lithium, and nickel-cadmium) be considered a hazardous waste as defined in Health and Safety Code (H&SC) Section 25117?

2) Are household batteries considered to be household hazardous waste for purposes of AB 2707 (Chap. 1406 of 1990 Statutes) and therefore subject to inclusion in household hazardous waste elements of integrated waste management plans?

3) Are household batteries, when accumulated in a collection program, considered to be a hazardous waste, subject to hazardous waste laws and regulations?

4) Under what conditions would the presence of household batteries in municipal solid waste, at the concentrations typically found (as

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17 *Household Batteries: Management or Neglect?*, Staff Report to the NYS Legislative Commission on Solid Waste Management, Albany, New York, September 1988

18 Reutinger, Nancy, *Batteries in the Waste Stream: A Feasibility Study of Household Battery Recycling and Collection for the County of Santa Cruz*, County of Santa Cruz, California, July 20, 1990

19 Minnesota Pollution Control Agency, 1991

20 U.S. EPA 1991

stated previously), violate existing laws or regulations regarding the disposal of municipal solid waste in landfills? In incinerators? In compost?

5) How do existing laws or regulations govern the disposal of household batteries? Do differences exist whether waste batteries are generated by households or businesses?

6) What restrictions exist on the collection, handling, storage, transport, and disposal of household batteries?

7) How do existing laws or regulations govern the recycling of materials contained in household batteries?

8) In a letter from the Department of Health Services to Senator William Campbell dated June 4, 1987 (copy attached), the Department concluded that feasible opportunities to recycle household batteries did not exist and that "...more hazard to the public health and environment could be created by the accumulation of dry batteries at retail outlets (neighborhood grocery stores)." Does this letter still reflect the position of the Department regarding the disposal of household batteries?

9) Is the Department aware of any instances where household batteries have been shown to have an effect on human health or the environment as a result of disposal in landfills, incinerators, or compost operations?

10) Is the Department aware of any instances where household batteries have been shown to have an effect on human health and the environment as a result of collection, sorting, storage, transfer, or recycling?

Your response to the questions listed above will be useful in the further development of our study for the CIWMB. Due to our restricted schedule for completion of this study, and submission of the study report to the State Legislature, we would appreciate receiving a response to these questions as soon as possible. If you have any questions regarding this letter, please contact me or Mr. Robert Reed at (916) 443-6756.

Very truly yours,

ERNST & YOUNG

James A. Gibson

James A. Gibson
Project Director

cc: Mr. Fernando Berton, CIWMB

Household Battery Components

Battery Type	Battery Size	Anode	Cathode	Electrolyte	1989 U.S. Market Size (Millions of Units)
Primary Batteries					
Alkaline	D, C, AA, AAA, 9V	Zinc	Manganese Dioxide	Potassium Hydroxide	1,795 (60.6%)
Carbon-Zinc*	D, C, AA, AAA, 9V	Zinc	Manganese Dioxide	Ammonium Chloride or Zinc Chloride	710 (24.0%)
Mercuric Oxide	Button**	Zinc	Mercuric Oxide	Potassium Hydroxide or Sodium Hydroxide	49 (1.7%)
Silver Oxide	Button	Zinc	Silver Oxide	Potassium Hydroxide or Sodium Hydroxide	83 (2.8%)
Zinc Air	Button	Zinc	Atmospheric Oxygen	Potassium Hydroxide	60 (2.0%)
Lithium	C, AA, 9V, Button	Lithium	Manganese Dioxide	Organic Solvent	5 (0.2%)
Secondary Batteries					
Nickel-Cadmium	D, C, AA, AAA, 9V	Cadmium	Nickel Oxide	Potassium Hydroxide	259*** (8.7%)

* Includes "General Purpose" and "Heavy Duty" batteries.
** Larger sizes of mercuric oxide batteries are manufacturered for special commercial, industrial, and military purposes. These larger sizes are not considered household batteries due to their special uses.
*** An estimated 80 to 85 percent of these batteries are sold together with cordless rechargeable products.

Source:

1) National Electric Manufacturers Association, Written Statement of the National Electrical Manufacturers Association and the Battery Products Alliance Concerning Household Battery Disposal, no date
2) Balfour, Raymond L., Household and Other Batteries: Source Reduction and Recycling, presented at the 10th Annual Resource Recovery Conference of the U.S. Conference of Mayors on behalf of the National Electrical Manufacturers Association and the Battery Products Alliance, July 12, 1991.

EXHIBIT 1

Metals in Household Batteries
(Percent by Weight)

Battery Type	Mercury	Cadmium	Zinc	Nickel	Silver	Lithium
Primary Batteries						
Alkaline	0.025 - 0.5	0.01	8 - 18			
Carbon-Zinc	0.01	0.03	12 - 40			
Mercuric Oxide	30 - 43		10 - 15			
Silver Oxide	1		10 - 15		30 - 35	
Zinc Air	2		35 - 40			
Lithium						??
Secondary Batteries						
Nickel-Cadmium		10 - 15		15 - 25		

Source:

1) Balfour, Raymond L., Household and Other Batteries: Source Reduction and Recycling, presented at the 10th Annual Resource Recovery Conference of the U.S. Conference of Mayors on behalf of the National Electrical Manufacturers Association and the Battery Products Alliance, July 12, 1991.
2) Northeast Waste Management Official's Association, Source Reduction for Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives, 1991
3) Northeast Washoe Management Official's Association, Source Reduction for Toxic Metals in Household Batteries: Federal, State, and Industry Initiatives, 1991
4) Balfour, Raymond L., Material Presented in Meeting with CIWMB and Ernst & Young on October 24, 1991.

EXHIBIT 2

Household Battery
USEPA (TCLP/SW846) Test Data

	Mercury (D009)	Cadmium (D006)	Lead (D008)
EPA Maximum	0.2 mg/l	1.0 mg/l	5.0 mg/l
Rayovac			
Alkaline (0.1% Hg)	0.072	0.014	0.345
Carbon-Zinc ("No Mercury')	0.029	0.522	0.340
Zinc Air	0.020		
Silver Oxide	0.150		
Eveready			
Alkaline (Energizer)	<0.025	<0.01	<0.05
Carbon-Zinc (General Purpose)	0.07	0.17	<0.1
Carbon-Zinc (Super Heavy Duty)	<0.025	0.2	<0.1

Source:

1) Letter from Raymond L. Balfour, Vice President, Rayovac Corporation to Paul Markowitz, Vermont Natural Resources Agency, September 18, 1991.
2) Balfour, Raymond L., Material presented in Meeting with CIWMB and Ernst & Young on October 24, 1991.

JUN -5 1987

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY

GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF HEALTH SERVICES
714/744 P STREET
SACRAMENTO, CA 95814
(916) 323-2913

Jun 4, 1987

The Honorable William Campbell
Member of the Senate
State Capitol
Sacramento, CA 95814

Dear Senator Campbell:

OPPOSITION OF SB 1098 (ORIGINAL)

I regret that the Department must oppose SB 1098 which would require retailers selling new dry batteries (everyday-use batteries) to accept the used batteries for purposes of recycling.

The Department has concluded that carbon-zinc (most common type of dry battery) is not economically feasible to recycle due to its low-value; nickel-cadmium batteries, specifically listed in the bill, are not accepted by any recyclers. The requirement that these types of batteries be recycled (as a hazardous waste) would create not only a disposal problem, but would require that the retailers comply with all the hazardous waste laws and regulations (including becoming permitted as a transfer station and/or storage facility).

It would be inappropriate to require recycling of dry batteries when no capacity exists. The cost to the retailer for recycling, when and if batteries became economically and technologically feasible to recycle, or for disposal would certainly be passed on to the consumer. New dry batteries would no doubt become quite expensive. Additionally, more hazard to the public health and environment could be created by the accumulation of dry batteries at retail outlets (neighborhood grocery stores).

If you have any questions concerning the Department's position on SB 1098, please contact me or David Willis, Deputy Director, at (916) 323-9723.

Sincerely,

Alex R. Cunningham

Alex R. Cunningham
Chief Deputy Director

Enclosure

cc: Kenneth W. Kizer, M.D., M.P.H.
Director

STATE OF CALIFORNIA—ENVIRONMENTAL PROTECTION AGENCY PETE WILSON, *Governor*

DEPARTMENT OF TOXIC SUBSTANCES CONTROL
400 P Street, 4th Floor
P.O. Box 806
Sacramento, CA 95812-0806

(916) 322-3670

March 9, 1992

Mr. James A. Gibson
Ernst & Young
555 Capitol Mall, Suite 650
Sacramento, California 95814

Dear Mr. Gibson:

HOUSEHOLD BATTERIES

This is in response to your letter in which you requested information as to household battery characterization and disposal alternatives. Your letter was in regards to the California Integrated Waste Management Board (CIWMB) study, conducted by your firm to meet the requirements of Assembly Bill 3530. Your letter included the background information you have obtained, in addition, to ten questions for our response. We have listed our responses to your ten questions below.

1. **Under what conditions would each type of household battery (alkaline, carbon-zinc, mercuric oxide, silver oxide, zinc-air, lithium, and nickel-cadmium) be considered a hazardous waste as defined in Health & Safety Code (HSC) Section 25117?**

   Section 25117 defines the term "hazardous waste", the regulations determine the criteria for classifying the waste as hazardous. To determine if household batteries are classified as a hazardous waste, our criteria is pursuant to Chapter 11, Division 4.5, Title 22, California Code of Regulations (CCR). For assistance in these determinations, contact our Waste Evaluation Unit at (916) 322-3670.

2. **Are household batteries considered to be household hazardous waste for purposes of Assembly Bill 2707 (AB 2707) (Chapter 1406 of 1990 Statutes) and therefore subject to inclusion in household hazardous waste elements of integrated waste management plans?**

   Yes, household batteries generated by a household are household hazardous waste which should be included in management plans by cities and counties. AB 2707 added household hazardous waste as a separate element to integrated waste management plans of cities and counties.

3. **Are household batteries when accumulated in a collection program, considered to be a hazardous waste, subject to hazardous waste laws and regulations?**

   Section 25201 (c), HSC, allows for a hazardous waste facilities permit not to be required for a household hazardous waste collection facility operated by a public agency, or by any person under an agreement with a public agency, if all the conditions of the section are met, including that the batteries are transported to a recycling facility. This section would exempt the collection facility only from obtaining a permit, and would not reclassify the waste collected. For more information on Household Collection Facilities, contact Ms. Judy Frantz at (916) 855-7759.

4. **Under what conditions would the presence of household batteries in municipal solid waste at the concentrations typically found (as stated previously), violate existing laws or regulations regarding the disposal of municipal solid waste in landfills? In incinerators? In compost?**

   Whenever the batteries are classified as a hazardous waste by meeting the criteria in Chapter 11, Division 4.5, Title 22, CCR, the waste should be managed and handled for proper disposal according to the hazardous waste laws and regulations. For further information on land disposal restrictions contact Ms. Peggy Harris in our Treatment Standards Unit at (916) 324-7663.

5. **How do existing laws or regulations govern the disposal of household batteries? Do differences exist whether waste batteries are generated by households or businesses?**

   Household waste is excluded by the federal regulations in Title 40, Section 261.4 (b)(1), Code of Federal Regulations (CFR). This exclusion removes waste generated by a household from classification and regulation as a hazardous waste. Also, the batteries could be exempted from federal regulation under the "conditionally-exempt, small-quantity generator" provisions of Section 261.5, CFR. However, the state hazardous waste control laws and regulations are more stringent than the federal. There are no state equivalents of Section 261.4 (b)(1), and 261.5, CFR. Any hazardous waste that meets the criteria and is generated under these circumstances is classified and regulated by the state as "non-RCRA hazardous waste". When the batteries are generated from other sources such as businesses where there is no federal exclusion, any batteries that meet the criteria

as hazardous waste would then be regulated as "RCRA hazardous waste".

6. **What restrictions exist on the collection, handling, storage, transport, and disposal of household batteries?**

There are no restrictions placed on household batteries that differ from the general hazardous waste requirements for proper handling and storage. There is a transportation exemption which allows for householders to transport their household hazardous waste including household batteries to a collection facility without a manifest. This is true for any persons transporting hazardous wastes to a permitted hazardous waste facility for transfer, treatment, recycling, or disposal, which does not exceed five gallons or 50 pounds from obtaining a manifest to transport if all the conditions of Section 25163(c), HSC, are met.

7. **How do existing laws or regulations govern the recycling of materials contained in household batteries?**

Article 10.6, Section 25216.1, HSC, "Management of Small Household Batteries", this section is for any household batteries generated as non-RCRA hazardous waste that are going for recycling. The recycling laws in Section 25143.2, HSC, which allow for exclusions and/or exemptions from the hazardous waste laws are not applicable to household batteries when going for recycling.

8. **In a letter from the Department of Health Services to Senator William Campbell dated June 4, 1987 (copy enclosed), the Department concluded that feasible opportunities to recycle household batteries did not exist and "... more hazard to the public health and environment could be created by the accumulation of dry batteries at retail outlets (neighborhood grocery stores)." Does this letter still reflect the position to the Department regarding the disposal of household batteries?**

A copy of the letter to Senator Campbell was not included with your attachments. However the Department has always encouraged recycling when technologically and economically feasible, to reduce our dependence on land disposal of hazardous waste and to protect the public health and environment.

9. **Is the Department aware of any instances where household batteries have been shown to have an effect on human health or the environment as a result of disposal in landfills, incinerators, or compost operations?**

   In the background information you provided levels of toxic metals listed for each battery type, when the toxic metals are released into the environment they can contaminate the air, surrounding water supply or accumulate in plants and animals. The potential harm of these metals to humans and the environment is a result of the disposal of these batteries in the municipal solid waste stream. Heavy metals from any source represents a potential problem. For additional information on the toxicology of these toxic metals and their effect on the environment and human health, contact our Technical Services Division at (916) 255-2007.

10. **Is the Department aware of any instances where household batteries have an effect on human health and the environment as a result of collection, sorting, storage, transfer, or recycling?**

    There is a need to always properly manage and handle hazardous recyclable materials when collecting, storing, transporting, and recycling to prevent any exposure to humans or the environment.

If you need further assistance or you have questions on this letter, please contact Ms. Claudia Moore of may staff at (916) 322-4742.

Sincerely,

Robert McCormick

Robert McCormick
Alternative Technology Division

cc: Mr. Ron Pilorin
Alternative Technology Division
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Ms. Claudia Moore
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RM:CM:cm/ba

STATE OF CALIFORNIA Pete Wilson, Governor

CALIFORNIA INTEGRATED WASTE MANAGEMENT BOARD
8800 Cal Center Drive
Sacramento, California 95826

January 3, 1992

Mr. Raymond Balfour, Vice President
Rayovac Corporation
601 Rayovac Drive
Madison, Wisconsin 53711

RE: California Household Battery Study

Dear Mr. Balfour:

The California Integrated Waste Management Board (CIWMB) has initiated a study of waste management practices concerning used household batteries. Household batteries include primary (non-rechargeable) and secondary (rechargeable) batteries typically used in a variety of consumer products. Excluded from the study are automobile (lead-acid) batteries and batteries specifically designed for industrial or military purposes. We are encouraging interested parties to provide input into the study, through contact with the CIWMB's study consultant, Ernst & Young.

Household batteries, as an item targeted for waste management and recycling, are currently receiving much attention from agencies such as the CIWMB. This study by the CIWMB is intended to identify the effects of household batteries on municipal solid waste landfills and incinerators, and the potential for collecting and recycling used household batteries. The study includes the following elements:

- Assessment of the effects of used household batteries on municipal landfills and incinerators in California, including potential adverse affects on human health or the environment

- Assessment of existing waste management practices, including source reduction, limitations on metal content, collection, recycling, and other processing programs

- Assessment of the need to reduce potential hazards from the dispsal of used household batteries

- Policy recommendations concerning household battery waste management strategies

The study report is to be completed and submitted to the California State Legislature by June 1, 1992.

We would like to invite you to participate in the study process. If you or your organization have information concerning household batteries and battery waste management practices that would be

important for us to consider, we would appreciate hearing from you. Information should be provided directly to our study consultant at the following address:

Dr. James A. Gibson, Project Director
Household Battery Study
Ernst & Young
555 Capitol Mall, Suite 650
Sacramento, California 95814
(916) 443-6756

If there are questions concerning this study, please call Dr. James Gibson, at the above number, or me at (916) 255-2348 in my Sacramento Office.

Sincerely,

Fernando Berton

Fernando Berton, Manager
Household Hazardous Waste Unit

cc: James A. Gibson, Project Director

CIWMB - Household Battery Study
List of Addresses
1/7/92

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