United States
Environmental Protection
Agency

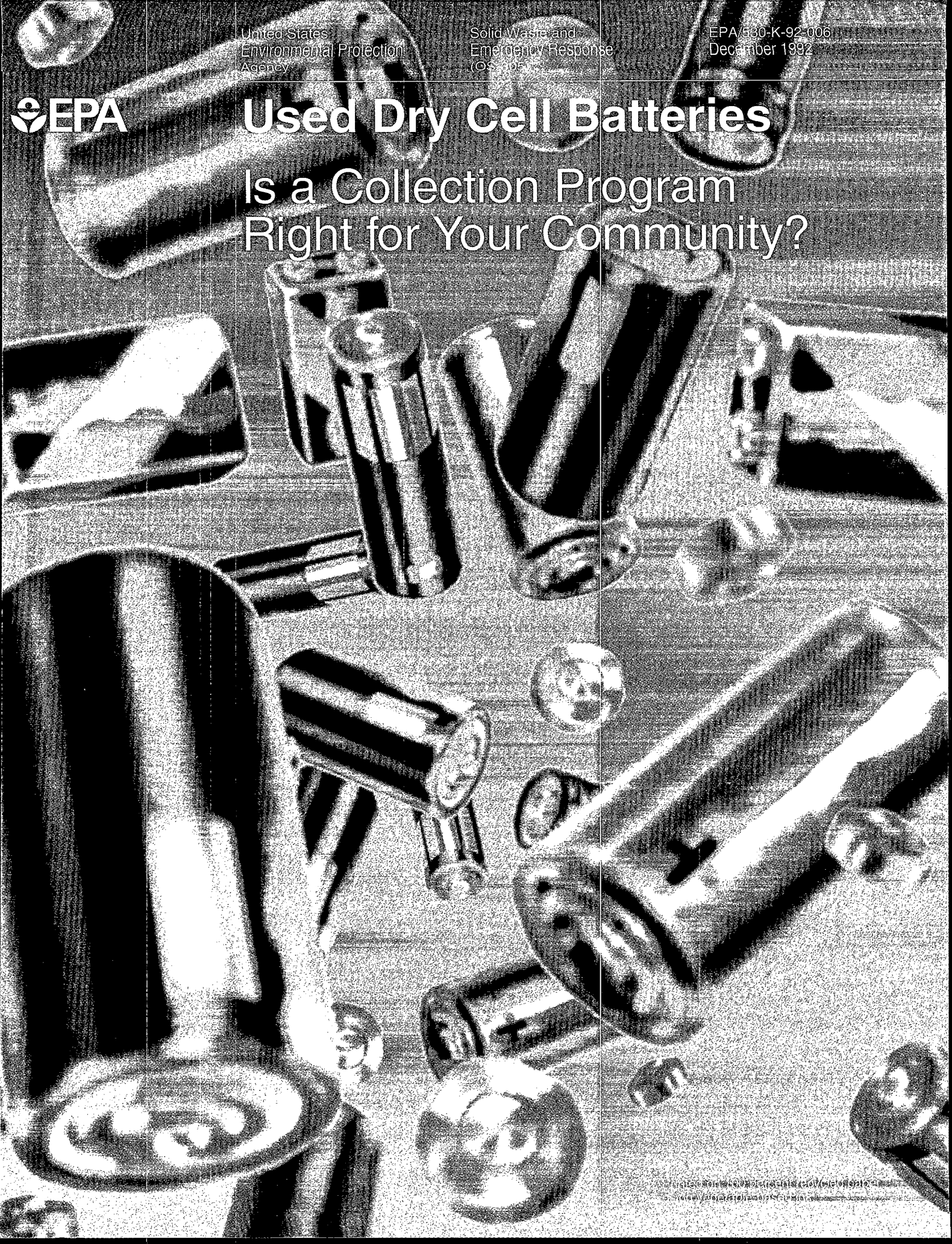
Solid Waste and
Emergency Response
(OS-305)

EPA/530-K-92-006
December 1992

EPA

Used Dry Cell Batteries

Is a Collection Program Right for Your Community?



EPA

Used Dry Cell Batteries

Is a Collection Program Right for Your Community?

About This Handbook

This handbook is designed to help communities determine whether establishing a program to collect used dry cell batteries is right for them. It is organized around 10 key issues related to setting up and running a collection program, from determining the types and amounts of dry cell batteries being discarded in the community, to evaluating whether industry or legislative trends will affect the decision to launch a program, to estimating the likely costs. Experiences of communities that have initiated battery collection programs are included to help communities gain an appreciation of the results that can be achieved. After thoughtfully reviewing the 10 issues outlined in this handbook, communities will be in a better position to determine if a program is right for them.

This handbook focuses primarily on *household* battery collection programs. If your community is interested in collecting used batteries from nonhousehold generators, see Appendix A. In addition, EPA's RCRA Hotline at (800) 424-9346 can provide further information.

Acknowledgments

The following individuals shared their knowledge and experiences in the area of used dry cell battery collections and commented on drafts of the handbook: Tim Forker, Carl Hirth, Marie Steinwachs, Don Seeburger, Karen Arnold, David Hurd, Randy Hukreide, Lynn Vendinelo, Terry Telzrow, Ray Balfour and other members of the National Electrical Manufacturers' Association, and members of the Portable Rechargeable Battery Association. Their assistance is greatly appreciated.

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INTRODUCTION

Every year, Americans purchase nearly two billion dry cell batteries to power such items as radios, watches, clocks, toys, laptop computers, cellular telephones, and household appliances. Dry cell batteries also are used for a variety of medical, commercial, industrial, military, and other nonhousehold applications. (Table 1 lists the principal types of dry cell batteries and their common uses.) The term "dry cell" refers to the type of electrolyte contained in these kinds of batteries. In "wet cell" batteries, such as those used in automobiles, the electrolyte is in the form of a liquid bath. In dry cell batteries, the electrolyte is absorbed or gelled in other materials rather than being a separate body of liquid (see Figure 1). Unlike wet cell batteries, the contents of a dry cell battery are not spillable.

Some dry cell batteries contain heavy metals (such as mercury, cadmium, and lead) that perform critical functions within the battery. Heavy metals are contained within the battery casing and pose no real risks while in use. But they can be of significant concern when discarded with ordinary municipal solid waste (as most batteries are). Even though dry cell batteries represent less than 1 percent by weight of municipal solid waste, they accounted for 52 percent of all the cadmium and 88 percent of all the mercury found in the municipal solid waste stream in 1989 (see Figure 2).

At present, most municipal solid waste is either landfilled or combusted. Neither of these methods is ideally suited for batteries that contain heavy metals. In landfills, heavy metals have the potential to leach slowly into soil, ground water, and surface water. When combusted, certain heavy metals, such as mercury, may vaporize and escape into the air. Other metals, including cadmium and lead, can concentrate in the

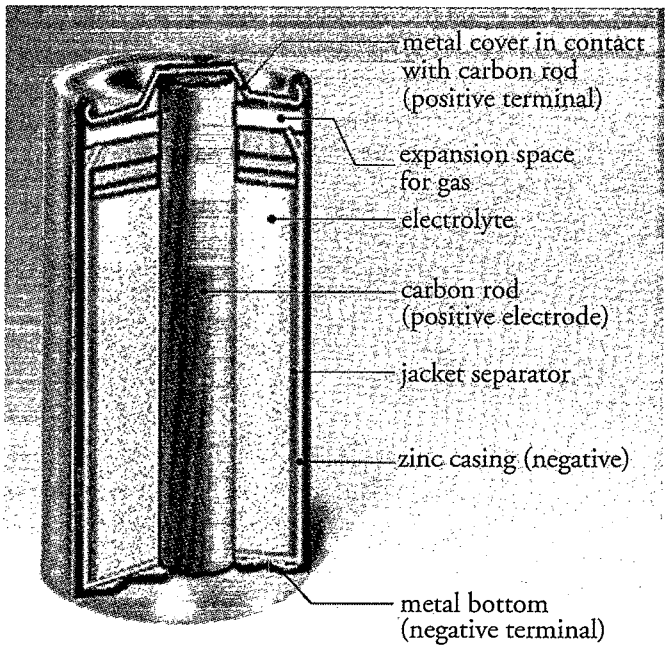


Figure 1. Cutaway view of a carbon-zinc dry cell battery.

TABLE 1. Types of Dry Cell Batteries Found in the Municipal Solid Waste Stream

PRIMARY CELLS (NONRECHARGEABLE)

Battery Types and Sizes	Common Uses
Alkaline and carbon-zinc (9-volt, D, C, AA, AAA, alkaline button)	Cassette players, radios, flashlights, toys, etc.
Mercuric-oxide (button, some cylindrical and rectangular)	**Household uses:** hearing aids (button batteries) **Nonhousehold uses:** heart monitors, communication devices, cameras
Silver-oxide and zinc-air (button)	Hearing aids, watches, cameras, paging devices, calculators
Lithium (9-volt, C, AA, coin, button)	Cameras, calculators, computers, pacemakers, watches

SECONDARY CELLS (RECHARGEABLE)

Battery Types and Sizes	Common Uses
Nickel-cadmium (9-volt, C, D, AA, AAA, battery packs)	**Household uses:** kitchen appliances, portable vacuum cleaners, power tools **Nonhousehold uses:** emergency lighting, portable communication devices, medical equipment backup
Small sealed lead-acid (flat plates (e.g., gum packs), pack configurations)	**Household uses:** camcorders, computers, portable radios and tape players, lawn mower starters, cellular phones **Nonhousehold uses:** emergency lighting, portable communication devices, medical equipment backup

ash produced by combustion. When disposed of, the metals in this ash can leach into the environment.

In the environment, certain types of heavy metals also can concentrate in the tissues of organisms and make their way up the food chain. High levels of mercury, for example, already have been identified in several bodies of water in the United States, prompting health, environmental, and other state and federal agencies to issue advisories against eating fish caught in those waters.

Because many communities are concerned about the potential health and environmental risks of current battery disposal practices, they are exploring alternatives for handling used dry cell

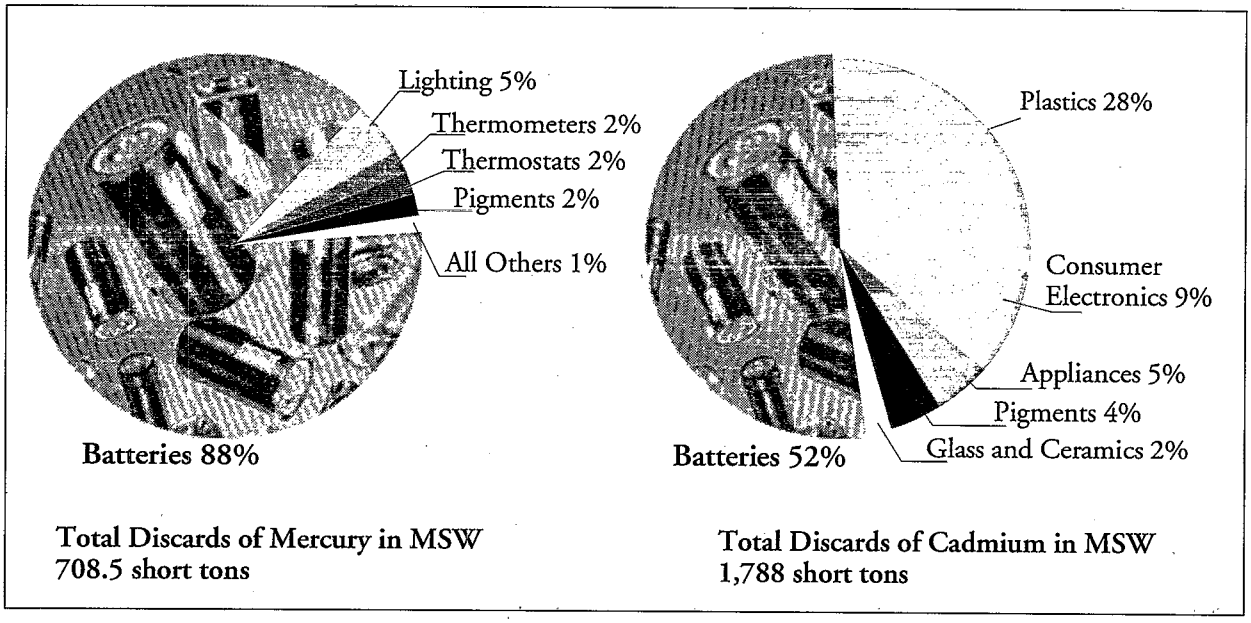


Figure 2. Dry cell battery contribution to mercury and cadmium in the municipal solid waste stream—1989.

batteries. One option is to set up a collection program for household sources of batteries. Battery collection programs can reduce the amount of heavy metals entering landfills and incinerators, recover metals through recycling, and help to expand public involvement in and understanding of issues related to municipal solid waste.

Communities that are thinking about setting up a battery collection program need to be aware, however, that most battery programs are still relatively new and have met with mixed success to date. Collection programs typically capture only 10 percent of the available batteries; the highest rate achieved in the United States has been 18 percent by weight after four years. In Japan, which traditionally has exhibited much higher recycling rates than other countries, the highest collection rate achieved has been just 20 percent. Collection programs also can be expensive to set up and operate, and worker safety and health concerns must be taken into consideration during the planning phase. Therefore, some communities and states are exploring other options—such as working with the battery manufacturing industry to develop workable systems for managing used dry cell batteries—rather than implementing collection programs.

Communities also should be aware that if a program collects batteries from nonhousehold sources, it will be subject to state or federal regulations governing the generation, handling, and disposal of hazardous waste. This might entail getting permits, complying with paperwork requirements, and taking other measures—all of which could increase the cost and complexity of a program. Communities in many states may be able to collect batteries from smaller businesses under state solid waste rules rather than hazardous waste regulations. See Appendix A for an explanation of when hazardous waste regulations apply to battery collection programs. There are steps municipal officials can take to address nonhousehold sources, such as initiating informal discussions with nonhousehold sources to educate and encourage

Household and Nonhousehold Sources

The different types of batteries found in a community's municipal solid waste stream can come from household or nonhousehold sources, or both. Virtually all batteries generated by households are disposed of with the rest of their solid waste. Nonhousehold sources include commercial, industrial, medical, and military facilities. These sources might dispose of their batteries with the community's solid waste, use onsite landfills or combustors, or ship batteries to offsite disposal facilities.

Nonhousehold sources could be a concern in your community. For example, if a hospital is combusting dry cell batteries containing mercury on site, the resulting emissions might be a potential health risk to the community. An industrial facility that disposes of its dry cell batteries in the municipal solid waste stream could be increasing the level of heavy metals entering landfills or being incinerated in the community. On the other hand, if a military installation ships its batteries off site for disposal, this facility might not be of significant concern to the community.

appropriate management of waste batteries. Communities might, for instance, discuss with hospitals the feasibility of recycling rather than incinerating dry cell batteries.

In addition, communities can conduct educational campaigns directed at potential sources of large quantities of nonhousehold batteries to inform them of their legal and social responsibilities in disposing of their waste batteries. And municipal officials can consider alerting inspectors who audit hazardous waste disposal activities to observe how waste batteries are handled by nonhousehold sources.

ISSUE 1

PROGRAM OBJECTIVES

Program objectives are the first issues to look at when considering a used dry cell battery collection program. Is your primary concern reducing the level of heavy metals entering the waste stream, recovering resources by recycling waste batteries, or both? Keeping specific objectives in mind will help ensure the success of your battery collection program.

Many communities that have initiated battery collection programs focus on diverting heavy metals from the waste stream. This is particularly evident in communities whose solid waste is combusted, since this process can emit heavy metals into the air and concentrate them in ash. In Warren County, New Jersey, for example, concerns over the possibility of cadmium in combustor ash and mercury air emissions provided the impetus for the county to establish a battery collection program in June 1989. In Hennepin County, Minnesota, concerns about heavy metals emissions from the county's municipal waste combustor prompted officials in 1988 to initiate a battery collection pilot program to divert all types of household batteries from the facility. Based on the results of the pilot program, successful drop-off and curbside collection programs were initiated. (Hennepin County's well-established, large-scale program is described in more detail in Appendix B.)

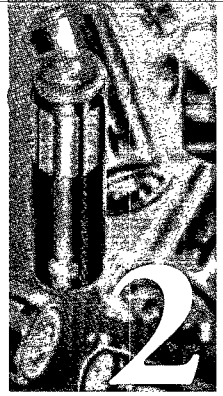
POINTS TO CONSIDER

- Is your community's solid waste currently combusted?
- Does ash from the combustor fail toxicity tests?
- Are air emissions from waste combustion a concern in your community?
- Is there a recycling facility that will accept collected batteries within a reasonable distance from your community? Does it have any special requirements? Can you meet them?

Another objective of some communities is to collect dry cell batteries for recycling. Through recycling, materials can be diverted from the waste stream, and resources can be recovered. In the case of battery recycling, metals are recovered from the used batteries, and the remainder of the product is discarded. In the United States, dry cell battery recycling efforts currently focus on recovering mercury or silver. Some U.S. companies also are disassembling dry cell batteries containing cadmium and sending them to facilities here or abroad for reprocessing. In addition, research is being conducted to explore the economic viability of recycling other types of batteries.

At this time, it is not cost-effective to recycle alkaline and carbon-zinc batteries, the most common types, because their heavy metal content is so low (see Appendix C). As a result, it is very difficult to find a recycling facility willing to accept them. The battery types that are recyclable, such as mercuric-oxide button and nickel-cadmium batteries, make up a very small percentage of household batteries. In addition, since only a few dry cell battery recycling facilities operate in the United States today, some communities could incur high costs to transport their batteries to the nearest facility. (Appendix D contains a listing of recycling facilities in the United States.) Since most of these facilities have minimum-quantity requirements, each community must collect enough batteries to make the program viable or team up with other nearby towns or counties in a regional program.

Despite limited recycling opportunities, however, many communities might still find it worthwhile to pursue a dry cell battery collection program. In the case of Whatcom County, Washington, a high level of public concern about waste in general and combustion in particular motivated the county to initiate its battery collection efforts. Although the lack of recycling markets has been a problem, the program has successfully diverted batteries from the county's combustor, raised public awareness of household hazardous wastes, and promoted safe battery management. Other successful programs are described in this handbook, and contacts for these programs are listed in Appendix E.



ISSUE 2

USED BATTERY GENERATION PATTERNS

Municipal officials should examine the used battery generation patterns in their communities to help determine if a collection program is appropriate. Typically, a community can expect to find the following types of batteries in its waste stream:

- Alkaline.
- Carbon-zinc.
- Mercuric-oxide, zinc-air, and silver-oxide buttons.

POINTS TO CONSIDER

- Are there large military, commercial, industrial, medical, or other nonhousehold facilities in your area discarding significant quantities of used dry cell batteries?
- Is the disposal of these batteries a matter of concern to your community?
- Are there demographic factors in your community that would indicate certain household battery consumption and disposal patterns?
- Are there staff or volunteer organizations available that can help identify and survey nonhousehold sources?

Currently, alkaline and carbon-zinc batteries are found in the greatest quantities. Button batteries are found in far fewer quantities, while rechargeable nickel-cadmium batteries and specialty batteries comprise only a small fraction of discarded batteries. Rechargeable nickel-cadmium batteries are being used increasingly as a substitute for conventional batteries, however, so more of these batteries will likely be found in the waste stream in the years to come. Newer types of batteries (such as lithium batteries) also are being introduced. In addition to household batteries, batteries used for specialized applications by nonhousehold sources have the potential to end up in a community's solid waste stream.

According to the battery industry, the number of dry cell batteries generated annually by households can be approximated by assuming that each person discards an average of eight dry cell batteries every year. Population demographics may influence battery consumption patterns in a particular area, however. For example, a community with an aging population might consume more button batteries (for use in hearing aids) than what is considered average.

The amounts and types of dry cell batteries generated by nonhousehold sources in the community can be estimated by identifying and surveying the largest generators and contacting their suppliers. Public officials or volunteers can scan business directories, telephone books, and maps to locate likely nonhousehold generators. Regional battery distributors, especially distributors of specialized batteries, also can help identify nonhousehold battery consumers in the area. General knowledge of the community and word of mouth will be useful as well. Once identified, phone interviews or site visits can be conducted to determine the types and quantities involved. Mail-in questionnaires also can be used, although the rate of return on such surveys typically is low. Battery manufacturers and distributors can provide further information on used battery generation patterns in your community. Other potential sources of information on the makeup of your community's solid waste stream include the Department of Public Works, local solid waste haulers, waste transfer facility operators, and landfill and combustor operators. Finally, any existing waste stream assessments or studies will help to provide more detailed information on the types and amounts of waste batteries generated in your community.

Gathering this preliminary information helps determine whether or not a battery collection program will divert a significant amount of heavy metals from the local municipal solid waste stream. If the research indicates that a collection program might not be effective, the community instead might elect to encourage industry efforts to reduce the heavy metal content of batteries.

ISSUE 3

LEGISLATIVE AND INDUSTRY TRENDS

Currently, at least 10 states have passed or are considering legislation for used dry cell batteries (see Appendix F). Several states have mandated heavy metal reductions in alkaline, carbon-zinc, mercuric-oxide, and zinc-air batteries. Laws passed in Connecticut, Minnesota, New Jersey, New York, Vermont, and Oregon require that rechargeable appliances be designed so that the nickel-cadmium batteries can be removed by the consumer. The laws also require the products to be labeled to inform the consumer of the types of batteries the products contain and how to dispose of them.

POINTS TO CONSIDER

- **Will recent or proposed legislation affect the need for a battery collection program in your community?**
- **Are industry initiatives (such as mercury reductions in alkaline batteries) likely to affect the amount of heavy metals entering your solid waste stream?**
- **Will battery substitutions change the types and amounts of heavy metals entering the waste stream?**

Disposal prohibitions or restrictions aimed at dry cell batteries with the highest heavy metal contents also have been established in several states. New Jersey and Vermont have passed legislation phasing out the disposal of nickel-cadmium and mercuric-oxide batteries in municipal solid waste. Minnesota prohibits households from discarding used rechargeable batteries; state agencies and other nonhousehold sources may not discard used nickel-cadmium, sealed lead-acid, mercuric-oxide, or silver-oxide batteries.

New Jersey, Vermont, and Minnesota require battery manufacturers to develop a system to ensure that certain types of batteries are recycled or disposed of properly. The Portable Rechargeable Battery Association (PRBA) is working with government agencies in these states to help develop workable systems for ensuring that rechargeable batteries are collected and recycled once they are no longer useful, as required by state laws. The PRBA is an organization of more than 105 manufacturers of batteries and battery products.

Various industry trends are becoming evident that might have a significant impact on battery collection programs, both now and in the future. One such trend concerns the reduction of mercury in dry cell batteries.

Between 1984 and 1989, battery manufacturers successfully reduced the overall amount of mercury in dry cell batteries by over 75 percent. Battery manufacturers consumed 276 tons of mercury in 1989, compared to over 1,100 tons in 1984. In addition, battery manufacturers project even further mercury reductions over the next decade.

Battery manufacturers also have reduced significantly the mercury content in alkaline batteries, which will contribute to a decrease in the amount of mercury entering the municipal solid waste stream in the future (see Figure 3). As of fall 1991, all major U.S. battery manufacturers had reduced the amount of mercury in their nationally marketed low-mercury alkaline batteries to 0.025 percent mercury by weight. Battery manufacturers predict that they will reduce further the amount of mercury in new alkaline batteries, possibly even eliminating it completely by 1993. Eveready's "Green Power" Energizer, which was put on the market in November 1991, was the first such zero-added mercury alkaline battery available in the United States. (Several mercury-free, heavy-duty, carbon-zinc batteries were put on the market previously and are available in the United States.)

Because of the decrease in the mercury content of batteries, by the year 2000 discarded household batteries are expected to contribute only 100 tons of mercury to the national municipal solid waste stream annually. Because of these reductions in mercury content, some communities may opt to encourage further battery manufacturer initiatives rather than to develop a collection program for diverting household batteries from the waste stream.

Another trend concerns the development of substitutes for certain types of batteries. For example, rechargeable nickel-cadmium batteries are being

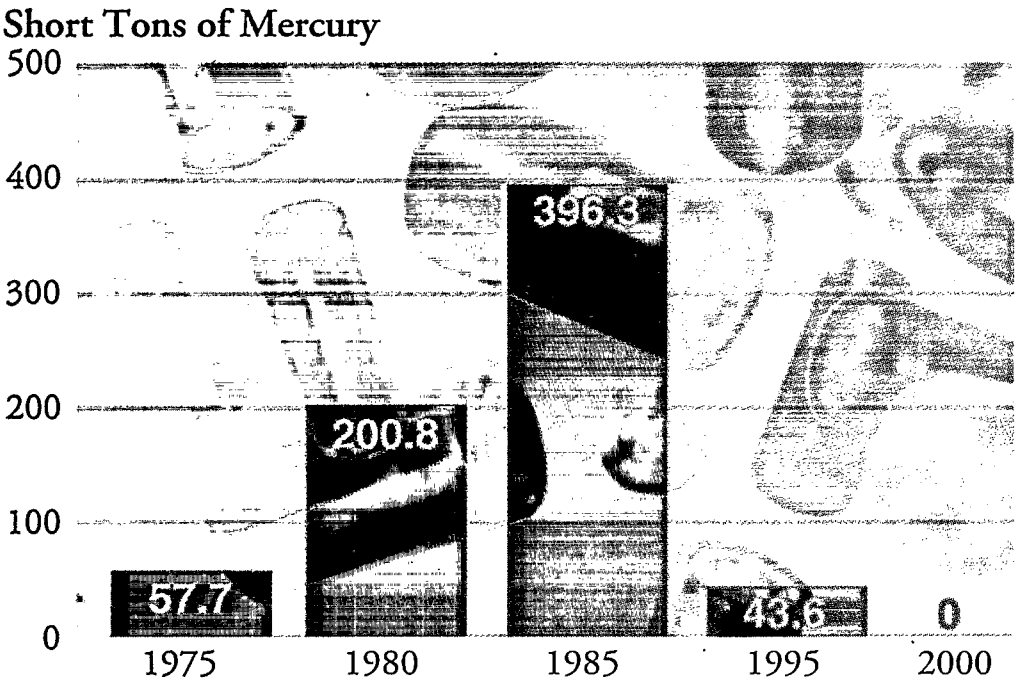
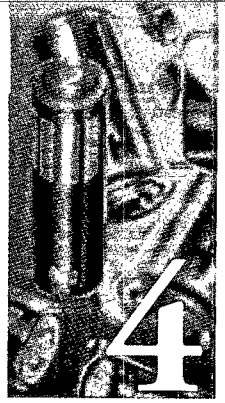


Figure 3. Alkaline battery contribution to mercury in the municipal solid waste stream since 1975.

used in place of alkaline batteries in certain applications. While the use of nickel-cadmium batteries can reduce significantly the *number of batteries* entering the waste stream, it might actually increase the *amount of heavy metals* entering the waste stream (unless such increased use is coupled with an effective collection and recycling program). Because the percentage of cadmium in nickel-cadmium batteries is much higher than the percentage of mercury in alkaline batteries, this substitution might only replace one heavy metal for another. In fact, given the escalating use of rechargeable appliances and batteries, EPA projects that cadmium use in rechargeable products will rise from 930 tons in 1987 to 2,035 tons by 2000.

Battery manufacturers currently are developing new rechargeable battery formulations, including a nickel-hydride battery that could substitute for nickel-cadmium batteries in a very limited number of applications. The nickel-hydride battery would not contribute any mercury or cadmium to the waste stream, but it is not likely to be a complete replacement since, among other reasons, it does not work well with power tools and other uses that require a high-energy drain rate.



ISSUE 4

Mixed Batteries Versus Recyclable Batteries

Where it appears that industry or legislative trends will not have a significant impact on the program, and your research indicates that a household battery collection program is feasible, municipal officials will need to decide which types of household batteries should be collected. Where the primary purpose is to divert the maximum total quantity of heavy metals from the waste stream, communities often conduct mixed battery collection programs, collecting all types of batteries together.

POINTS TO CONSIDER

- Does your community have the resources and personnel to sort collected batteries?
- Will the bulk of the collected batteries have a sufficiently high metal content to make recycling feasible?
- Is the market share of these battery types expected to rise or decline?
- Are the batteries your community is targeting for collection accessible? Can people distinguish them?

A significant advantage of mixed collection programs is that they do not require households to sort the batteries. This can boost public participation, since many individuals have difficulty telling one type of battery from another. For example, the battery collection program in Whatcom County, Washington, originally planned to collect only recyclable button and nickel-cadmium batteries, but soon discovered that the public was having difficulty distinguishing between recyclable and nonrecyclable varieties. After seven months, the program shifted to collecting all types of household batteries.

To date, mixed collections have met with only limited success, however. Despite accepting all battery types, these programs rarely capture more than 10 percent of the waste batteries in a community. In addition, separating out the recyclable batteries requires the dedication of personnel and resources. Some recycling companies will accept mixed batches of batteries, sort them, and dispose of the nonrecyclables themselves. Usually, however, substantial fees are charged for this service. A community may find that it costs less to handle its own sorting and disposal of nonrecyclable batteries than to ship the

batteries to a recycler and pay for the company to do this work.

Because of the costs of sorting mixed batteries and disposing of all the collected nonrecyclable batteries, some communities choose to collect only recyclable household dry cell batteries. Often, collections that target just recyclable batteries divert larger quantities of these battery types from the waste stream than mixed collections. If a community is considering collecting just recyclable batteries, it needs to consider a number of issues related to these types of batteries, including:

- **Metal content.** Recycling is only cost-effective if a high amount of metal can be recovered. Currently, mercuric-oxide button batteries contain the highest concentration (percent by weight) of mercury, but the number of these battery types sold is declining, and they are expected to be phased out of the market entirely by the mid-1990s. For most common household uses, mercuric-oxide buttons are being replaced gradually by silver-oxide and zinc-air button batteries, which contain significantly less mercury. In fact, over the next few years, some battery manufacturers might eliminate mercury from silver-oxide and zinc-air button batteries altogether. For communities interested in battery recycling, a button battery collection may be a good option at present, but this approach could become less feasible over time if the mercury concentration in the majority of button batteries continues to decrease.

- **Market share.** The market share of a battery type refers to its volume of sales relative to other types of batteries in a given market. The market share of recyclable batteries in a community will affect the number of these battery types the community will be able to collect and how much metal can therefore be recovered. The market share of mercuric-oxide button batteries used in hearing aids, for example, is declining because silver-oxide and zinc-air button batteries increasingly are replacing them.

- **Accessibility.** Some batteries are permanently sealed in appliances, making them difficult or impossible to recover for recycling. Currently, 80 percent of all nickel-cadmium batteries, for example, are permanently sealed in appliances, but some states have passed new legislation mandating consumer-accessible batteries for such appliances. This should result in increasing numbers of nickel-cadmium batteries available for recycling.

- **Ability to be distinguished.** It may be difficult for consumers to differentiate one type of battery from another. While button batteries are easy to distinguish from other battery types, most button batteries will look alike to consumers. Unless labeled, nickel-cadmium batteries not encased in an appliance look very similar to alkalines. Some states now require both these appliances and the batteries they contain to be labeled for recycling.

Appendix C provides more details on these issues for each type of battery likely to be found in the municipal solid waste stream. Appendix G provides a series of calculations for determining the contribution of metals from household waste batteries in the solid waste stream.

ISSUE 5

MANAGEMENT OPTIONS

Communities opting to initiate a collection program must decide how to manage the collected batteries. The primary options are to dispose of collected batteries at a hazardous waste facility or to recycle them. (Appendix E presents a list of various battery collection programs along with their chosen management strategy.) If batteries are to be disposed of in a hazardous waste landfill, a licensed facility must be located prior to initiation of the program. If they are to be recycled, a reputable recycler must be identified beforehand. Because of the high costs of shipping collected batteries, facilities as close as possible to the community should be sought.

POINTS TO CONSIDER

- **Is there a hazardous waste landfill or recycling facility for collected batteries near your community?**
- **Is the facility properly managing the waste batteries it receives?**
- **Will your collection program require long-term storage or extended stockpiling of collected batteries?**

If a community cannot locate a hazardous waste disposal or recycling facility that will accept the collected batteries before its program starts, long-term storage will be necessary. Some communities have launched collection programs, intending to recycle as many types of batteries as possible, but have ended up stockpiling batteries for extended periods of time while they search for a recycling facility that will accept the batteries. Communities that anticipate storing batteries should be aware that household dry cell batteries are exempt from storage, transportation, and disposal requirements under federal hazardous waste regulations but might be subject to state and local laws. Regardless of whether state or local regulations exist, stockpiling batteries should be avoided whenever possible, and certain safety procedures should be incorporated into any storage design, as described under the "Worker Health and Safety" section of this handbook.

Care should be taken in selecting a recycling or disposal facility that has a good environmental record and is in compliance with all applicable regulatory requirements. If possible, planners should visit all potential facility sites prior to accepting any bids. These inspections can help a community avoid future liability problems, specifically in regard

to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund"). Under this Act, if a community collects batteries and sends them to a recycling or disposal facility that is later designated as a Superfund site, the community could be partially or wholly liable for the costs of cleaning up the site.

ISSUE 6

COLLECTION SYSTEMS

Choosing the most appropriate collection system is vital to designing a successful, cost-effective program. The advantages and disadvantages of the different collection systems must be analyzed to develop a program that meets the community's specific needs. There are three main approaches to collecting household dry cell batteries:

- *Joining existing household hazardous waste collection programs.* Your community might already have annual or semiannual household hazardous waste collection days or a permanent household hazardous waste drop-off site. In either case, qualified professionals are responsible for handling the collected household hazardous waste and ensuring its safe disposal. If a household hazardous waste collection day or drop-off site already has been established, incorporating dry cell battery collection into the existing program might be the easiest and lowest cost collection option for your community.
- *Establishing battery drop-off collections.* Public drop-off sites (such as retail outlets, recycling centers, and libraries) can be an effective, low-cost option for some municipalities. Appropriate sites include stores that sell large volumes of batteries or products such as hearing aids, toys, electronics, or power tools. Drop-off collections avoid the labor and equipment investment costs associated with curbside collection operations. Drop-off collections have not been characterized by high participation rates, however, primarily because residents must assume the responsibility for collection. To encourage participation, communities should strive to make the drop-off points as convenient as possible. While drop-off sites can work in both urban and rural areas, in less densely populated areas they tend to be more suitable than curbside programs. However, they require that all residents be well informed about the

POINTS TO CONSIDER

- Does your community currently sponsor a household hazardous waste collection program or have an established household hazardous waste drop-off site?
- Are enough residents likely to participate in a drop-off program to make the collections effective?
- Does your community have the resources to establish a curbside collection program?
- Should a combination of collection methods be considered?
- Are there volunteer organizations willing to help collect batteries?

need for a collection program, the benefits of participating, and the logistics of the program.

- *Curbside collections.* In a curbside collection program, used batteries are collected from bins or boxes that residents place outside their homes. While curbside collection programs typically offer the advantage of higher participation rates than other methods, these collections are more expensive. The additional costs may be justified, however, by the number of batteries diverted from the solid waste stream, especially in communities with very high levels of heavy metals in the waste stream. In addition, the cost of curbside collections for batteries will be reduced (and might even be minimal) if the program can be coordinated with curbside collections of other materials.

When deciding among these options, communities should consider the size and distribution of the population, the convenience to households, the quantity of discarded batteries, the location of the sources of these batteries, and the available funding for the program. (Appendix E lists various collection programs implemented by communities across the nation.)

The frequency of collection will depend on whether the program utilizes curbside or drop-off collections, population size and density, the quantities of batteries discarded, and the budget. Schedules for curbside battery collection, for example, can range from a weekly collection in combination with other curbside programs to a single, annual collection. Curbside household hazardous waste collection programs should be coordinated with ongoing garbage collections and other curbside collection programs.

The New Hampshire/Vermont Solid Waste Project, a household battery collection program initiated in May 1987, is an example of a successful drop-off program. There are 74 sites that collect used batteries in 29 towns in the two states. Many of the sites are in retail stores, where 5-quart silver buckets with the project's battery collection logo are located next to battery sales displays to encourage consumers to return their used batteries. Additional battery collection sites have been established at government offices, transfer stations, and recycling centers. As of April 1992, over 24 tons of household batteries, or eighty 55-gallon drums, have been collected.

The Household Hazardous Waste Project in Springfield, Missouri, developed a drop-off program in 1988 to combine and enhance the efforts of watch, hearing aid, and camera retailers that were already collecting mercuric-oxide and silver-oxide button batteries for recycling. Over 50 jewelers, pharmacies, and camera stores in a 23-county area agreed to participate in the program by serving as drop-off points for used dry cell batteries. The names of the participating stores were included in community recycling directories, and communities in the counties involved in the program now update their own lists. The unique feature of the program is that responsibility for recycling or disposing of the batteries rests with individual retailers instead of with the Household Hazardous Waste Project or participating communities.

Some programs combine different collection systems. In Warren County,

New Jersey, batteries are collected at over 70 drop-off sites, including retail stores, post offices, public schools, libraries, and municipal buildings located across the county, and through curbside collections in nine municipalities. Batteries are collected at the municipal recycling center in 15-gallon containers and then sorted by type. The sorted batteries are then picked up by the program's staff person and brought to the main county recycling center, where they are stored in shipping containers to await delivery to a recycling facility. For curbside collection, households place their commingled batteries in a plastic bag on top of the other items collected for recycling. The program's staff sorts the nonrecyclable batteries from the recyclable button and nickel-cadmium batteries. The batteries are then sent to the recycling center for storage. When a sufficient quantity is available, the recyclable batteries are shipped to a recycling facility. Nonrecyclable batteries are stored until the county's semiannual hazardous waste cleanup day, when they are disposed of through the county's household hazardous waste vendor.

ISSUE

WORKER HEALTH AND SAFETY

Unlike most other commodities collected in recycling programs, such as aluminum cans, newspapers, and plastics, dry cell batteries pose special health and safety risks if not properly handled. As a result, a few simple steps should be taken during the collecting and storage of dry cell batteries to minimize the risk of explosion or adverse health effects that could result from inhalation or dermal contact.

POINTS TO CONSIDER

- Is ventilated storage available?
- Does your community have the resources available to ensure workers are properly trained and equipped?
- Are additional precautions needed for volunteer groups helping with the collection? Is your community prepared to take them?

First of all, drums or other used battery containers should be placed in a ventilated location to minimize worker exposure to concentrated vapor emissions during storage and handling. Mercury vapors can accumulate in a sealed drum if stored for an extended period of time. Under Hennepin County, Minnesota's current permanent program, mercury emissions are monitored at the site where mixed batteries are collected, sorted, packed for transport, and stored to detect emissions. As a precaution, program coordinators in Warren County, New Jersey, have installed building ventilation and require all workers to wear protective gloves and goggles at the storage site. To date, no mercury emissions have been detected.

Explosion is another potential risk when batteries are stored in contact with one another. Since waste batteries still contain a residual charge, when collected together they may discharge each other, forming hydrogen gas. If the container is not properly ventilated, there is a danger of explosion. Consumers and municipalities should adopt basic safety procedures for handling discarded batteries, including using well-ventilated containers and storage facilities.

Another safety concern is the potential for partially charged or corroded batteries to leak caustic chemicals. If proper precautions are not taken, workers sorting a mixed batch of batteries can get chemical burns on their skin. They can protect themselves simply by wearing proper protective clothing, including rubber gloves, eye protectors, and heavy canvas or rubberized aprons.

Because of these health and safety issues, only properly trained and equipped workers should handle collected waste batteries. The New Hampshire/Vermont Solid Waste Project originally planned for local civic groups, such as the Boy Scouts, to sort its batteries. Due to concerns about the hazards and liability of hand sorting the collected batteries, however, this plan was dropped. Instead, the collected batteries are kept commingled and disposed of twice each year by a qualified contractor at a hazardous waste landfill.

ISSUE 8

PUBLIC EDUCATION

Public education efforts are essential to the success of a battery collection program. A public education program can heighten the community's awareness of the need to reduce heavy metals in the waste stream, involve more residents in the collections, and increase the number of batteries collected. Depending on a community's publicity needs and its budget, a range of educational materials can be developed, including posters, brochures, stickers, flyers, and newsletters. In addition, press releases promoting the program can be sent to local newspapers, radio, and cable television stations. Public education programs can provide guidance to those retailers serving as collection points. Many communities work with retailers to develop and distribute educational materials. A variety of other creative channels, including distributing flyers through community schools or utility bill inserts, can be investigated for promoting the program.

POINTS TO CONSIDER

- **What promotional or educational efforts will be needed to demonstrate the importance of a collection program, encourage participation, and provide logistical details of the program? Does your community have a budget to develop the necessary materials?**
- **Are there volunteers or civic organizations that can help spread information regarding the program?**
- **Can retailers or corporate sponsors be enlisted to assist with the program?**

In Whatcom County, Washington, a corporate sponsor gave retailers buckets for collecting used batteries, along with a poster, flyers, stickers, and other program information. Newspaper articles and posters publicizing the program were made available at the collection points. In June 1990, when a decision was made to collect batteries countywide, a publicity campaign kicked off the expanded program. This included sending mailers to households through the schools, issuing press releases, providing posters to recycling coordinators in each municipality, and sending a newsletter to every household in the county.

The City of Detroit publicized its program through press releases, a direct mail brochure to over 450,000 households, local television and radio public service announcements, and paid radio commercials. Working with the local water department, the program places inserts in water usage bills sent to property owners, and there are plans to do the same with the local electric and gas companies. Attempts are also being made to work actively with the Detroit Public School System, since initial

contacts with local schools have resulted in increased participation.

In addition to promoting the program, educational materials can inform consumers of safe battery handling and storage practices. Participants in collection programs usually accumulate used batteries in their homes rather than immediately disposing of them with household refuse. Every year, health departments receive some reports of small children swallowing batteries. Although few of these incidents result in death or serious illness, they can cause vomiting, abdominal pain, or fever. Collection programs should, therefore, warn the public of the dangers of battery ingestion.

Minnesota's Hennepin County developed safety precautions for retailers serving as collection points and gave these stores brochures describing basic safe battery storage practices to distribute to community residents. Hennepin County's precautions include keeping battery collection containers in an area inaccessible to the public (such as behind a counter or in a back room) and instructing employees to collect batteries from the public and deposit them into collection containers. Some communities also may choose to minimize such risks by providing households with "piggy bank" style containers to hold batteries until they can be dropped off at a recycling center.

ISSUE 9

PROGRAM COSTS

Communities considering a battery collection program should analyze the costs associated with each of the different program components to determine the overall feasibility of implementing such a program. Meeting financial expectations will be critical to the program's long-term success. The majority of the costs incurred will be related to battery collections and disposal, including purchasing collection boxes, operating the collections, shipping to hazardous waste or recycling facilities, and paying any fees set by those facilities. Officials also should consider other potential costs such as battery sorting and storage, safety equipment and training, program staff, and promotional materials. (Table 2 lists the major program components that communities should consider when developing a budget.)

POINTS TO CONSIDER

- **Will most collected batteries have to be disposed of as hazardous waste? Can these costs be provided for in a program budget?**
- **Can curbside battery collection costs be defrayed by combining them with other pickups using volunteers or by locating corporate sponsors?**
- **Will a large public education campaign be needed?**

Some communities might receive some money from recycling companies for collected mercury, silver-oxide, or nickel-cadmium batteries, which can help offset some of the costs of the battery collection program. Public officials should be aware, however, that the money paid by the recycler for these batteries will be minimal (see Table 3). Even programs that focus exclusively on recyclable button batteries with a relatively high metal content cannot expect to fund their programs with payments from the recyclers. In addition, the amount paid often will be unpredictable, varying with demand and the cost of processing. In fact, some recycling facilities may charge for their services. Most communities find that payments received do not even cover the cost of shipping the batteries to the recycler.

The costs of a collection program depend on its scope. In Whatcom County, Washington, program expenses included $3,000 to develop promotional materials and purchase battery collection buckets. In addition, funds were required to pay the salary of one part-time staff person. Minnesota's Hennepin County spent over $5,000 on posters, brochures, and collection boxes for its recyclable button-battery collection program. A full-time staff person

TABLE 2. Components of a Battery Collection Budget

- Staff to collect and analyze information about community generation patterns and disposal.
- Telephone or postage costs for any surveys conducted in the community.
- Staff to oversee and manage the program.
- Collection buckets or boxes.
- Transportation of collected batteries (including labor, gasoline, insurance, and maintenance).
- Workspace and personnel to sort batteries.
- Storage (including drums, rental of storage space, and safety monitoring).
- Training, equipment, and insurance for workers.
- Management of collected batteries (including hazardous or municipal waste disposal charges, costs of shipping recyclable batteries to a recycler, and potential recycling charges).
- Design, production, and distribution of educational and publicity materials.
- Program followup and evaluation expenses.

was used for three months to set up the program, at a cost of $3,500. Warren County, New Jersey, budgeted a total of $50,000 for the first year of a countywide program. This figure included the salary of one staff person to collect and sort batteries, and the costs of developing promotional materials, purchasing a collection vehicle and storage barrels, and disposing of the collected batteries. The cost of disposing of the batteries as hazardous waste is $160 per 55-gallon drum. Each year, after a competitive bid process, Warren County, New Jersey, officials hire a vendor to dispose of the batteries.

The hazardous waste disposal costs encountered by communities are often the largest single expense, ranging from $175 to $300 per 55-gallon barrel, or approximately $600 to $1,000 per ton (since a 55-gallon drum of batteries generally weighs between 550 to 650 pounds). These costs are substantially higher than the average municipal landfill tipping fees of $11 to $64 per ton, where most batteries that are not segregated from the municipal solid waste stream would otherwise be disposed of. Therefore, considering both disposal and other program costs, dry cell battery collections might be an expensive method of diverting heavy metals from the municipal solid waste stream.

Some communities find other ways to offset the costs of their battery collections. Volunteer groups or local civic organizations can be sources of both labor and funding. Such organizations may donate collection buckets, gather

TABLE 3. Sample Recycling/Disposal Charges and Payments[1]

TYPE OF BATTERY	DISPOSITION	PAYMENT FOR RECOVERED METALS	CHARGE
Mercuric-oxide	Recycled on site	No payment	$1.50 per pound
Silver-oxide	Recycled on site	The current silver price per pound	No charge
Nickel-cadmium	Recycled at another facility	No payment	$0.65 per pound
Alkaline, carbon-zinc, zinc-air	Sent to a secure landfill for disposal	No payment	$0.39 per pound
Lithium	Deactivated then sent to a secure landfill for disposal	No payment	$6.00 per pound

[1] Figures charged/paid by the Mercury Refining Company, Inc. (MERECO). All figures are current as of February 1992.

them from collection points and transport them to the storage facility, and help support the program with promotional materials, fund raisers, and public forums. Locating corporate sponsors can be especially rewarding. In Whatcom County, Washington, the bulk of the expenses, including the costs of transporting and disposing of the 12 drums of alkaline and carbon-zinc batteries, were borne by a corporate sponsor in the City of Bellingham.

ISSUE 10

PROGRAM EFFECTIVENESS

Program evaluation is critical to the long-term success of a battery collection project, especially since the issues and problems associated with dry cell batteries are not static. This is a rapidly evolving matter, with technical research and legislative efforts under way that can affect the battery collection and recycling plans developed by communities. Program staff members will need to reassess the project periodically, reevaluate their objectives, and adjust their collection and disposal strategies accordingly.

POINTS TO CONSIDER

- **Is your collection program flexible enough to adapt to potential legislative, industry, or other changes in battery design and use?**
- **Should your community consider focusing on nonhousehold sources of dry cell batteries?**

One issue to which communities should pay particular attention is the battery industry's mercury reduction efforts. In 1985, dry cell batteries contained 55 percent of all the mercury used in the United States. Since the majority of that mercury was found in alkaline batteries, communities that collected these batteries successfully reduced the amount of mercury entering the municipal solid waste stream. Today, the significant reductions and anticipated elimination of mercury in alkaline batteries by the end of 1993 are bringing about a shift in the focus of battery collection programs from alkaline batteries to mercury and rechargeable nickel-cadmium batteries.

As heavy metals are increasingly phased out of household batteries, communities might want to focus on nonhousehold batteries in the future. Some nonhousehold sources currently generate significant quantities of waste batteries on a regular basis, and this trend will most likely continue in the years to come. These sources also tend to use larger batteries, which generally contain greater quantities of heavy metals than household batteries.

Commercial users also are more likely than household users to continue generating batteries that contain heavy metals such as mercury, rather than rely on substitutes. For example, a hospital that has life-support equipment will probably still want to use mercury batteries rather than a mercury-free alternative that might be less reliable for a particular application. Broward County,

Florida, however, has been successful in working with local hospitals to reduce the number of mercury medical batteries they generate. By selectively substituting zinc-air batteries for mercury batteries, the county diverts nearly one ton of mercury annually. When the avoided costs of managing used mercury batteries are accounted for, this substitution results in savings for area hospitals.

In designing a battery management program, communities should keep in mind that many of the factors affecting battery management will continue to change. Battery manufacturers' mercury-reduction achievements, new market trends, and state legislative actions all will have an impact on the nature of communities' concerns about heavy metals entering the municipal solid waste stream from dry cell batteries. Thus, communities should attempt to build a level of flexibility into their collection programs, and plan to evaluate their programs regularly to determine whether the approach they are using is still the most effective method, given changing conditions. Table 4 lists the types of questions communities might ask when evaluating program effectiveness.

TABLE 4. Followup Questions

- Is the program diverting a significant proportion of heavy metals from the municipal solid waste stream?
- Are batteries being recycled cost-effectively?
- Are most collected batteries being disposed of as hazardous waste? Are these disposal costs provided for in the program budget?
- Has long-term storage or extended stockpiling been necessary? Will it be in the future?
- Have there been safety-related problems with battery handling or storage?
- Is the contractor/recycler operating in an environmentally sound manner?
- Are more (or fewer) drop-off points or more (or fewer) frequent pickups necessary?
- Are educational and promotional efforts working? Should other methods be considered to promote the program, increase participation, or ensure segregation of recyclable batteries (if necessary)?
- Are industry developments reducing the heavy metal content of batteries to the extent that household battery diversion is no longer productive?
- Are federal or state legislative and regulatory developments making nonhousehold collection a practical alternative?

RESOURCES

Dozens of household battery collection programs have emerged around the country. Collection program coordinators may be contacted for information and suggestions. Appendix E lists a number of collection programs and provides the names of program contacts and their phone numbers. The following articles and reports also might be helpful to communities considering setting up a battery collection program:

Adamo, Janeen, et al. *Policy Options for Source Reduction of Toxic Metals in Household Batteries (Draft).* Boston, Massachusetts: Tufts University for the Northeast Waste Management Officials Association, August 1990.

Arnold, Karen, Nancy Misra, and Randy Hukriede. *Household Batteries in Minnesota: Final Report of the Household Battery Recycling and Disposal Study.* St Paul, Minnesota: Minnesota Pollution Control Agency, March 1991.

Forker, Timothy. *Household Batteries: Recycling and Toxicity Reduction in Europe.* New York, February 2, 1990, and *Strategic Approaches to the Used Household Battery Problem: A Report on European Experiences and Their Implications for Action in the United States.* New York, New York: Environmental Action Coalition, November 10, 1989.

Hurd, David J., David Muchnick, Michael S. Schedler, and Tom Mele. *Feasibility Study for the Implementation of Consumer Dry Cell Battery Recycling as an Alternative to Disposal: Final Report.* Brattleboro, Vermont: Council of State Governments/ Northeast Recycling Council, April 1992. Developed under the New York State Department of Economic Development, Secondary Materials Utilization Grant Program.

Minnesota Pollution Control Agency. *Household Battery Recycling and Disposal Study.* St. Paul, Minnesota: Minnesota Pollution Control Agency, June 1991.

Montgomery County Department of Environmental Protection. *Options for the Recovery and Handling of Household and Automotive Batteries in Montgomery County, Maryland.* Rockville, Maryland: Montgomery County Department of Environmental Protection, September 1990.

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

Seeburger, Donald. *A Study of Two Collection Methods for Removing Household Dry Cell Batteries from a Residential Waste Stream, Hennepin County, Minnesota.* Presented in Seattle, Washington, September 14, 1989.

U.S. EPA. *Household Hazardous Waste Management: A Manual for 1-Day Community Collection Programs.* Washington, DC: U.S. EPA Office of Solid Waste and Emergency Response, 1993.

U.S. EPA. *Characterization of Municipal Solid Waste in the United States: 1992 Update.* Washington, DC: U.S. EPA Office of Solid Waste and Emergency Response, July 1992.

U.S. EPA. *The Solid Waste Dilemma: An Agenda for Action.* Washington, DC: U.S. EPA Office of Solid Waste and Emergency Response, February 1989.

U.S. EPA. *Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000.* Washington, DC: U.S. EPA Office of Solid Waste and Emergency Response, January 1988.

U.S. EPA. *Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000.* Washington, DC: U.S. EPA Office of Solid Waste and Emergency Response, April 1992.

U.S. EPA. *Preliminary Use and Substitutes Analysis of Lead and Cadmium in Products in Municipal Solid Waste.* Washington, DC: U.S. EPA Office of Solid Waste and Emergency Response, April 1992.

APPENDIX A

RCRA REGULATIONS APPLICABLE TO NONHOUSEHOLD SOURCES OF BATTERIES

Management of used nonhousehold batteries is complex because waste batteries from nonhousehold sources are subject to the federal Resource Conservation and Recovery Act (RCRA) hazardous waste regulations (or equivalent state regulations) if they exhibit one or more of the following hazardous characteristics: (1) ignitability; (2) corrosivity; (3) reactivity; or (4) toxicity (as identified through the Toxicity Characteristic Leaching Procedure, or TCLP). In general, some portion of batteries tested will be identified as hazardous waste because of their corrosivity, reactivity, or toxicity.

Waste generators are responsible for determining whether their waste batteries exhibit hazardous characteristics. EPA has not independently verified industry data, but according to industry sources, nickel-cadmium batteries typically exhibit hazardous waste characteristics, whereas low-mercury alkaline and carbon-zinc batteries do not. Alkaline batteries with higher concentrations of mercury and larger mercury batteries would be likely to test as hazardous, and some lithium batteries might exhibit the reactivity characteristic. Whether button batteries test as hazardous depends on their type and size.

Highlights of the federal RCRA regulations that apply to nonhousehold generators of waste batteries (such as business, retail, service, manufacturing, medical, and military establishments) are presented below. These descriptions are intended to give only a general sense of the regulations and should not be considered a complete review. In addition, many states have implemented their own hazardous waste regulations. These regulations must be at least as stringent as the federal requirements, and in many cases they are more stringent. Communities interested in collecting nonhousehold batteries should contact their state and local environmental, safety, and health agencies to determine all applicable requirements. Communities are encouraged to call EPA's RCRA Hotline at (800) 424-9346 for information on the federal

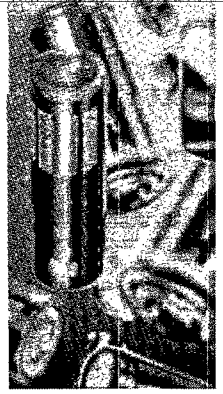
hazardous waste requirements and for state environmental agency contacts.

- **Conditionally exempt small quantity generators.** Nonhouseholds that generate less than 100 kilograms (220 pounds) of *all* types of hazardous waste (not just batteries) per month are known as conditionally exempt small quantity generators (CESQGs). Hazardous waste batteries generated by CESQGs are "conditionally exempt" from most federal hazardous waste regulations. One of the conditions for the exemption is that the hazardous waste must be managed at certain types of facilities. A facility that is permitted, licensed, or registered by the state to manage municipal or industrial solid waste is one type of facility that is allowed under the conditional exemption. Therefore, if a household hazardous waste collection program is permitted or registered by the state to manage municipal solid waste, waste batteries from conditionally exempt small quantity generators may be collected in such a program.

- **Regulated generators.** Nonhousehold generators that generate more than 100 kilograms (220 pounds) of hazardous waste per month are regulated generators and must comply with the hazardous waste regulations under RCRA. They may send their waste only to a permitted hazardous waste facility (or certain recyclers) and must ship the waste using a hazardous waste transporter. In addition, shipping papers known as manifest tracking forms must be used. Communities may not collect hazardous waste batteries from regulated generators unless the collection program complies with the hazardous waste regulations under RCRA. Failure to comply with the regulations could result in civil or criminal penalties against the community.*

- **Exemption for regeneration by battery manufacturers.** Used batteries that are returned to a battery manufacturer for regeneration are exempt from federal hazardous waste regulations. Used battery regeneration consists of replacing or repairing defective cells, or replacing electrolytes. It is very unlikely that dry cell batteries would be regenerated.

*The federal regulations discussed above may be revised in the future to make combined collection of household batteries and batteries generated by regulated generators easier. EPA has proposed a program under which regulated batteries could be collected under greatly streamlined requirements to facilitate separation of the batteries from the municipal waste stream and to encourage proper treatment and/or recycling. Household and regulated batteries could be collected together as long as the collection program complies with requirements such as basic good management practices and a minimum of recordkeeping. This proposal, known as the Universal Wastes Rule, was published in Februrary, 1993 and is scheduled to be finalized by September, 1993. The rule will not become effective in most states, however, until the state incorporates it into the state hazardous waste regulations.



APPENDIX B

A DRY CELL BATTERY COLLECTION PROGRAM IN ACTION: HENNEPIN COUNTY, MINNESOTA

The Hennepin County dry cell battery collection program is a well-established program that can serve as a model for other communities interested in diverting used batteries from the municipal solid waste stream. It is the largest used dry cell battery collection program in the United States. The program serves approximately one million county residents spread out over 47 municipalities, including Minneapolis and the surrounding suburbs. The county pursued two pilot studies and then conducted a survey of commercial battery users. As a result, a retail collection program of button batteries was initiated countywide. Curbside collection is available for all types of batteries in the City of Minneapolis and at numerous drop-off locations throughout the county.

Pilot Comparative Collection Programs/All Batteries

Concerns about emissions of heavy metals from the county's municipal solid waste combustor prompted a two-part pilot program in 1988 to divert all types of household batteries from the combustor. Two suburbs, each with a population of about 20,000 people, were selected to test different collection approaches. In one community, mixed household batteries were collected over a 10-month period in drop-off buckets placed at retail stores. The program was publicized through newspaper inserts and other promotions. In the second community, household batteries were collected at the curbside on two different dates, less than five months apart. Households received a direct mail flyer with instructions to place the batteries in a washed 1/2-gallon milk carton or one-quart sealed plastic bag that was to be placed on top of their recycling container on the specified battery collection dates.

The pilot program gathered comprehensive data on the quantities and types of batteries collected. Ninety-three percent

of all collected batteries were nonrecyclable alkaline or carbon-zinc batteries.

The county received permission to store collected batteries for up to one year at a public works garage. Batteries were separated by type, stored in different barrels, and marked as hazardous, corrosive materials. The seven 55-gallon drums of batteries collected during the pilot program were all disposed of as hazardous waste at a cost of $700 per drum. This was a much higher cost than the county would have been able to negotiate with another vendor, but the one-year limit for storing batteries had almost expired, and there was insufficient time for alternative arrangements. The current cost to dispose of collected batteries is about $300 per drum.

Commercial Battery Waste Audit

In January 1990, Hennepin County, Minnesota, conducted a survey of 83 local businesses thought to use significant numbers of dry cell batteries. The sample included organizations involved in medical care, security, communications, building maintenance, transportation, computer maintenance, government, and traffic control. The survey goals were to get an idea of the types and quantities of batteries used by businesses in Hennepin County and to determine the disposal practices used.

Organizations surveyed were asked the following questions:

- During the past 12 months, how many types of batteries did your company use?
- What is your company's primary use of each type of battery (type of equipment powered by batteries)?
- How long does your company keep each type of spent battery on site before disposal?
- How does your company dispose of each type of spent battery?

This survey identified both individual companies that were particularly high battery consumers and the total numbers of batteries entering the municipal solid waste stream from these nonhousehold sources. For example, the survey identified one company that used 34,000 alkaline batteries in one year. Transportation, construction, and communication organizations surveyed consumed a total of 17,000 nickel-cadmium batteries. The medical care industry was the dominant user of mercuric-oxide batteries, discarding over 3,500 mercury batteries in one year.

The majority of the organizations surveyed discard their waste batteries into the municipal solid waste stream. In many cases, these batteries are the same types and sizes of those purchased by household users over the counter. The county uses the survey information to plan strategies for helping local businesses identify alternative disposal methods for problem batteries.

Retail Collection/Button Batteries

Based on the results of the pilot program and the commercial battery waste audit, a countywide retail collection program was established in January 1990. The program began with the

collection of button batteries. Mercuric-oxide and silver-oxide button cells are easy to market for recycling because of their high mercury content by weight and because they pose reduced storage risks. Button batteries were collected at more than 150 points throughout the county, including jewelry and photography stores.

Newspaper advertisements, window cards, handouts, flyers distributed at senior citizen centers, and counter displays at participating stores publicized the program. About $5,000 was spent on purchasing collection boxes and developing brochures and posters. A full-time staff person was hired for three months to set up the program at a cost of $3,500 per month.

In its first year, the button battery collection program accumulated and shipped 292 pounds of mixed button batteries to Mercury Refining in Albany, New York. This recycling company processed approximately 140 pounds of silver-oxide button batteries, which provided the bulk of the dollar value paid to the county. Another 123 pounds of mercury cells were processed — resulting in the diversion from the municipal solid waste stream of some 49 pounds of pure mercury during the program's first year. In the program's second year, approximately 800 pounds of mixed button batteries were collected and shipped for recycling and disposal. Today, Hennepin County has nearly 500 drop-off sites, including retailers, libraries, nursing homes, and hospitals.

Collection of All Batteries

A curbside collection program was initiated in October 1990 for the City of Minneapolis, which has over 100,000 households. This collection program was modeled after the pilot curbside collection of all batteries. In addition to curbside collections, 140 drop-off points located at stores that sell all types of dry cell batteries were established to serve the rest of the households in Hennepin County. Batteries and small appliances containing rechargeable batteries also can be brought to Hennepin County's permanent household hazardous waste collection site.

During the first six months of the program, Hennepin County collected between 3,500 to 4,000 pounds of mixed household batteries in Minneapolis and 900 pounds from the suburban drop-off locations every week. All batteries are brought to a Vocational Service Program, where they are sorted by chemical composition for recycling or hazardous waste disposal. While the majority of batteries collected are alkaline and carbon-zinc batteries, the collection of nickel-cadmium batteries has been as high as 20 percent of the total. In 1991, the program collected and shipped over 70 tons of batteries. The program's budget for 1991 was $263,000, which included all program costs (start-up, sorting, shipping, and disposal costs, as well as some modest promotion of the program).

APPENDIX C

DRY CELL BATTERY ISSUES AFFECTING RECYCLING

BATTERY TYPES	ACCES-SIBILITY	DISTINGUISHABLE	MARKET SHARE	TYPICAL HEAVY METAL WEIGHT PER CELL	CUR-RENTLY RECY-CLED
Primary Cells (Nonrechargeable)					
Alkaline, carbon-zinc	Accessible	Alkaline, carbon-zinc, and nickel-cadmium batteries are similar in size and shape, although nickel-cadmium batteries are labeled as such.	Alkalines make up 75 percent of all battery sales and are increasingly replacing carbon-zinc because of their better performance in high-power drain appliances.	Mercury[1]: 0.025 percent or none in alkaline batteries; 0.010 percent or none in carbon-zinc batteries	No
Mercuric-oxide button	Accessible	Mercuric-oxide button batteries are easy to distinguish from nonbutton types of batteries, but not from other buttons.	Mercuric-oxide button batteries are expected to be phased out by the mid-1990s.	Mercury: 35–50 percent	Yes
Silver-oxide button	Accessible	Silver-oxide button batteries are difficult to distinguish from mercuric-oxide buttons.	Market share is projected to remain stable. Silver-oxide batteries, along with zinc-air batteries, are replacing mercuric-oxide button batteries.	Mercury: 0.4–1.0[1] percent	Yes

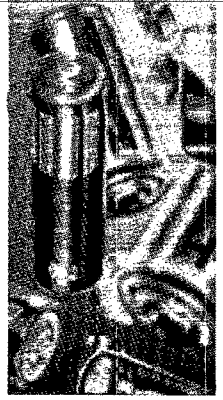
BATTERY TYPES	ACCES-SIBILITY	DISTINGUISHABLE	MARKET SHARE	TYPICAL HEAVY METAL WEIGHT PER CELL	CUR-RENTLY RECY-CLED
Zinc-air button	Accessible	Zinc-air batteries are easily identifiable by the holes in the bottom.	Market share is growing and projected to continue to increase. Zinc-air batteries, along with silver-oxide batteries, are replacing mercuric-oxide button batteries.	Mercury: 0.4–1.0[1] percent	No
Lithium	Virtually all are accessible except those placed within certain products during the assembly process and used for memory back-up applications.	Most large lithium batteries are labeled with the word "lithium" or the initials "LI." Lithium button batteries are smaller and lighter than most types of button batteries and are also unique because they come with only a 3-volt charge.	New, but growing market share.	n/a	No
Secondary Cells (Rechargeable)					
Nickel-cadmium	80 percent are sealed in appliances.[2]	Alkaline, carbon-zinc, and nickel-cadmium batteries are similar in size and shape, although nickel-cadmium batteries are labeled as such.	Only 15–17 percent are purchased directly by consumers through retail outlets.	Cadmium: 10–15 percent	Yes[3]
Small sealed lead-acid flat plates	Virtually all are sealed in appliances.[2]	Most are enclosed in battery packs and are not easily distinguishable.[2]	Use in consumer appliances has been limited, but their market share is growing and projected to continue to increase, particularly in cellular phone applications.	Lead: 50–75 percent	Yes[4]

[1]These weights reflect data available as of June 1992. Older batteries have higher contents of heavy metals.

[2]This will change as new legislation is adopted requiring easy accessibility and clear labeling of these batteries. All will be easily removable by July 1, 1993.

[3]Currently being recycled by only one company in the United States (Inmetco, Elmwood City, PA), though accepted for export by others.

[4]Currently collected in Hennepin County, Minnesota, and sent to a local lead smelter for recycling. While these batteries can be recycled in facilities that recover lead from automotive lead-acid batteries, it is not done commonly due to their inaccessibility and low volume of use.



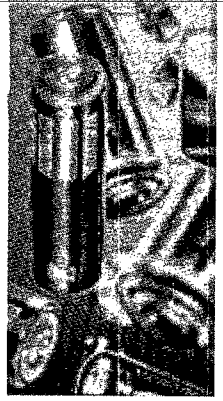
APPENDIX D

DRY CELL BATTERY RECYCLERS[1]

COMPANY	TYPES OF CLIENTS	TYPES OF BATTERIES ACCEPTED	MINIMUM QUANTITY REQUIREMENTS	PAYMENT/ CHARGE	WHERE PROCESSED
Bethlehem Apparatus Hellertown, PA (215) 838-7034	Battery manufacturers, industry	Mercury (pre-sorted)	5-gallon bucket	Pays $770 per 5-gallon bucket	On site
Doe Run Company Boss, MO (800) 633-8566	Industry, consumers	Lead-acid	No minimum requirements if batteries are delivered	Price paid depends on lead content and price of lead, among other factors	On site
Inmetco Elmwood City, PA (412) 758-5515	Industry, some municipalities	Nickel-cadmium (requires that batteries be manifested)	400-pound minimum	Pays $275 per net ton delivered	On site
Mercury Refining Latham, NY (518) 785-1703	Industry, consumers	Mercury	None	Pays $0.10/pound	On site
		Silver-oxide	None	Pays the current silver price per pound	On site
		Nickel-cadmium	None	No charge/ payment	Exported
		Lithium	None	Charges $6/ pound	Deactivated, then securely landfilled
		Alkaline, carbon-zinc	None	Charges for secure land disposal	Landfilled

COMPANY	TYPES OF CLIENTS	TYPES OF BATTERIES ACCEPTED	MINIMUM QUANTITY REQUIREMENTS	PAYMENT/ CHARGE	WHERE PROCESSED
Saft-NIFE, Inc. Greenville, NC (919) 830-1600	Industry, consumers	Nickel-cadmium	$100 minimum fee	Pays $0–$0.70/pound, depending on volume received	Limited processing on site; exported to Sweden
Sanders Lead Troy, AL (800) 633-8744	Filling stations, automobile dealers, industry, telephone companies, consumers	Lead-acid	One ton if client delivers, one truckload if company picks up	No charge and will pay freight	On site
Skuylkill Metals Forest City, MO (816) 446-3322 Baton Rouge, LA (504) 775-3040	Manufacturers, industry, hospitals, consumers	Lead-acid	None, willing to accept all batteries as community service; requests that batteries not be mailed	No charge	On site
Universal Metals & Ore Mt. Vernon, NY (914) 664-0200	Battery manufacturers, appliance manufacturers	Nickel-cadmium	None	No charge for small quantities; pays $0.15-$0.20/pound for larger quantities	Exported to France or Asia

[1]This list is current as of February 1992. Inclusion on this list does not signify EPA recommendation or approval.



APPENDIX E

SAMPLE DRY CELL BATTERY COLLECTION PROGRAMS: A LISTING OF PROGRAMS AND CONTACTS

BATTERY COLLECTION PROGRAM	CONTACT	TYPE OF COLLECTION PROGRAM	TYPES OF BATTERIES COLLECTED	MANAGEMENT OF BATTERIES
Huntsville, Alabama	Karen Schoening (205) 880-6054	Curbside collection, with recyclables	All types	Will be sent to a hazardous waste landfill
Gainsville, Florida	Norman Thomas (904) 495-9215	Collected in conjunction with other household hazardous waste collection	All types	Batteries are encased in cement, to be sent to the municipal solid waste landfill after one year
Overland Park, Kansas	Ron Tubb (913) 382-5252	Drop-off at six retail stores	Button batteries only	Recycled
Louisville, Kentucky	Ray Hillbrand (501) 625-2788	Pilot drop-off at recycling center	All types	Sent to hazardous waste incinerator
City of Detroit, Michigan	Phillip Brown (313) 876-0144	Drop-off at retail stores, municipal offices	All types	Will be sent to broker for sorting prior to recycling or hazardous waste disposal
Dakota County, Minnesota	Gayle Prest (612) 891-7020	Pilot curbside collection; drop-off at over 70 locations	All types collected at curb; drop-off sites accept button batteries only	Batteries are sorted for recycling or hazardous waste disposal
Hennepin County, Minnesota	Chery Lofrano-Zaske (612) 348-6509	Drop-off, curbside collection, and hazardous waste site drop-off	All types and rechargeable appliances	Recycled or disposed of as hazardous waste

BATTERY COLLECTION PROGRAM	CONTACT	TYPE OF COLLECTION PROGRAM	TYPES OF BATTERIES COLLECTED	MANAGEMENT OF BATTERIES
23 counties, Southwest Missouri	Marie Steinwachs (417) 889-5777	Drop-off at retail stores	Button batteries only	Recycled
29 towns in New Hampshire and Vermont	Dodi Carr (603) 543-1201	Drop-off at retail stores, municipal offices, and transfer stations	All types	Sent to hazardous waste landfills
Somerset County, New Jersey	Mike Elka (201) 231-7031	Curbside collections with recyclables, four times per year	All types	Sent to hazardous waste landfill
Warren County, New Jersey	Mary Briggs (908) 453-2174	Curbside collection in 9 communities; drop-off at municipal offices or recycling centers in 14 communities	All types	Batteries sorted for recycling or hazardous waste disposal
Little Valley, New York	Richard Preston (716) 938-9121	Drop-off at transfer stations; curbside; looking to expand to retail stores	All types	Sent to recycling company for sorting prior to recycling or hazardous waste disposal
New York City, New York	Nancy Wolf (212) 677-1601	Drop-off at retail stores, healthcare facilities, and schools	Button and nickel-cadmium batteries	Currently stored, plan to recycle; used in research
Poestenkill, New York	Lois Fisher (518) 283-5100	Drop-off at landfill or recycling center	All types	Sent to recycling company for sorting prior to recycling or hazardous waste disposal
Rochester, New York	Alice Young (716) 244-5824	Drop-off in municipal buildings and retail stores	Button batteries only	Recycled
Rye, New York	Frank Culross (914) 967-7404	Drop-off at recycling center	All types	Sent to recycling company for sorting prior to recycling or hazardous waste disposal
Scarsdale, New York	Jim Rice (914) 723-3300	Drop-off at recycling center and incinerator	All types	Sent to recycling company for sorting prior to recycling or hazardous waste disposal

BATTERY COLLECTION PROGRAM	CONTACT	TYPE OF COLLECTION PROGRAM	TYPES OF BATTERIES COLLECTED	MANAGEMENT OF BATTERIES
Southold, New York	Jim Bunchuck (516) 734-7685	Drop-off at retail stores and recycling center	All types	Sent to recycling company for sorting prior to recycling or hazardous waste disposal
Woodstock, New York	Bill Reich (914) 679-6570	Drop-off at retail stores and recycling center	All types	Sent to recycling company for sorting prior to recycling or hazardous waste disposal
Lancaster County, Pennsylvania	Stephanie Crable (717) 397-9968	Curbside collection with trash pick-up (placed in bright orange zip-lock bag)	All types	Will sort recyclable batteries for recycling; remainder will be sent to municipal landfill
Pottstown, Pennsylvania	Jim Crater (215) 323-8545	Drop-off at community recycling center	Button batteries	To be determined
York County, Pennsylvania	Jeff Fox (717) 845-1066	Drop-off arrangement with one convenience store chain, plus over 100 buckets at retail stores, municipal offices	All types	Sent to recycling company
Chesapeake, Virginia	Jennifer Ladd (804) 420-4700	Curbside collection	All types	Plan to send to recycling company for sorting prior to recycling or disposal
Town of Hartford, Vermont	James Gruber (802) 295-9353	Curbside collection with recyclables	Button only	Not yet determined
Town of Randolph, Vermont	Karen Odato (802) 728-9262	Drop-off at 16 locations, mainly retail stores	All types	Not yet determined
Whatcom County, Washington	Lisa Schnebele (206) 384-1057	Drop-off at retail stores and recycling center	All types	Batteries sorted for recycling or hazardous waste disposal

Source: Adapted from Dana Duxbury & Associates, 1990.

APPENDIX F

SAMPLES OF STATE BATTERY LEGISLATION*

TOXICS REDUCTION	RECHARGEABLE BATTERY RECYCLING	DISPOSAL PROHIBITIONS	OTHER
Connecticut			
Prohibits the sale of alkaline batteries with more than 0.025 percent mercury by weight. By January 1, 1993, prohibits the sale of carbon-zinc batteries containing more than one part per million by weight of mercury.	By July 1, 1993, rechargeable appliances may be sold only if batteries or battery packs can be removed. The packaging or battery casing must indicate the presence of a nickel-cadmium battery that requires proper disposal. Municipalities must recycle nickel-cadmium batteries in consumer products.	By January 1, 1993, the disposal of used mercury batteries is prohibited except by delivery to a retailer, a wholesaler, a manufacturer of mercury batteries, or a recycling center.	By January 1, 1993, a mandatory take-back system will be established whereby retailers and wholesalers are required to accept used mercuric-oxide batteries. Retailers must advise customers that used mercury batteries are hazardous waste and require separate disposal, and that the retailer is required to accept used mercury batteries. Senior citizen centers must establish programs to collect mercuric-oxide batteries for safe disposal or recycling.
Minnesota			
Prohibits the sale of alkaline batteries with more than 0.025 percent mercury by weight. After 1996, prohibits the sale of alkaline batteries with any mercury (except alkaline button cells). Prohibits the sale of alkaline button cell batteries that contain more than 25 mg mercury. Prohibits the sale of mercury batteries. Prohibits the sale of new battery chemistries unless approved by the Minnesota Pollution Control Agency.	By July 1, 1993, rechargeable batteries can be sold only if the battery is removable by the consumer. The product and the rechargeable battery must be clearly marked for recycling. A sign must be posted at retail outlets informing consumers that disposal of rechargeable batteries is prohibited and that the batteries should be recycled. Battery manufacturers must implement collection or other management pilot programs and report results by November 1993.	Mercury, silver-oxide, nickel-cadmium, and lead-acid batteries used by a government agency or an industrial, communications, or medical facility may not be discarded in mixed municipal solid waste. Rechargeable nickel-cadmium batteries and lead-acid batteries used by households may not be discarded in mixed municipal solid waste.	Battery manufacturers must ensure that a system for the proper collection, transportation, and processing of waste batteries exists for purchasers in Minnesota. They can do this by accepting waste batteries or by identifying or contracting with collectors, transporters, and processors of waste batteries. Manufacturers must provide a phone number for information on returning batteries for recycling or proper disposal.

*Current as of January, 1993.

TOXICS REDUCTION	RECHARGEABLE BATTERY RECYCLING	DISPOSAL PROHIBITIONS	OTHER
New Jersey			
Prohibits the sale of alkaline batteries (except button cells) and mercury batteries with more than 0.025 percent mercury by weight. Prohibits the sale of all alkaline button cells with more than 25 mg mercury per cell. Prohibits the sale of zinc-carbon batteries with more than 0.0001 percent mercury by weight. By January 1, 1996, prohibits the sale of alkaline batteries with more than 0.0001 percent mercury by weight.	By July 1, 1993, rechargeable products may be sold only if the batteries can be removed by the consumer. The rechargeable products must be labeled, alerting consumers that the battery is prohibited from entering the solid waste stream and must be recycled. The instruction manual for the product must include information on proper disposal.	By 1993, the disposal of mercury, nickel-cadmium, and lead-acid batteries in the solid waste stream is prohibited.	By 1993, battery manufacturers of mercury, nickel-cadmium, and lead-acid batteries must design and publicize a system for the collection of these batteries and design a strategy for implementing an industry-wide uniform coding system. Retailers will be required to participate in the collections and program publicity. All dry cell battery manufacturers must submit a collection plan to increase the collection of dry cell batteries and to implement an industry-wide uniform coding system.
New York			
Prohibits the sale of alkaline batteries that have more than 0.025 percent mercury by weight. Prohibits the sale of carbon-zinc batteries that have more than 0.0001 percent mercury by weight.	By July 1, 1993, rechargeable appliances may only be sold if the batteries can be removed. The rechargeable battery must be clearly marked for recycling.	The combustion of dry cell batteries is prohibited. Combustion facilities must provide a program to prevent dry cell batteries from being accepted and/or treated at the facility.	Reports must be submitted to the governor in 1993 reviewing the technological feasibility of eliminating mercury from alkaline batteries, establishing a schedule for collecting batteries for recycling or disposal, and indicating the appropriate role of battery manufacturers, retailers, consumers, and recyclers.

TOXICS REDUCTION	RECHARGEABLE BATTERY RECYCLING	DISPOSAL PROHIBITIONS	OTHER
Oregon			
Prohibits the sale of alkaline batteries with more than 0.025 percent mercury by weight (except button cells if they contain less than 25 mg mercury by weight).	By July 1, 1993, prohibits the sale of products containing nickel-cadmium batteries in consumer products unless the battery is removable by the consumer. The battery and the package containing the battery must be labeled with the recycling symbol, the symbol "Cd" for nickel-cadmium, and "Pb" for lead-acid. For nonconsumer products, prohibits the sale of products containing nickel-cadmium batteries unless the batteries can be removed.	N/A	N/A
Vermont			
Prohibits the sale of alkaline batteries with more than 0.025 percent mercury by weight. Prohibits the sale of button cell alkalines with more than 25 mg of mercury by weight. By January 1, 1993, prohibits the sale of button cell batteries containing more than 25 mg of mercury by weight. By January 1, 1996, prohibits the sale of batteries containing any mercury.	By July 1, 1993, rechargeable batteries used in tools and appliances must be easily removable, and the product, battery, and packaging must be labeled indicating that the battery should be recycled or disposed of properly.	Mercury, silver-oxide, nickel-cadmium, and lead-acid batteries used by a government agency or an industrial, communications, or medical facility may not be discarded in landfills. By July 1, 1992, rechargeable batteries generated in any municipality in which there is an ongoing collection program may not be disposed of in landfills. By January 1, 1993, mercury, silver-oxide, nickel-cadmium, and lead-acid batteries may not be disposed of in landfills.	Nonconsumer users of mercury, silver-oxide, nickel-cadmium, and lead-acid batteries are required to separate and return such batteries to a designated facility. Battery manufacturers must implement a collection system, inform purchasers of the landfill prohibition, and include the cost of collection in the sales transaction. All button cells must be labeled by type of electrode. The Vermont Agency of Natural Resources was required to develop a used battery management plan; this plan was published in January 1992.

APPENDIX G

CALCULATIONS OF CONTRIBUTIONS OF METALS FROM WASTE HOUSEHOLD BATTERIES IN THE SOLID WASTE STREAM

The following appendix shows the types of calculations that a community might go through to determine the contribution of metals to the MSW stream. (Excerpted from *Household Battery Recycling and Disposal Study*, prepared by Minnesota Pollution Control Agency, June 1991.)

In 1985, the U.S. population was 238,741,000; 4,192,000 of those were living in Minnesota (U.S. Department of Commerce, 1988). The population in Minnesota was 1.75587 percent of the total U.S. population.

1990 Button Battery Sales (Household use only)

Mercuric-oxide battery sales for hearing aids:	43,100,000
Zinc-air battery sales for hearing aids:	45,700,000
Silver-oxide battery sales for hearing aids:	900,000
TOTAL SALES:	89,700,000

Source: Personal communication, Raymond Balfour, National Electrical Manufacturers Association (NEMA).

1990 Nickel-cadmium Battery Sales (Household use only)

Estimated U.S. sales:		225,000,000
Percent for household use:		77.5
TOTAL SALES:	225,000,000 × 0.775 =	174,375,000

Source: Personal communication, NEMA sources.

Contribution of Metals to the 1985 Municipal Waste Stream*

MULTIPLICANDS	BUTTON BATTERIES		
	SILVER	MERCURY	ZINC-AIR
Average Weight	1.57 gm	3.6 gm	1.57 gm
Number Sold	2.984979×10^6	2.984979×10^6	2.984979×10^6
Market Share	0.05	0.30	0.65
Mercury Percent	0.01	0.35 – 0.5	0.02
Conversion Factor	0.0352746	0.0352746	0.0352746
Total Amount Mercury	82.655442 oz. 5.17 lbs.	39,801.105 – 56,858.7 oz. 2,487.57–3,553.67 lbs.	2,149 oz. 134.3125 lbs.

Total amount mercury in waste stream from waste button batteries: 2,627.05 –3,693.15 lbs.

MULTIPLICANDS	CARBON-ZINC BATTERIES
Number Sold	10.886394×10^6
Mercury Weight	0.001 – 0.05 gm
Cadmium Weight	0.001 – 0.05 gm
Lead Weight	0.001 – 0.05 gm
Zinc Weight	3 – 22 gm
Conversion Factor	0.0352746
Total Amount Metals	384 – 19,200.66 oz. mercury, cadmium, lead (24 – 1,200 lbs. mercury, cadmium, lead) 1,152,039.6 – 8,448,290.3 oz. zinc (72,002.475 – 528,018.14 lbs. or 36–264 tons zinc)

NOTE: To recreate these Total Amount Metals, work the calculations through separately for each metal.

MULTIPLICANDS	ALKALINE BATTERIES
Number Sold	21.07044 × 106
Mercury Weight	1 gm
Zinc Weight	1–24 gm
Cadmium Weight	0.01 gm
Lead Weight	0.01 gm
Conversion Factor	0.0352746
Total Amount Metals	743,251.34 oz. mercury (46,453.209 lbs. or 23.2 tons mercury) 7,43,251.34 – 17,838.032 oz. zinc (46,453.209 – 1,114,877 lbs. or 23.2 – 557.4 tons zinc) 7,432.5134 oz. cadmium, lead (464.53 lbs. cadmium, lead)

NOTE: To recreate these Total Amount Metals, work the calculations through separately for each metal.

MULTIPLICANDS	NICKEL-CADMIUM BATTERIES
Average Weight	37.2 gm
Number Sold	175,587
Cadmium Percent	0.17
Conversion Factor	0.0352746
Longer-Use Factor*	0.325
Total Amount Metals	11,232.39 – 18,720.64 oz. nickel (702 – 1,170 lbs. nickel) 12,730 oz. cadmium (795.6 lbs. cadmium)

NOTE: To recreate these Total Amount Metals, work the calculations through separately for each metal.

*Calculating the Longer-Use Factor for Nickel-Cadmium Batteries

20% of nickel-cadmium batteries are accessible:

50% of those last for up to 1 year =	0.02 ÷ 0.510	= 0.10
50% of those last for up to 4 years =	0.20 ÷ 0.5 ÷ 4	= 0.025
100% of the accessible batteries		

80% of nickel-cadmium batteries are in appliances:

100 % of these last up to 4 years =	0.80 ÷ 4	= 0.20
100% of those in appliances		

100% of waste nickel-cadmium batteries annually in the waste stream = 0.325

Contribution of Metals to the Municipal Waste Stream in the Early 1990s*

MULTIPLICANDS	BUTTON BATTERIES	
	SILVER	ZINC-AIR
Average Weight	1.57 gm	1.57 gm
Number Sold	1.57872×10^6	1.57872×10^6
Market Share	0.01 – 0.10	0.90 – 0.99
Mercury Percent	0.02	0.01
Conversion Factor	0.0352746	0.0352746
Total Amount Mercury	17.5 – 174.9 oz. (1.09 – 10.9 lbs.)	786.9 – 865.6 oz. (49.2 – 54.1 lbs.)

Total amount mercury in waste stream from waste button batteries: 50.29 – 65 lbs.

MULTIPLICANDS	CARBON-ZINC BATTERIES
Number Sold	4.9×10^6
Cadmium Weight	0.001 – 0.05 gm
Mercury Weight	0.001 – 0.05 gm
Conversion Factor	0.0352746
Total Amount Metals	172.8 – 8,642.3 oz. mercury, cadmium (10.8 – 540.1 lbs. mercury, cadmium)

MULTIPLICANDS	ALKALINE BATTERIES
Average Weight	57.7 gm
Number Sold	$33,9856 \times 10^6$
Mercury Percent	0.00025
Conversion Factor	0.0352746
Total Amount Mercury	17,293 oz. (1,080.8 lbs.)

MULTIPLICANDS	ALKALINE BATTERIES
Number Sold	$33{,}9856 \times 10^6$
Cadmium Weight	0.01 gm
Conversion Factor	0.0352746
Total Amount Cadmium	11,988.3 oz. (749.3 lbs.)

MULTIPLICANDS	NICKEL-CADMIUM BATTERIES
Average Weight	37.2 gm
Number Sold	3.062×10^6
Cadmium Percent	0.17
Conversion Factor	0.0352745
Longer-use Factor	0.325
Total Amount Cadmium	221,994 oz. (13,875 lbs.)

Pre-Legislation Estimate of Mercury Contribution from Alkaline Batteries to the 1990 Municipal Waste Stream

MULTIPLICANDS	ALKALINE BATTERIES
Average Weight	57.5 gm
Number Sold	$33{,}9856 \times 10^6$
Mercury Percent	0.005
Conversion Factor	0.0352745
Total Amount Mercury	344,666.3 oz. (21,541.6 lbs.)

*KEY:

Multiplicands are the numbers to be multiplied together to arrive at the Total Amount Metals; exceptions are noted for carbon-zinc, alkaline, and nickel-cadmium batteries.

Average Weight by battery type was calculated from weights found in Linden, 1984, except for that of the alkaline batteries which came from personal communication with Raymond Balfour, NEMA.

Number Sold (in 1985) was found in Dodds and Goldsberry, 1986 prorated for Minnesota.

Market Share was taken from Erico, Slater, and Dickenson, 1985.

Metal Percent per battery was taken from NEMA, 1988.

Metal Weights per battery were taken from Franklin and Associates, Ltd., 1988.

Conversion Factor converts grams to ounces.

Longer-Use Factor prorates these rechargeable batteries over four years and was based on Franklin and Associates, Ltd., 1988.