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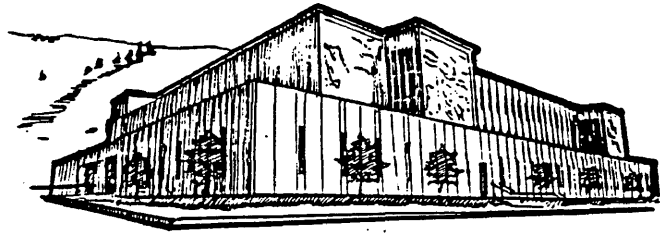
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University of
Montana

**A BATTERY MANAGEMENT PROGRAM
FOR A COMMUNITY WITH A SOLID
WASTE LANDFILL**


by

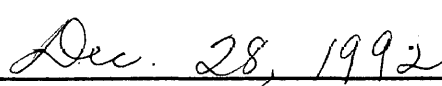
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**Presented in partial fulfillment of the requirements for the
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1992**

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Dean, Graduate School


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ABBREVIATIONS

Ag	silver
amp	ampere(s) (capacity)
BCI	Battery Council International (Pb-acid)
Cd	cadmium
C-Zn	carbon-zinc cell
CESQG	Conditionally Exempt RCRA SQG
CERCLA	the superfund act
CFR	Code of Federal Regulations
CNS	central nervous system
DoT	U.S. Department of Transport
EPA	U.S. Environmental Protection Agency
Fe	iron
g	gram
Hg	mercury
HMTA	Hazardous Materials Transportation Act
kg	kilogram (1 kg = 2.205 lbs.)
KOH	potassium hydroxide
Li	lithium
MCL	maximum contaminant level
Mg	magnesium
Mn	manganese
NEMA	National Electrical Manufacturers Association
NiCd	nickel-cadmium cell
NiMH	nickel-metal hydride cell
n.o.s	not otherwise specified (HMTA hazard class)
-OH	hydroxide compound
ORM	other regulated material (HMTA package group)
OSHA	Occupational Safety & Health Administration
Pb	lead
ppm	parts per million (milligrams/liter, mg/kg)
ppb	parts per billion (micrograms/liter)
PRBA	Portable Rechargeable Battery Association
PSA	public service announcement
RCRA	Resource Conservation & Recovery Act
redox	reduction-oxidation reactions
RQ	reportable quantity (CERCLA)
S	sulfur
SDWA	Safe Drinking Water Act
SQG	Small Quantity Generator (RCRA)
v	volt(s), voltage
Zn	zinc

INTRODUCTION

INTENT

This paper describes a battery management program whose intent is to decrease the risk posed to human health by battery heavy metals in drinking water; and to educate the public on the management of a hazardous waste. The paper will also serve as a proposal to the community of Missoula, Montana for implementing the battery management program. It is a further goal of this project to make the information gathered available to those interested in battery management.

PROBLEM AND SOLUTIONS

Batteries, or cells¹ are a convenient, versatile and portable form of power. Americans use over one billion battery operated devices (Consumer Reports 1987). We dispose of at least eight dry cells each, or nearly 2.5 billion a year² (EPA Mar 1992) in operating an average of nine battery powered devices per house, necessitating 30 battery purchases a year per household (Vizard).

The main components of a battery are two electrodes, which

¹A battery being a collection of cells, as in "a battery of cannons". Wet cells have a liquid electrolyte, dry cells have a paste or solid electrolyte. Also a 'cell couple', to connote the two electrodes that create the electricity.

²Unclear whether this figure includes cells in cordless appliances.

usually are composed of a metal. Several of these metals, cadmium, lead and mercury, are especially toxic and may pose a hazard to human health after the cells are disposed. Batteries also contain a corrosive acid or alkaline electrolyte that contributes to the corrosion of cell casings in landfills. When batteries are thrown away, their metals are disbursed to the air and soil through incineration (including landfilled ash), or to water and soil through dissolution in landfills. In landfills they dissolve in leachate and are transported into groundwater. *The extent to which this occurs is largely unknown* and happens in an extremely complex system of physical conditions that is incompletely understood.

Missoula's landfill is situated above a part of its drinking water aquifer. At such monitoring wells as have been placed around Missoula's landfill, there have been occasional elevated measurements of these metals. New areas of the landfill will have a clay and synthetic liner that will retard the leakage of leachate for as long as the liner lasts, but the currently used section of the landfill is unlined. At threat from landfill leachate contamination are businesses between the Clark Fork river and the landfill--downgradient of groundwater flows from the landfill--with individual drinking water wells. At least five of these (three active) are within a mile downgradient of the landfill (Chen-Northern 1987). Neither of the two water companies serving the area nor the county keeps track of properties with private wells. A few private home wells (that do not require periodic testing for heavy metals) may exist in this area (Ward).

The national figure (Franklin Associates) for number of cells disposed of interpolates to about 750,000 cells

disposed in Missoula's landfill yearly, or 2,100 a day.³ Half of those come from residents of urban Missoula, and the rest from other areas served by the landfill. Rough estimates of the annual inputs of cadmium (Cd), lead (Pb) and mercury (Hg) from batteries into Missoula's landfill, derived from Franklin Assoc. (see section on heavy metal inputs), are:

Pb (vehicle batteries)	20,000 lbs. ⁴
Cd	1,450 lbs. ⁵
Hg	72 lbs. ⁶

As batteries comprise the largest source of these heavy metals in a landfill (Franklin Assoc., see chapter 1), an effective collection and battery use education program would keep a significant amount of hazardous metals out of Missoula's landfill. This will help maintain the quality of the city's sole source drinking water aquifer.

Beyond aquifer protection, this program will aim for the larger goal of hazardous waste reduction as it is easier to prevent waste than it is to clean it up. The program will have two separate components, limited collection and education, the education component aimed at waste reduction.

³Allowing for 7 cells disposed of per person because of lower incomes and probable lower consumption levels in Montana.

⁴Only 61-800 lbs coming from gelled Pb-acid appliance batteries, the vast majority, 19,700 lbs, coming from vehicle type batteries.

⁵Haight et al. report alkalines contain 0.4% Cd, which would contribute about 250 lbs of the load, the remaining 1,250 lbs coming from NiCds.

⁶Will decrease to about 40 lbs. as certain types of batteries containing mercury are phased out of production beginning this year.

The program will also conserve a small amount of valuable mineral resources, and the corresponding amount of energy used in refining them from their mineralized state. *More importantly this battery management program will be teach the values of managing and taking responsibility for hazardous waste consumers generate in general. As such it has been accepted as a local test case for developing publicity and educational methods for managing household hazardous waste by the local Solid Waste Task Force.*

Two hurdles must be surmounted by a program that seeks citizen participation: 1) public acknowledgement of a problem; 2) resources committed to it. Some concern about the threat of batteries in Missoula's landfill has been expressed spontaneously to this author. More generally, public consciousness of the need to protect the city's only source of drinking water has been demonstrably raised over the past few years. The aquifer has received designation under the federal Safe Drinking Water Act (SDWA) as a sole source of drinking water aquifer, making it eligible for certain federal funds for its protection, including through education. Local government and Missoula's main drinking water supplier, Mountain Water Company, are developing well-head protection public education programs. The Missoulian has published a few stories a month for the past few years dealing with the threat; and other media outlets have also focused on the issue. In general there seems to be little opposition to protecting our aquifer. The actual threat posed by cells by their contribution to any elevated levels of metals in Missoula's drinking water is unknown. *The levels of these heavy metal loadings to the landfill and the fact that, nationally, cells are the largest source of these metals to the municipal waste stream, suggest the benefit of a cell management program.*

The general commitment of citizens to aquifer protection, recycling resources and reducing waste is offset by their general opposition to paying more taxes or user fees. Recognizing the difficulty of fighting for a share of existing revenues, or for new revenues, *this program will be limited in size and flexible in its goals so as to not put off potential funders.*⁷ The wide variety of potential funders (chapter 5) each with a self-interest in participating in a battery management program, should help sustain the program.

COLLECTION COMPONENT

These factors argue against collection and must be taken into account:

- collection and proper disposal is more expensive than throwing batteries away;
- the few companies accepting batteries for reclamation of metals charge for most of the cell types;
- changes in battery manufacture have reduced the amount of toxic and valuable heavy metals in cells, including in the largest selling alkaline type;
- the other high volume cell type, carbon-zinc (C-Zn), does not contain hazardous quantities of toxic heavy metals;⁸

⁷Potential funders: parties either involved in battery use and disposal or who deal with potential consequences of battery disposal. Other potential funders are government or private agencies with an interest in pollution prevention and or resource protection.

⁸Most dry cells are the C-Zn and alkaline types. Their large volume makes them expensive to collect, and their metals are not extremely toxic. They make up about 80% of the number of consumer cells. About 10% of the number of cells are buttons, another 10% are pocket NiCds and lithiums.

- the purported end of manufacture of mercuric-oxide button size cells (contain 35% mercury by weight);

- a promising non-hazardous substitute for nickel-cadmium cells has recently entered the market;

- the non-hazardous zinc-air cell has taken a large share of the button battery market;

Nevertheless, several battery types--nickel-cadmiums (NiCd, 10-15% cadmium by weight), mercuric-oxides (35% mercury), some button cells⁹ and lead-acid cells (Pb-acid, 80% lead), are worth targeting for collection because of their high heavy metal content. Coincidentally these types have a higher market value with the reclamation companies.¹⁰ Users of these types usually generate unmixed waste cells, making collection, and publicizing of the collection program, easier.

Despite the movement away from the use of toxic metals in manufacture, old cells still contain hazardous metals. Other collection programs have found themselves collecting very large amounts of stored up batteries at start-up. These cells are somewhat corroded and contain higher amounts of heavy metals.¹¹ They are worth keeping from the landfill.

⁹Zn-air and silver oxide buttons continue to use about 1.0-1.5% mercury by weight, less than a gram of mercury each.

¹⁰It is possible that other cells' metals may gain market value sometime in the future, especially if government creates incentives or mandates such as return deposits, tax credits for recycling, or relief from hazardous waste regulations. Several countries have pilot or operating plants that reclaim low value and less toxic metals from unsorted batches of cells.

¹¹The zinc electrode (found near the perimeter in many consumer size cell types) corrodes due to the normal reactions

Finally, batteries sent for reclamation from Missoula will in a small way send a market signal and help develop the market for recycling of cells.

*A full scale collection effort is not necessary.*¹² Focusing on button cells and other 'niche' type cells--NiCds and Pb-acids in appliances, mercuric-oxides from hospitals and other institutional users, and lithium¹³ cells--that are basically pre-sorted will lower collection costs and so somewhat increase the market value of the collected cells.

The scope of this collection program will depend upon funding, with the more hazardous types: NiCds, Pb-acids and mercuric-oxides cells, looked at first.

in a cell (especially in the alkaline environment of most cylinder and button cells). Until recently mercury was used to amalgamate the zinc and prevent this corrosive reaction. In an effort to reduce toxicity manufacturers have been reducing the amount of mercury in these most popular cells. Whereas in the past up to 10%-12% mercury by weight was added, and 2.5% to 1% more recently, manufacturers are now--1992--producing mercury free cells. It takes 2 years, on average, for a disposable cell to go from manufacture, inventory, sale and use to disposal (Balfour). Perhaps more than half of the alkaline cells made in '92, and all thereafter, will not be formulated with mercury. Declining amounts of mercury will *continue* to be added to the landfill for approximately two years from this source.

¹²Collection programs exist in at least 60 communities in the U.S., largely because of the health hazard posed by the growing number of solid waste incinerators that volatilize heavy metals and contaminate highly leachable landfilled ash with heavy metals. In other cases activists, government, manufacturers and reclamation companies are supporting collection.

¹³Lithium cells are becoming more popular because of their power, but are worth managing because lithium is extremely reactive, and most formulations contain other hazardous materials.

EDUCATION COMPONENT

Approximately 80% of cells will not be targeted for collection because of the manufacturer's mercury reductions and because of the expense of collecting and disposing of such large volumes. Substantial amounts of hazardous metals from batteries that are not collected can be kept from the landfill by a relatively small expenditure on an extremely visible, on-going educational effort whose focus is maximizing the life, and proper disposal of, batteries.

Beyond reducing the number of cells headed to the landfill, the educational program will serve as a high visibility hazardous waste management program. It will target a hazardous material (batteries), show that we all are responsible for generating a disposal problem, point out the hazards its disposal creates, and provide an example of how *reduction, reuse and substitution* can avoid such hazards. It will attempt to inculcate these values in the minds of consumers.

Cells now have so many applications, often non-essential, that there is room for a battery education campaign emphasizing reduced and substituted uses. Consumers generally do not realize that cells cost from *100 to 6,000 times the price of household electricity per KWH*.

Substituting longer lived cell types and using "spent" cells in lower power requirement applications has both economic and environmental benefits. Using cells with more discrimination requires lifestyle changes, but an appeal for such a change might be linked to aquifer protection, which is prominent in the public mind.

Not only are consumers largely unaware of the performance characteristics of their batteries, but there have been many

changes in both old and new cell type technologies. For example, the new nickel-metal hydride (Ni-MH) substitute for NiCds generally has better performance characteristics and does not contain cadmium. Too, consumers know little about matching the use with the proper cell type to gain maximum efficiency.¹⁴

This type of information, contained largely in appendix 5 (the performance sections) will be made into educational materials arranged by cell type and by application. There will also be generic materials on how to get the most out of batteries. Point-of-sale signs and pamphlets, advertisements and PSA's, news stories and school presentations will contain educational information on usage tips, substitutes, reduced use and proper disposal appeals. As with most hazardous material uses, choices can be made in battery use to lessen the effects of their disposal. The usual waste management hierarchy, *"reduce consumption, then reuse, finally recycle"*, applies.

¹⁴For example, many people buy alkalines for low power uses, e.g. flashlights or smoke detectors, when the older C-Zn type can deliver the same amount of energy for less cost.

Ch. 1: METALS IN MISSOULA LANDFILL

INPUTS OF HEAVY METALS

Estimate of heavy metals from batteries entering Missoula's landfill:

Pb	20,000 lbs.
Cd	1,450 lbs.
Hg	72 lbs.

lead

Nationally about 65% of lead in municipal solid waste, bound for incineration or landfills, comes from batteries¹⁵ (Franklin Assoc.). Despite increased recycling levels of Pb-acid batteries since the early 1980's,¹⁶ the amount of lead from batteries in the waste stream is expected to increase by some 9% to 182,000 tons in ten years. More than 99.9% of this lead apparently will come from wet-cell vehicle batteries, while 101 tons is projected to come from gelled Pb-acid cells used as competition to NiCds in cordless appliances and consumer electronics.

Based on 1990 national consumption levels and interpolated for the 100,000 people (Leiter) currently served by the Missoula landfill, 61 pounds of lead a year enter the Missoula landfill from gel Pb-acid batteries with a gelled electrolyte that are a substitute for NiCds. The national

¹⁵TV picture tubes are the other main source of lead in the solid waste stream, 85,000 tons by year 2000.

¹⁶When low market prices for lead combined with new hazardous waste regulations for lead recyclers.

101 ton figure seems low and may not account for the recent rapid growth in gelled Pb-acid use. Assuming, for arguments sake, that 1 million appliances containing 2 pounds of lead in their batteries will be sold annually, 800 pounds a year of lead from gel Pb-acids would be entering the Missoula landfill in years to come. Somewhat less cadmium from NiCds would enter as they compete with NiCds. Total cordless appliances sales are still growing rapidly, however.

Assuming the current national recycling rate of 85% for vehicle Pb-acids applies to western Montana, 19,700 pounds (9.85 tons) are entering from this source. This indicates the largest input by far of a heavy metal into the landfill, despite the high rate of recycling. Probably some of these batteries are in abandoned and unused vehicles and in garages, lowering the 9.85 ton figure.

cadmium

Seventy five percent (75%), or 2,035 tons, of cadmium in the national municipal solid waste stream will come from batteries¹⁷ by year 2000 (Franklin Assoc.), a 30% increase from current levels caused by a 110% increase in NiCd battery production. According to the assumptions made above for lead, 1,250 pounds of Cd a year enter Missoula's landfill from NiCds.¹⁸ Again, it is likely that somewhat less actually is landfilled, due to stockpiling of old appliances.

Alkalines reportedly contain between 0.04 g (AAA size) to

¹⁷Other sources of year 2000 solid waste stream cadmium are pigments in plastics (384 tons) and electronics (100 tons).

¹⁸A 10% reduction in the amounts entering the landfill might be made for Montana's lower income level and probable lower consumption level.

0.53 g (D size) cadmium per cell (Haight et al.), possibly as a result of cadmium being closely allied with zinc in geological deposits. This additional 250 pound annual load¹⁹ to Missoula's landfill is in the estimate.

Mercury

By contrast mercury use in cells is down to 15%, or 276 tons, of all 1989 US mercury consumption (Balfour). This level will fall further as mercury is eliminated from batteries and if production of button size mercuric-oxides is phased out. Of the remaining larger cylindrical mercuric-oxides, 60% are used by the military (NEMA) and generally do not end up in the *municipal* solid waste stream. The 25% of these used by hospitals and the 15% used by industry (NEMA) represented 43 tons of mercury nationally in 1988 (NEMA) and 35 pounds entering Missoula's landfill. It is possibly some institutional users recycle these batteries through their distributors however. Missoula's hospital's have incinerators, or use their contracts with medical waste firms. Their mercuric-oxide cells may pose a hazard through other routes than the landfill.

As long as button mercuric-oxides are still being manufactured, and while alkalines and C-Zns with 0.5%-1.0% mercury are still entering the waste stream, up to 37 pounds a year will enter the landfill. A little mercury is still used in most button cell types, probably less than a pound of mercury a year to the landfill.

notes

These metal inputs do not include industrial or military

¹⁹Calculated as there being 5 times as many alkaline as Nicd cells, each containing 1/20th the amount of cadmium as a Nicd.

wastes (Franklin Assoc.) that find their way into municipal solid wastes.²⁰ Additionally, the population served by the landfill, and the amount of trash heading to it, is growing rapidly as new stricter federal regulations on the siting, operation and closing of landfills are being phased in, forcing small undercapitalized landfills to close.

Disposable alkaline, C-Zn and zinc-air cell use is growing rapidly but the compounds in those cells are found in very small quantities or are not particularly hazardous. However mercury free consumer batteries are only this year being phased in. Declining amounts of mercury from disposable alkaline and C-Zn will continue to enter the waste stream for two more years.²¹

HYDROGEOLOGY AND POSSIBLE METAL MOBILITY

hydrogeology

Missoula's landfill is situated on the first foothills rising from the Missoula valley floor immediately north of Interstate route 90. These foothills almost completely surround and differentiate the Missoula valley and its

²⁰The inputs are calculated from the market size and share of each cell type and size multiplied by the metal content and the percent left after recycling.

²¹The amount of a heavy metal in a single cell will vary not only with its size but with the type of cell. NiCds, 10-15% cadmium by weight, contain from <1 gram (g) cadmium in buttons, to 1-12 g in consumer sizes, to 10-100 g and more in most appliances, with industrial use NiCds containing much more. Sealed Pb-acid batteries, 80% lead, have 50-500 g of lead, more if extra-large. Vehicle (wet cell) Pb-acids about 8,000 g. Mercuric oxides, 30-40% mercury, have from <1-5 g mercury in buttons, 8-30 g in consumer sizes. Amounts are expressed per cell for consumer and button sizes but per battery pack for other sizes.

aquifer, which exists in the sediment material of the valley floor, from the geology of the landfill. The soil profile at the landfill shows little organic matter. It is composed of fine silt, sand, pebbles, rocks, boulders and a few lenses of clay.

There are apparently two groundwater units at the landfill. One unit, with a gross permeability (porosity) on the order of 10^{-3} cm/sec., is in the sediments of the ephemeral drainage that bisects the current active area and the area now in preparation for use.²² The second unit, with a permeability about 100 to 1,000 times slower, or around 10^{-6} cm/sec., is above this drainage on both sides (Chen-Northern 1987). Groundwater flows in the direction of the Missoula valley.

The Missoula valley aquifer (south of the I-90 and the landfill boundary) is confined and somewhat isolated by the different geology of the foothills rising out of the valley, but its exact boundary near the landfill has not been determined. There is some measured movement of groundwater from the landfill to the main aquifer, whose water table is 80 feet lower (Chen-Northern Sep. 1992).

Groundwater is scarce at the monitoring wells drilled downgradient of the fill area that are adjacent to, but not in, the sediment drainage. The downgradient monitoring wells drilled off the landfill property, south of the interstate and in line with the more water producing drainage at the landfill, also produce little water. Chen-Northern assumes

²²The new fill area, due to come on line soon, will have a plastic and 60 mil bentonite liner that should retard metal migration. The EPA says that all liners will fail to some extent over time, depending on physical stresses and waste composition.

the more productive sediment drainage in the landfill is confined, on evidence of lower observed porosities in other areas and the shallower water table in this drainage. The very steep groundwater gradient from the landfill system to the system south of the interstate is thought to indicate impermeable material and/or a completely separate system (despite detection of some groundwater movement between the two). Insufficient wells exist to fully map the flow of water from the more productive ephemeral drainage. This polluted water carries most of the fill area's leachate.

heavy metal levels in groundwater

A major flood over frozen ground in February 1986 infiltrated garbage,²³ leading to elevated dissolved metal measurements including cadmium in exceedance of SDWA maximum contaminant levels (MCL's) for drinking water. Cadmium has continued to exceed its MCL, 10 ppb, at the monitoring well in the porous sediment drainage at the foot of the fill area, from 20 ppb after the flood to below detection levels by 1988, back up to 12-13 ppb by 1991 and 1992 (Chen-Northern Sep. 1992). There have been two measurements (lead and mercury) slightly above detection levels at wells at the foot of the active area, prior to the flood. A far downgradient monitoring well south of I-90 in the relatively impermeable zone has not detected the three metals except cadmium once recently, at the detection limit of 5 ppb.

In sum, elevated measurements of these three metals are most common in the monitoring well immediately below the fill area and in more porous soil. Cadmium measurements here continue to be elevated after the slug of contaminants

²³After this BFI built a diversion to channel surface water on partially frozen ground away from the active fill area, and presumably is doing the same for the new fill area.

presumed to be caused by the flood in 1986 passed, and there has been one detection of cadmium beyond the boundary of the landfill (which may be associated with the flood event). Mercury and lead have only been detected once each apart from the flood slug. For now metal contaminants seem to be attenuated as they both disburse and encounter less porous soils in the foothills. Continued metal inputs, the presence of contaminants in the groundwater system associated with the main valley aquifer, and the lack of a complete monitoring system all make it possible that heavy metals (whose main source is batteries) may contaminate the drinking water of the Missoula valley aquifer.

metal mobility

(See appendix 4 for discussion of metal mobility at landfills, mobility is caused by the metals being in a water soluble form). A lack of organic matter at Missoula's landfill may prevent metals from solubilizing, but the lack of clay ligands increases the probability. Heavy metal immobilizing iron and manganese hydroxides are probably common, but only at redox boundaries such as the top of the low oxygen zone of the garbage fill area. Metal oxides are soluble and mobile at natural (6 to 8) pH's, the general pH of Missoula's landfill groundwater.

The monitoring well at the foot of the active fill area in the ephemeral drainage, where most metal contamination has been measured, shows typical reductions of dissolved oxygen and increases in temperature that indicate microbial degradation of organic matter (garbage), as well as other indications of polluted water. It has an average pH of 6.5 over the years (the landfill's upgradient background levels well showing an average of about 7). The low pH doubtless is causing some amount of metals to solubilize and move as pH is the largest factor in metal mobility.

This well also shows very reduced levels of sulfate, between 0 and 10 ppm, compared to background levels of 50-130 ppm. This may support the idea that there are insufficient levels of sulfur inputs in the garbage to immobilize metals as sulfide precipitates, though it may also mean that sulfide precipitating ions are just not being measured.

Ch. 2: WASTE AND COLLECTION LAWS

CURRENT AND PENDING HAZARDOUS WASTE REGULATIONS

rcra

(generally, title 40 CFR, parts 260-270, 1991 ed.)

Under the Resource Conservation and Recovery Act, RCRA, the nation's basic solid and hazardous waste management law, generators, treaters or storers of any defined hazardous waste in amounts greater than 100 kg/month²⁴ are subject to a set of "cradle-to-grave" treatment, transportation, storage and disposal regulations. Handlers of greater than 1,000 kg/month are subject to an even more restrictive set of regulations. Importantly, if the regulated waste is mixed with a non-hazardous substance, such as water to dilute, the whole batch normally is considered hazardous.

Certain compounds in solid form--including the metals of most concern in battery management--cadmium, lead and mercury--are specifically listed hazardous wastes under RCRA²⁵ and are regulated if treated, stored or generated in quantities greater than 100 kg/month and if, after an extraction into solution procedure,²⁶ they are found in a

²⁴ 100kg = 220.5 lbs, about 2/5ths of a 55 gal. barrel.

²⁵To be regulated, wastes need not be listed by name, they may exhibit defined characteristics of toxicity, corrosivity, ignitability.

²⁶The toxicity characteristic leaching procedure (TCLP, pronounced "tea clip").

concentration greater than:

lead	5.0 parts per million (ppm)
cadmium	1.0 ppm
mercury	0.2 ppm

(One ppm, a mg/liter, corresponds to .0001 of 1% (.0001%) concentration)

According to industry, the new low mercury alkalines and C-Zn cells do not test toxic under the RCRA toxicity leach procedure for their metals content. EPA has not done the metal leaching test itself but tentatively accept the industry's data (EPA Mar. 1992). *Consequently collection of these type cells from even small and large quantity generators (greater than 100 and 1,000 kg/month) is not currently RCRA regulated.* The required state of the battery in the test--whole and uncorroded or partially crushed and leaking-- is a major determinant in its outcome.

The highly alkaline or acidic electrolyte of batteries might make them fail the RCRA corrosivity test and also be regulated as hazardous wastes if they are collected, stored or handled in quantities greater than 100 kg a month. No collection program is known to have indicated this problem.

A ban on disposing certain listed hazardous wastes on land, including some heavy metals such as some forms of mercury, was passed in the 1984 amendments to RCRA (the mercury ban went into effect in May of 1992). The land ban prohibits disposal even in licensed hazardous waste landfills. While elemental mercury, for example, is land banned, mercuric-oxide batteries, in sufficient quantities to be regulated, may not be. Several new mercury reclamation companies that are accepting these batteries indicates they may be.

The RCRA regulatory state of battery collection is in flux.

In August 1990 the EPA apparently provisionally declared that spent NiCds (in quantities greater than 100 kg/month) are a regulated waste (Electrical World). On the other hand, an exemption to RCRA regulation has been granted to the wet cell Pb-acid recycling industry, on the reclamation rational, to encourage recycling.

Some wastes can be exempted from RCRA regulations, or their regulatory burden reduced, if they are reused as their original use or if a component constituent is reclaimed for reuse, e.g. mercury or cadmium. NiCd and mercuric-oxide batteries are reported to be RCRA regulated as useful secondary materials, not as hazardous wastes (DRMS).

Anyone storing RCRA hazardous wastes for longer than 6 months, or storing such wastes *generated off-site* for even an hour, must obtain a RCRA Part B permit, under which the most restrictive RCRA regulations apply (Part A permits are routinely granted to hazardous waste generators). This might apply to a battery collection program. RCRA does allow temporary "speculative accumulation" of recyclable (non-waste) hazardous materials beyond the storage limits (DRMS). This is to give recyclers flexibility in finding markets.

EPA has for several years been discussing a "universal waste" regulation (similar to the one that has been granted to the lead-acid battery reclamation industry) applied to discrete, ubiquitous wastes such as motor oil and batteries, to encourage their recycling by making them exempt from these regulations.²⁷ The worry is that large quantities of

²⁷Apparently named "Modification of the Hazardous Waste Recycling Regulations: Universal Wastes". A notice of proposed rule making date is listed as '11/00/92'. Its tracking RIN # at the EPA is 2050-AD19, contact is Mitch Kidwell OS-332 US EPA 401 M St SW wash DC 20460, tel: 202-260-8551.

heavily contaminated wastes would be illegally disposed of through these unregulated channels. In the meantime recycling efforts for these common household hazardous wastes have lagged as recyclers hesitate, not knowing if their business will be heavily regulated or not. The exemption rule is stuck in Office of Management and Budget review prior to public commenting (NEMA, Weinberg).

EPA is to clarify whether cells collected from conditionally exempt small quantity generator (CESQG) sources (less than 100 kg/month), and households (which are completely exempt no matter what their quantity) that are stored in large enough quantities (> 100 kg/mo.) to be RCRA regulated; will nonetheless be exempt from those regulations (Dry Cell). Several hazardous waste programs currently operate under this exemption, including the many small units of Region 1 of the US Forest Service here in Missoula (McNenny).

EPA has this year interpreted RCRA to mean that RCRA wastes collected from both unregulated CESQG's and regulated generators will not be regulated after being mixed (HHWMN Aug. 1992). This decision may apply only to household hazardous waste collection days but probably does not. Municipalities can operate under the exemption (Gansecki).

RCRA regulations cover transportation. A generator, treater or storer of regulated quantities of RCRA wastes must have an EPA ID number (Part A permit) to ship them, and is responsible for maintaining the manifest that accompanies the waste to its final disposition, detailing its complete transit history. Most states exempt SQG's (100-1,000 kg/month) from manifest requirements though hazardous waste shippers may require them.

hmta

(generally, title 49 CFR, parts 171-180, 1991 ed.)

The Hazardous Materials Transportation Act (HMTA) of 1981, administered by the U.S. Department of Transportation²⁸ (usually directly if it is interstate transportation), works in conjunction with, and in addition to, EPA's RCRA shipping regulations for waste. The HMTA universe of regulated hazardous materials (substances and wastes) includes RCRA, Superfund and other wastes. Both the shipper and carrier of an HMTA listed material are responsible for a set of training, packing, labeling, handling, vehicle routing and package durability regulations, depending on the dangerous property class, 1-9, of the material.²⁹ There are three packing group standards, in decreasing order of hazard (I-III) covering most classes. An alphabetized hazardous materials table (49 CFR 172.101-102), cross-referenced with the U.N. classification³⁰ (49 CFR 172), gives this and labeling, transport mode and quantity limits information for most regulated items.³¹

²⁸Office of Hazardous Materials.

²⁹Explosive, gas (flammable, poison or non), flammable liquid, flammable or dangerous when wet solid, oxidants and peroxides, poisonous and infectious, radioactive, corrosive, miscellaneous); or no class (forbidden or other regulated material--ORM).

³⁰HMTA is apparently being revised to be fully compatible with the international regulations.

³¹An appendix (49CFR172.101 app.) gives a reportable quantity (RQ), or a solution concentration of the RQ, that qualifies certain hazardous material as hazardous substances, subject to additional requirements. The RQ applies per package shipped. The RQ for mercury and lead is 1 lb, for cadmium 10 lbs, for nickel 100 lbs., and for zinc 1,000 lbs. The RQ for not otherwise specified (nos) corrosive, such as KOH, and reactive substances is 100 lbs. The RQ for items listed in the table but not in this appendix is apparently 5,000 lbs. The

It is assumed that shipped waste batteries will be HMTA regulated if their hazardous constituents are listed in the table, e.g. "cadmium compounds", "mercury", "mercury-oxide", "mercury compounds, solid, n.o.s.", "lead dioxide", "lithium battery, solid cathode", "potassium hydroxide, solid". There is an entry (for corrosivity) for "batteries, dry, containing potassium hydroxide solid, electric, storage", which seems to cover all dry-cell batteries with KOH electrolyte (alkaline, NiCd, NiMH, some mercuric-oxides and lithiums). The only other specific dry-cell battery entry is for lithiums, due to lithiums' extreme reactivity.

Despite these seeming stringent requirements, few collection programs indicate they ship according to HMTA rules. Except for lithium cells, no reclamation companies seem to be requirement HMTA rules for different cell types. Communications with the DoT (Weiss, Tarr) and reclamation companies and local hazardous waste shippers was insufficient to clarify the matter. Many people seem to assume the RCRA shipping requirements, from which households and generators of less than 100 kg a month are exempt, are the applicable transportation rule. Collection programs around the country ship via UPS and common carrier.

Batteries without hazardous metals, such as the new mercury free alkalies and C-Zns, may qualify for an exemption granted to class II corrosives (i.e. the KOH electrolyte), allowing up to 30 kg per package (5 kg per inner package) to not meet certain package strength, labelling and placarding requirements.

listed RQs are taken from Superfund, and include RCRA listed and characteristic (ignitable, corrosive, reactive, toxic).

Wet (with their electrolyte) electric storage batteries are exempt (49CFR173.159(e)) if transported by rail (part 174.810) or road (part 177.839(c)) alone, with terminals protected from short circuiting, and properly braced. Waste button lithium cells are exempted (49CFR173.185(j)) if they are packaged in "strong"³² outer packaging, their terminals protected from shorting, and do not contain more than 12 g (0.42 oz.) lithium (Reutlinger, CFR).

osha

The 1970 Occupational Safety and Health Act, administered by the Occupational Safety and Health Administration (OSHA), covers a very wide range of workplace safety rules, including exposure to hazardous materials. Operations with few employees are usually covered to some extent. A communication with a local office indicated that no specific OSHA regulations exist specifically for battery recycling (diTommaso). Applicable regulations for an operation with employees would include ambient air concentrations of hazardous materials, personal protective equipment, machine maintenance and materials labeling.

OSHA also maintains the chemical hazard communication rule that requires manufacturers of hazardous chemicals to notify any employee (of any company that will handle the materials as they are sold and used, who may come into contact with them) of the hazards.³³ Manufactured products such as

³²Conforming to 49 CFR part 173.24 but not to the greater requirements of part 178.

³³Done through training, labeling and material safety data sheet, or MSDS. Data must include a contact; acute, chronic and other health effects, including suspected carcinogenicity; exposure limits; and basic safety and exposure procedures.

batteries must have them. They are useful for determining the hazardous constituents of batteries and certain basic safety precautions.

superfund

There is no RCRA-like small quantity generator exemption from the strict--i.e. no need to prove negligence--and wide ranging Superfund (CERCLA) liability for helping create toxic waste sites. EPA has been discussing the possibility of such a rule, again to encourage legitimate recycling, but has not drafted one. Meantime this is a legitimate business worry.

Parties determined by EPA to be responsible for pollution at a Superfund site are also jointly and severally liable, i.e. any one party has unlimited liability for other liable parties. A rule has been discussed to limit the liability of municipalities, generators and transporters that send hazardous substances to a future Superfund site to 4%, which could be paid with in-kind services (Weinberg).

CERCLA also requires reporting to the National Response Center purposeful or accidental releases of listed hazardous compounds above their Reportable Quantity (RQ). EPA has just proposed lowering the RQ for lead compounds to 10 pounds (Weinberg) as part of its touted war on lead exposure.

CURRENT/PROPOSED STATE, NATIONAL COLLECTION LAW

Current state legislation concerning dry cells falls into approximately 5 categories:

- reduction in heavy metal content
- labeling on batteries in appliances that are built in, along with making these appliances so that the batteries can be removed by the consumer,
- cell collection information at point of sale or with appliance,
- reclamation or proper hazardous waste disposal requirements,
- solid waste landfill or incineration bans.

Several states (MN, NJ, OR, CT, NY and VT; at least) have passed mandates in some of these five areas (EPA Mar. 1992). *As a result industry has begun to adopt them on a national level, especially reducing the mercury content of the common alkaline cells.* The four manufacturers in the US of consumer alkalines--Duracell, Eveready, Rayovac, and Matsushida (which manufactures Panasonic and Kodak cells)--will be mercury free by the end of 1992 or sooner. Button cells, will still contain small amounts of mercury (Balfour). Manufacturers' use of mercury has declined from 1100 tons (55% of U.S. mercury consumption) to 276 tons in 1989 (15% of consumption in 1990) (Balfour), and will drop more as mercury in alkalines is eliminated, leaving mercuric-oxide cells as the industries' sole user of mercury.

Mercuric-oxide and NiCd cells, with their high heavy metal content, would fall under recently proposed legislation (S. 2579, 102nd Congress) that covers all five areas listed above, and would require coding on cells for easy separation. Manufacturers would have to accept cells from collection programs and would bear the costs of reclamation or proper hazardous waste disposal. They would also have to advertise at point of sale that a "convenient" recycling method is available. Either the appliances or the cells (or

battery packs) would have a label to the effect of:

"NICKEL-CADMIUM (OR SEALED LEAD-ACID) BATTERY. MUST BE DISPOSED OF PROPERLY. (manufacturers name, possibly toll free telephone number or address)".

The bill was written with the participation of the dry-cell battery industry and is fully supported by the industry. It was marked up into the current draft of the RCRA reauthorization bill in the Senate with the approval of industry, and has an excellent chance of being passed in 1993 when the new congress reconsiders RCRA reauthorization.

Ch. 3: PROPOSED COLLECTION PROGRAM

This chapter contains a description of the necessary elements to establish a collection program. Costs are discussed in chapter 5.

GENERAL

Mixed batches of cell types complicates reclamation. Even a single cell type contains a mix of compounds. Even more than with other recycled materials, pre-sorting of different types increases their value. However consumers are generally unaware of the different cell couples (Ni-Cd, Zn-MnO₂, etc.). Some of the cells proposed for collection will generally come from users who generate a single unmixed type, but collection of other types will require some education of users to increase the level of pre-sorting.

Depending on available resources, collection sites for NiCds, gel Pb-acids, buttons, mercuric-oxides and lithium cells will be proposed for high traffic public areas such as the public library, the County building, etc. Retail stores that sell cells are ideal locations as consumers will have had batteries, and possibly the hazards of batteries, in mind as they go to make a battery purchase.

Since alkalines and C-Zns will still be contributing about half the mercury from batteries to the landfill for the next

two years,³³ cells of these types inadvertently collected should not be thrown back in the landfill; for two more years anyway. As no companies accept them for reclamation of their metals, most collecting communities send them to burial in hazardous waste landfills. Charges for disposal roughly equal the cost of reclamation of metals from cells. Depending on resources, expansion into proactive collection of these two cell types (that account for nearly 80% of the number of cells disposed), with a full scale promotional effort, could take place for the first part of the two year interim. If resources are immediately lacking for proper disposal of these two types, incidentally collected ones will be stored. Other programs have collected large numbers of stored-up cells of all kinds at the beginning of their collection efforts. These alkalines and C-Zns will be old, corroded and contain mercury.

Lithium cells (Li), becoming more popular because of their very high (~3 volts) power output, are targeted for collection. Lithium is extremely reactive, and Li cells often contain a variety of hazardous solvents, electrolytes and cathodes (see appendices 2, 4) and because there is at least one existing market for their neutralization. They will be collected at specialized retailers, generally in conjunction with the collection sites for button cells, and at general public collection sites, as resources allow.

As resources allow, individual (non appliance) NiCd cells will also be collected from retail locations for reclamation.

Distributors of cells to drug stores, supermarkets and other

³³The length of the manufacture to disposal cycle from the date of full scale production of mercury free cells, 1992.

retailers are being contacted through the Missoula Chamber of Commerce to help determine the largest retailers, or specialized cell type retailers, to aid in setting up the public collection sites.

There is a danger of ingestion by children, *especially button cells*, if collection bins are uncovered. Yet covering storage containers tightly creates an explosion danger and toxic vapors (EPA Mar. 1992). Bins will have to be well vented but secure, e.g. with one way slots.

Fast food restaurants and other popular retailers will be given the opportunity to offer coupons for their products for a given amount of batteries collected by students, scouts, as well as disadvantaged workers e.g. those employed by Opportunity Industries. These and other community service groups will be contacted to help out in the collection effort.³⁴ They can be employed in collecting and sorting cells from homes and public collection centers such as schools or supermarkets. They can also be employed in sorting and packaging batteries for shipping.

Graphical representations at collection sites (Smith) and in promotional materials will help users easily identify the cell types accepted (e.g. NiCds, buttons, mercuric-oxides, lithiums, Pb-acids) and those not accepted (e.g. alkaline, C-Zn). This effort will increase cell value, ease sorting logistics and lower costs.

Possible future inducements to recycling of hazardous cells include return deposits and rebates for battery exchanges. Deposits would have to be set higher for rechargeable cells

³⁴Missoula's volunteer service coordinating agencies, such as RSVP, U. of MT's V.A.C.; will be contacted for help.

because they stay in use long enough for the deposit to be forgotten. Some rebates already exist for rechargeable cells. They would work well with the proposed reverse distribution collection system proposed by industry for cordless appliance rechargeable.

BUTTON CELL COLLECTION

The share of silver-oxides in the button cell market has dropped from 14% in 1981 to 2% in 1987 (Balfour) and will continue to fall as the new zinc-air cell technology takes over--despite its characteristic of constant decrease in power output over time. Less than one million silver-oxides were expected to be sold in 1990, or only 300 in urban Missoula. Though the most valuable cell, due to its silver content, its decreasing market share has apparently deactivated several reverse distribution collection programs such as the American Watchmakers Institute's.

As noted earlier, mercury-oxide button cells may be eliminated by manufacturers by 1996 and be replaced by Zn-air buttons. Their current plan, based on requirements passed in a handful of states to collect mercuric-oxide cells (chapter 2) is to set up and finance an interim national button cell collection program with drug stores, photo shops, etc. mailing in their small containers to a regional storage facility (NEMA). As mercuric-oxides have a more constant power output than zinc-air, it may be that they will continue to be manufactured. On the other hand, zinc-air cells continue to gain market share from mercuric-oxides.

With the small production of silver oxide buttons, the elimination of button mercuric-oxides, and the negative

market value and low toxicity of used zinc-air buttons it does not seem the manufacturer's collection program is designed to last beyond the purported phase-out of button mercuric-oxides.

Any nationwide industry collection program could be strengthened in Missoula by setting up additional collection sites, especially at specialty retail shops such as jewelers, watch makers, photo shops, and the electronic gear sale areas of drug stores and other general merchandise retailers. There is at least one active button cell collection program, however.³⁵ The proposed national program can also be enhanced by distributing information to aid the separation of button cell types, and generally assisting consumers with their inquiries.

According to Perez, the color of nylon grommet visible around the top of button cells indicates the cell type, though the code is perhaps not followed by every manufacturer. Most button cell collection programs apparently turn in buttons unsorted while reclamation companies pay a premium for sorted button cells.

Button cell coding scheme

Yellow	low discharge rate merc-oxide
Blue	high rate mercuric-oxide
Clear	low rate silver
Green	high rate silver
small hole on bottom	zinc-air
???	lithium, alk., etc. buttons

³⁵Associates for Hearing and Speech, tel. 549-7040.

LARGE (CYLINDRICAL) MERCURIC-OXIDE COLLECTION

More than a third of mercury used in batteries goes into large³⁶ cylindrical mercuric-oxide cell production for use by industry, the military and the medical community. These generators of waste cells fall under the RCRA regulations if they generate greater than 100 kg/month of any RCRA defined hazardous waste. As a result they must manage their mercuric-oxide batteries (which presumably fail RCRA's TCLP toxicity leaching test because they contain ~35% mercury) along with their other hazardous waste, and are limited in how they dispose of them.

A large hospital may use 250-1,200 cells a month, generating 10-47 lbs of mercury a month,³⁷ depending largely on the number of their cardiac care beds. The use per bed seems to vary greatly, from less than 1 a month to 30 a month (adapted from Price).

Both hospitals in Missoula have, or have had in the past, state issued incineration permits that allow incineration of medical wastes (including large amounts of plastics) on site, despite being in the middle of the urban area. It is also possible that batteries may have been mixed in the infectious and pathological waste streams that ended in incineration, thus volatilizing their toxic metals in an urban area. Currently both hospitals are using BFI Inc.'s medical waste service. Which waste stream--infectious, pathological, solid waste--mercuric-oxide cells and other types are ending up in needs determining.

³⁶ E.g. 9 V, D size; and larger battery packs.

³⁷ At 35% mercury content for a 1.8 oz. cell.

Hospitals in Broward Co. FL, because their municipal waste was going to incineration (Price), have switched their 8.4 v mercuric-oxide battery packs to zinc-air cells, which last longer despite not having a constant power output. *Cardiac monitors that get frequent use apparently can have their batteries replaced before power in the zinc-air drops off. Hospitals would also save money by switching, considering the lower price of zinc-air cells and the large volumes of mercuric-oxides used.*

As with collection from commercial and industrial users, distributors will first be contacted to help determine the largest users of mercuric-oxide cells. Hospitals and industrial/commercial users will in any case be contacted to determine their volume and disposal practices, including any current recycling of mercuric-oxides. This is another well segregated single cell type waste stream.

COLLECTION FROM COMMERCIAL/INDUSTRIAL GENERATORS

Commercial/industrial sources often generate large, homogenous quantities of batteries at a single location. Potentially large quantities of toxic metals can be kept from the landfill. The most commonly used types are Pb-acids and NiCds.³⁸ Individuals from both Montana Rail Link and the U.S. Forest Service (USFS) Regional Office have, unsolicited and before the proposed program received publicity, contacted this author with concerns about their waste batteries, indicating some level of concern in the

³⁸Some cell couple types used in railroads (possibly Ni-iron?) have a liquid alkaline electrolyte. Diluted, the spent electrolyte can be used to precipitate (recondition?) cleaning solutions (what types? Russian railroads idea, check with MRL, Burlington Northern).

community about the large quantities of non-consumer waste cells being generated.

The yellow page index and the blue pages of the Missoula phone book show these potential commercial/industrial generators:

- USFS, Post Office, FAA & NWS, GSA, Ft. Missoula, BLM
- State Dpts: Lands, Highway, Transp'tn, Disaster/Emerg. Svcs.
- Msls Co. Road and Sheriff Dpts, Disaster & Emerg. Services
- City Engr, Fire, Parks & Rec, Police, Sewer & Street Dpts.
- St. Patrick, Community Medical Center hospitals
- Stone Container, Washington Corporations
- Mountain Water Co, Montana Power, US West
- Mountain Bus Line, Beach Transportation
- Montana Rail Link, Burlington Northern
- truck companies, couriers and express delivery companies
- telecommunications (2-way radio, cellular, eqpmt. back-up)
- retail stores
- office machine sales and repair
- photography, A-V, large and small appliance sales & repair
- electrical equipment sale and repair
- machine shops, power tools, generators, pumps
- general contractors, construction companies
- mining, oil & gas exploration companies

The following companies are listed as suppliers of batteries (non-vehicle):

- Exide Corporation
- Northwest Distributors
- Okies Electric & Machine
- Ax-Men Battery Discount Center
- Mincoff Ignition & Motor Parts
- Quality Supply Inc.
- Battery Supply of Missoula
- Interstate Battery Systems of Helena
- Missoula Auto Electric.

These wholesale suppliers can help reveal the general pattern of cell distribution--who uses the most of which types locally. They may also provide contact individuals

with the commercial/industrial generators.

If the companies, due to their volume of hazardous wastes, already fall under RCRA regulations for hazardous waste management, there is an incentive for them to have the cells' metals reclaimed. Hazardous waste disposal costs are roughly the same or more than shipping to a reclaimer, or more if payment is received for the cells. Recycling these cells may actually lower their costs.

RECHARGEABLE APPLIANCE BATTERIES COLLECTION

It appears that consumer appliance manufacturers will institute a nationwide reverse distribution system within a year or two because of requirements passed by a handful of states (chapter 2). Returning these rechargeables will be up to the consumer, who, after reading a sign in or on the appliance may (or may not) call a toll-free number for specific instructions on getting the easy to remove battery pack back to the appliance manufacturer, who will be required to turn them in for reclamation. There will be no universal return centers for all brands of battery packs.

The new Portable Rechargeable Battery Association--PRBA, comprised of appliance and battery pack manufacturers, is putting together a four part pilot program to meet Minnesota law and *in anticipation of the national legislation (NEMA):*

1. **Reverse distribution:** an advertised toll free telephone number will advise consumers who will accept their brands' battery pack. If their product or battery brand is made by a PRBA member with a take back program, specific instructions will be given. Products of PRBA members with no specific take back program will fall under a common take-back set of instructions, either a mailing or advisal of nearest retail center for that

brand--the same general system as for companies with their own program. Consumers with products *not* made by PRBA members and with no plan filed with the state the 800 number will take information on that company to notify the state to establish a program by 1994; if it joins the PRBA it may use PRBA's generic collection program. Consumers will be advised to hold these products until the company has a program. News releases, PSA's and press contacts will publicize the program. The recycling infrastructure, public and private, will receive instructions for the batteries they collect.

2. Retail collection: Retail collection points will be geographically spaced to accept batteries from PRBA members brands only. Shipping costs, even for hazardous waste, will be arranged and paid by PRBA member companies. This aspect of collection will also be publicized.

3. Drop-off at rural hazardous waste collection sites.

4. Curbside and other recycling program sites.

Obviously, PRBA member companies do not want to pay for the costs of recycling other companies' batteries. No information is available about ultimate recycling after collection. Apparently only two secondary smelters accept the small cordless appliance Pb-acids.

Gates Energy Products and other manufacturers of appliance battery packs are beginning to shape the terminals of their cordless appliance cells so that primary cells cannot be substituted. This creates an explosion danger when they are recharged. This advance now allows manufacturers to make these cells removable, and recyclable, by consumers (Hogan).

Sanyo and SAFT offer mailback tubes with the sale of their individual cell NiCds, for ultimate recycling in Japan and France. Consumers pay shipping but receive substantial discount coupons for new cells, or a free cell with proof of purchase (Soviero).

Missoula could increase the percentage of returned appliance batteries by publicizing the national program. Some consumers will not realize or have forgotten that their appliances contain hazardous materials. Also, extra merchants could be enlisted in the reverse distribution network, in the same way as with the button cell reverse distribution system.

VEHICLE Pb-ACID BATTERIES

The market price of lead dropped from around 53¢/lb in 1979 to 19¢/lb in 1985 before recovering to 40¢/lb in 1989. New RCRA operating regulations combined with low prices drove many small secondary lead smelters out of business (EPA Jan. 1992). With the recycling rate now back up to 85% plus, battery retailers are able to offer around \$2 for old batteries, as K-Mart is doing (Halverson). Retailers also are developing deposit programs so as to make a profit collecting old vehicle batteries--shipping costs are minimal in a reverse distribution system.

The industry association, The Battery Council International (BCI), supports legislative mandates to require take-back, ban disposal, post signage advising consumers of state law, *and now supports charging a deposit* to consumers buying a new battery without bringing in an old one (EPA Jan. 1992). Thirty four states have new laws on vehicle batteries, a handful require deposits. *If the market price of lead falls in the future, only a deposit system will continue the current high recycling rate because no states' laws have enforcement provisions* (EPA Jan. 1992). Only Rhode Island is collecting data on return rates at various points along the chain.

EPA, under pressure from industry and the Bush administration, recently decided not to require collection of vehicle batteries heading for incineration or landfills, despite the hazards and its touted 'war on lead', because of *current* high recycling rates and the costs of collection. On the other hand EPA has for several years allowed the collection, storage and smelting of batteries to be exempted from RCRA hazardous waste regulations. This also was a cause of the resurgence of recycling Pb-acids.

While the price of lead is high, this program need do no more than remind citizens that almost all retailers are accepting old batteries, and where they can redeem their deposits or collect a fee for turning in undeposited batteries (50¢ each is the current price paid by local recycling marketers and scrap dealers, \$2 at K-Mart, etc.). Since there is no national law requiring take-back (by retailers and wholesalers) and the other features recommended in the BCI model legislation *that legislation and a deposit requirement will be introduced at the next session of the Montana legislature* with the help of the Montana Environmental Information Center (MEIC). A deposit requirement insures that the recycling rate does not drop again to 25% if the price of lead falls.

FLUORESCENT BULBS

Americans use around 500 million fluorescent bulbs a year-- 75% commercially--containing 22 tons (HHWMN Feb. 1992) or 38 tons (Balfour, from US Bureau of Mines data) mercury. Each bulb, including the new compacts, contains only 15-50 mg (5-18 ten thousandths of an ounce) mercury. About 5% of the mercury americans discard annually comes from light bulbs (NEMA). The mercury absorbs electrons from the electrical

current), causing it to emit u.v. light which then strikes the phosphor coating on the tube to finally generate visible light.³⁹

In no way should energy efficient (usually three to four times) fluorescent bulbs be discarded in favor of incandescent bulbs. Electricity generated by burning coal, the most common method, causes the emission of more mercury into the environment as coal contains mercury, often in high concentration.

California, followed by several eastern states have banned the disposal of commercial/industrial quantities of fluorescents. The issue is also being considered in RCRA reauthorization. The EPA Characterization and Assessment Division of the Office of Solid Waste will probably going to begin drafting for public and industry comment a regulation requiring the recycling of fluorescent bulbs (Watson 1992). NEMA, the National Electrical Manufacturers Association, has proposed regulatory or statutory language that would ban fluorescents from incineration (but not landfilling), require labelling as to the hazard, and exempt the recycling of fluorescents from hazardous waste rules (because they sometimes test as toxic under the TCLP procedure (ch. 2).

Fluorescent bulbs are expensive to recycle, around 10¢/foot, or 60¢ and 80¢ per standard tube (Watson 1992). Aluminum bases are usually recovered and recycled. Three companies in California now recycle fluorescents. At least one company accepting mercuric-oxide batteries is planning to build eight lamp recycling plants around the country (appen. 1). Duxbury Associates has a continually updated list of

³⁹The new compact fluorescent bulbs use rare earth phosphors that emit a more natural and warm light.

contacts in the field of fluorescent recycling. This program will track the development of fluorescent bulb recycling to determine whether their collection is feasible.

Pre 1979 fluorescent bulb fixtures may have ballasts that contain PCB's, an extremely persistent and hazardous organic compound. Pre 1988 bulbs had a small amount of cadmium to increase lumen output. Different lamps have small amounts of other hazardous elements for the same purpose and to determine light color.

COLLECTION PROGRAM PUBLICITY

Many avenues will be used to make the community aware of the collection program. Though materials from the battery use education program and from publicizing the collection program will intertwine, the education program is not a subsidiary of the collection program. *It has the broader goal of reducing use of batteries, beyond keeping them out of the landfill.* Outlets for collection program publicity:

- talks and presentations
- media contacts (on-going, to develop stories)
- public service announcements, advertisements
- mailings in utility bills and off school lists
- brochures, posters and flyers at public locations
- door hangers
- cash register tapes, point-of-sale material
- existing distribution systems (Extension Service, Chamber of Commerce, Env. Health Dpt., etc.).

All will be used to inform the public of where to go and what to bring. Contents will include maps of locations, graphical aids to identify different cell types and which are acceptable, telephone numbers and addresses for more information; and exhortations to keep toxic metals from the landfill, to use batteries wisely, to use drop-off sites.

Ch. 4: PROPOSED EDUCATION PROGRAM

The education program on wise battery use will be independent of any form of the collection program and will take precedence over collection for revenues needed after in-kind donations. Education has the broader goal of educating hazardous waste generators of all types of their responsibilities. It will promote (for all wastes) reuse, substitution and reduction before recycling.

CONTENTS

Point of sale signs and pamphlets, advertisements, news stories and school and business presentations will contain educational information on usage tips and substitutes. Also information on collection of buttons, mercuric-oxides, NiCds, Pb-acids and lithiums.

Consumers of cells will need to be aware of the relative hazards posed by different cells, as well as the cell types relative performance characteristics, in order to be persuaded to change their habits. All components of the education program will have goals of reduction, reuse and substitution, or collection and reclamation that correspond with consumers habits during:

PURCHASE:	reduction
CONSUMPTION:	reuse, substitute
DISPOSAL:	collection, reclamation

Specifically, the contents of materials will include:

- cell performance characteristic comparisons
- alternatives and substitutes, maximizing cell life
- hazard potential of disposed cells
- benefits of reclamation.

This sometimes technical information will be reshaped into ready to grasp "nuggets".

Educational materials will not isolate batteries from other hazardous wastes generated by consumers. They will emphasize that the hazards of batteries, and the solutions to the hazards (think, reduce, reuse, substitute, recycle), are part of the overall problem of hazardous materials. Various hazardous wastes (oil, petroleum products, dry cleaning and automotive solvents) are currently recognized by the public as posing a threat to the city's sole source of drinking water (the Missoula aquifer), so the aquifer protection issue can be used to make the link between batteries and other consumer wastes. As a discreet and frequent direct purchase of products known to contain a hazard, consumers seem very aware that their battery use is a problem. From that position it is easier to convince them that they bear some responsibility for other products.

Materials will contain indirect and direct messages that batteries and hazardous wastes are a responsibility of the consumer (both directly and indirectly, through the use of hazardous materials generated to produce what consumers and businesses buy). These messages will then be tied to solutions in the materials for maximum effect.

The public's conceptions of proper cell use (which type for which appliance, how to discharge rechargeables, etc.) has not kept up with the changes in cell technology described in appendix 5 (battery type comparison by performance criteria

section). That and other information on proper cell use contained in this report, will be made into materials, arranged by cell type and by application. It will also be arranged generally, to include usage tips that apply to all or most cell types (appendix 5, general performance tips).

Sophisticated chargers (appendix 5, performance section) for rechargeables and voltmeters will be used by this program. Rather than take a chance on a battery powered machine dying, many users replace batteries on a periodic basis, often while they have substantial capacity and while they are still outputting a constant voltage. Determining a cell's state of charge or discharge is a quick process, and with some education can be instituted into users normal routines. The cost saving potential is large, as is the environmental benefit. This will be a high funding priority.

EDUCATION PROGRAM LOGISTICS

Distribution of materials on wise battery use will be similar to materials publicizing the collection program. As these materials will generally be more extensive they will be available at more public locations rather than be included as a whole in mass mailings. Public sites, especially retail battery sale locations will be favored. Speaker presentations will be emphasized.

Ch. 5: COSTS

The costs of this two part--limited collection, education--battery management program are highly variable, depending in large part on the extent of the collection element. The battery use education program will take precedence over collection should there be a funding shortage.

COLLECTION, TRANSPORTATION AND DISPOSAL COSTS

There are many unknown costs in running a collection program. Handling, storage and transportation expenses can climb rapidly if the batteries must be handled as hazardous wastes (chapter 2). Expenses in other collection programs have included: liability and/or general business insurance, purchase of drums and packing materials, building and equipping safe storage space, hiring trained hazardous waste technicians and publicity expenses.⁴⁰

Spokane disposes its unsorted collected cells to a secure hazardous waste landfill at a cost of only \$89 per 55 gallon drum, including a one time only waste characterization cost (DuBois). This is for shipping and disposal only. Spokane reports total costs, start-up and operating, of \$612/ton, or

⁴⁰A.D. Little, consultants, have determined that a mixed cell reclamation process on the East Coast, with its nearby supply and small distances to reclamation companies, would cost 4.1¢ a cell exclusive of collection costs (Dry Cell, no cost breakdown reported). Japan and several european countries have pilot *mixed cell* reclamation plants, but they need subsidizing, usually with a user fee or uncollected deposits. U.S. has none.

about \$150/drum (for 550 lb 55 gal drums) (DuBois). This is for curbside collection of all cell types including the ubiquitous alkalines and C-Zns, collected with other recyclables (the pro-rated pick-up cost of cells is not included). All types except button cells are sent to a hazardous waste landfill. No revenues are collected but sorting costs are minimal. Without explanation, they project future disposal costs to be as high as \$500/drum.

Minneapolis metro area (Hennepin County) spent \$450,000 (all costs, including surveys and studies) to collect and dispose of 237 drums of all types, including the high volume alkalines and C-Zns, via reclamation and hazardous waste landfill (Oyaas). This cost is \$1,900/drum.

Other collection programs often report costs in the \$300-700/drum range, sometimes with the admission that a contract for disposal had not been planned for because they did not anticipate large volumes of cells (alkalines, C-Zns) not having a reclamation value while still containing mercury. Most of these programs document having to deal with an unexpectedly large number of cells coming from people that have accumulated them for years, not wanting to send them to incineration or a landfill. Collection programs report recovering alkalines and C-Zns at around 80% (Spokane) and 90% (Hennepin Co.) of all cells collected.

The RCRA or HMTA⁴¹ status--hazardous or solid waste--of a shipment is often the largest component in determining transportation costs, which themselves are a large component in proper disposal of hazardous waste. Greater than 100

⁴¹Lithium cells are HMTA regulated, other cells may be if the shipment container has greater than the listed quantity of the heavy metal or electrolyte of concern.

kg/month generation of any hazardous waste requires that it be shipped according to strict RCRA rules and be disposed of in an approved manner.⁴² Most hazardous waste service companies provide a complete service from pick-up and characterization through transportation and final disposal.

All collection programs so far have been able to transport cells to reclaimers by regular surface transport. *This could change depending on EPA or DoT determinations*, but is not likely to. EPA is considering whether to grant an exemption from RCRA regulation for hazardous waste containing compounds such as batteries since they are largely collected from exempt sources (generators of less than a 100 kg/month and households).

Common, non-hazardous, carrier rates to East Coast locations of reclamation companies are around \$45 or \$55 a hundredweight (100 lbs.) for a 250 or 500 lb. load, respectively; cheaper for larger shipments. This is \$157 to \$193 a 350 lb. barrel.⁴³

4th class mail (maximum 70 lb. and 108" combined girth and length) and UPS are cheaper. The US Post Office is considering various regulations to control the movement of various types of hazardous waste, including batteries, (TV news broadcast, 1991).

⁴²Generally incineration, hazardous waste landfill, treatment to make non-hazardous, or reclamation, depending on the waste.

⁴³Though Spokane reports shipping 550 lb. 55 gal. barrels. *Fitting 100 C size cells to a gallon (6 to a cup) works out to 3,500 cells a barrel weighing 350 lbs. Perhaps the Spokane barrels had no overpack, which takes up about 20 gal. of space.*

EDUCATION PROGRAM COSTS

Spokane spent \$28,000 in its first year on education-publicity costs (DuBois). Pro-rated for population, Missoula's cost would be around \$8,000. However Spokane used no volunteer or in-kind donations. Subsequent years would need a certain percentage of the first year cost to keep people aware of the program and to communicate changes in procedures.

Publicity, promotion, printing and media costs of any educational program, such as those of the collection program and the battery use education program, are good vehicles for in-kind donations as they are common costs to most businesses, and the donator can put their name on the printed product.

PROJECTED COSTS AND REVENUES, MISSOULA PROGRAM

See also appendix 8, a copy of the funding proposal.

Additional revenues or services remaining after the costs in fig. 1 (below) have been met will be used to increase collection and disposal of the number of 2 year interim alkaline and C-Zn cells with mercury; or to increase collection sites; or for a storage facility. Retailers and other parties should be interested in supporting, financially or with in-kind services, collection of cells. They benefit from the publicity of being a part of the solution for a problem to which they play a part in, e.g. selling the batteries in the case of retailers (see section below).

Against the costs listed in fig. 1, grants and in-kind

services are being sought, with some success:

-BFI, Missoula's garbage hauler and landfill owner/operator, has agreed to support this program. In addition they may offer their trucks for curbside pick-up of cells, which convenience would increase the participation rate. BFI needs to confirm that hazardous waste regulations won't escalate costs or create undue liability before supporting the collection component.

-Preliminary presentations have been made to the Conservation Committee of the City Council for a grant of \$2,000 to defray start-up costs. Reaction has been positive thus far.

-EPA Region 8 Municipal Solid Waste Program grant was applied for under Recycle Missoula non-profit status, winners will be announced in December 1992. Other possible grants identified so far are EPA environmental education and pollution prevention grants, MT DNRC water grants, Washington Foundation (Missoula).

-Large scale generators of hazardous batteries will be asked to contribute in the cost of reclaiming the cells. If sufficient cells are generated for them to be classified as a regulated hazardous waste generator, it will be cheaper for them to have the batteries reclaimed than to safely dispose of them.

-Retailers of batteries, being a part of the problem, will be contacted for financial support or asked to donate floor and shelf space, and maintenance of collection areas. The Chamber of Commerce has been contacted to secure a recommendation that the project can be beneficial to businesses. Storage of collected batteries conceivably could be at one or various retailers, obviating rental cost.

-Other retailers and businesses will be asked to donate in-kind services such as hazardous waste barrels, fire extinguishers, printing & design; in exchange for publicity, e.g. their name on printed products.

-Manufacturers are also part of the problem, and have already provided technical and specifications; and additional reverse distribution systems for cell collection. They also would benefit from being associated with the program.

-Mountain Water Company bears responsibility for groundwater protection, and could benefit from being associated with the program.

-Integration with Missoula Solid Waste Task Force (MSWTF), Well-Head Protection programs and proposed Water Quality District. The MSWTF is developing a comprehensive solid and hazardous waste management plan that includes elements applicable to this program, e.g. education (including hotlines and point-of-sale) and promotion (such as a local merchant green seal of approval program). The MSWTF will be recommending this program as a model hazardous waste education program when its recommendations are presented to local government for funding. Mountain Water Company and the Health Department are developing funded programs to protect Missoula's SDWA designated Sole Source Drinking Water Aquifer. The Water Quality District will, if approved by taxpayers, collect a water use fee to be spent for aquifer protection. *None of these programs currently specifically provide funds or assistance for a program such as battery management.*

-Recycle Missoula, Inc. has non-profit IRS status to receive discount postal rates (and other retail price discounts such as printing, that are not donated); as well as a truck and several dozen volunteers. Several members have already expressed interest in becoming involved.

-Video production listed @ \$30/hr: Missoula Community Access TV (MCAT) facilities and the services of an excellent producer have been secured, for free if necessary.

-For the tasks listed at \$6/hr, Opportunity Industries, the RSVP program, schools, Scouts and other impaired worker or volunteer labor groups will be contacted. This is an approximate price.

-All labor costs listed at \$10/hr are available free from the author, as necessary.

(fig. 1a) FIRST YEAR OPERATING COSTS

ASSUMES A 15% COLLECTION RATE, NO DONATIONS, NO HAZARDOUS WASTE REQUIRMTS.

general business insurance	\$2,000
collection pick-up, sorting, & packing @ \$6/hr (contract labor) (250hr)	\$1,500
local transportation costs (gas, depreciation, etc.)	\$ 100
barrels & overpacking	\$1,400
fire extinguishers & acid/base neutralizers	\$ 200
rental storage space	\$1,200
reclamation by common carrier of 2 barrels Ni-Cds	\$ 600
reclmtn. by common carrier 2 barrels merc-oxides	\$ 350
reclmtn. by common carrier four 5 gal. button cells	\$ 220
haz. waste landfill 30 barrels alkalines & C-Zns w. mercury ⁴⁵	\$3,600

	\$11,170

⁴⁵@ \$120/barrel, based on Spokane's cost of \$89/barrel, incl. one time waste characterization fee. Alkalines and carbon-zincs are 80% of all cells (aside from vehicle lead-acids). Their manufacture to disposal cycle is about 2 years. The 30 barrels above allows for an initial surge of cells stored at home and the first 9 months of the 2 year cycle, when the most cells with mercury will be in the waste stream. Assumed 15% collection rate excludes vehicle Pb-acids and is 315 cells a day.

(fig. 1b) FIRST YEAR PUBLICITY AND EDUCATIONAL PROGRAM COSTS

production radio & TV spots @ \$30/hr (60 hr)	\$1,800
production printed materials @ \$10/hr (120hr)	\$1,200
printing, brochures, leaflets	\$ 800
point-of-sale signage, 36 locations	\$ 900
printing, one mass mailing to 20,000 homes	\$ 600
mass mailing, 10¢ ea (non-profit rate)	\$2,000
distribution printed materials incl. mass mail @ \$6/hr (65 hr)	\$ 390
arrange cell collection & info distribution sites @ \$10/hr (160hr)	\$1,600

	\$9,290

SUMMARY

This proposed program has two primary goals: to lower the risk to Missoula's drinking water aquifer from batteries containing heavy metals discarded at the landfill, and to serve as a hazardous waste education program. To that end two components of a battery management program have been proposed: a limited collection program for batteries with the most hazardous metals and the highest reclamation value, and an education program on the proper use and proper disposal of batteries.

A secondary goal is to make the information gathered researching the proposal available to others interested in battery management or hazardous waste education. A database of 120 contacts and an annotated bibliography of 150 publications and articles have been assembled; and along with the text of this report, they will be made available through electronic abstracting services.

The dry-cell battery industry continues to be in the grip of technology. New cells and reformulations offer both improved performance and less hazardous alternatives, e.g. the alkaline cell mercury reduction, and the new Ni-MH and zinc-air cells. Meanwhile the battery industry, government, and activists are beginning to deal with the remaining hazardous batteries; as shown by the industry supported appliance battery return program. This is the time to begin involving battery consumers, too.

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appendix 1: BATTERY RECLAMATION

RECLAMATION METHODS

There are two general methods for extracting metals, heat and chemicals. It is a challenge to extract relatively pure, economically sufficient quantities of metals from cells, especially if they are poorly sorted. Most battery reclamation in the U.S. relies on starting with pure batches of cells with high percentages of lead, mercury or cadmium. Dry cells also have the disadvantage of their metals being in a powder or gel formulation with other compounds, while larger vehicle, power application and industrial batteries electrodes are large metal plates, easily dissassembled. These types of battery metals generally have a cost advantage from the reduced energy, typically 1/3 (Dodds) it takes to smelt virgin ores. Often the natural cost advantage is hidden by artificial price signals such as transportation or mining subsidies (tax treatment, etc.) for virgin materials.

Contamination, e.g. 1% alkaline batteries in a NiCd batch (Cadmium Council & Association), can throw off the extraction methods that depend on certain physical parameters of volatility, pH, reactivity, etc.

Japan, which collects mixed cells, has investigated automatic sorting and/or reclamation from mixed batches with a pilot scale plant (Clean Japan Center), recently closed. An interim report found the process economically feasible if it received revenue from the waste battery generators, also depending on spot market prices for the recovered metals.

A new Swiss method (Recytec) vaporizes and condenses metals from mixed batches, followed by shredding, water wash/evaporation and magnetic separation. The non-ferrous fraction then proceeds to electrolysis in an acidic solvent, flouroboric acid, to increase metal solubility, especially avoiding zinc and nickel hydroxide precipitation for maximum electroplating efficiency. Excess hydrogen gas generation from the acid solvent is avoided, and each metal is extracted, by adding the metal fluoroborate of the metal just extracted.

SNAM & SAVAM (largely the Hempel Group company) of France operates a smelting process for recovering metals from NiCds, NiFe's and mercuric-oxides collected from across Europe (David). The NIFE company of Sweden (Anulf) also

pyro-metalurgically recovers cadmium, in open oxidizing conditions (cadmium oxide) and in reducing conditions by distillation.

Economies of scale indicate that collecting unsorted cells, followed by an automatic sorting process, would be the cheapest sorting method. Japan and European countries that mandate collection of various cell types are experimenting with automatic sorting methods based cell density--either x-ray spectroscopy or flotation+other (heavy fraction: mercury, lead-acid; medium fraction: NiCd, alkaline; light fraction: lithium, C-Zn) methods. Electrical resistance, magnetic inductance and ultrasound response differences also are used to separate cells (New et al.). Machine readable coding systems have been discussed and are being considered by manufacturers.

Higher collection value

type:	use:
Pb-acid	vehicles, cordless appliances
button merc-oxide	hearing aids
button silver-oxide	photo and watches
cylinder merc-oxide	medical machinery
cylinder NiCd	cordless applncs, consumer

Lower collection value

type:	use:
cylinder carbon-zinc	general purpose, consumer
cylinder heavy-duty	" " "
C-Zn cylinder	" " "
alkaline	hearing aids, low power uses
button zinc-air	all sizes and uses
lithium	high power uses, many sizes

Cadmium is apparently expensive to reclaim, so that companies generally do not pay for NiCds despite cadmium's high value (GBB). Zinc too is difficult to extract, and has less value, despite the large quantities available. The large quantities of manganese, also with high value, may not be easily extractable because it is in an oxidized state.

RECLAMATION COMPANIES

**AERC (Advanced Environmental Recycling Corporation)--
Allentown PA: mercuric-oxides, fluorescent lamps.**

Subsidiary of Advanced Env. Recycling Corp. Began operation this year. Handles all types of mercury wastes and other precious metals. Agreement with one of the California fluorescent bulb recycling companies (Mercury Technologies, Inc.) to set up eight bulb recycling plants around the country. RCRA permitted by Pennsylvania.

B.C. Recycling--Salt Lake City UT: all types?

TES company (below) uses BC for the batteries it collects.

BDT, Inc--Clarence NY: Lithium, alkalines.

Has RCRA Part B (a complete TSD--treatment, storage and disposal--permit) hazardous waste permitted facility. Patented shredding and spray/immersion process to neutralize reactive lithium, which is then sent to hazardous waste landfill (*no reclamation*), waste liquids further treated for disposal. No cited violations of hazardous waste regulations by state as of 1992. The new mercury-free alkalines will also be accepted for neutralization of their KOH electrolyte.

Charge \$4-\$15/lb.

Bethlehem Apparatus--Hellertown PA: Mercuric-oxides, 5 gal. minimum, pay for cells.

Electric furnace & condensation recovery followed by triple distillation purification. Have full RCRA (part B) permit. Serve mainly battery manufacturers and industry.

Pay \$770/5 gallon bucket.

INMETCO--Elwood City PA: NiCds, 400 lb. minimum.

Subsidiary of International Nickel Co. (INCO). Rotary hearth furnace after shredding and pelletizing reduces the various metal oxides, submerged arc furnace smelting follows. High temperature process. Use KOH electrolyte to maintain alkaline pH for metals precipitation in their waste water treatment. The cadmium apparently volatilizes and is recovered with other metals from the air pollution control equipment (wet scrubber and baghouse) residue.⁴⁶

There are many other NiCd reclaimers in the US, but they handle industrial size NiCds that are constructed with large individual plates the way vehicle batteries are, to be easy to disassemble.

Applied for full RCRA (part B) permit. No known permit violations. Shipment must be manifested. Serve industry and some municipalities.

Charge \$0.23/lb with \$400 minimum (~1 ton). \$100 min. chemical profile sample (one time).

MERECO--Latham NY: All types, pay for mercury and silver cells.

Lithium cells to BDT, NiCds tentatively to SNAM in France. Silver button cells to *another company or on site?. Alkalines and C-Zns to a hazardous waste landfill. Mercury cells baked, vapor collected by condensation and water trap; further purified with dilute nitric acid.

Mereco was declared a superfund site due to its early activities (it is several decades old). In 1985 it removed mercury contaminated soils. It has been required by the state to add air pollution control equipment and to modify its storm drain system. It has applied for a full (part B) RCRA permit. A recent (1990 or 1991) inspection resulted in only minor record keeping violations; NY DEC feels it is being conscientious. Its new mercury recovery system is designed as a closed loop.

⁴⁶Another process uses ammonium ions to bind Cd and Ni in soluble form to extract 90-99% of Cd and 15% of Ni ((Stevens). An alternative--for industrial size NiCd's--to recovery processes like Inmetco's is to recondition them, generally costing twice the recovery price, about \$1,000/ton (Electrical World) though cost of buying new batteries has to be factored in.

Charges (Apr 1991):

unsorted	\$0.50/lb
alk., C-Zn	\$0.39/lb (haz waste landfilling)
lithium	\$6/lb
NiCd	\$0/lb or varies e.g. \$0.42-.70/lb
merc. ox.	\$1.50/lb ????
silver ox.	Pay 1.05x spot market price

Prices paid will change with market prices for silver and mercury, which are currently low.

NIFE--Greenville NC: NiCds to Sweden, pay

KOH electrolyte removed and purified for reuse. Nickel and Cadmium shipped to parent company in Sweden for closed loop reuse (used to make NiCd batteries). Have full RCRA (part B) permit.

Pay \$0-\$0.70/lb, *depending on volume*. \$100 minimum processing fee.

Quicksilver Products--Brisbane CA: Mercury batteries

Has full RCRA (part B) permit. All types of mercury wastes. Brochure does not mention reclamation method, or batteries specifically.

charge 5 gal. special: \$327, including the waste characterization fee.

Reclamation & Recovery Inc (RRI)--Pecos TX: all types

Major acceptor of batteries from industry including rejects from manufacturers. Claims to recycle or sell within the US all products including plastic and carbon. Lithium processing beginning in 1992. Applied for part A (temporary storage facility) RCRA permit. Attempt to claim battery heavy metals fit EPA definition of scrap metal (non hazardous) in literature. New operation. Planning to ship overseas when possible, probably for landfill or incineration, meaning they are charging much more than most peoples garbage bill. Associated with

personnel from defunct and fined Pacific Environmental Corp. RRI may be former Basalt Industries of Texas, which was connected to employees of Pacific Env.

Charges: \$0.10 (alkalines) to 0.50/lb (discount if over 1 ton), mercury \$2.50/lb.

Universal Metals & Ore--Mount Vernon NY: NiCds to France or Asia; pay.

Serve battery and appliance manufacturers, but take any amount.

pay \$0-0.20/lb, depending on quantity.

appendix 2: STORAGE AND SAFETY

OSHA regulates worker exposure limits of many compounds. The applicability of these regulations to any storage and sorting facility for this program will be investigated.

in Minnesota, Hennepin Counties battery storage facility showed brief increases in airborne mercury concentration above OSHA workplace standards upon opening barrels of alkaline batteries that had been shut for three months (anonymous). *Ventilated barrels and rooms are required* for to meet this hazard in addition to the explosion hazard from H_2 gas.

Sufficient supplies of vinegar and baking soda should be kept on hand to neutralize spills and ruptures of KOH and H_2SO_4 (respectively) if batteries with these electrolytes are stored.

The corrosion of the zinc electrode found in many cell types, which is especially strong in alkaline electrolyte cells, releases H_2 gas⁴⁷ which can build up pressure inside the cell and further weaken it, or present an explosion hazard. Traditionally mercury has been used to react with the hydrogen gas (Tebbutt) to prevent it from reacting with and corroding the zinc electrodes. If the outer casing of the cell is not zinc--as in older standard C-Zn cells--the casing does form a barrier to release of cell contents by corrosion.

Refined lead contains small amounts of arsenic and antimony (and deep cycle Pb-acids cells have antimony added) some of which is released to the atmosphere as hazardous AsH_3 and SbH_3 with the out-gassing that occurs when Pb-acid cells are charged.

Many primary cells will overheat and explode when run in reverse (attempted charging) or short circuited. Charged positive electrodes, e.g. MnO_2 and HgO , are flammable (Arnold). High ambient temperatures increase the fire or explosion risk of many cells.

⁴⁷ possibly: $KOH + Zn \rightarrow 1/2 H_2 + ZnO + K \text{ compound?}$

lithium cell safety

The charged lithium electrode (unoxidized) is itself very explosive in contact with water, acids or oxidizing agents (Arnold), including normal air. Li cells are generally manufactured with exceedingly strong and airtight casings to handle high pressure from the chemical reaction of some types and to protect the reactive lithium. They have a vent safety valve to prevent explosion or rupture. Normally these cells pose less of an H_2 out-gassing risk than other types (Arnold).

Beyond explosion or fire there is a danger of release of the many and various compounds contained in the many types of Li cells. Since water cannot be used as the solvent for the electrolyte paste that is in contact with the lithium salt, many different organic solvents have been used in at least some experimental cells, e.g. methyl acetate, acetonitrile-propylene carbonate, nitromethane, tetra-hydro furan and dimethyl sulfoxide (DMSO). Many of these solvents are reactive, flammable or hazardous. The cathode of lithium cells is made out of any number of compounds, some of which are hazardous. With their high voltage potential, a high discharge rate can lead to trouble (NASA) especially with tight hermetic seals.

Two types of lithium cells are made, unbalanced and balanced. Unbalanced $Li-SO_2$ cells have a surplus of lithium. A discharge that uses up all the SO_2 has caused the excess lithium to react with acetonitrile electrolyte to release lithium cyanide, heat and methane (NASA, DRMS). The methane can build up and rupture the cell or at least open the safety valve.

SO_2 can incapacitate humans at concentrations of 50ppm (BDT). Vanadium pentoxide, lead bismuthate (BDT), manganese dioxide, silver chromate and thionyl chloride (Hunget) are other lithium cell couples that contain hazardous materials.

(fig. 2a) SAFETY, FROM PURCHASE TO DISPOSAL (adapted from GBB by permission)

key: low or no danger = '-' // some danger = '0' // definite danger = '+'

DANGER:	Gassing?	Leak?	Shorting?	H ₂ ?	Fire?
alkaline:	-	-	+/-	0	+/-
c-zinc:	-	+/-	-	-	-
zinc-air:	-/0	-	-	0	-/0
silver-ox:	-/0	-	-	0	-
merc. ox.:	-/0	-	+/-	0	+/-
lithium:	0	0	+/-	0	+/-
NiCd:	-	+/-	+/-	-	-
lead-acid:	(no data)				

(fig. 2b) SAFETY, FROM COLLECTION TO STORAGE TO TRANSPORTATION
(adapted from GBB by permission)

DANGER:	Gassing?	Leak?	Shorting?	H ₂ ?	Fire?
alkaline:	-	+/-	-	+/-	-
c-zinc:	-	+	-/0	-	-/0
zinc-air:	-/0	-/0	-/0	-/0	-/0
silver-ox:	-/0	-	-	-/0	-/0
merc. ox.:	-/0	-	+/-	-	-
lithium:	0	0	+/-	-	+/-
NiCd:	-	+/-	+/-	-	-
lead-acid:	(no data)				

notes for fig. 2 (derived from G.B.B. and other)

Gassing: Decreases with age, discharging. With new construction materials, methods few cells will discharge gasses generated by reactions. Li cells do not gas.

Leaking⁴⁸: Increases with age and discharge. Salts may be deposited. Prevalent in C-Zns after discharge, somewhat in alkalines before discharge and NiCds after discharge. Cells with air electrodes, Zn-air and Ni-MHs tend to dry up.

Short circuiting: Leads to heat build up and possible rupture, explosion or fire. A concern with some of the more hazardous batteries, NiCds, Li, merc oxides. With NiCds a high discharge rate makes internal short circuits more likely. *Important to keep away from conducting materials, e.g. metal drums and other cells.* Alkalines--very common cells--somewhat more likely to short when charged, as is any cell with a higher voltage. Old but unused cells more likely to develop shorts or to have weak casings. The Zn-air cell reaction stops when directly shorted. Short circuits are more likely with closely packed cells, increasing the likelihood of - to -, or + to +, terminal contact.

Hydrogen gas accumulation: Increases with age. Hydrogen is often a byproduct of the redox reactions occurring in cells that may exist as a gas (H_2). Alkaline cells somewhat susceptible in long term storage. NiCds generate H_2 . Some cells are manufactured with a pressure vent. *Ventilation, and uncovered storage bins, are crucial as hydrogen is extremely flammable and explosive.*

Fire hazard: Decreases with discharge. Only a threat when cells accumulated very close to each other and in presence of flammable or ignitable materials. Close packing increases danger of shorting (heat build up) and sparking from physical movement. Short circuiting can build up heat especially in incompletely discharged cells, often secondary ones (NiCds). NiCds are capable of rapid discharge and create intense heat very rapidly when short circuited.

⁴⁸Electrolytes are often corrosive. The commonly used electrolyte KOH has a pH of 13.5-13.7 (Oyaas) and is therefore also a regulated (corrosive) hazardous waste under RCRA if generated in large enough (> 100 kg/month) quantities.

appendix 3: BRIEF TOXICITIES OF RELEVANT METALS⁴⁹

CADMIUM (Cd)

Geochemical Behavior: Cadmium hydrolyses as insoluble forms only at high pH and in the absence of other anions (Moore). Fairly stable and insoluble bound with humic organic ligands (Moore). Methylation not found in natural systems (Moore).

Effects: Transported into blood where it sticks to proteins. Deposited in muscle, kidneys and liver with a half life of 10-30 years, e.g., in the kidney (Kazantzis 1987). Moderate covalent bonding strength leads to affinity for sulfhydryl groups and so to high lipid solubility and toxicity (Moore). Toxicity partly a function of stronger affinity than zinc for sulfhydryl groups found in some enzymes in liver, and kidneys--high or low zinc levels can enhance or obliterate toxicity here. Kidney damage is main adverse effect, also bone damage in humans at high levels. Teratogen at lower exposure levels--accumulates in placenta. Epidemiologic evidence of prostrate and respiratory cancers, associated mostly with inhalation (Moore). Also some epidemiological evidence of mutagenicity.

Both kidney damage and bone disfiguration are seen in people who ingest Cd. 200-250 ug/g (ppm) of Cd in the renal cortex is the critical level at which permanent kidney damage begins. An inhalation exposure of 40µg/m³ would achieve this level in about 20 years (Ellis).

While lung cancers have been induced in lab animals by inhalation of various Cd compounds, sometimes at below regulatory level exposure rates, the epidemiological human evidence is not clear. Prostrate cancer evidence in humans is unclear too (Kazantzis 1990). Ingestion does not cause tumors. Some mutagenic activity (Kazantzis 1990).

Action levels: In drinking water: EEC directive 0.001mg/L (1 ppb), WHO (1983) 5 ppb. SDWA 10 ppb.

⁴⁹There are many databases containing detailed results of toxicity studies of tens of thousands of compounds. The two used for the following incomplete survey were N.I. Sax's 6th Ed. Dangerous Properties of Industrial Materials (paper), and OHMTADS, the Oil & Hazardous Materials database (microcomputer version).

LEAD (Pb)

Geochemical Behavior: Most +2 charged Pb salts are insoluble in water, except nitrates and acetates (Moore). Insoluble Pb hydroxide-- $\text{Pb}(\text{OH})_2$ -- is formed at pH of 10.0 from Pb phosphate or sulfate in oxic environment. Strong binder to S, O, N and hydrated iron hydroxides and organic matter. Short of soluble complexers it will form precipitates in the 6.0-6.5 pH range. Sorbs more to clay at lower pH, and solubilizes as humic compounds at higher pH, if humic matter present (Moore).

Effects: Absorbed into blood where it resides and also distributes. Acts like calcium and accumulates in bone (Moore). Interferes in the adherence of oxygen to hemoglobin in the blood. Also affects the central nervous system including the brain, and interferes with kidney membrane function. Can be chemically methylated anaerobically as well as biologically. Lead-carbon bond is weak, especially in straight chain C. Inorganic Pb is less toxic. Many oxidated Pb compounds--chlorides, sulfur oxides, potassium oxides and hydroxides are insoluble in natural conditions and therefore not toxic; other S and O lead compounds are soluble (Moore). Contradictory mutagenic results, but a probable kidney carcinogen at high levels, some other epidemiological cancer evidence (Schlag).

Action levels: SDWA 50 ppb.

LITHIUM (Li)

Geochemical Behavior: Extremely reactive in elemental form. Forms very strong, caustic, base with hydroxide.

Effects: Reacts strongly with water in living tissue. Lithium ion is toxic to CNS. Various lithium compounds cause kidney damage in large doses and are associated with development of aplastic anemia (Sax). Some mutagenic activity.

Action levels: Secondary (largely non-toxic) SDWA contaminant: 5mg/L (5 ppm).

MERCURY (Hg)

Geochemical Behavior: Elemental Hg prevails in reducing conditions except in presence of reduced sulfur compounds. Extremely electropositive, and has a high affinity for thiols and easily forms covalent bonds, e.g. with carbon,

that results in biotransport and biomagnification. Abiotic methylation (i.e. transformation into organic mercury by chemical reaction) occurs as well as biotic (by microbes), from reduced Hg^{2+} (Moore). 1-2 parts methyl mercury in 10,000 parts total mercury has been reported in some dry cells (Yamaguchi).

Effects: Organic mercury compounds (e.g. methyl mercury) show a high level of biological activity. They are easily absorbed intestinally; inorganic Hg dermally. Organic Hg distributed widely in body though can accumulate in brain. If de-alkylated it can accumulate in kidney and liver especially (Fan). Severe CNS depressant. Teratogen, crosses placenta. Affects blood system and is a mutagen (Moore). Conflicting evidence as carcinogen.

Action levels: SDWA 0.2 ppb.

NICKEL (Ni)

Geochemical Behavior: ?

Effects: Nutrient up to ~400µg/day intake; used in enzymes, especially in blood. Elemental Ni and most salts are not considered to cause poisoning by ingestion (Sax). Does compete with a few minerals, especially Cu. Adversely affects some enzyme and heme production in liver. Nickel(III) apparently causes stronger biological effects (Kasprzak). Nickel is a strong respiratory intake carcinogen, also by absorption.

Action levels: SDWA 100 ppb.

SILVER (Ag)

Geochemical Behavior:

Effects: Silver does not demonstrate toxic effects in humans except for skin discoloration, where it accumulates. It is toxic to aquatic life. It is found in small quantities in batteries compared to the other hazardous heavy metals.

Action levels: SDWA 50 ppb.

ZINC (Zn)

Geochemical Behavior: ?

Effects: Not very toxic, some skin irritation and pulmonary irritation. A nutrient in many enzymes, including DNA building and repair. Does not react much with S groups in tissues. Homologue in electronic state to other metals, especially Cd, so presence of Zn can mitigate toxicity of cadmium.

Action levels: SDWA 100 ppb.

appendix 4: ACTIVITY OF HEAVY METALS IN LANDFILLS

HAZARD OF HEAVY METALS

The term heavy metal is ill defined. In general they are those metals to the right of calcium in the periodic table of the elements. In their elemental state their outer electron shell configuration--the number of electrons in each orbital--is unstable and therefore reactive. In their ionic state they have lost electrons to be two or more electrons short in their valence shells, making them highly charged and reactive cations⁵⁰, and so hazardous. Several metals, mostly Cd, Hg and Pb, that serve as cell electrodes are heavy metals. The high reactivity of heavy metal ions that makes them toxic also makes them useful in cells.

The charged nature of metal ions attracts them to water, a polar (oppositely charged at both ends) molecule. This makes them water soluble and more available to travel and be taken up into organisms. The same multitude of factors that determines their solubility and mobility (below) also affects their availability for intake, either by ingestion, inhalation or absorption through skin. Metals in solution are likely to be absorbed through the intestinal track and be available for biological action.

Once absorbed a soluble metal can move from intercellular space through a cell wall and into a cell. The movement may be facilitated by the soluble metal being made an organic compounds by bonding with carbon, which makes the metal compound more neutral and soluble in fat. Fat-like molecules such as cholesterol make up most of non-plant cell walls.

Once inside a cell, or even outside the cell, a metal can be attracted to proteins, whose structure contains negatively charged nitrogen and oxygen portions. Many enzymes, which are proteins, are specifically built by the genetic code to incorporate a metal cation, such as iron containing hemoglobin. Several metals are necessary nutrients, in micro quantities. Yet a heavy metal may unexpectedly be attracted to an enzyme, destroying or altering its function; or to the protein builder of enzymes, DNA, also altering its function. Their highly charged nature makes them potentially reactive

⁵⁰Ions with a positive charge. Anions are negatively charged ions.

with many molecules in an organism, in fact.⁵¹

HEAVY METAL MOVEMENT IN LANDFILLS

Several classes of compounds and conditions contribute to the solubilization and transport of heavy metals. Metals participate in oxidation-reduction reactions⁵² that can

⁵¹A distinction is made between short term or acute toxicity, often measured in lethal doses, and long term or chronic toxicity, whose effects may be harder to detect. Some compounds, especially metals, can be both a necessary nutrient and a toxic agent, sometimes within a narrow range. Carcinogenic compounds are sometimes classified as cancer initiators and cancer promoters. They always should be cited as either proven or suspected animal, plant or human carcinogens. Mutagenic effects are usually measured in cultures of cells though studies of more complex effects on body organs and systems such as the immune system are becoming more common. Teratogenic effects are those passed on to the next generation. Epidemiological evidence is indirect, gathered from correlating symptoms and disease with exposure, either from past records or in a controlled study. It is a 'preponderance of the evidence' matter as a multitude of confounders can also account for the effect, e.g. smoking, incomplete information or genetic disposition.

Symptoms known to be the result of chronic low level exposure usually arise from a fairly strong direct exposure, e.g. fumes at a smelter or cooking with a utensil with hazardous components. However the long term effects of low level exposure are still largely unknown for almost all compounds. Duplicated results under different conditions or direct tests on mammals may indicate a low level chronic danger for a compound. Predictions are also made based on the shape and charge(s) of compounds.

Except for direct injection of a metal into the organ that develops cancer, few metals show a clear link to cancer (Furst). They can act as cancer promoters in combination with other compounds or conditions that initiate cancer. e.g., they may tie up an enzyme that works to protect DNA from mutations. More common effects tend to be the destruction and malfunction of organs.

⁵²In this category of chemical reactions the strength of charge on the reacting species, as determined by the relative number of protons in the nuclei vs. electrons of the reacting species, determines the rate of reaction. For each oxidation half reaction, the donation of electrons, there is a reduction

transform them to an oxidized form with a positive charge (cations). In this state they are more soluble⁵³ in water and therefore free to migrate. It is difficult to predict whether a metal will be bound by water and so be free to travel, or be bound onto solids and immobilized by negatively charged ligands⁵⁴ in the soil or in solution or suspension in the water. The solute chemistry of landfill leachate, with its multitude of charged species, is extremely complex and migration is even more difficult to predict.⁵⁵

In rough terms adsorption and precipitation immobilize metals while complexing and solubilization into water release a metal to migrate into groundwater. These processes are largely dependent on the state of charge of the species involved, as affected by system conditions of E_h , pH, ionic strength, etc. and the proximity of reacting species. Increased surface area of an adsorbent also decreases metal mobility. Principal sorbents are organic matter, clay and newly formed iron or manganese oxides and hydroxides. Generally, mercury is the most mobile of the metals studied here.

Inorganic metal ligands

Several measurements⁵⁶ are made to determine the oxidation-

half reaction, the acceptance of electrons.

⁵³Water is a strongly polar (opposite charges at either end) molecule, this makes it a great solvent as it is attracted to many negative or positively charged compounds. Metal cations may also be mobile and dangerous when suspended, not dissolved, in water. In groundwater, however, suspensions don't stay in the water phase for long unless the soil is very unreactive, e.g. pure sand.

⁵⁴ligand: an oppositely charged species, or a molecule with areas that are oppositely charged, that is attracted to and binds another species.

⁵⁵One known factor is that most battery electrodes are powdered or granulated metals, increasing the surface area in contact with leachate. The major exception is wet-cell vehicle Pb-acids, but they are by far the largest input into landfills of Pb from batteries.

⁵⁶Another measurements is ionic strength (μ) which measures the overall charge as determined by the number and strength of charge of ions. pH is the negative log of the

reduction, or "redox" state of systems such as portions of landfills or leachate. E and E_h , in volts, are the basic redox measurements⁵⁷. The E_h of most inorganic ionic species has been measured relative to a standard hydrogen electrode (SHE) with a nominal E_h of 0, creating the ability to predict the redox reactivity of ionic or other species. The more positive the E_h , the more of a reducer that species is, and the more negative, the more the species is an oxidizer. The greater the difference in E_h between two species, the more they will want to react.

The redox state is the major controlling factor in determining the fate or partitioning of any given metal compound. In combination with pH and physical conditions it controls solubility versus sorption and therefore the mobility of toxic metals. Landfills create a reducing--low oxygen or anoxic--environment. Oxygen is depleted in the decomposition of the organic matter in trash. Daily cover layers of soils also prevent oxygen replenishment from the atmosphere. Dissolved oxygen (DO) gives a broad indication of the redox state of leachate, while the pH of municipal landfills leachate seems to vary a lot, in the range of pH 4-9. Generally, a low pH and a reducing environment solubilizes metal species.

According to Hounslow desorption or solubilizing is generally caused by increased reduction potential, elevated salt levels whose alkaline metals replace adsorbed heavy metals, elevated levels of complexing agents that form soluble compounds with heavy metals, or alkylation--metal-carbon bond formation--of metals by microbes.

concentration of H^+ cations, which create acidity and also contribute to state of charge. pE is the negative log of the concentration of electrons, and is the analogue of pH . Alkalinity is a measure of the basic (negatively charged) components in solution that do not react with strong acids. One base, the chloride ion, Cl^- , is often measured in groundwater and leachates because it is usually present in leachate, stays in solution under a wide range of conditions and is a useful tracer.

⁵⁷The redox state is a measurement of the state of charge of the ions that make up the system, as determined by their lack, or surplus of bonding electrons. The state of charge can be measured as electrical potential, in volts. Oxygen carries a strong negative charge, but other elements are also termed oxidizers.

Clay: Clay has areas of negative charge that serve to bind cations such as heavy metals. They also can exchange cations, with cations of a greater charge difference replacing others bound to the clay. Different types of clay vary in their cation exchange capacity (CEC). In sufficient quantities clays immobilize heavy metals, though mercury immobilization in clay is problematic (Haight et al.).

Sulfides: Sulfides, produced by bacteria from sulfates in a reducing environment, will bind and immobilize all non-alkaline group metals in the absence of oxygen. In anoxic water metals may be bound by sulfides produced by the microbial reduction of sulfate to H_2S , though the metal may also form a mobile complex with sulfides or organic matter (Kersten). Microbial activity can partition some metals into the microbes, making them transportable. Bacteria can also change the physical E_h/pH environment, causing a shift in soluble species, or the metals may be enzymatically acted on to form more soluble species (Forstner). Covalent bonding of metals to organic matter is often carried out by bacteria. A 10^{-9} mol/L concentration of sulfide ion is enough to bind and precipitate metal cations freed from oxides by reducing, anoxic, conditions (Forstner). This effect was not observed by Forstner in the anoxic pore water of a bay sediment. He found the metals still mobile, in solution.

Some families of anaerobic⁵⁸ microbe species can oxidize sulfide to sulfate, especially if the pH is low, potentially reducing the number of sulfide ions to immobilize metals.

Chlorides: Like sulfides, chlorides will generally bind Ag, Pb and sometimes Hg, but not Cd (Smith, Bourg). Only a concentration of chloride ions approximate to that of the cations will immobilize Hg. Under high concentration of chloride ion the soluble ion $HgCl_3^-$ predominates under most E_h/pH conditions (Smith). Other metal chlorides are soluble and persistent (Moore). In any case, neither species, sulfides or chlorides, is likely to be present at sufficient concentration to immobilize many solubilized metals should system conditions warrant that.

Iron and manganese hydroxides and oxides: The Fe and Mn compounds precipitate at geochemical boundaries, e.g. the oxic/anoxic boundary where the E_h gradient is largest. Fe and Mn oxides and hydroxides are found as coatings on minerals and as dispersed particles. Most heavy metal hydroxides that form are soluble at acidic and natural pH ranges (below ~7.5) found in landfills (as well as above 9)

⁵⁸Metabolizing in a no oxygen environment.

(Gowman).

Low pH: Acidity, a surplus of H^+ ions, causes competition with the metal cations for adsorption sites and reduces the surface/solution charge difference, freeing up metal cations to migrate. Acidity is the most important factor in assessing metal mobility. Metal cation species will also exchange from the binding surface into solution due to this presence of H^+ ions (acidic conditions), freeing them to migrate (Smith). Landfill leachate is not always acidic.

Organic ligands

Organic matter--soil--also binds metals, but often the resulting complex is at least partially water soluble. In the presence of clay, metal cations caught up in organic-clay complexes are immobilized. Soil is made of minerals and organic fulvic and humic acids, and humin. The fulvic acid fraction is completely water soluble, the humic fraction is soluble above pH 2, and the humin is completely water insoluble. Generally the fulvic components have more binding sites, though this is the smaller component. Organic matter overall has substantially more adsorption sites than clays or hydroxides (Forstner). Organic molecules use acidic functional groups, e.g. carboxyls ($COOH$) and alcohols (OH) to attract and bind metals. Different metals may sorb onto deeper, more stable areas of a complexing molecule, or more loosely onto surface areas. Mercury binds easiest with organic matter and often becomes mobile in this manner.

CO_2 resulting from degradation of organic matter in trash possibly can solubilize metals as carbonates (Kersten). Organic-metal complexes can keep metals in solution even at higher pH's. Synthetic complexing agents, chelators, are found in detergents, which may help mobilize metals at landfills.⁵⁹ This effect has been observed with occasional high loadings, such as at sewage treatment plants. Moderate pH levels are needed for complexing (Kersten). Di- and tri-valent⁶⁰ heavy metal ions are preferentially adsorbed by any available organic matter, especially in diluted solutions (Forstner).

⁵⁹Chelators are also a treatment for metal poisoning. They solubilize metals from tissue for ready excretion.

⁶⁰The outer (valence) electron ring of an atom is unstable and therefore reactive unless it has eight (usually) electrons. Heavy metal ions are missing two or three valence electrons and so are highly oxidized and reactive.

ACCELERATED LANDFILL CORROSION FROM CHARGED BATTERIES

The specific electrical conductance (or inversely its resistance)⁶¹ of leachate is important in landfills containing batteries, as a conducting leachate can either accelerate or retard the corrosion and subsequent leaking of batteries. This is especially true if they are not fully discharged or if the outer casing is an electrode as is the case with some button cells whose bottom casing is the entire cathode. Though newer C-Zns have a steel sleeve around the outer Zn anode, the anode will eventually be exposed, especially since the Zn anode is already thin after discharge (Jones et al). Oppositely charged ions in the leachate attack any exposed electrode, with extra vigor if the electrode can still carry a charge.⁶²

SPECIFIC STUDIES OF BATTERY LEACHING IN GARBAGE

Jones et al. found that oxygen rich conditions promote the fastest corrosion of casings in simulated one year exposure to landfilling, though some cell types corroded severely in an anoxic environment. The leachate test was a worst case scenario in that the batteries were immersed, providing a constant conductance path for corrosion to occur. Partially discharged cells corroded more rapidly than fully discharged cells. Organic matter did not significantly affect leachate heavy metal concentration, and pH correlations also varied, though Zn and Mn levels were pH dependant.

Allowing for a five orders of magnitude attenuation rate in the concentration of cadmium from hypothetical leaking NiCd batteries to downstream drinking groundwater, Bromley et al estimated that, to not exceed a 5 ppb (parts per billion) cadmium drinking water standard, NiCd batteries could constitute 0.86% of garbage, by weight. This figure ought to be 0.3-0.4%, as NiCds contain 10-15% Cd, not the 5% they cited, but in any case NiCds do not approach 0.3% of the garbage stream. The attenuation factor was derived from leachate column experiments in which packed (aerobic and anaerobic) garbage columns were irrigated with a 100 ppm Cd

⁶¹An interface between two parts in contact of a system with different E_h 's directly related to its redox potential.

⁶²There is some confusion in the literature as to the nomenclature of electrodes. The attack by the anions in the leachate (chloride, sulfide, etc.) will be to a positively charged electrode.

solution, simulating a typical concentration from leaking batteries, for 6 months. Included in the 10^{-5} attenuation factor is a 2.3×10^{-3} attenuation factor for the rate at which Cd escapes from cells.

Though conservative in that further attenuation from immobilization by soils after leakage was not accounted for, this study does not take cumulative loadings into account. Conceivably NiCds, at 75% of all Cd in municipal garbage, could eventually contribute enough Cd to reach the 5 ppb drinking water standard under some geochemical and physical conditions.

Haight et al., for the Canadian Battery Manufacturers Association, reported that neither cadmium nor mercury from consumer dry cell batteries pose a risk to drinking water except for a small increased risk for children from cadmium intake. Though their assumptions are practically unexplained, it is clear that this study assumes 170 kg (400 lbs) of Cd and 3.8 kg (8 lbs) Hg from consumer dry cells are annually entering a landfill serving 100,000 people (as is Missoula's). U.S. figures (Franklin Assoc's) show *this should be 1,250-1,500 lbs for Cd and 35-70 lbs for Hg.* Exposure levels in this study are also apparently based on 0.05% (or 1 part in 2,000) of battery metals solubilizing annually, based on exposure of electrode surfaces of 1 cubic cm, apparently. The geology of this particular landfill (Waterloo, Ontario) is not explained, nor really are the potential ingestions or hazard indexes used, though the bioavailability of the ingested metals is set conservatively at 100%.

Chen-Northern (1987) briefly modeled the likelihood of contaminants, including metals, reaching the main valley aquifer from Missoula's landfill. After reviewing major assumptions (garbage density, soil types, groundwater flow) and assuming correct values for precipitation and waste composition, no metals were predicted to reach the aquifer in a thirty year model run. A retardation factor of 10 was used for soluble metals for the low porosity of the soil. Leachate production and runoff were distributed evenly but should have been concentrated in the ephemeral drainage.

appen. 5: CELL PRINCIPLES, COMPOSITION, PERFORMANCE

PRINCIPLES OF CELL FUNCTION

Galvanic or voltaic cells (batteries) take advantage of the differing charges on the atoms and ions of their two electrodes⁶³ to cause a spontaneous⁶⁴ flow of electrons--the current. The two electrodes' elements have different charges arising from their relative number of protons versus electrons.⁶⁵ The relatively negatively charged **anode**⁶⁶ electrode's excess electrons are attracted to the deficit of electrons on the **cathode** and travel, via an external circuit through a load such as a radio, to it.⁶⁷

The electron flow in **secondary**--rechargeable--cells can be reversed by applying an outside current to the cathode. **Primary** cells are disposed when discharged. Primary cells are disposed of when the electron flow has equalized the charge of the electrodes. This is the complete discharge state. To some extent, the components of one electrode are attracted to the other when the cell is not in use, causing self-discharge and decreasing cell efficiency.

An **electrolyte** keeps the overall cell reactions in balance (and resistance low) as the electrons flow. As electrons

⁶³Usually a metal and a metal oxide.

⁶⁴No free lunch here, it has taken a lot of energy to get the elements into this state.

⁶⁵This is what determines the difference between any two elements, e.g. a hydrogen atom has one each proton and electron; helium two each.

⁶⁶As in "anion" and "cation", the prefixes of the words anode and cathode denote a negative and positive charge, respectively. The commercial and industrial battery literature can be confusing, it refers to the anode as the electrode that *becomes* negatively charged, as the cathode *becomes* positively charged.

⁶⁷Metallic (reduced) atoms are good conductors because they form a crystal structure in which the electrons they possess are delocalized and shared by adjoining metal ions (an electron "sea"). Charges imparted at the electrode-electrolyte interface are transmitted through the bulk metallic electrode.

leave one electrode its metal ions change in charge. Attempting to keep in electrical balance, the electrode's ions seek out components of opposite charge at the other electrode, but cannot travel fast enough to balance the electron flow at nearly the speed of light. This would cause a rapid rise in electrical resistance and shut down the cell's flow of electricity. The electrolyte's ions are prevalent enough to be found by, and even migrate towards, the oppositely charged ions of the electrodes in time to keep up with the unbalancing caused by the electron flow, moving nearly at the speed of light. (Smith).

An electrolyte is made up of two oppositely charged ions that are able to react easily with both electrodes. Potassium hydroxide, $K(OH)$, for example, may be split into K^+ and OH^- . Usually a porous physical separator is impregnated with the electrolyte and placed between the two electrodes. This allows the electrolyte to conduct current while keeping the electrodes from reacting directly with each other.

Cell reactions can also be understood in terms of energy (Tebbutt). In the absence of an external energy input such as heat or the recharging current to a cell, chemical reactions will always go towards more stable products, i.e. products with less energy than the reactants. When a cell is inserted into an appliance to complete the circuit between its two electrodes, the reaction proceeds spontaneously. Whether the two electrode reactants are oxidized, meaning the loss of electrons, or reduced--a gain of electrons--the resulting chemical compounds electrons will carry less energy. Rather than actually move along the circuit, an electron's change in energy causes a reaction in the electrons of the adjacent atom so that the initial change in energy is carried forward all along the circuit.

There is an intrinsic maximum electrochemical potential or **voltage** arising from the relative number of protons and electrons any two paired electrode compounds (a cell couple) have. The greater the charge difference in the opposing electrodes, the greater the voltage of the cell type. The **current**, or the number of electrons that are released by the "pressure" of the voltage gap, is measured by how many electrons pass a given point, in amperes. In general, the larger a cell, or the more quantity of an electrode that can be packed in, the more **capacity** a cell has. This is independent of the intrinsic voltage generated by different cell couples, which determines the **power** of a cell. Power (P , in watts) is the product of the electromotive force, voltage (E) times the flow of electrons, the current (I):

$$P \text{ (watts)} = I \text{ (amps)} \times E \text{ (volts)}.$$

The electromotive force or voltage (E), arising as said out of the differences in charge state of different atomic elements, is equal to the current in amperes, I, times the resistance to the current in ohms, R:

$$E \text{ (volts)} = I \text{ (amps)} \times R \text{ (ohms)} \quad \text{Ohm's Law.}$$

One volt pushes one amp of current through one ohm of resistance. Any given cell couple can not deliver more than its maximum theoretical potential voltage, E or V. As the cell discharges the charge difference between the electrodes narrows, this is measured in a decreasing voltage. The reduction and oxidation half reaction at each electrode contributes half the voltage potential.

Increases in capacity--current, I--can be had by increasing the amount of electrode material or available surface area. Amp-hours or miliamp-hours, and watt-hours measure a cells capacity. Rate of discharge or charge (for secondary cells) in amperes is given by capacity in amp-hours divided by the number of hours to charge or discharge at this rate. Time units cancel out leaving amperes. For example, a cell with a capacity of 0.5 amp-hours (A-hr) discharged in 10 hours discharges at 0.05 amps. Both this cell and a 5 A-hr cell discharging 0.5 amps have a .1 C rate because their discharged in 10 hours. *Always compare amp-hour ratings or C rates based on the same cycle time (Stickel).*

Cell voltage should be specified to be either the theoretical maximum voltage, operating voltage (the practical maximum deliverable after internal losses and usually around 90% plus of the theoretical voltage), open-circuit or without a load voltage, nominal voltage (the voltage when half discharged) or terminal voltage (use after which the operating voltage begins to drop off rapidly).

Voltage adds up in cells connected in **series**, positive to negative terminals. Alternately, current capacity can be made to add up in cells connected in **parallel**--all positive terminals connected together and all negative terminals together. Appliances with circuits designed to run on high currents (parallel connected cells) which then require less voltage and fewer (expensive) cells needs to be built rugged to handle the high current. This is expensive. Then again, only a large, expensive battery pack of serially connected cells is develops sufficient voltage to power some appliances. Here the low current allows use of delicate or cheaply made appliances, though more cells mean a larger failure rate of expensive cells (Perez, Stickel). Circuits in appliances are designed to operate from a battery pack with a given voltage that drains the pack most efficiently

(Stickel). Circuit miniaturization of electrical circuits (that has been and will continue to occur) creates circuits that need less power and capacity (or can't handle it).

Cells connected in parallel allow current to flow backwards into any cell that is delivering less voltage (Perez). This can destroy its electrodes. Or it will shut down the appliance if the appliance is designed to cut out below a certain voltage (Scholefield). Generally cells in a pack should be of the same age, use history and production batch (Scholefield). In short they should have similar capacity in amp-hours as they are used so their voltage remains similar. As cells near the end of their life, or if used cells are used in another appliance, any one cell with a substantially lower voltage output could go into reverse charge. Cells with a flat voltage discharge curve (mercuric oxides, NiCds) might give no warning they are at the end of their charge.

Secondary (rechargeable) cells may be vented or sealed. The ability to add electrolyte generally enables vented cells to be charged and discharged at higher rates. Though flammable and explosive hydrogen and oxygen gas and heat are evolved from the water in the electrolyte during charging, these products are vented. Despite higher charge rates vented cells tend to be durable as they receive constant maintenance and monitoring of I, R or E. High capacity uses, back-up power or engine starting are common.

Sealed cells of all types generally have to be designed to withstand the generation of gasses but the problem is more acute in rechargeable cells, where heat can be generated by too high charging rates. Sealed NiCds, for instance, are made with an excess of cadmium over nickel (Cadmium Assoc. & Council, Ettel) so that on recharge the Ni electrode is charged first (recombined into a nickel hydroxide with one more oxygen atom). This allows the O_2 generated after the electrode is fully charged to migrate to the cadmium electrode to form cadmium hydroxide the discharged form of the electrode, so that this electrode is never fully charged and can not generate H_2 gas. A deficiency of electrolyte is necessary to allow the O_2 to migrate. A little of the opposite electrode's material on the other electrode also is used to absorb the O_2 , preventing overcharge or reverse charging of fully discharged cells.

(fig. 3) COMPOSITION OF COMMON CELL TYPES WITH PERCENT PROPORTIONS¹
 (from Arnold, others; % compositions from Dry Cell and Haight)

electrode:²

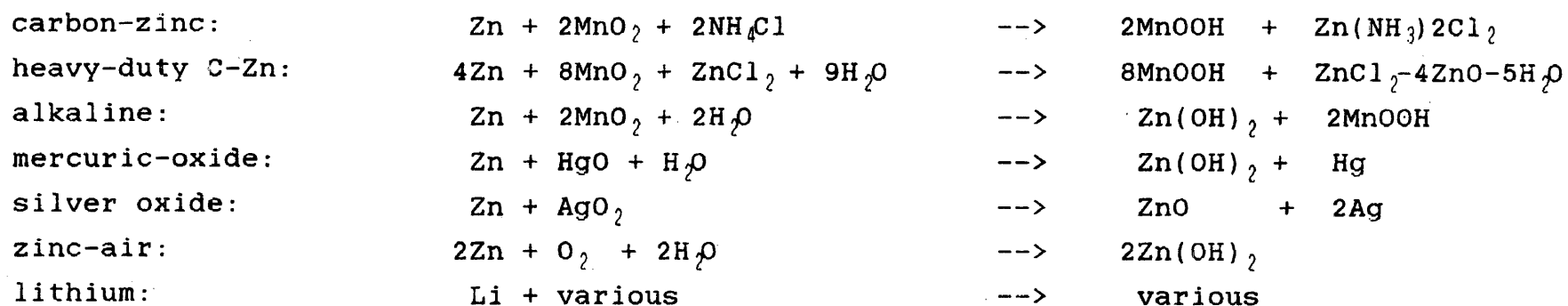
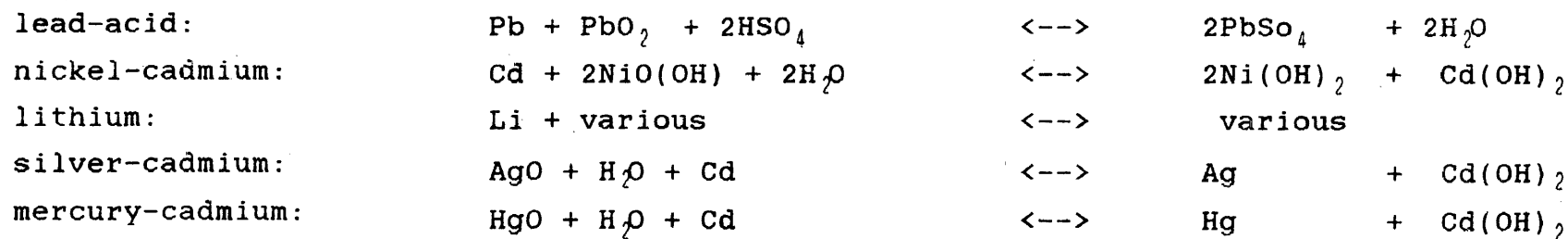
	ANODE	CATHODE	ELECTROLYTE
Secondary: ³			
lead-acid	Pb	H ₂ SO ₄	H ₂ SO ₄
nickel-metal hydride	H ₂	NiO(OH)	KOH
nickel-cadmium ⁴	Cd, 10-18%	NiO(OH), 15-25%	KOH
lithium ⁵	Li, 10-30%	Mn, O, S, Cl, F, ...	various organic
 Primary cylinder:			
alkaline ⁶	Zn, 8-18% ⁸	MnO ₂ , 28-35% ¹⁰	KOH
carbon-zinc ⁷	Zn, 12-40% ⁹	MnO ₂ , 20-40% ¹¹	NH ₄ Cl and ZnCl ₂
heavy duty carbon-Zn	Zn, 12-40%	MnO ₂ , 20-40%	ZnCl ₂
lithium ³	Li, 10-30%	Mn, O, S, Cl, F, ...	various organic
mercuric-oxide	Zn	HgO, 35-40%?	KOH, NaOH/ZnO
 Primary button:			
mercuric-oxide	Zn, 10-15%	HgO, 35-40%	KOH, NaOH/ZnO
silver-oxide	Zn, 10-15%	AgO ₂ , ¹² 30-35%	KOH or NaOH
zinc-air	Zn, 30-40%	O ₂ , ? %	KOH or NaOH

Note the anode of all the popular cells (not rechargeable and the new lithiums), is zinc; and their electrolyte is usually alkaline, usually potassium hydroxide (KOH). The vast majority of consumer cells, including buttons, are alkaline. Everyday use (and this reports syntax) of the term "alkaline" means the popular Zn-MnO₂ couples. The term "cylindrical" will include the small 9 v and larger lantern batteries.

1. All these electrodes and electrolytes are found in large quantities, typically 10% to 40% of cell weight (EPA RREL). More in Pb-Acid cells.
2. The positive or negative terminals on a battery may be either the anode or cathode current collector, depending on battery type, and therefore *do not indicate* the anode or cathode.
3. Of the new generation rechargeable cells, lithiums contain small amounts of arsenic, vanadium and organics and halogens; while nickel-hydrides have traces of the rare earth metals, lanthanum, cerium, cobalt and neodymium (Arnold). Any cell is likely to have trace amounts of various heavy metals as a result of geologic or refining processes. C-Zn's have been reported to have 7 ppm cadmium and traces of mercury.
4. mercury-cadmium and silver-cadmium couples are produced also with a KOH electrolyte. They have specialty uses.
5. A lithium cell's positive electrodes are made up from the elements listed above into a host of different types.
6. Haight et al. report alkalines have .4% cadmium (0.04-0.53 g) per cell; C-Zns .01% cadmium.
7. The carbon in C-zn cells is not an electrode in the cell-couple redox reactions, it gathers the current generated.
8. D size cells 14-18% / 9v size 8-12% / AAA size 10-15% / others 12-15%.
9. D & C size, 15-20% / AA 20-25% / AAA 34-40% / 9v 12-15%.
10. D & C size 30-35% / AA 32-35% / AAA & 9v 28-32%.
11. D, C & AA size 24-30% / AAA 35-40% / 9v 20-25%.
12. Cathode may be AgO.

(fig. 4) CELL REACTION MECHANISMS

(various sources, electrolyte reaction not always shown)

primary**secondary**

PERFORMANCE, CAPACITY AND POWER

Cells and batteries are not an efficient source of electricity. It takes around 50 times as much energy to make a cell as the energy it can produce; their power is between 1,000 and 100,000 times more expensive than mains electricity (Eutrotech). However the U.S. uses 2.5 billion annually because they are convenient source of electricity in locations and situations where regular electrical power can't be had or is impractical.

Technology has continuously introduced new cells and improved the performance of old cell types and continues to do so at an accelerating rate. No one cell type even comes close to meeting all requirements listed below, and the cell types usually cover a wide range in a given performance characteristic; therefore there tends to be a specific cell type for a specific use.

The type of battery used depends on the performance specifications of that cell type. Power density (by volume or weight, a function of the difference in electronegativity of the two electrodes and of capacity) is needed for pulses of high power applications such as photo flashes; and for continual high power demand such as motors (incl. toys and cassettes), and flashlights. For these requirements large consumer sizes--cylinder type--alkalines or lithiums are best (Consumer Reports 1987). For many critical applications such as medical monitoring machines or hearing aids a flat discharge curve is necessary; mercuric or silver oxide cells are used. C-Zn, cylinder alkalines (Zn-MnO_2) and zinc-air buttons fade out (Crompton 1990). This can be an inconvenient advantage as it gives warning of failure.

Power: Power output of a cell is completely described with a discharge curve that plots voltage against capacity in amp-hours for a given temperature and discharge rate (Stickel). Each cell type has a rate of discharge (I , in amps) for which the most power (E , in volts) is outputted. At too high a rate of discharge voltage delivered drops off because of internal resistance by compounds impeding the flow of current. Heat, not power, is delivered. Yet if too low a current is drawn the cell will discharge internally from diffusion of species involved in the cell charge reactions, shortening its life.

$$E_{\text{effective}} = E_{\text{theoretical}} - (I \times R)$$

Two other factors, charge competition from the concentration of ionic species, and polarization, play a role in reducing the maximum theoretical power output (Smith).

Usually no more than 40% of a cell's theoretical power is usable (Perez), mostly due to reductions in the surface area of electrodes. Most published efficiencies are calculated on available power basis, not the theoretical maximum. Little additional capacity is gained going beyond the point where the cell's voltage drops off rapidly.

Capacity: Sintering, amalgamating powdered metals with heat onto an extremely porous substrate, gives an electrode with a high surface area to mass ratio, increasing capacity. A common practice, sintering lowers internal resistance and not only increases capacity but seems to improve high rate and extreme temperature discharge (Cadmium Assoc. & Council). Charge retention suffers and sintered electrodes tend to wear out quicker (Perez).

Other ways of increasing cell capacity by increasing electrodes surface area include impregnating fibrous matter with the metal and using a jellyroll construction. Using a very fine mesh in the plastic weave separator most cells use to separate the two electrodes prevents large crystals or dendrites from forming (Soviero) and causing many small short circuits.

Most electrolytes are liquids or gels to allow easy migration of oppositely charged ions, some new cells use a plastic substrate with an amorphous, irregular molecular structure. The electrolyte ions dissolved in the substrate move freely necessitating less electrolyte and allowing very thin strips of cells, e.g. .25mm, to be molded in the recesses of appliances or even autos; and avoiding the hazard of liquid electrolytes (Economist 1989).

Appliances that generate a lot of heat can impair cell performance by destroying delicate separator membranes or the electrodes. Good design--placement, high surface area (Stickel)--helps. Sanyo reports that the NiCds in their portable phones were dying from membrane destruction after two years (this application requires fairly rapid recharge rates, .2C and higher). A replacement membrane balanced durability with wetability.

BATTERY TYPE COMPARISON BY PERFORMANCE CRITERIA (from Scholefield and many others)

Many of the performance figures reported below are midpoints in ranges. Sometimes there were direct conflicts in reported values from different sources, this may reflect the latest physical construction method, a purer grade of chemical, etc. Many commercial cell types are not listed here: rechargeable silver-oxides and silver-cadmium, industrial

nickel-iron, liquid lead-acid and nickel-cadmium rechargeable for storage of generated electricity at home or in industry, vented Pb-acids for shallow discharge--e.g. vehicles that use an alternator to trickle charge the battery.

The '>' symbol indicates a substantial gap in performance in that attribute. Cell types listed on the same line are similar to each other but listed in general order.

- COST (on a power basis; a function of energy density and voltage potential)

best

rechargeables⁶⁸ (Pb-acid > NiCd, Ni-MH)

>

rechargeable lithium

zinc-air buttons

alkaline

heavy duty C-Zn⁶⁹

carbon-zinc⁷⁰

button lithium

some lithiums

mercury-oxide buttons

silver-oxide buttons

? silver-cadmium, mercury-cadmium

exotic lithiums

worst

The above and the following cost comparisons are *often meaningless* as they are easily and strongly skewed by factors such as temperature, rate of discharge, etc.

⁶⁸Varies with cycling care.

⁶⁹ about equal in cost to alkaline in low drain applications because they recover some capacity when resting.

⁷⁰Cheapest in dollars but drain fast even in low drain use: almost never cost effective.

(from Perez except for rechargeable):

C-Zn:	\$0.10 W-hr (\$100 kW-hr!)
Alkaline	\$0.13 "
Merc-ox(button)	\$2.30 "
Silv-ox(button)	\$3.00 "
Zn-air (button)	\$0.09 " (cheapest button)
Lithium	\$2.00 " (but decreasing)
<i>rechargeables</i>	0.2 ¢ " (200 cycle life & charger)

- volume energy density @ 20°C (if space is tight)

best

button silver-oxide:	500 Watt-hours/Liter
button mercuric-oxide:	470 W-hr/L
cylinder lithium:	450 W-hr/L
button lithium:	400 W-hr/L
cylinder silver-oxide:	400 W-hr/L
>	
cylinder mercuric-oxide:	325 W-hr/L
>	
cylinder alkaline:	220 W-hr/L
>	
heavy duty C-Zn:	135 W-hr/L
button alkaline:	135 W-hr/L
carbon-zinc:	100 W-hr/L
nickel-metal hydride:	90 W-hr/L
nickel-cadmium:	80 W-hr/L
gelled lead-acid:	70 W-hr/L

worst

- weight energy density (when portability counts)

best

cylinder lithium:	240 W-hr/Kg
button lithium:	200 W-hr/Kg
>	
button silver-oxide:	120 W-hr/Kg
cylinder mercuric-oxide:	110 W-hr/Kg
cylinder mercuric-oxide:	105 W-hr/Kg
button mercuric-oxide:	100 W-hr/Kg
alkaline:	95 W-hr/Kg
nickel-metal hydride:	90 W-hr/Kg

>
 heavy duty C-Zn: 75 W-hr/Kg
 carbon-zinc: 65 W-hr/Kg
 >
 button alkaline: 38 W-hr/Kg
 nickel-cadmium: 35 W-hr/Kg
 gelled lead-acid: 30 W-hr/Kg
worst

- discharge rate capability (usually wanted to be high, but if intrinsically high may not be suitable for low rate appliances, e.g. calculators, even if it is a very small cell). For any cell a low discharge rate means a low internal resistance and greater efficiency of discharge and capacity, though NiCds, for example, are the most efficient at a high rate of discharge. Be sure to compare cell capacities based on same discharge rate)

best

alkaline: high, 31 mAmp/Cm² Zn surface (D)
 lithium: high, ?
 heavy duty C-Zn: 23 mAmp/Cm² (D size)
 nickel-cadmium: to 20-25C rate
 gelled lead-acid: to 10-20C rate
 carbon-zinc: low, 15 mAmp/Cm² (D size)
 nickel-metal hydride: to 3-5C rate
 mercuric-oxide: low
 silver-oxide: low

worst

? zinc-air

- operating voltage when fresh (not the maximum, no load V). Needs to be high in some appliances; can be increased by connecting cells in series, pos. to neg. terminals)

best

lithium: ~2.70 volts
 >
 gelled Pb-acid: ~1.90 v
 >
 silver-oxide: ~1.55 v
 alkaline, C-Zns: ~1.45 v
 >
 mercuric-oxide: ~1.25 v
 nickel-metal hydride: ~1.23 v

nickel-cadmium:	~1.15 v
silver-cadmium:	~1.00 v
mercury-cadmium	~0.90 v

worst

- capacity (amp-hours)

strictly a function of the size or weight of cell or battery, and surface area of electrodes. Can be increased by connecting cells in parallel, with all positive terminals together, and all negative terminals together. A larger cell of the same type is almost always cheaper. Expensive electrodes limit the capacity of some types.

- flat discharge curve (constant voltage over time until spent, especially with a high discharge rate. Beneficial for equipment that is sensitive to voltage, such as heart monitors; but these cells don't give warning of impending exhaustion. Dependant on temperature and discharge rate)

best

mercuric-oxide
 silver-cadmium
 >
 silver-oxide
 lithium
 mercury-cadmium
 >
 zinc-air
 nickel-cadmium
 alkaline
 C-Zn (regular & heavy duty)
 nickel-metal hydride
 gelled lead-acid

worst

- low temperature operation (power output falls off)

best

gelled lead-acid:	-40°C
NiCd, silver & merc.-cadmium:	-30°C
lithium:	-30°C?

alkaline:	-20°C
heavy duty carbon-zinc:	-10°C
carbon-zinc:	- 5°C
mercuric-oxide, Ni-MH, lead-acid:	0°C

worst

- high temperature operation (high current or ambient:
destroys electrodes)

best

mercury-cadmium:	100°C
silver-cadmium:	80°C
nickel-cadmium:	70°C
lith., alk., Ni-MH, gel Pb-acid, mercuric-oxide:	55°C
heavy duty C-Zn:	50°C
carbon-zinc:	45°C

worst

- storage temperature; (self discharge accelerates at high
temperature)

best

lithium:	-20/+40°C; (0.25% chrg loss/mo @ 20°C)
merc-cadmium:	-21/ ? °C; (no loss, to ~50°C w. loss)
merc-oxide:	-20/+25°C; (0.33% loss/mo.)
alkaline:	-40/+25°C; (0.6% loss/mo.)
C-Zn&heavduty:	-40/+20°C; (1.25% loss/mo.)
gel Pb-acid:	?; (2-30%/mo, 3yr on shelf chrgd)
NiCd:	?; (15-30%/mo, indefn. shelflife)
Ni-MH:	?; (60% loss/mo.)

worst

- rechargeable lifetime (number of deep discharge cycles.
very dependant on proper charging, discharge)

best

Ni-MH:	200-3000	cycles
nickel-cadmium:	100-750	cycles

gel Pb-acid: 100-200 cycles
worst
 lithium ???

- withstand overcharge (rechargeable)

best
 gelled lead-acid, nickel-metal hydride
 nickel-cadmium
worst
 lithium ???

- withstand deep discharge (rechargeable)

best
 liquid electrolyte (vented) cells
 nickel-cadmium, nickel-metal hydride (solid electrolytes)
 >
 gelled lead-acid
worst
 lithium ???

- withstand storage in discharged state (rechargeable)

best
 nickel-cadmium, nickel-metal hydride,
 >
 gelled lead acid (sulfation reduces efficiency)
worst
 lithium???

- portability

best
 solid, gel electrolyte sealed cells (need not upright)
 weight and volume energy density also factors
worst

PERFORMANCE BY BATTERY TYPE

Primary cells

C-Zn: Heavy duty carbon-zincs use an artificially made manganese dioxide which is purer and therefore provides more MnO_2 than regular C-Zns. Also, leaving ammonium chloride out of the zinc chloride electrolyte lowers internal resistance (Perez). Shelf life is long when stored below 68°F , about two years. Conversely, low operating temperature, e.g. 32°F , cuts capacity in half (Perez). High discharge rates, a draw of .2 amps or more for a D cell, make this cell uneconomical, ruling out many uses. They have the advantage of being able to somewhat recover their charge between intermittent uses because they have low internal resistance (Perez), making the heavy duty ones marginally cost competitive with alkalines for those uses (Consumer Reports 1987) because alkalines last twice as long but cost more.

Alkalines: These popular cells have a purer grade of materials than C-Zns and an internal design that maximizes contact between electrodes to produce much greater capacities than C-Zns (Perez). Powdered zinc is used over sheet zinc. Synthetically produced--very pure--powdered manganese dioxide, mixed with graphite, makes up the other electrode. They both increase surface area to mass ratio for greater conductivity--lower resistance. The powdered electrodes allow for high surface interaction with the electrolyte. The purer KOH electrolyte is very conductive.

Same potential as C-Zns, 1.5 V. More powerful (energy density 2 to 6 times greater than NiCd). Devices with outputs over 5 watts make alkalines cost effective compared to C-Zns. They perform better at low temperatures (-29°C vs. -7°C for C-Zns and 0°C for mercuric-oxides) (Crompton 1990). Voltage declines with discharge but not as severely as C-Zns. Cylinder alkalines have especially low impedance or resistance, < 1 ohm (Perez) which aids power. Shelf life is high, 4 years at 68°F (Perez) allowing new uses in seldom used devices.

Lithium: Lithium can be substituted for the usual zinc electrode of most common cells and coupled with many other compounds to create cells. Being an extremely electro-positive atom: lithium cells have a uniquely high nominal voltages of around 3v, roughly twice that of alkalines. Some lithium cells are primary, others are rechargeable. Many types are now coming onto the market for the first time and offer the very highest power output--about twice the power density of the next best cell--a wide operating temperature

range, and long life span.

Since lithium will react with both water and air, shelf life is generally achieved by an airtight hermetic seal and the fact that the lithium electrode forms a protective (reversible?) oxidized layer on its surface from a reaction with the cathode (Perez). A shelf life of 10 years or longer is common, though the electrolyte must be a dry one. 90% of power is available at temperatures from -15°F to 125°F ! Output voltages range from 2.6 to 3.6V (Perez) and remain flat during discharge at low drain rates (Perez). Some Li couple combinations do not last long at moderate and high drains, possibly because their volume power density is not as high as their weight power density, meaning larger sizes are needed for some applications. The high voltage is useful for connecting cells in series (sequentially) to achieve battery packs of voltages (12V, 48V, 120V) that most appliances are designed to run on (inverters can be used to chop the direct current into alternating current for appliances designed for utilities electricity. The losses associated with electromagnetically transforming a low voltage to a higher one can be avoided.

Lithium cells are not economical for these large battery pack/high current uses yet. Their voltage can fluctuate (Methvin).

Buttons: Consumer uses of button cells used to be well defined. Mercuric-oxides dominated the hearing aid market due to their flat discharge (power over time) curve, and had the majority of the camera market before features such as auto-focusing and built in flash required larger, more powerful cells. Silver oxides were used in a fair percentage of watches and some cameras while zinc-air were used in calculators and cameras (Eutrotech). As with other cell types, new technologies and performance improvements have changed applications. Mercuric-oxides (apparently not to be manufactured in button configuration after 1996 because of their high mercury content) are losing market share to zinc-air, the longest lived buttons. Since air is the cathode, humidity can lower performance. High altitudes such as Missoula's may decrease the amount of oxygen available for the cell reaction. Silver oxides are not made in larger sizes because of the cost of silver. They also are losing some market share to button Zn-air. *Combining the extremely high cost, lower performance in some respects, and the environmental hazard of mercury and silver buttons, many applications are switching en masse to the newer zinc-air.*

High discharge mercuric-oxides use a potassium hydroxide electrolyte. Low discharge designs use NaOH/ZnO electrolyte. Very low discharge appliances such as

watches (C/600), calculators remote heart telemeters, etc. extend the period of high voltage discharge (Perez) beyond that of alkalines. Energy density is 2-3 times C-Zns. Shelf life, 2 years+, and operating temperature optimum, 68°F, are also midway between C-Zn and alkalines.

Silver oxide buttons use a silver peroxide electrode in their high output versions, silver oxide for low output. The extra oxygen increases the electronegativity and the output voltage--more energy density, about 50% than mercuric-oxides. The electrolyte also varies for high output cells with the same differences as mercuric-oxides. Their discharge voltage remains completely stable and long (due to the low discharge rate applications). Shelf life is superior, 3 years at room temperature (Perez). Low temperature has little effect on output, about a 25% decrease at 32°F from room temperature. These characteristics add up to a performance advantage of silver oxides over mercuric-oxides. Very small appliances benefit from the increased volumetric power density, and the temperature performance and longevity are superior.

The gas electrode in **Zn-air** cells give them a performance advantage since more of the cells zinc electrode can then be packed in to provide more capacity. A disadvantage is that dirty or wet air will decrease performance; and once the cell has been activated it continues to discharge until dead, therefore they cannot be substituted in applications where the appliance sits around without being used. However the shelf life is indefinite before being activated. Output voltage is a bit low, 1.4V, but the weight energy density is about double that of other buttons. A fan can improve performance when tucked away in recesses of appliances (Methvin). Volume energy density is roughly the same. Discharge capacity supposedly very high. Since they drain under no load they should not be used in critical devices, e.g. smoke detectors, medical equipment.

Secondary cells

Nickel-Metal Hydrides: Due in part to cadmium toxicity concerns, nickel-metal hydride (with a partial KOH electrolyte) cells are beginning to replace rechargeable NiCds. Over 8 million units a month will be produced by Japanese manufacturers (Economist 1992), indicating a major switch to Ni-MHs in appliances. They have *major performance advantages* over NiCds. They store nearly twice the power (will even last 2/3rds as long per charge as alkalines). An AA size has a capacity of 1,100 mA, C size 3,500 mA. Capacity will continue to improve, possibly doubling the

current NiMHs (Hoper) and so surpassing current alkalines! They do not have the alleged "memory effect" of NiCds, where they will only recharge up to the point the user partially discharges them.

Some versions of this cell use water electrolysis to create hydrogen gas (H_2) for the anode, but more commonly a metal compound is used that readily absorbs hydrogen gas. Weight is added, but the large pressures created in the former type are avoided (Crompton 1982). They have nearly twice the weight energy density as NiCds, and are durable--last ~50% longer, perhaps 500 cycles (Methvin, Magnus). Ni-MHs have deep discharge capability and have similar inherent overcharge insensitivity to NiCds. Ni-MHs are not as susceptible as NiCds are to reverse charge damage; the fate of one weak cell in a battery pack does not harm others (Bailey 1992). They currently cost the same as NiCds per energy unit produced.

Their first charging when new may need to be repeated 2 or 3 times. For some reason--not a need for power--AA size Ni-MHs are a small bit fatter than other AA's and do not fit if their compartment is tight.⁷¹ Ni-MHs are not suited for very high pulse discharge rate applications (power tools, flashes) due to their high internal resistance (Methvin), though (Bailey 1992) reports positive test result for high discharge of an improved version. Internal resistance also causes a significant higher than NiCd rate of self-discharge (Metzger). Same extremely low nominal voltage as NiCds, ~1.2 V. Producing the nickel alloy can be problematical in construction (Magnus) and they may contain some amount of hazardous metals titanium, vanadium and chromium (Metzger), perhaps no more contamination than any other type of cell. Only operate down to about -10°C (Metzger). Take longer to charge at a given rate than Nicds since they hold more energy.

NiCds: Volume energy density of some NiCds has been significantly improved to about half that of alkalines but is still about 50-100% less than that of Ni-MHs and rechargeable Li cells. Some AA sizes can store 700 mA, C size 1,800 mA, D size 4,000 mA. The larger the size the greater the improvement over older designs; the D size being a four fold improvement while the AA size is only a 40% improvement (Real Goods). One company (the Infinity brand), now offers an owners lifetime guarantee, so they may also be

⁷¹Other cells, such as Kodak's alkalines have been designed this way, perhaps to maximize capacity. Senseless.

more durable than their infamous predecessors.

With low internal resistance they are able to sustain a very high rate of discharge--higher than the competing gel Pb-acids and Ni-MHs-- ideal for motors camera flashes, etc., throughout their life. Self discharge is also favorable compared to Pb-acids and Ni-MHs even with old age; about half the capacity remains after 2 months (Perez). Low temperature does not affect output as it does with Pb-acids except at very high discharge rates (Perez). Voltage output is fairly steady over time.

Their output voltage is only 1.25V, the lowest of any cell, consequently have less power than their gel Pb-acid competition--despite high rate of current flow. 300-1000 cycles, depending partly on how quickly they are charged, is a normal NiCd lifetime but often they only last 100 cycles due to bad use and charging practices. The first charging when new may need to be repeated 2 or 3 times. New fast charge NiCds use high temperature materials to withstand the high charge currents (Bailey).

Sealed Pb-acid: When the sulfuric acid electrolyte is turned into a gel, these cells make good, cheap substitutes to NiCds; with a 2.1V output compared to 1.25V for NiCds. Energy density can be higher than NiCds on volume basis only but often is lower. Always lower on weight basis. Good low temperature operation compared to regular (liquid) Pb-acids; it is comparable to NiCds. Less lifetime cycles than NiCds. They may tend to accumulate sulfur on the electrodes if left discharged (Perez). They can be and in many applications are continually overcharged without harm at low rates. Though voltage output is not steady with discharge, this does provide a method of easily determining the state of charge (Perez).

Wet-cell (vehicle) Pb-acid: Among the more common liquid electrolyte Pb-acid cells there are two varieties, regular or maintenance free, and deep cycle. The regular lead electrodes are rather spongy to maximize surface area, and when repeatedly deeply discharged will disintegrate. Calcium can be added to harden them--maintenance free--and reduce gassing, though this increases internal resistance (Perez). Deep cycle batteries' electrodes are much thicker and have up to 16% antimony for hardness without increasing internal resistance (Perez). They are used for alternative power systems and are meant to be discharged by 80-90%. Deep discharge high antimony Pb-acids batteries used in power back-up systems applications suffer from antimony being oxidized from the positive to the negative plate,

necessitating more current in charging, also causing shortened life by faster loss of the electrolyte (Herritty). Addition of calcium to the lead prevents this but drastically shortens the life to 50 cycles. Added selenium solves this but narrows the optimum operating temperature range (Herrity).

New Pb-acid cell designed by AT&T (Reason) uses pure Pb electrode, instead of the antimony or calcium normally used to provide strength against distortion from build-up of charge contaminants, so that the cell actually increases in capacity with age as pure Pb corrodes into the second electrode component of this cell-- PbO_2 . Plates are stacked horizontally as pure Pb is soft and weak. Pure Pb also slows the rate of plate distortion, increasing lifetime and making cells safer because casings are not cracked, and allowing best ion flow through undistorted grid openings. Size of grid members enlarges along the radius towards the outside to allow constant shape as cell ages so contact areas are maximized for maximum capacity. The horizontal stacking of the cell allows precision placement of plates to avoid later micro short circuiting. The cells however are easily contaminated when electrolyte is topped off, battery racks need to be redesigned to the new shape.

Isuzu claims a new car battery of unknown electrode couples recharge in 30 seconds, has 40 times the starting power and has long life. It can take any shape, has nominal voltage of 1.2 V. Based on activated charcoal (Maskey); Nissan also is working on quick recharge Lead and NiCd batteries (Auto. Marketing).

Silver-cadmium & mercury-cadmium: Merc-Cds develop a .9V potential but it is constant under different loads and can both operate or hold a charge at extremely high temperature. Silver-cadmiums develop a very constant .9-1.0V under load, operate at high temperature, retain a charge and have a longer lifetime than NiCds. Volume energy density is higher.

Lithium: Li cells are very light, and have an even greater advantage when energy density is measured by weight (Economist 1992). For their performance Li cells are still expensive, and are not seen in most cordless appliances yet. Rechargeable lithiums have more power than even alkalines, but do not handle overcharging or deep discharge well without expensive special circuitry (Arnold). Li polymer cells are said to cost 1/10th the manufacture cost of NiCds and way outperforms it in power in capacity (Hooper).

Cylinder Mercuric-oxides: 35-40% mercury content. Have flat power discharge curve necessary in critical machines such as cardiac monitors.

Thermal batteries: When heated some electrode couples melt an otherwise non-conductive inorganic salt electrolyte to generate impressive voltages and current. Calcium-calcium chromate is one type. They are being experimented for large scale uses.

GENERAL PERFORMANCE TIPS

-The cost of electricity from cells ranges from \$70-\$3,000 per thousand watt hours (KWH) (Perez). By contrast, mains electricity is as low as 5-6¢/KWH, or 100 to 6,000 times less. Also, the energy used in making cells is about 50 times the energy they contain. While they do not seem to cost much when purchased a pair at a time, a consumer might save \$10-\$100 a year by knowing where, how and when to use batteries; if there is mains power available; if there is a similar appliance that uses mains; whether the application is suitable for rechargeables (whose life is increased by proper use); and whether the appliance is really needed.

-Carnegie-Mellon University estimates that 876 disposable cells are used up in operating a cassette player for three years, costing \$650 and adding up to 105 grams of mercury to the waste stream; while it could also operate on one rechargeable set costing \$11 and adding 16g of cadmium (Soviero). While the cost advantage still holds, two self-canceling factors affect this toxicity comparison: the reduction of mercury in disposables, and the emergence of non toxic Ni-MHs. It also assumes the rechargeable are treated properly to last their full life; often they die after 50-100 cycles.

-switch to a low power application, e.g. tv channel switchers after they can not power other applications.

-Scrape terminals of primary cells periodically to increase current flow and to completely discharge. Rechargeable batteries generally should not be completely discharged or they will lose life.

-OK to recharge primary cells once (at low rate for safety, with current limitation if possible) for an extra 10% output. Expect possible leaking; do not charge for more than

a few hours. Remove if hotter than luke-warm.

-if in series (i.e. end to end) switching order of cells wont help.

-test a cells voltage to save money. Any voltage reading under a load such as an appliance or a resistor of applicable Ohms, correlate voltage output with remaining life for cells with a sloping discharge curve⁷². A cell tested by itself can result in falsely high readings, as can high temerature, and a cell that has been nearly fully discharged but allowed to rest.⁷³ A light bulb (whose glow intensity indicates the voltage output) screwed into the drilled hole of a copper strip that is bent to make contact with the two electrodes will however give a good indication of remaining life (Babiak). Manufacturers have tables indicating a cells expected life given the discharge rate, temperature and appliance use in. A loaded voltage test result can be compared to the published tables⁷⁴ to tell in a second how many hours a cell has for a given use and ambient temperature. It can be used to extend the life of a cell, or to substitute used cells into another application that does not demand as high a voltage. A safety factor should be allowed, not only to avoid the inconvenience of the appliance dying, but to prevent any one cell with a substantially lower volyage output from suddenly draining completly. This causes reverse charging, where one or more (in parallel connections) cells can build up gas, causing rupture and equipment damage (Wilberg). Upside down insertion in a series arrangement causes a short circuit that can build up heat. The number of cells in either arrangement can speed the dangerous processes.

-disassemble your cordless appliances (e.g. toothbrushes, drills, laptop computers, camcorders) at the end of their

⁷²Voltage over time. Typically falls rapidly at first, evens out over much of the cells life, then falls rapidly when dying (see above comparison by characteristic table for cell types discharge curves).

⁷³Duracell batteries, sold with a chemical voltage tester whose color indicates life span, are an example of improper voltage testing.

⁷⁴Or test your own cells under load under all temp., rate of charge conditions (and possibly for ea. manufacturers formulation, as they optimize for a mix of low and high drain uses--this is not crucial). Test new, at several points in discharge at at the point where the voltage begins to drop badly.

useful life to remove their batteries which will likely be NiCds, possibly Pb-acids or Ni-MHs.

-Ni-MH⁷⁵ cells available (\$5-10 each), in AA, C sizes from:

Harding Energy Systems
821 Washington Av.
Grand Haven MI 49417
tel: (616) 847-0989

Real Goods (catalog)
833 Mazzoli St
Ukiah CA 95482-3471
tel: (800) 762-7325

Currently they are not available over the counter. As with other cells they can be too fat to fit in some appliances.

MAXIMIZING SECONDARY CELL LIFE

A large component of the education program will bring consumers up to date on changes in the rechargeable market. Old NiCd rechargeables were short lived, held low capacity and contained an extremely hazardous metal, cadmium. Today, not only are NiCds themselves more powerful, but there is an alternative cell, the Ni-MH, that performs better in most respects and does not contain a highly hazardous (to humans) metal. Due to the improved performance of the Ni-MHs, manufacturers seem to be switching to them in their appliances.

There is also new activity in promoting pocket size (D, AA, etc.) rechargeables, both NiCds and Ni-MHs. At least one manufacturer (Gates Energy Products) is guaranteeing their NiCds against early failure. To encourage consumers to overcome their resistance to the high initial cost of rechargeables and rechargeer companies are using coupons, rebates and trade-in of used cells to lower the cost of rechargeables. Of course, even though moderate mistreatment in charging shortens their life, rechargeables are much cheaper to operate than disposables.

charging secondary cells

⁷⁵Ovonic of Troy MI developed this cell and has licensed the technology to five manufacturers (Gates Energy Systems, Varta, Matsushita Electric of America, Harding and ?). *Harding is the only one making them in consumer sizes, others are putting them in cordless appliances.* Price will likely decline as they become popular.

Certain charging practices should be practiced across different cell types (Sotcher), unless your charger is sophisticated and you know it allows other practices:

-Do not overcharge batteries, especially sealed cells. Too much current creates heat and gasses that may damage the cell or create an explosion and/or fire. Do not charge batteries heated from rapid discharge or recharge them in a cool environment to prevent damage from overheating.

-Do not discharge batteries beyond the point at which appliance performance begins to fall off--this is probably a greater killer of NiCds than the putative "memory effect". However do not place batteries with sufficient power in the charger. This may overcharge and heat them.

-Slower charge rates are best if time allows, potentially less heat is created to damage cells (Stickel).

Rechargeable cells may be damaged by going beyond the point where voltage rapidly falls off, and any cell performs best when discharged just beyond the point where performance and voltage fall steeply, though of course primary cells should be used up as far as possible.

Fast chargers: Fast--15 minute--charges are a recent development. Sophisticated chargers speed up the charge rate by applying high rate of charge to start and then using various methods to sense state of charge and slowing down the charge rate so cells are not overheated and so that gas does not build up in sealed cells. Detection is often based on the small voltage drop caused by heat build-up after the cell is fully charged, or on sensing the heat generated.⁷⁶ Heat sensing may not be accurate enough to prevent damage; either there is a lag time to reach the surface of the cell (Bailey), or heat may be dispersed and never sensed, as in a battery pack, or never build up enough to cause the small voltage drop (Ettel). Low external temperatures generate a false voltage drop signal. They also slow the recombination of gasses generated by overcharge (Ettel), whether or not the cell components are proportioned to encourage

⁷⁶These chargers should only be used on cells that are in the same state of charge since the voltage drop is measured across the whole set of cells connected in series, causing undercharge if one cell starts off more charged, and overcharge if one cell starts less charged (Perez 1985, Bailey).

recombination and leading to damage in sealed cells, or loss of electrolyte in open cells leading to eventual damage.

Gelled lead-acid cells: They benefit from a low rate overcharge to prevent sulfation (Stickel). Their voltage increases suddenly near the end of the charge cycle, allowing voltage detection and therefore faster charging (Stickel). Input voltage can be held steady (while the current flow is decreased) in charging Pb-acids as these electrodes are able to regain their potential difference rapidly. Despite being pushed by a large voltage the rate of charge current is limited and can protect too deeply discharged cells from damage (Perez 1985). Pb-acids must be charged slowly to avoid heating, and gassing in liquid Pb-acids (Perez).

NiCd charging: In traditional NiCds charging the charge voltage is usually decreased (while current is held steady) at the end of the charge process to prevent structural damage by overheating, as the electrical potential of the electrodes cannot be restored fast--especially if a load is present (Perez 1985). This takes more time. Fast charge methods need to overcome NiCds tendency to begin overcharge gassing reactions before being completely charged. This does not happen at lower charge rates. Rapid charging and discharge cycles leave the battery too warm for heat sensing rapid chargers to work. Discharging beyond 80-90% can damage NiCds. Do not store them in the discharged state. Slower charging (C/10) does allow a day or two of overcharge without harm; at C/20 and slower overcharging can be indefinite (Perez).

NiCds *may* develop a **memory effect** so that when they are repeatedly shallow discharged to the same level they will no longer discharge beyond this point. It does not occur with more random cycling (Perez), in NiCds discharged beyond 1 volt (from ~1.25 volt when fully charged), or in cells that receive overcharge (Stickel). The memory effect is apparently due to large cadmium hydroxide crystals that form on the Cd electrode. They discharge at a different rate than the normal small crystals, causing a localized higher current density and a drop in voltage due to the competing current outputs (Crompton 1982). It is not wise to too deeply discharge NiCds in an effort to erase the memory effect. *This probably is a greater killer of NiCds than the more famous memory effect.*

A similar effect is **voltage depression** (Stickel), caused by excessive continual overcharge, a practice that unfortunately is believed to help cure the memory effect. Proper NiCd use seems to be sharply constrained:

do not deep discharge
do not shallow discharge
do not overcharge.

Zapping: NiCds may be rejuvenated in two ways (Perez). The memory effect can be erased by discharging at a rapid rate, C/2 or faster. For a .5 amp-hour NiCd this is a .25 amp load for two hours. Charge rapidly, repeat about five times. If a NiCd reads below .8V after charging, or 1.0V after rapid charging, or if it self discharges in one or two days, a more drastic procedure, zapping, may help. Metallic dendrites of metal on the electrodes cause many small short circuits between the electrode and the compound the electrode is supposed to react with. A very high current, C/.02--or 25 amps for the above capacity cell--is applied for less than one second to vaporize the dendrites. Left for longer the cell will be damaged from the heat generated and may rupture and burn skin, or explode. *Wear gloves and safety goggles, and do not apply the procedure to cells larger than D size. The cell should be refrigerated prior to zapping because a lot of heat is generated.* Car batteries have high enough current for D size cells and have conveniently flat tops on their electrodes. Place the negative NiCd electrode on the negative car battery electrode and for *less than a second* touch a 12 gauge (2mm) or thicker wire to complete the circuit from the positive car battery electrode to the positive NiCd terminal. *Expect sparking, possible rupture.* Repeat the procedure once or twice at 24 hour intervals. For C size cells a 6V motorcycle cell provides the right amount of current. *For smaller cells only use a 2V source to zap. NEVER use an AC power source.* Perez reports salvaging 67 of 70 NiCds with three ruptured.

This availability of this procedure, but not the procedure itself, will be made known to consumers. It will only be carried out by qualified personnel.

New rapid charge technologies: Other rapid chargers send a high current and voltage in decreasing intervals to allow heat to dissipate but damage cells by creating high internal resistance. By using very short, frequent current interruptions and measuring the state of charge during those few milliseconds maximizes the current possible--without damage--at all states of charge, allowing a safe 15 min. charge apparently (Ettel). An important byproduct is doubling the lifetime of NiCds, measured in cycles, from traditional 4 hour charges with a 50% overcharge.

appendix 6: RESEARCH METHOD

Readers interested in putting together a battery management program, or any hazardous waste management or education program should find the following brief discussion of the way this project was researched useful. Further, the bibliography and contacts database file described below will be available to other interested parties country-wide as Missoula's collection program joins the various public lists of collection programs, e.g. EPA, Dana Duxbury Associates. Every effort will be made to get the paper listed or abstracted in pertinent electronic databases.

To establish a baseline from which to evaluate the effectiveness of a battery collection program, these questions needed answering:

What is the composition of the dry cells? The composition of cells--compounds and rough amounts--is given in the literature of researchers and industry.

What is the volume of cells heading to the landfill? The volume of disposed cells in Missoula is determined by either the cells sales figures of merchants or distributors, or assumed from published cell consumption figures for other cities (in either case factors that could skew the figures need to be considered).

What happens to them in the landfill? The fate of the hazardous compounds is not easily determined. The acidity or alkalinity and the electronegative potential of the many different compounds in a landfill combined with the physical environment (temperature, densities, adsorption and absorption coefficients, water flows) of the landfill and the soil types all affect whether cell constituents will solubilize and reach the aquifer. Despite knowing the inputs of metals from batteries into the landfill, it is not easy to determine the risk posed by the cells.

Secondary research began with relevant--listed below--CD-ROM and online database searches most of which included Boolean logic operator searches to track related subjects. For example the search phrase:

(batter# OR cell#) AND landfill#

in many databases will retrieve all the records containing the words "landfill(s)", but only if together with the words

"battery(ies)" or the word "cell(s)".

The broad subject areas of the databases, and the subjects that were searched covered:

-industry (trade) and environmental advocacy publications: existing collection programs, government regulations;

-research journals, texts and proceedings: cell reactions, cell degradation in landfills, metal and electrolyte toxicity, reclamation processes;

-US government reports: all the above.

From these sources a computer database, filename BAT.DBF, was developed containing 152 contact names, organizations, telephone numbers and a memo field for particular information about that organization or individual (appendix 7). The records in this database include manufacturers, activists, government agencies, cell and collection experts, trade associations and collection programs.

The records in BAT.DBF were used to mail a request for information (sample letter follows below) containing specific questions pertaining to cell toxicity, reclamation process, collection and cell performance characteristics. Questions in the letter were tailored to the type of organization the request for information went to, resulting in three versions of the letter:

- technical information (6 questions)
- collection program information (7 questions)
- both (11 questions).

In each of the three form letters the last question left space for the contents, if any, of the memo field in BAT.DBF to be printed. This explained that organization's utility to this project so that the information request was unique to the recipient's expertise.

As information came in it went into the two bibliographies, briefly annotated if it was especially valuable. Follow up phone calls to 10 or so organizations that had not responded and who seemed most promising sources indicated that the letter may have contained too many questions and been too harsh in tone to encourage responses. The phrase "You need only respond to the questions you are most familiar with" may have increased the response rate.

CD-ROM or online databases used

Agricola
 Applied Science & Technology Index
 Biological Abstracts
 Biological & Agricultural Index
 Chemical Abstracts
 Dissertation Abstracts
 Energy Research Abstracts (paper)
 Energy Policy Abstracts (paper)
 Environmental Bibliography
 EnviroLine
 EPA Online Library System (OLS)
 Government Printing Office (GPO) Master Catalog
 GPO Publication Reference
 Info-Trac (Gen. Periodicals Index); academic & business
 Missoula Public Library catalog
 Pollution Abstracts
 Social Sciences Index
 Western Library Network

The following databases helped in tracking down addresses for companies, associations and interest groups in aid of mailing out the informational letter (they usually are available in more than the form listed--paper, online, CD-ROM):

Encyclopedia of Associations (paper) 26th Edition Gale Research Inc, Detroit MI.

Annual directory of associations, interest groups, etc. Thorough. Great subject cross index.

Disclosure, Inc. (CD-ROM) Disclosure Information Services.

Complete publically released financial data on public companies.

Dun's Electronic Yellow Pages (online) Dun & Bradstreet Information Services, Murray Hill NJ.

Addresses, telephone numbers, etc. for most public and private companies and organizations. Includes Standard Industrial Classification (SIC), county census data and number of employees. Has most establishments in U.S!

Dun & Bradstreet Million Dollar Directory (paper, online) D&B Information Services.

Summary data on public and private companies over \$500,000 assets (or sales?). More complete than other paper corporate directories. State/City and SIC code cross indices.

Government Reports (paper, online) National Technical Information Services (NTIS), Dept. of Commerce.

Monthly listing of thousands of new reports generated yearly by US government agencies that are deemed technical (broadly defined) and useful by the agencies. The reports are written in or for (EPA apparently is not making as much effort as it used to to get its technical reports listed). Cross indexed by author, agency (*almost all EPA reports begin with a "PB" NTIS report number*), contract/grant number, and keyword. Available on paper and microfiche--cheaper--or whichever media produced in. These reports are expensive.

Regional, State & Local Organizations 1990-91 (paper) 2nd ed., Gale Research.

Directory. Does not seem too thorough yet. Not cross indexed by subject area as their Encyclopedia of Associations (above) is.

Sample of the request for information letter:

recycled paper (10% post-consumer, 50% overall)

30 April 1992

Anthony Tweedale
EVST
Rankin Hall, U. MT
Missoula MT 59812

tel: (406)542-1709
fax: (406)523-4781

In order to implement a pilot program for the collection of household batteries in Missoula MT, pop. 60,000, I am looking for pertinent information. The collection program is my masters degree thesis in the Environmental Studies program at the U. of Montana. The project has been enthusiastically endorsed by local government through the Missoula Solid Waste Task Force, and has the support of the Chamber of Commerce.

Can you provide me with information in the following areas

that you're knowledgeable in, and anything else you feel may be helpful. Also point me to additional sources. Please pay **specific** attention to the items listed under the general subject areas below. You may want to send printed materials to avoid lengthy explanations.

Please respond by Tue, 20 May. You may fax to the number above. Materials may be mailed C.O.D. (1st class please, so copy double-sided if possible!). I'll be at the tel. no. above Tue. and Thu. mornings and at other hours to answer questions, or leave a message.

- 1) **Collection program logistics:** collection sites, collection, sorting, storage, haz. waste regulations, disposal (including transportation), other.
- 2) **Collection program promotion:** please describe methods for encouraging public to go to the trouble of recycling their batteries.
- 3) **Collection program funding and costs:** describe fees, taxes, grants, deposits on batteries, and disposal costs (net of revenue from cells) as they are used to keep the program going. // Discuss disposal cost differences (button vs. alkaline and carbon-zinc) and how this affects program viability.
- 4) **Education:** describe programs encouraging conservative use of household batteries.
- 5) **Degradation of cells in acidic landfill environment:** (or due to alkaline electrolytes)--information concerning reactions, rates, species, transport, partitioning.
- 6) **Storage hazards:** explosions re: charged vs. uncharged state, Reactivity of lithium cells. Other.
- 7) **Composition of cells:** (I need this to explain the potential threat to our aquifer from our landfill): any non-proprietary information such as Material Safety Data Sheets (MSDS's), with quantities if possible, including: electrodes, electrolyte; and mercury used as anti-corrosive.

check here :__: if you want this information kept
UNDISCLOSED

check here :__: if you want this information kept
ANONYMOUS

(please contact me with any concerns about confidentiality).

8) **Reclamation & disposal:** please describe the non-proprietary aspects of the reclamation method in as much detail as possible (this project includes an evaluation of disposal methods). Metals reclaimed.

9) **Recycling of fluorescent lightbulbs:** do you know anything about their collection or processing (re: mercury content)?

10) (may be blank):

Please check here |__| if you'd like your information to be disseminated publically, where appropriate.)

Thank you, very much, for your cooperation

appendix 7: TEXT OF CONTACTS DATABASE

152 records, each field in a record separated by commas (and quotation marks if it is a character field), blank numerical fields appear as a zero.

Sorted by TYPE field, then by ORGANIZATION field.

Description of fields in each record, in order printed:

TYPE: (see immediately below)
 CONTACT NAME
 ORGANIZATION
 ADDRESS
 CITY/STATE
 TEL. NO.: (not divided by dashes)
 FAX NO. or 2nd tel. NO.
 PUBLIC COMMENT: contents prints in letter (appendix 7)
 PRIVATE COMMENT
 REPLY: what was sent buy recipient of letter

Code scheme for the first field (field name TYPE, 1 character long). May appear in upper or lower case:

"C" = collection info wanted
 "T" = technical info wanted
 "B" = both wanted
 "M" = manufacturer
 "P" = collection program
 "U" = univ/other resarch
 "F" = fluorescent bulbs
 "R" = reclaimer/recycler
 "*" = new information (after the mass mailing)
 "" = miscellaneous

Text of the database contents:

"","RICHARD HILL","ENV. PACIFIC","", "LAKE OSWEGO
 OR",0,0,"","OUT OF BUSINESS ACCORDING TO TES INC. // UNDER
 INVESTGN. & FINED BY STATE",""

"","TERRI GOLDBERG","NE WASTE MGMT OFFICIALS ASSOC
 (NEWMOA)","85 MERRIMAC ST","BOSTON MA 02114",6173678558,
 ,""SOURCE REDCTN /TOXIC METALS /HOUSEHOLD
 BATT's--FEDRL,STATE & IND. INITIATIVES" REPORT","", "DIN'T

SEND LETTER; GOT THIS RPT FROM EPA RGN 1 LIBRARY"

"", "", "TWI", "", "ENSCO AK", 0, 0, "SAME AS ENV. SERV. CO.
(ENSCO)?! INCINERATES LITHIUM BATTRS (NO RECOVERY?)", "", ""

"", "", "", "", "SANDERS LEAD", "see Assoc of Batt
Recyclers", "", "", "", "", ""

"*", "MURRAY COOK", "CADMIUM ASSOCIATION", "42 WEYMOUTH
ST", "LONDON W1N 3LQ, **ENGLAND**", 714998425, 4931555, "", "ALSO
David Wilson", ""

"B", "SUMNER P WOLSKY, PRES", "ANSUM INDUSTRIES", "1900 COCONUT
RD", "BOCA RATON FL 33432", 4073913544, 0, "ORGNZR 3RD INTL
SEMINAR BATTERY WASTE MGMT (CONNECTED TO IND. BATTERY MANUF.
ASSOC.?)", "ALSO (508) 771-0094", "PHONED HIM, UNWILLING TO DO
MY RESEARCH FOR ME!"

"B", "*JOS. C SABATINI, BATT WASTE M", "ARTHUR D LITTLE CO", "5
ACORN PARK", "CAMBRIDGE MA 02140", 6178645770, 0, "DO PERIODIC
SURVEYS / *DID "ASPECTS OF RECYCLING...BATTERIES"", "ALSO
ANTHONY MONTRONE, BRIAN BARNET", "SENT LIST OF PUBLICATIONS.
MORE INFO AVAILABLE ON RENUMERATION"

"B", "KENNETH CAMBELL, EXEC DIR", "ASSOC. OF BATTERY
RECYCLERS", "SANDERS LEAD CO, SANDERS RD", "PO DRWR 707 //
TROY AL 36081", 2055661563, 0, "FORMERLY SECONDRY LEAD SMELTERS
ASSOC// *ONLY 3 2ry SMELTERS ACCEPT CORDLESS APPLIANCE
PB-ACID BATT'S?", "*800-633-8744, PAY FREIGHT", ""

"B", "", "B-C RECYCLING", "349 W VAN BUREN", "SALT LAKE CITY,
UTAH 84115", 8014668813, 0, "ACCEPTS FROM INDUSTRIAL SOURCES //
HANDLES BUSINESS FROM TES (OR)", "", ""

"B", "*ANN NOLL, ACCT MNGR", "BATTERY COUNCIL
INTERNATIONAL", "111 E WHACKER DR", "CHICAGO IL
60601", 0, 0, "ANNUAL YEARBOOK", "EDW FRAFT, EXEC DIR", "DIDN'T
SEND YEARBOOK, INCL LIST OF 2ndry SMELTERS & RECYCLERS"

"B", "*SHERRY CHOATE, CUSTOMER SVC.", "BDT", "4255 RESEARCH
PKWY", "CLARENCE NY 14031", 7166346794, 0, "LITHIUM NEUTRLZR, TO
HAZ WASTE LANDFILL", "7592868 (MAIN #)", "PROMO PCKG INCL.
SHIPNG INFO, DESCR PROCESSES, SAFETY OF Li"

"B", "", "BETHLEHEM APPARATUS", "3890 FRONT ST", "HELLERTOWN PA
18055", 2158387034, 0, "MERCURY OX, 5 GAL MIN.
*(\$770/BUCKET)", "", ""

"B", "MURRAY COOK", "CADMIUM ASSOCIATION", "34 BERKLEY
SQUARE", "LONDON W1X 6AJ
ENGLAND", 4998425, 4931555, "COUNTRPART TO CAD, COUNCIL IN

US, HOLD TRIANNUAL CONF IN CONJUNCTN, DO A Nicd BATTERY CONF
BIANNUALY", "telex 261286", "PRICE LIST OF PUBLICATIONS"

"B", "HUGH MORROW, EXEC DIR", "CADMIUM COUNCIL", "GREENWICH
OFFICE PARK, BLDG 2", "GREENWICH CT
06830", "2036250911,0", "COUNTERPART TO CAD. ASSOC. IN LONDON,
THEY HOLD TRIENIAL CONF.-->*ASK FOR INDEX OF
PROCEEDINGS*//NEXT IN '92 (S.F.?)", "", "RECEIVED PROCEEDINGS
OF 2 CONFERENCES & OF 2 Nicd BATTERY CONFERENCES, OTHER
MATERIAL"

"B", "", "CANADIAN BATTERY MANUFACTURERS ASSOCTN", "1 YONGE ST
(ste 1400)", "TORONTO ON M5E 1JP *CANADA*", "0,0", "", "", ""
"B", "MICHAEL BENDER", "CENTRAL VT REGIONAL PLANNING COMM", "26
STATE ST", "MONTPELLIER VT 05602", "8022290389,4666", "", "MAY BE
SAME PROGRAM AS Central VT Public Service Commission", ""

"B", "DANA DUXBURY", "DUXBURY ASSOC'S", "16 HAVERHILL
ST", "ANDOVER MA 01810", "5084703044,3384", "ASK TO PUT NOTICE OF
MY PILOT PROJECT IN HHW MGMNT NEWS TO GET FEEDBACK // ASK
LIST OF FLUORES. BULB RECYCLERS & EXPERTS", "", ""

"B", "INDIRA NAIR", "ENGINEERING & PUBLIC
POLICY", "CARNEGIE-MELLON U.", "PITTSBURGH PA
15213", "4122683645,0", "*ALSO McMICHAEL // *HOUSEHOLD BATTERY
RECYCLING BY GG JONES", "*SEE OTHER C-M U. RECORD", "PHONED,
HAVEN'T HEARD FROM AS OF 1 JUL 92"

"B", "BETH O'DOUD", "ENV HAZ MGMT GROUP (EHMI)", "10 NEW MARKET
RD // *BOX 932", "DURHAM NH 03824", "6088681496,1547", "", "ALSO
AMY DYRE-CABANISS", "SMALL PCKG INFO RECIEVED"

"B", "SHAWN HECHT/KEVIN TAYLOR", "ENV. ACTION COALITION", "625
BROADWAY (2ND FLR)", "NYC NY 10012", "2126771601,0", "GET INFO ON
6 MONTH NYC DEMO PROJ, OTHER. DROP OFF AT RETAIL. BUTTONS &
Nicd's. ONLY STORING UNTIL CHECK OUT MERECO", "", "PHONED, NO
RESP. AS OF 1 JULY 92"

"B", "", "ENV.SYSTEMS CORP (ENSCO)", "BX 1957", "EL DORADO AR
7(?)1731", "5018637173,0", "SAME COMPANY AS TWI, WHO HANDLES
LITHIUM BATT'S (INCINERATION)?", "", ""

"B", "ELLEN PRATT, OSWER", "EPA", "401 M ST SW", "WASHINGTON DC
20460", "2022607597,4196", "", "SENT ADDTL LTR WITH RCMDTNS FOR
CHANGES TO DRAFT OF ABOVE RPT ~5/10", "SENT 2 RPTS INCL DRAFT
(MAR 92) OF OSWER "...IS A COLLECTN PRGMM RIGHT FOR YOUR
COMMUNITY?" & A GOOD CONTACT LIST"

"B", "FRED FRIEDMAN", "EPA REGION 1 LIBRARY", "JFK FEDERAL
BLDG", "BOSTON MA 02203-2211", "", "", "SENT 2 RPTS + RESULTS"

OF A DATABASE SEARCH (ENCIROLINE, POLLTN ABS, ETC.)"

"B", "MARGORIE FRANKLIN, PRES", "FRANKLIN ASSOC LTD", "4121 W 83rd ST, STE 108", "PRAIRIE VILLAGE KS 66208", "9136492225,0", "*"CHARACTZ OF Pb & Cd IN SOLID WASTE...YEAR 2000"--ALREADY GOT IT ON M-FICHE", "", "SEE publ FIELD"

"B", "MARIE STEINWACHS", "HHW PROJECT", "1031 E BATTLEFIELD, STE 214", "SPRINGFIELD MO 65807", "4178895000,5012", "23 CO'S. DROP OFF AT RETAIL. BUTTONS. MERECO", "OLD ADDR: BX 87, 901 S NATIONAL, SW MO STATE U.", ""

"B", "MARY ANN SMITH, SECR.", "IIT RESEARCH INST.", "10 W 35TH ST", "CHICAGO IL 60616", "3125674000,0", "DOES CONTRACT RESEARCH ON BATTERY USE, DISPOSAL ('74 ES&T ARTICLE)", "", ""

"B", "CELWYN HOPKINS, EXEC SCTRY", "INDEPENDENT BATTERY MANUFACTURERS ASSOC", "100 LARCHWOOD DR", "LARGO FL 33540", "0,0", "ANNUAL BUYERS GUIDE (SL19)/ANNUAL MEETING (ARE THEY CONNECTED TO ANSUM IND.?)", "", ""

"B", "", "INFORM", "381 PARK AVE S.", "NEW YORK NY 10016", "2126894040,0", "RESEARCHED OVERSEAS PROGRAMS/RECYCLERS?", "", "INCL A GOOD ARTICLE ON HOSPITALS & HgOx'S"

"B", "*JOHN ONUSKA", "INMETCO", "BOX 720 // 245 PORTERSVILLE RD", "ELWOOD CITY PA 16117", "4127585515,0", "NICD, LARGE QUANT", "NICD, LARGE QUANT", "SENT PROMO PCKG INCL DESCR PROCESS, SHIPPING INFO"

"B", "JEROME COLE, PRES.", "INT'L LEAD ZINC RESEARCH ORGANIZATION", "2525 MERIDIAN PARKWAY//BX 12036", "RESEARCH PARK TRIANGLE, NC 27709", "9193614647,0", "", "", ""

"B", "JEROME SMITH, EXEC DIR", "LEAD IND. ASSOC.", "295 MADISON AVE", "NEW YORK NY 10017", "2125784750,0", "", "", ""

"B", "DAVID COHEN, V-P", "MERCURY REFINING CO", "790 WATERVLIET-SHAKER RD", "LATHAM NY 12110", "5187851703,0", "ALL TYPES", "*LEO (?) COHEN ?? // ALSO VICKY G HART, MKTNG MNGR", "SENT PROMO PCKG INCL SHIPING INFO"

"B", "KAREN ARNOLD", "MINN POLLTN CONTROL AGENCY", "520 LAFAYETTE RD", "ST PAUL MN 55155-3898", "6122978368,8676", "WROTE MN'S STUDY (ALREADY HAVE IT)", "ALSO LESLIE GOLDSMITH, SPVSR SPECIAL WASTES UNIT, HAZ WASTE DIV", ""

"B", "*LISA SILVERSTONE", "NATIONAL ELECTR. MANUFACT. ASSOC. (NEMA)", "2101 L ST NW *ste 300", "WASHINGTON DC 20037-1581", "2024578424,0", "HAS HANDBOOK ON BATTERY

LITERATURE//ASK RE FLOURESC. BULB RECYCLING INFO", "", "TALKED
20 MAY 92 re: MERC OX'S, NEMA BUTTON COLLECTION PRGRM,
FLUORESCNT TUBES..."

"B", "CARL HIRTH, DIR", "NH/VT SOLID WASTE PROJ", "MOODY BLDG,
RM 336", "CLAREMONT NH 03743", 6035431201, 0, "29 TOWNS. DROP
OFF @ TRANSFER STATIONS, MUNI OFFICES & RETAIL. ALL TYPES.
HW LANDFILLED BY LAIDLAW", "", ""

"B", "BO NORLING, MGR", "NIFE INC.", "251 INDUSTRIAL BLVD // *
BX 7366", "GREENVILLE NC *27835", 9198301600, 0, "SEALED NIDC'S
TO SWEEDEN // ARNE NILSSON, EXEC. V-P", "", ""

"B", "*JOHN KIMMELMAN", "NRDC", "40 W 20TH ST", "NYC NY
10011", 2127274479, 0, "", "ALSO ALLEN HERSHKWITZ", "PHONED, NO
REPLY AS OF 1 JUL 92"

"B", "NORM ENGLAND, EXEC DIR", "PORTABLE/RECHARG. BATTERY
ASSOC.", "210 INTERSTATE N PARKWAY, STE 7", "ATLANTA GA
30339", 4049806688, 6695, "*Pb-ACID CELLS USED INTERCHNG. W.
NiCd'S//NEED FOR RCRA "UNIV. WASTE " REG (EASY TO HANDLE,
MULT SOURCES) FOR EXEMPTN", "STE 700--?", "SAY NATNL PLANS FOR
TAKE BACK GOING AHEAD (S. BILL). PCKG W. LEGISL UPDATE &
DESCR. OF MN PILOT PRGRM FOR TAKEBACK OF APPLIANCE BATT'S"

"B", "JOHN TEKIN. PRES", "RADIAC RESEARCH CORP", "259 KENT
AVE", "BROOKLYN NY 11211", 7189632233, 0, "", "REFERENCED IN
DUXBURY LIST AS HHW CONTRACTOR)", "", ""

"B", "LISA MEUCCI", "RECOMP INC.", "1524 SLATER RD", "*FERNDAL
WA 98248", 2067347368, 0, "'P'. CURBSIDE W. RECYCLABLES & DROP
OFF AT RETAIL. ALL TYPES. CHEM WASTE LANDFILL, OTHERS
MEREKO. ASK RE: ENV. PACIFIC", "VISITED ENV. PACIFIC // *SAME
AS WA/BELINGHAM LISA SCNEBELE", "SEE priv FIELD"

"B", "DAVID HURD", "RECOVERAB. RESOURCES/BORO BRONX 2000
INC", "1809 CARTER AV", "NYC NY
10457", 2127313931, 5832047, "*NEW "Getting a Charge Out
of...", **COMPLETE** ANALYSIS OF BATT RECYCNG.", "", "SPOKE
W.--GENERALLY PESSIMISTIC. RPT WILL BE AVAIL FOR COST ~\$30."

"B", "BILL MEADOR, PRES", "RECOVERY & RECLAMATION INC", "2001
WESTERN AVE // BX 571", "PECOS TX 79772", 9154473272, 0, "*WAS
BALFOUR IND.", "BOUGHT SOME OF ENV PACIFIC ASSETS, ALSO 2
EMPLOYEES (THROUGH TES INC)", "ANSWER BY RBT CURRY SR:
DESCRIPTION OF PROCESS & MSDS"

"B", "JESSIE LANG or ANNETTE DU BOIS", "SPOKANE SOLID WASTE
DISPOSAL PROJECT", "E 1225 MARIETTA ?", "SPOKANE WA
99207", 5094567403, 0, "ASK RE \$89/DRUM(CHEAP!): INCL
CHARACTERIZATION FEE? VARY W. DISTANCE TO LANDFILL OR W.
SMALL VOL?//WKLY CURBSD, ALL TYPES", "", ""

"B", "STEVE BIEDEL, PRES", "TES INC", "BX 1581", "LAKE OSWEGO WA 97035", "5036973455,0", "", "& CARL KOSTOL, BOTH FORMER ENV. PACOFIC EMPLOYEES/NO LONGER W. BASALT IND, WITH B.C. OF UTAH", ""

"B", "", "TRI CIL CANANDA", "1829 ALLANSFORT RD", "THORROLD ON L2V 3X9", "4162277872,0", "ACCEPT FROM DE. PRGRM", "", ""

"B", "ANGELA MURRAY, SECR.", "VERSAR, INC.", "6850 VERSAR CTR.", "SPRINGFIELD VA 22151", "7037503000,0", "DID RESEARCH FOR EPA ON BATT'S ('74 ES&T ARTICLE)", "", ""

"B", "VOEST-ALPINE ENV. ENGNR'S", "VOEST-ALPINE INT'L", "60 E 42nd ST", "NYC NY 10165", "2126611060,0", "", "J SIECHART EXEC VP OF PARENT (RE RECLMTN)//REFERENCED IN RES REC.3/'88", ""

"B", "CONNIE LEACH", "VT SOLID WASTE DIV/AGENCY NAT. RESOURCES", "103 S MAIN", "WATERBURY VT 05676", "8022447831,5141", "*ALSO CNTRL VT PSC (800-382-2877): OWN COLLECTION PRGM?", "ALSO ANDREA COHEN, HHW COORD", "SENT 1 RPT (Ms COHEN), VT STATE STUDY"

"B", "ENV. AFFAIRS MANAGER", "VULCAN LEAD, INC.", "1400 W PIERCE ST", "MILWAUKEE WI 53204", "4146452040,0", "T.L.S. COLLECTION PRGRM FREIGHT CHG. ONLY TO DOE RUN CO./800-932-LEAD", "TLS:TOTAL LEAD STEWARDSHIP // 800-932-LEAD", ""

"B", "DONALD A SEEBERGER", "WA DPT ECOLOGY, SOLID/HHW PRGRM", "3190 160TH AV SE", "BELLEVUE WA 98008-5452", "2066497131,7098", "", "", "PHONE CONVER 5/5/92, SENT DRAFT ANALYSIS OF HENNEPIN CO EXPERIENCE (*WANTS KEPT ANONYMOUS*)"

"b", "*CONNIE SOUTER", "ALARON CORP", "*3 BETHESDA METRO CENTER (750)", "BETHESDA MD 20814", "3019611963,0", "MIXED BATT(INCL MgO2) RECLAMTN PROCESS(ACID,REDUCING)/ ASK IF Cd OR Hg HINDER RECOVERY OTHER METALS?", "INCL DESCR OF 2 SWISS (MORGES, SWITZ) OPERATIONS (XEROXED)", "CALLED--WAS RECYTEC AMERICA IN CEDAR KNOLLS NJ."

"b", "GEO. MAYER CMRI BAT TECH CENTR", "CARNEGIE-MELLON U.", "", "PITTSBURGH PA 15213", "", "READ PAPER FOR DRY CELL W-SHOP (EPA RREngLab, NOV 90), WOULD LIKE ADDRESSES FOR THAT LIST OF ACADEMIC CENTERS FOR BATT's", "ALSO McMICHAEL (DPT ENGNRNG & PUBLIC POLICY)", "PHONED FOR A RESPONSE, NONE AS OF 1 JUL 92"

"b", "", "CLEAN JAPAN CENTER, No 2 AKYAMA BLDG.", "3-CHOME 6-2 TORONOMON, MINATO-KU", "TOKYO 105 JAPAN", "34326301", "MIXED CELL PROCESSOR (Hg, Fe, Zn) ALSO FLOURESC's// ROASTER, ALSO PEELS SKIN OFF R-20's (D CELLS?)", "TELEX CLEANJC

J32415","*(OUT OF BUSINESS ACCORDING TO D. HURD OF R2B2--WAS A PILOT PRGRM)"

"b","DAVID BUSSARD, Charactzn Asmnt","EPA","401 M St SW","WASHINGTON DC 20460",,,,"COPY OF 'Relief From Appl of TC to Used NiCd's Destined for Reclamation' (1 Jul 91) BY BATT PRODCAT ALLIA,RELTD PUBLIC MTRL","*ALSO JULIE LYDDON (Re: RCRA EXEMPTN RULE FOR FLUORESCNT BULB RECYCLING)",""

"b","* ELIZABETH WOOD","GERSHMAN, BRICKNER & BRATTON",,,,"FALLS CHURCH VA",0,,,"OK TO USE TABLE IV-7 IN YOUR WI STUDY? / RQST COPY OF "Dispsl of Household Batt's in Landfills" FOR KING CO, WA; APR. 89","REFRNCED IN REPORT FOR WI DPT NAT RES BY GB&B","TEL W. PERMSN TO USE TABLES, SAID ABOVE RPT FOR KING CO WAS OLD, NO NEW INFO"

"b","M. MASAO SHINOHARA","JAPAN BATTERY & APPL.INDUSTRIES ASSOCTN.",,"#9 MORI BLDG 2-2 ATAGO 1-CHOME",,"Minato_ku TOKYO 105 >>JAPAN<<","",,"",,""

"b","SHELLEY DRESSER","N E RECYCLING COMPETITION",,,,"8022543636",,,,"*SENT NO LETTER // *TOLD OF BY D. HURD OF R2B2--WHY?",""

"b","SIR/MADAM","UNIVERSAL METALS & ORE","Bx 187","MOUNT VERNON NY 10551",9146640200,,,"NiCd--EXPORT TO FRANCE",,,,""
"c","JOHN PRICE, SPECIAL PROOJECTS","BROWARD CO. OFFICE INTEGRATED WASTE MGMT","200 PARK CENTER BLVD #5","POMPANO BEACH FL 33064",3059700177,,,"READ YOUR ARTICLE OF MERC OX CELLS/HOSP's IN msw mgmt, WANT MORE ON THIS, ESP. ABILITY TO SUBST. GIVEN TYPE OF HOSP MACH","BERT LUER OF WMI 305-771-9850",,""

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"C","MICHAEL DANNER, ADM DIR","AMERICAN WATCHMAKERS INST.",,"3700 HARRISON AVE","CINCINNATTI OH 45211",5136613838,0,"COLLCTN PROGRM PROCEEDS TO SCHOLARSHIPS FOR WATCHMAKERS",,,,""

"C","MICHAEL SPINDLER, COO","APPLE COMPUTER CORP",,"20525 MARIANI AVE",,"CUPERTINO CA 95014",4089661010,0,"TAKE BACK SPENT NICD'S / * APPARANTLY USE LEAD-ACID'S",,,,""

"C",,,,"CENTRAL VT PUBLIC SCV COMMISN",,,,"8003822877",,"COLLECT NiCd's AND BUTTONS // *PRBA PUTTING TOGETHER THEIR APPLIANCE BAT PROGRAM",,"MAY BE SAME PROGRAM AS Central VT Regional Planning Commision",,"SENT BRIEF LEAFLET"

"C","BUTTON BATTERY COLLCTN COORDNT",,"DAKOTA COUNTY

BOARD", "1500 HWY 55", "HASTINGS MN
55033", 6124384418, "", "", ""

"C", "", "F W HEMPEL & Co, INC.", "*1370 Ave of the
Americas", "*NEW YORK NY 10019", 2125868055, "", "NiCd's LARGE
QUANTITY ONLY, TO FRANCE", "NO LETTER (INDUSTRIAL NiCd's
ONLY)", ""

"C", "RANDY JOHNSON, CO COMMSNR", "HENNEPIN CO BOARD", "2400
GOVMNT CENTER", "MINNEAPOLIS MN
55487", 6123482088, 0, "", "", "SENT REPORT REVIEWING CO'S
COLLECTION PRGRM"

"C", "MILTON DENTCH", "POLAROID CORP", "868 WINTER ST, BLDG
5", "WALTHAM MA 02254", 6176842069, 0, "", "", ""

"C", "", "QUICKSILVER PRODUCTS, INC.", "*200 VALLEY DR, Ste
I", "*BRISBANE CA 94005", 4154682000, "", "BUY MERCURY
CELLS", "*POSTCARD IN PLACE OF LETTER SINCE LATE
ADDITION", "BROCHURE, ETC."

"C", "*OREN KRONICK, CUSTOMER SERVIC", "SEVENTH
GENERATION", "49 HERCULES DR", "COLCHESTER VT
05446-1672", 8026556777, 2700, "SELL SECONDARIES, ETC IN
CATALOG & "BATTERY" STICKER FOR COLLECTION
CONTAINERS", "8004561177", "SENT LIST OF ONE CONTACT"

"C", "LISASCHNEBELE", "WA/BELLINGHAM", "", "", 2063841057, 0, "SAME
TEL# AS RECOMP//DROP OFF AT RECYCLING CENTER AND RETAIL
STORES. ALL TYPES. ALKALINE, C-ZN SENT HW LANDFILL.
MEREKO", "", "TALKED--NOW AN IND. CONSULTANT, MOSTLY SOL WASTE
& INCINRTN."

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"M", "", "CATALYST RESEARCH", "1421 CLARKVIEW RD", "BALTIMORE MD
21209", 3012967000, 0, "LiI--PRIMARY", "", ""

"M", "", "DURACELL INC", "BERKSHIRE INDUSTRIAL PARK", "BETHEL CT
06801", 8004229001, 0, "", "LiMgO2--PRIMARY", "", ""

"M", "", "ELECTROCHEM INDUSTRIES", "10000 WEHRLE DR", "CLARENCE
NY 14031", 7167597320, 0, "LiCl--PRIMARY", "", ""

"M", "", "EVER READY CO. (HOLDINGS) LTD", "CENTRAL LABORATORIES
ST ANN'S RD", "LONDON ENGLAND N15 3TJ", 0, 0, "", "", ""

"M", "", "EVEREADY BATTERY CO", "CHECKERBOARD SQUARE", "ST
LOUIS MO 63164", 3149822000, 0, "LiMgO2,
LiFeS--PRIMARY", "", "also 25225 Detroit Rd, Westlake OH 44145
(216)835-7527 (Mike Babiak, Quality Assurance"

"M", "", "KODAK-ULTRA TECHNOLOGIES", "RT 88S // PO BX
267", "NEWARK NY 14153", 8002422424, 0, "LiMgO2--PRIMARY", "", ""

"M", "", "MAXELL CORP", "22-08 RTE 208", "FAIRLAWN NJ
07410", 2017945938, 0, "LiMgO2, --PRIMARY", "", ""

"M", "", "OVONIC", "", "*TROY MI", 3133621750, "", "*VARTA LICENSES
THEIR NiHydr's?", "*LATE ENTRY-SENT NO LETTER", ""

"M", "", "SAFT AMERICA // PORTABLE BATTERY DIV.", "711
INDUSTRIAL BLVD.", "VALDOSTA GA 31601", 9122472331, 0, "Pb's &
Li's", "", ""

"M", "", "SANYO ENERGY CO // BATTERY DIV.", "200 RISER
RD", "LITTLE FERRY NJ 07643", 2016412333, 0, "NiCd's &
Li's", "", ""

"M", "", "SANYO ENERGY CORP", "1201 SANYO AVE", "SAN DIEGO CA
92073", 6196616620, 0, "LiMgO2", "", ""

"M", "", "VARTA BATTERIES INC", "300 EXECUTIVE BLVD", "ELMSFORD
NY 10523", 9145922500, 0, "LiMgO2 DEVELOPING 2ry IN
ENGLAND", "", ""

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"P", "RON TUBB", "", "", "OVERLAND PARK
KS", 9133825252, 5993151, "DROP OFF AT 7 RETAIL STORES.
BUTTONS. MERECO", "TEL POSSIBLY 381-5252 (CITY HALL)", ""

"P", "KARENSCHOENING", "AL/HUNTSVILLE", "", "", 2058806054, 0, "CUR
BSIDE WITH RECYCLABLES. ALL TYPES. SENT TO CHEMWASTE AND
LANDFILLED IN A HW LANDFILL", "", ""

"P", "JOHN FLOWERS", "FL/GAINESVILLE", "", "", 9044959215, 0, "DROP
OFF AT RURAL SW COLLECTION CENTERS AND AT HHW COLLECTION
DAYS. ALL TYPES. SEAL IN CONCRETE AND STORE UP TO ONE
YEAR", "SENDING TO MUNICIPAL SOLID WASTE LANDFILL", ""

"P", "RAYHILLBRAND", "KY/LOUISVILLE", "", "", 5026252788, 0, "PILOT
DROP OFF AT RECYCLING CENTER ALL TYPES. SENT BY WASTE
MANAGEMENT OF KENTUCKY TO A HW INCINERATOR", "", ""

"P", "HANNE CASTLE", "MA/ANDOVER", "", "", 5084754735, 0, "DROP OFF
AT RETAIL STORES AND COMMUNITY CENTERS. BUTTON BATTERIES.
SORTED BY TYPE THEN SENT TO MERECO", "", ""

"P", "ED GREEN", "MI/DETROIT", "", "", 3132618450, 0, "CURBSIDE
BATTERY ONLY COLLECTION AND DROP OFF AT RETAIL STORES. ALL
TYPES. BATTERY LEAD SALVAGE", "", ""

"P", "MARTHABECK", "MI/FARMINGTON", "", "", 5178874312, 0, "CURBSIDE WITH RECYCLABLES. ALL TYPES. MERECO", "", ""

"P", "MARTHA BECK", "MI/INGHAMCOUNTY", "", "", 5178874312, 0, "DROP OFF AT COMMUNITY CENTERS AND RETAIL STORES. BUTTON BATTERIES. MERECO", "", ""

"P", "CHERYL LOFRANZO VASK", "MN/MINNEAPOLIS", "", "", 6123488952, 0, "CURBSIDE WITH RECYCLABLES", "DROP OFF AT RETAIL STORES. ALL TYPES. SORTED & PLACED IN 55 GALLON CONTAINERS THEN HAULED TO HW FILL", ""

"P", "PATTI BURCHETTE", "NC/ROWAN COUNTY", "", "", 7046368747, 0, "DROP OFF AT RETAIL STORES AND RECYCLING CENTERS. ALL TYPES. BUTTON BATTERIES ARE SENT TO MERECO OTHER TYPES ARE SENT TO I", "", ""

"P", "ANN TURNER WILLIAMS", "NJ/BURLINGTON COUNTY", "", "", 6094491001, 0, "DROP OFF AT RETAIL STORES AND COMMUNITY CENTERS. BUTTON BATTERIES", "", ""

"P", "CHET BURTT", "NJ/MANMOUTH", "", "", 9089224815, 0, "DROP OFF AT RETAIL STORES AND COMMUNITY. ALL TYPES. CARBON/ZINC AND ALKALINE ARE SENT TO HHW CONTRACTOR (RADIAC) OTHER", "TYPES BEING STORED", ""

"P", "MARY BRIGGS", "NJ/WARREN COUNTY", "", "", 2014532174, 0, "DROP OFF AT MUNICIPAL OFFICES RECYCLING CENTERS IN 14 COMMUNITIES CURBSIDE WITH TRASH PICKUP IN 9 COMMUNITIES. ALL TYPES", "NICADS ARE SENT TO MERECO ALL OTHERS ARE SENT TO HW LANDFILL", ""

"P", "SHARON FISHER", "NY/BETHLEHEM", "", "", 5187679618, 0, "DROP OFF AT COMMUNITY CENTERS AND RETAIL STORES. ALL TYPES. MERECO", "", ""

"P", "SUSANATTRIDGE", "NY/BRUNSWICK", "", "", 5182793565, 0, "WEEKLY CURBSIDE WITH RECYCLABLES", "DROP OFF AT RECYCLE CENTERS. ALL TYPES. MERECO", ""

"P", "RICHARD PRESTON", "NY/LITTLEVALLEY", "", "", 7169389121, 0, "", "DROP OFF AT TRANSFER STATIONS CURBSIDE & RETAIL STORES. ALL TYPES. MERECO", ""

"P", "CLAUDIA NG", "NY/MAMARONECK", "", "", 9143815671, 0, "DROP OFF AT RETAIL STORES AND COMMUNITY CENTERS. ALL TYPES. MERECO", "", ""

"P", "MARY KATES", "NY/MILLBROOK", "", "", 9146778254, 0, "DROP OFF AT COMMUNITY CENTERS. ALL TYPES. MERECO", "", ""

"P", "MICHAEL MCHUGH", "NY/NEW CASTLE", "", "", 9142388945, 0, "DROP OFF AT COMMUNITY CENTERS AND RETAIL STORES. ALL TYPES. MEREKO", "", ""

"P", "LOIS FISHER", "NY/POESTENKILL", "", "", 5182835100, 0, "DROP OFF AT LANDFILL/RECYCLING CENTER. ALL TYPES. MEREKO", "", ""

"P", "ALICE YOUNG", "NY/ROCHESTER", "", "", 7162445824, 0, "DROP OFF IN MUNICIPAL BUILDINGS AND RETAIL STORES. BUTTON BATTERIES. MEREKO", "", ""

"P", "JOE CARLUCCI", "NY/RYE", "", "", 9149677464, 0, "DROP OFF AT DPW RECYCLING CENTER. ALL TYPES. MEREKO", "", ""

"P", "JIM RICE", "NY/SCARSDALE", "", "", 9147233300, 0, "DROP OFF AT RECYCLING CENTER AND INCINERATOR. ALL TYPES. MEREKO", "", ""

"P", "NEAL WALTERS", "NY/SENECA", "", "", 3159465654, 0, "DROP OFF AT RETAIL STORES AND COMMUNITY CENTERS. ALL TYPES. MEREKO", "", ""

"P", "MIKEHOTALING", "NY/SLINGERLANDS", "", "", 5187652681, 0, "DROP OFF AT HIGHWAY GARAGE. ALL TYPES. MEREKO", "", ""

"P", "JIM BUNCHUCK", "NY/SOUTHOLD", "", "", 5167347685, 0, "DROP OFF AT RETAIL STORES. ALL TYPES. MEREKO", "", ""

"P", "BILL REICH", "NY/WOODSTOCK", "", "", 9146796570, 0, "DROP OFF AT RECYCLING CENTER AND RETAIL STORES. ALL TYPES. MEREKO", "", ""

"P", "RACHEL ROSENWEIG", "PA/LANCASTER COUNTY", "", "", 7173979968, 0, "CURBSIDE WITH TRASH AND DROP OFF AT TRANSFER STATIONS. ALL TYPES. MEREKO", "", ""

"P", "JIM CRATER", "PA/POTTSTOWN", "", "", 2153238545, 0, "DROP OFF AT COMMUNITY RECYCLING CENTER. BUTTON AND ALKALINE. MEREKO", "", ""

"P", "JENNIFER LADD", "VA/CHESAPEAKE", "", "", 8044204700, 0, "DROP OFF AT RECYLING CENTERS", "CURBSIDE. ALL TYPES. TIDEWATER FIBER IS STORING", ""

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"R", "SIR/MADAM", "SKUYLKILL METALS", "Bx 156", "FOREST CITY MO 64451", 8164463322, "ALSO BATON ROUGE (504)775-3040 / ALL QUANT'S PB-ACID (DON'T MAIL)", "", ""

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"T", "DR. PANDIT PATILE CE-321/FORS", "DEPARTMENT OF ENERGY", "100 INDEPENDANCE AVE SW", "WASHINGTON DC 20585", "2025868055,0", "RESEARCHES BATTERIES FOR DoE", "CONSERVATION DPT, ELECTR & HYBRID//586-6768?", "(NO COVER LETTER) SENT 1 RPT, NO USE."

"T", "JEFFREY ZELMS, PRES", "DOE RUN CO.", "1885 LACKLAND RD", "ST LOUIS MO 63146", "3149917100,0", "Pb SMELTER IN BOSS, MO // VULCAN LEAD INC. SENDS PB HERE", "*800-633-8566", ""

"T", "*V H BRANNERY, EXEC SCTY", "ELECTROCHEMICAL SOCIETY", "*10 S MAIN ST", "PENNINGTON NJ 08534", "0,0", "JOURNAL OF... // MEET TWICE YEAR", "REMAILED LETTER TO NEW ADDRESS", ""

"T", "WALT STEVENSON", "EPA OFFICE AIR QUAL & PLANNING STANDARDS", "RESEARCH TRIANGLE PARK", "NC 27711", "9195415264,0", "", "", "2 INTERNAL DOCUMENTS ON DECISION NOT TO REMOVE BATT'S FROM INCINERATION WASTE STREAM."

"T", "", "EUTROTECH INC.", "", "SAINT ROBERT", "QUEBEC CANADA", "0,0", "", "ON St LAWRENCE BETWEEN QUEBEC CITY & MONTREAL. TEL # IN THE SOREL DIRECTORY", ""

"T", "TERRY TELZROW, STNDS/PROD.SAFT", "EVEREADY BATTERY CO", "BX 45035", "WESTLAKE OH 44145", "2168357629,7387", "", "", ""

"T", "BILL PERUSEK, V-P *P.R./PERSONL", "GATES ENERGY PRODUCTS", "BX 114", "GAINSVILLE FL 32602", "9044623911,0", "NiCd, Pbs MANUFACTR", "", "REFERED MY LETTER TO PRBA (PORTABLE RECHRG BAT ASSOC)"

"T", "H B GEORGE", "GEORGE CONSULTING INT'L", "", "CONCORD MA 01742", "3710056", "DOES RESEARCH ON Ni-MH'S", "LATE ENTRY-NO LETTER SENT, TELEPHONED", ""

"T", "", "GREEN SEAL", "1875 CONNECTICUT AVE NW (300A)", "WASHINGTON DC 20009-5818", "", "SETTING A GREEN STANDARD FOR BATTERIES", "NO LETTER", ""

"T", "MANNY SOUSA, VP OPERTNS", "INTERSTATE LEAD CO", "1247 BORDEN AVE SE", "LEEDS AL 35094", "2056996171,0", "", "REFERENCED IN BATT COLLECTN PRGRM LIST (DUXBURY)", "LETTER RETURNED: >>Company Out of Business<<"

"T", "TODD COY", "KINSBURSKY BROS SUPPLY INC.", "1314 N LEMON", "ANAHEIM CA", "7147388516,0", "ONLY(?) PROCESSORS OF NiCd'S IN WEST//SAY NiCd'S NEED FULL PART B RCRA PERMIT EVEN IF COLLECTED FROM EXEMPT (HOUSEHOLDS)", "", "5/11/92: RCVD PHONE CALL 'WE DOONT GNOW NAWTING'..."

"T", "", "MATSUSHIDA", "", "JAPAN", "0,0", "MAKE PANASONIC, KODAK

BATT'S // HAS DEVELOPED A Ni-MH (MKTED IN JAPAN)", "", "SEE PANASONIC (NO LETTER MAILED)"

"T", "CHARLES MONAHAN", "PANASONIC (PRBA)", "2 PANASONIC DR 7A-2", "SECAUCUS NJ 07094", "2013926464,0", "HOME COMPANY: MATSUSHIDA (JAPAN)", "KODAK & PANAS. BY MATSUSHIDA./ RAYOVAC BOUGHT LICENSE FOR Hg FREE ALK's", "PHONE CONV 5/3/92 MOSTLY ABOUT Hg REDUCTION BY MANUF'S & EPA REGS"

"T", "", "PHOTOGREEN", "BOX 124", "HAMPTON NJ 08827", "", "DEAL WITH ENV. QUESTIONS FOR PHOTOGRAPHERS", "LETTER IN MID JULY", ""

"T", "RAYMOND BALFOUR, V-P", "RAYOVAC CORP", "601 RAYOVAC DR // BX 4960", "MADISON WI 53711-2497", "6082754584,4577", "", "", "SENT GBB STUDY, SEN MGMT BILL, DRAFT EPA HANDBOOK, Hg DATA..."

"T", "JOHN SHAEFFER, PRES", "REAL GOODS", "966 MAZZONI ST", "UKIAH CA 95482", "7074689214,4680301", "OFF-GRID SPECIALISTS & SELL SECONDARY BATT'S IN CATALOGS (800-762-7325)", "", ""

"t", "*MIKE WEATHERRED", "BLACK & DECKER", "*10 NORTH PARK DR", "*HUNT VALLEY MD 21030", "3015277008,7996", "", "ORGNL LTR TO WLM HILL (DIR PROD MGMT), SENT ME THIS NAME TO CONTACT", ""

"t", "SIR/MADAM", "HARDING ENERGY SYSTEMS", "1 ENERGY CENTER", "NORTON SHORES MI 49441-5629", "6167987033", "MANUFACTURE Ni-MH IN CONSUMER SIZES (ADVTSD IN Real Goods CATALOG)", "", ""

"t", "M HERB WANG", "MOLI ENERGY LTD", "3958 MYRTLE", "ST BARNABY, B.C., >>CANADA<<", "0,0", "MOLICELL" LiMgO2, ALSO A 2dary LiMbs2 SINCE '85", "", ""

"t", "", "SAFT AMERICA", "107 BEAVER CT", "COCKEYSVILLE MD 21030", "3017713200,0", "NiCdS, LiSO2, LiCl--PRIMARY", "SUBSIDIARY OF Compagnie General d'Electricite, FRANCE//*(800)556-6764", ""

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"U", "KORDESCH", "", "", "GRAZ, AUSTRIA", "", "FROM CARNEGIE-MELLON U. TECHN. LIST", ""

"U", "HAMPSON", "", "", "LOUGHBOROUGH, U.K.", "", "FROM CARNEGIE-MELLON U. TECHN. LIST", ""

"U", "PAVLOV", "", "", "BULGARIA", "", "FROM CARNEGIE-MELLON U. TECHN. LIST", ""

"U", "SKYLLA-KRATICOS", "", "", "", NSW
AUSTRALIA", , , , "FROM CARNEGIE-MELLON U. RECYCLING RESEARCH
LIST", ""

"U", "BENNION", "(U. of?) UTAH", "", "", , , , "FROM
CARNEGIE-MELLON U. TECHN. LIST", ""

"U", "CHEH", "COLUMBIA U.", "", "", , , , "FROM CARNEGIE-MELLON U.
RECYCLING RESEARCH LIST", ""

"U", "SALKIND, KELLY", "RUTGERS U.", "", "", , , , "FROM
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"U", "MacDONALD, McKUBRE", "SRI", "", "", , , , "FROM
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SEMINAR W. U. LUND", "FROM CARNEGIE-MELLON U. RECYCLING
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"U", "WHITE", "TEXAS A&M", "", "", , , , "FROM CARNEGIE-MELLON U.
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"U", "BROCK, APPLEBY", "TEXAS TECH", "", "", , , , "FROM
CARNEGIE-MELLON U. TECHN. LIST", ""

"U", "CAIRNS et al", "U. CAL-BERKLEY
(LLL/LBL)", "", "", , , , "FROM CARNEGIE-MELLON U. TECHN.
LIST", ""

"U", "SMYRL, DOUGLAS", "U. MINNESOTA", "", "", , , , "FROM
CARNEGIE-MELLON U. RECYCLING RESEARCH LIST", ""

"U", "TEM CENTR//BACKMAN & LINDQUIST", "U. OF LUND", "", "",
, SWEDEN", , , , "SEE TECHNOLOGICAL INSTITUTE, DENMARK", "FROM
CARNEGIE-MELLON U. RECYCLING RESEARCH LIST", ""

"U", "BERKEY", "U. PITTSBURGH", "", "", , , , "FROM
CARNEGIE-MELLON U. RECYCLING RESEARCH LIST", ""

"U", "LINDSTRUM", "U. of?", "", "STOCKHOLM, SWEDEN", , , , "FROM
CARNEGIE-MELLON U. RECYCLING RESEARCH LIST", ""

"U", "SUNDHOLM", "U. of?", "", "HELSINKI, FINLAND", , , , "FROM
CARNEGIE-MELLON U. RECYCLING RESEARCH LIST", ""

"U", "GARCHE", "U. of?", "", "DRESDEN, GERMANY", , , , "FROM
CARNEGIE-MELLON U. RECYCLING RESEARCH LIST", ""

appendix 8: FUNDING PROPOSAL

(also includes copies of 3 newspaper articles from when program was first announced.)

PROPOSAL FOR FUNDING AND/OR ASSISTANCE:

A DRY-CELL BATTERY MANAGEMENT PROGRAM FOR MISSOULA, MT

NOVEMBER 1992

by TONY TWEEDALE

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Batteries, or cells, are a convenient, versatile and portable form of power. About 2,100 a day are disposed of in Missoula. The main components of a battery are two electrodes, which usually are composed of a metal. Several of these metals, cadmium, lead and mercury, are especially toxic and may pose a hazard to the environment or human health after the cells are disposed by incineration or landfilling. Rough estimates of the annual inputs of cadmium (Cd), lead (Pb) and mercury (Hg) from batteries into Missoula's landfill (derived from Franklin Associates national figures) are:

lead (largely car batteries)	20,000 lbs.
cadmium	1,450 lbs.
mercury	72 lbs.

As batteries comprise the largest source of these heavy metals in a landfill (Franklin Assoc.), a modest but effective collection and battery use education program will keep a significant amount of hazardous metals out of Missoula's landfill. This will help maintain the quality of the city's sole source drinking water aquifer.

Beyond aquifer protection, this program will aim for the larger goal of hazardous waste reduction, as it is easier to prevent waste than it is to clean it up. A further goal is to promote awareness of our responsibilities in generating hazardous wastes generally, using batteries as an example. The program will have two separate components, limited collection and education, the education element focusing on the latter goals.

This proposal for assistance is directed at parties who are involved in the problem or who could aid in accomplishing these goals. For example those who sell batteries, or who are involved in protecting the aquifer, may be interested. Specific examples of what sort of financial and in-kind assistance are being sought are found in the budget (fig. 1) and the associated list of involved parties, some of which have already agreed to be involved. These and others supporting the project will be public sponsors of the program and will get full credit for tackling the problem. Questions of cost, liability and sustainability of the program are addressed below.

The project will begin immediately with the preparation of the educational program materials, and proceed with their distribution and the implementation of the collection program. This will give residents and businesses notice to save their batteries for collection. More importantly, the most effective element will begin first.

EDUCATION COMPONENT

The education component is based on the waste management hierarchy: "first reduce, then reuse, finally recycle". It will be independent of

the collection program and will take funding precedence over collection as it: 1) has the potential to keep more batteries from the landfill, and 2) has a broader goal of educating hazardous waste generators of all types of their responsibilities in Missoula.

The first step in this program is to assemble the contents (as described below) of the educational component. This sometimes technical information has already been gathered and will be reshaped into easy to grasp educational materials to be distributed in one mass mailing, in radio and TV spots, through press stories, speaking engagements and with point-of-sale printed signs, brochures, and leaflets placed for maximum visibility. Materials will include publicity for the collection program: where to go, what types of batteries to take, and safety precautions.

Design, layout and printing help will be sought, whereas production of the electronic materials has already been secured, at reduced cost if necessary. Finally, agreements will have to be reached with the owners or managers of locations, including reporters and radio and TV station managers, for the placement and distribution of the materials. The program will be responsible for their upkeep, and a contact name will be given to each location.

content

To meet the goal of waste reduction, consumers of cells will need to be aware of the environmental hazards posed by different cell types, as well as the type's performance characteristics--so as to change their habits during purchase, consumption and disposal.

Specifically, the contents of educational materials will include:

- cell type performance characteristic comparisons
- alternatives and substitutes; maximizing cell life
- hazard potential of disposed cells
- benefits of reclamation; disposal options;

and be arranged by cell type and by application as well as generically (to include usage tips that apply to all or most cell types).

The public's conceptions of proper cell use (which type for which appliance, how to discharge rechargeables, etc.) has not kept up with changes in cell technology. For example, a new cell is on the market that performs much better than rechargeable NiCds and does not contain cadmium. Sophisticated chargers and voltmeters can prevent cells with usable energy left in them from being thrown away. Checking a cell's state of charge or discharge is a quick process, and with education can be instituted into users' normal routines.

Finally, the educational materials will tie in the hazards of indiscriminate battery use to the overall problems of indiscriminate hazardous waste generation, using especially the example of our

aquifer's vulnerability to contamination.

COLLECTION COMPONENT

Mixed batteries from households will be collected from a few sites selected for their high visibility and traffic, and in some cases for being retail locations where consumers buy their batteries (after negotiations with owners or managers). Simple, highly graphic signage will help keep batteries sorted by type (not size), as will information distributed through various public media (see education program).

Better segregated cell types will be collected by individual arrangement with high volume battery generators, such as the mercuric-oxide cells hospitals use; the NiCds used in two-way radios by police, railroads, etc; and hearing aid & photo shops. These generators will be asked but not required to contribute towards the cost of reclamation of their batteries (almost all reclamation companies charge to have cells shipped to them). If the generators are regulated hazardous waste generators, the cost of battery reclamation is going to be cheaper than the cost of proper hazardous waste disposal.

Labor and volunteers will be hired and trained to pick-up, sort and pack batteries collected from all locations for shipping, for which the reclamation companies and basic safety requirements dictate exact procedures.

The vast majority of batteries are the alkaline and carbon-zinc (C-Zn) types that no longer contain mercury, and have no reclamation market for their metals anyway. Funds instead will be used to collect certain types--nickel-cadmium (NiCd), mercuric-oxide, lead-acid (Pb-acid), lithium, button cells--that are more hazardous, have established markets for reclamation, and tend to be somewhat sorted from having special uses. Since other collection programs have been inundated at start-up with old alkalines and C-Zn's, and since these cells contain mercury, safe disposal of up to 30 barrels has been budgeted.

HAZARDOUS WASTE CONCERNS

The costs of running the collection program would climb rapidly should the batteries need handling as hazardous wastes. Generation, collection or handling of hazardous waste of greater than 100 kg/month requires that all hazardous wastes be stored, shipped and disposed of according to strict rules.

Montana's Hazardous Waste Program (Dept. Health & Environmental Sciences) has indicated that any quantity of batteries that is collected from exempt households and small businesses is not subject to regulation (Reinke). Sufficient quantities of NiCds (15-20% cadmium), mercuric-

oxides (35% mercury), and reactive lithium batteries, though hazardous materials and collected from businesses large enough to be regulated, would not be regulated (initial interpretation of the HWP) so long as they are promptly shipped for reclamation (as opposed to disposal). Written assurances will be sought from the MT HWP.

The U.S. EPA has proposed a regulation to exempt hazardous waste batteries from regulation as hazardous waste if they are being reclaimed. The rule has been under OMB review for some months.

Old alkaline and C-Zn batteries, collected at start-up from stockpiles, and containing 0.5%-2.0% mercury might have to be handled as hazardous waste since they have no reclamation market and may contain enough mercury to be classified hazardous. Variances from regulation have been granted for one time safe disposal. Ongoing collection of these two types would not be subject to regulation because they no longer contain mercury. Variances can also be applied for based on not holding or treating the batteries, or if the batteries are collected from exempt (less than 100 kg/month) hazardous waste generators.

LIABILITY

Under Superfund any party involved in a battery collection program can be made liable for remediation of hazardous waste problems at a site to which the program has shipped its batteries (in good faith they would be properly reclaimed or disposed). Other collection programs investigate reclamation and disposal companies to assure themselves they are licensed and following applicable hazardous waste laws.

VIABILITY

Every attempt will be made to assure parties involved that the program will be ongoing. A key is to involve many parties, each contributing out of their own interest. In this regard the expertise of BFI in solid and hazardous waste management is especially helpful. They have agreed to be involved. The collection program is modest and flexible, to accomplish what it can for a given level of funding. Funds however will not be skimmed on in order to insure safe storage and transportation of collected cells, as well as effective educational materials. A thorough educational program can accomplish some of the same goals of a collection program, though it can't ever keep the heavy metals belonging to batteries that must be used out of the environment.

COSTS

Missoulians have been educated as to the fragility of their drinking

water aquifer.⁷⁷ There is general agreement that recycling resources and reducing waste is important. However these predilections are offset by a generalized opposition to paying more taxes or user fees. Recognizing the difficulty of fighting for a share of existing revenues, or for new revenues, this program will be limited in size and flexible in its methods so as to not put off potential funders. The wide variety of potential funders, each with a self-interest in participating in a battery management program (described below), will help sustain the program. Recycle Missoula, Inc.'s non-profit status has been and will continue to be used to apply for grants and to reduce costs, such as postage and printing.

The status--hazardous or solid waste--of a shipment of batteries for reclamation is often the largest component in determining transportation costs. Aside from EPA administered hazardous waste regulations covering transportation, the Dept. of Transportation (DoT) also has rules regarding transportation of a few types of batteries, beyond a minimum quantity. All other collection programs have been able to transport cells to reclaimers by regular surface transport.⁷⁸

Other major expenses for a collection program can include liability and/or general business insurance, purchase of drums and packing materials, building and equipping safe storage space, hiring trained hazardous waste technicians and publicity expenses. Not all these outlays are necessary, especially for segments of the program not operating under hazardous waste regulations, but they do reduce liability and financial exposure.

⁷⁷Contamination events (perchloroethene, gasoline, sewage, pesticides) have received good media coverage. Mountain Water Company and the Health Dept's Well-Head Protection Programs, and the well received (so far) proposed Water Quality District have aquifer educational components.

⁷⁸Common, non-hazardous, carrier rates to East Coast locations of reclamation companies are around \$45 or \$55 a hundredweight (100 lbs.) for a 250 or 500 lb. load, respectively; cheaper for larger shipments. This is \$157-\$193 a 350 lb. barrel. Fourth class mail (maximum 70 lb. and 108" combined girth and length) and UPS are cheaper. The US Post Office is considering various regulations to control the movement of various types of hazardous waste, including batteries, (TV news broadcast, 1991).

(fig. 1a) FIRST YEAR COLLECTION COSTS

(15% collection rate, no donations or hazardous waste regulations)

general business insurance	\$2,000
contract labor: collection pick-up/sort/pack, \$6/hr (150hr)	1,500
local transportation costs (gas, depreciation, etc.)	100
barrels & overpacking	1,400
fire extinguishers & acid/base neutralizers	200
rental storage space	1,200
reclamation by common carrier 2 barrels Ni-Cds	600
reclamation by common carrier 2 barrels mercuric-oxides	350
reclamation by common carrier two 5 gal. button cells	110
one-time secure disposal 30 barrels alk./C-Zns w. mercury ⁷⁹	3,600

	\$11,060

(fig. 1b) FIRST YEAR PUBLICITY AND EDUCATIONAL PROGRAM COSTS

production radio & TV spots @ \$30/hr (60 hrs)	\$1,800
production printed materials @ \$10/hr (120 hrs)	1,200
printing, brochures, leaflets	800
point-of-sale signage, 36 locations	900
printing, one mass mailing to 20,000 homes	600
mass mailing, 10¢ ea (non-profit rate)	2,000
distribute printed matrls. incl. mass mail @ \$6/hr (65 hrs)	390
set-up collection & information distribution sites @ \$10/hr	1,600

	\$9,290

⁷⁹@ \$120/barrel (Spokane's cost is \$89/barrel) including a one time waste characterization fee. Alkalines and C-Zns are 80% of all cells (aside from vehicle lead-acids). Their manufacture to disposal cycle is about 2 years. The 30 barrels above allows for an initial surge of cells stored at home and the first 9 months of the 2 year cycle, when the most cells with mercury will be in the waste stream. Assumed 15% collection rate excludes vehicle Pb-acids and is 315 cells a day.

Ongoing annual costs after the first year might be \$1,000-\$2,000 for education; \$5,000-\$7,000 for collection. Any revenues received beyond the budget will be used to improve safety and reliability of collection facilities to minimize liability; to increase collection sites; and to increase educational efforts.

In-kind services may lower the budget even as grants and donations help meet it. Retailers and other parties, especially those with a direct involvement in the problem, should be interested in supporting the program. They will benefit from the publicity of being a part of the solution for a problem to which they play a part in, e.g. selling batteries, operating the landfill, or supplying our drinking water.

Against the costs listed in fig. 1, grants, donations and in-kind services are being sought, with some success already as indicated below:

- BFI, Missoula's garbage hauler and landfill owner/operator, has agreed to support this program. In addition they may offer their trucks for curbside pick-up of cells, which convenience would increase the participation rate. BFI needs to confirm that hazardous waste regulations wont escalate costs or create undue liability before supporting the collection component.

- Preliminary presentations have been made to the Conservation Committee of the City Council for a grant of \$2,000 to defray start-up costs. Reaction has been positive thus far.

- EPA Region 8 Municipal Solid Waste Program grant was applied for under Recycle Missoula non-profit status, winners will be announced in December 1992. Other possible grants identified so far are EPA environmental education and pollution prevention grants, MT DNRC water grants, Washington Foundation (Missoula).

- Large scale generators of hazardous batteries will be asked to contribute in the cost of reclaiming the cells. If sufficient cells are generated for them to be classified as a regulated hazardous waste generator, it will be cheaper for them to have the batteries reclaimed than to safely dispose of them.

- Retailers of batteries, being a part of the problem, will be contacted for financial support or asked to donate floor and shelf space, and maintenance of collection areas. The Chamber of Commerce has been contacted to secure a recommendation that the project can be beneficial to businesses. Storage of collected batteries conceivably could be at one or various retailers, obviating rental cost.

- Other retailers and businesses will be asked to donate in-kind services such as hazardous waste barrels, fire extinguishers, printing & design; in exchange for publicity, e.g. their name on printed products.

-Manufacturers are also part of the problem, and have already provided technical and specifications; and additional reverse distribution systems for cell collection. They also would benefit from being associated with the program.

-Mountain Water Company bears responsibility for groundwater protection, and would benefit from being associated with the program.

-Integration with Missoula Solid Waste Task Force (MSWTF), Well-Head Protection programs and proposed Water Quality District. The MSWTF is developing a comprehensive solid and hazardous waste management plan that includes elements applicable to this program, e.g. education (including hotlines and point-of-sale) and promotion (such as a local merchant green seal of approval program). The MSWTF will be recommending this program as a model hazardous waste education program when its recommendations are presented to local government for funding. Mountain Water Company and the Health Department are developing funded programs to protect Missoula's SDWA designated Sole Source Drinking Water Aquifer. The Water Quality District will, if approved by taxpayers, collect a water use fee to be spent for aquifer protection. None of these programs currently specifically provide funds or assistance for a program such as battery management.

-Recycle Missoula, Inc. has non-profit IRS status to receive discount postal rates (and other retail price discounts such as printing, that are not donated); as well as a truck and several dozen volunteers. Several members have already expressed interest in becoming involved.

-Video production listed @ \$30/hr: Missoula Community Access TV (MCAT) facilities and the services of an excellent producer have been secured, free if necessary.

-For the tasks listed at \$6/hr, Opportunity Industries, the RSVP program, schools, Scouts and other impaired worker or volunteer labor groups will be contacted. This is an approximate price.

ANTHONY TWEEDALE

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WORK:

(4/92-present) **Battery management program for Missoula, MT.** (Researched as professional paper), has both collection and hazardous waste education components. Also researched and wrote report for the U.S. **Forest Service** on national waste battery management practices.

(7/92-Present, part time) **Prof. G. Smith**--translating technical and regulatory language into english for citizens at the Paradise MT creosote Superfund site. **Prof. J. Brownson**--Organizing papers/books, and researching for a database on alternative energy & construction.

(6/90-12/91, work-study basis) **Missoula Env. Health Div., City/County Health Dept.**--Learned and wrote programs for dBaseIII+ software to search, view and edit in radon, shallow injection well and other databases. Researched the risk of creosote treated railroad ties used in irrigation ditches. Misc. go-fer and simple programming duties.

(1982-93) **Miscellaneous dBase programing contract work.**//**Hotel management jobs** (auditor, front office manager) Wash. DC, '82-89.

EDUCATION:

1989-92) **M.S. ENVIRONMENTAL STUDIES, U. Montana**--undergraduate level chemistry (9 courses & labs), biology (3), meteorology, statistics, risk assessment, misc. graduate seminars (advocacy, toxics). Research papers on marine pollution treaties, PAH's, stratospheric ozone depletion, life cycle analysis of paper vs. plastic product environmental effects.

(1979-83) **B.S. in HOTEL & RESTAURANT MANAGEMENT, Cornell U.**--Including accounting and management courses. One year off to work in the field.

(1978-79) **HOTEL, REST. & INSTNL. MGMT, Michigan State U.**--Transferred.

(1974-78) **AMERICAN SCHOOL IN LONDON**--high school degree in 1978.

ACTIVITIES:

(1989 on) **Recycle Missoula**--Researched payroll taxes, learned about and filed for 501(c)(3) tax exempt status. Developed databases on receipts, members; develop recycling and reduction materials for households, write "citizen science" articles for newsletter. Some media relations. Regular on truck collecting recyclables. Helping start up a **MT community recyclers association** (1992).

(1991 on) **Missoula Solid Waste Task Force**--Researched Small Quantity Hazardous Waste Generator regulations and disposal alternatives, also researching grant applications. On citizens committee drafting **MT State Solid Waste Plan** (1992).

Other--Missoulians for the Pesticide Sign Ordinance/Referendum (graphics, fund raiser). Treasurer and other duties for a neighborhood recycling group (worked to expand items accepted); unpaid intern ILSR, an env./social interest group. Gathered 2nd highest # of signatures to place the D.C. Bottle Bill on the ballot in 1987. In-depth reader of env. science journals, solid and hazardous waste and regulatory periodicals, any other materials of interest.

Good research skills.

References available. 32 years old, top health, single.