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Abstract

There is still much that needs to be known about the specific problems that are presented to the ecosystem as a result of battery disposal in landfills. This report explores the various effects that the toxic metals in batteries (specifically mercury, cadmium, lead, nickel, zinc, and lithium) have on the entire ecosystem, detailing the damages that these metals may cause to the human body. The most predominant effects that these metals have on humans include neurological damage, kidney damage, birth defects, and cancer. Next, lithium-based battery technology is explored, highlighting the development of these batteries and the various applications they are used for. An assessment of the risks that lithium battery disposal poses to the environment is also performed, using estimated lithium battery consumption information. The environmental policies of the United States, Europe, and industry are described as well.

The Ecological Impact of Batteries

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1. The potential harm that batteries present to the ecosystem

The toxic properties that compose batteries make dumping them dangerous to the entire ecosystem: land, water, plants, animals, and humans. Each of these is affected by pollution in different harmful ways. This section will detail these effects and the reasons for their occurrence. First, the process through which the waste from batteries enters the environment through landfills will be explained. The ways in which pollution harms each member of the ecosystem will be described next. From the available data, it will then be determined what tests need to be completed to find the toxicity of each metal. The data available will be analyzed, and it will be decided which materials cause the most harm to the ecosystem.

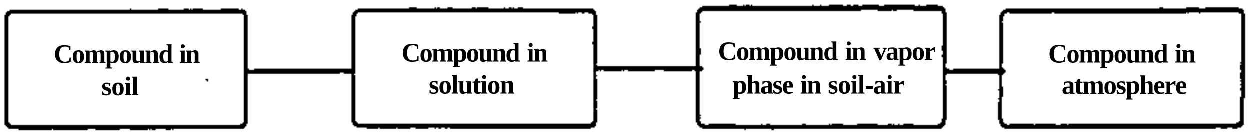
1.1. How battery residue escapes from landfills to the environment

According to the American Society of Civil Engineers (ASCE), a sanitary landfill is "an engineered method of disposing solid waste on land in a manner that protects the environment by spreading the waste in thin layers, compacting it to the smallest practical volume, and covering it with compacted soil by the end of each working day or at more frequent intervals as may be necessary" (Knowles, 1987). Landfills are lined with an "impermeable material" such as clay in an attempt to prevent leakage into the environment (McKee, 1990).

Today's landfills are much safer than the open landfills of the 1970's, but remains from waste dumped in landfills still enters the environment because of the leachate that is formed from the dumped garbage. Leachate is the liquid that comes into contact with the solid waste (which may be toxic) and leaves the landfill, contaminating the soil and ground water and creating environmental havoc (Knowles, 1987). In turn, ground water contamination may lead to the pollution of municipal water supplies. Gas may be generated through the decay of solid waste (and through leachate coming to the surface) and this may also prove to be harmful to the environment. (Knowles, 1987). In the past, this gas was often collected and used, although this practice was deemed harmful to the ecosystem since use of the gas allowed the toxins in the gas to be released into the environment. (Ham, 1993).

Today, there are ordinances that prevent open dumping and enforce the use of liners and leachate collection systems and encourage gas control (Ham, 1993). However, even with these precautions, battery residue still enters the environment via landfills. A 1984 article in Chemical Engineering magazine reported a study of 50 industrial landfill sites. Of these 50 sites, 40 experienced heavy-metal departure from the landfill because of improper landfilling (Dragun, 1984).

Once the compound of toxins is absorbed into the soil, the following chain reaction occurs:



(data from Chemical Engineering Magazine, November 26, 1984)

The compound reaches the soil through leachate and is next found in solution. The compound is then detected in a vapor phase and, after mixing with the ambient air, can be found in the atmosphere.

The leachate process into the soil is compounded by the soil's capacity for those metals. According to a report published by the World Health Organization (WHO), most types of clay soils have a high capacity for lead, zinc, cadmium, and nickel and a moderate capacity for mercury. All soils, except for loamy sand, have a high capacity for lead, a lower capacity for mercury, and a moderate capacity for the remaining metals (WHO, 1992).

Toxins from batteries may easily enter the environment through leachate that finds its way to the soil. Through the soil, the toxins may find their way to the ground water and

in turn pollute the entire ecosystem. Toxins may also enter the environment through the gases that leachate produces, which mix with and contaminate the atmosphere. Since the toxic chemicals may easily **enter the ecosystem through any of these ways, dumping batteries into landfills does present a hazard to the ecosystem.**

1.2. Ecological risks that materials present to humans

The materials that compose batteries pose no real risk to humans while the batteries are in use. After the battery energy is spent, and the batteries are thrown away, however, the battery waste may enter the ground water and soil. Furthermore, this waste may enter the water that people drink and the foods that people eat. The potential hazards that the toxic materials in batteries present to the environment have been pointed out by the Environmental Protection Agency (EPA), who, in a 1989 paper on solid-waste disposal, cited that cadmium and lead are the two toxic chemicals whose disposal most need to be reduced (Damian, 1991). Once humans are contaminated by the toxic chemicals, they may experience various health problems including brain or kidney damage, deafness, and vision problems. There is still much that **needs to be learned about the effects that these toxic** chemicals have on humans.

The effects that appear from **chemical contamination are based upon many factors.** Not only do they depend upon the chemical **that one comes** in **contact** with, **but the effects** are also determined by the "element's concentration in **the** environment and the duration of the exposure" (Nriagu, 1990). Effects of **long-term exposure to** low concentrations of **a** metal could include any of the following health problems: lesions and reduction of cells, tissues, and organ capabilities (Nriagu, 1990). One reason why these toxic chemicals are so harmful is because symptoms may not be recognized at all or until damage is already done to the body. Since many of these toxic chemicals accumulate progressively in **the** body (or in the ecosystem), "long-term exposure to low concentrations can lead to adverse effects when the toxic dose is reached" (Nriagu, 1990).

1.2.1. Mercury

It has been said that since no known organism is directly helped by mercury that "all mercury may be bad mercury" (OECD, 1974). Although efforts are underway to ban it from household batteries altogether, mercury is still a small, but common component (0.025% of mercury in batteries in most cases) of the primary alkaline batteries that are used today. Even though the percentage of mercury in batteries is small and steadily decreasing, its toxicity makes even this diminutive amount of mercury dangerous to the ecosystem when these batteries are dumped in landfills.

The amount of mercury that composes batteries has been consistently decreasing because of concerns over mercury's potentially toxic effects to humans. This is observed in information cited in the Marketing Development Strategies for Recyclable Materials, which was published by the New Jersey Department of Environmental Protection (NJDEP) in 1989. In this data, it can be observed that from 1983 to 1988, the amount of mercury used in all sizes of commercial primary alkaline batteries decreased:

Mercury Content in Primary Alkaline Batteries

CELL SIZE	AMOUNT OF MERCURY, 1983	AMOUNT OF MERCURY, 1988
AAA	0.096	0.016
AA	0.220	0.036
C	0.652	0.109
I)	1.413	0.237
9-Volt	0.287	0.048

(data taken from NJDEP, 1989)

The amount of mercury in these consumer cells has decreased in some cases because of new state laws forbidding addition of mercury to batteries and to increased consumer awareness about the threat that mercury causes to the environment. In the big picture, the amount of mercury used in commercial batteries has significantly decreased. The National Electrical Manufacturers Association (NEMA) has found that in 1984, 778.1 tons of mercury was used to produce batteries while it was estimated that only 167.9 tons was to be used in 1989 (NJDEP, 1989). This number was forecasted to decrease continually. The battery industry's efforts in environmental protection (and specifically its efforts to cut mercury use in batteries) are described in more detail in section 3.3.

According to a report completed by the Organization for Economic Cooperation and Development (OECD) in 1974, inorganic mercury compounds are released into the environment by batteries. This causes environmentalists a great deal of concern since inorganic mercury may turn into methylmercury under aerobic conditions (OECD, 1974). Methylmercury is slowly absorbed by animals while people absorb it very quickly. (OECD, 1974). The effects that methylmercury may have on humans vary. For example, in 1969, an American family dined upon meat from an animal that had eaten seedgrain coated with methylmercury. The children of the family suffered serious health problems-three of the children had acute brain damage, acquired impaired vision, and in the end were comatose (OECD, 1974). A seemingly healthy child was born eight weeks after the meat was consumed. Even though the infant was not breast-fed, at eight months old he was hypotonic (had less than normal muscle tone), blind, and retarded, apparently because his mother ate the meat while pregnant with him (OECD, 1974).

A 1978 study published by the National Research Council confirms that methylmercury does have an especially damaging effect on developing fetuses and infants. In fact, the growing brain of a fetus or infant may be the organ most sensitive to methylmercury. In studies comparing mercury's differing effects on mothers and children, methylmercury is more damaging to the fetus that to the adult animal. Mercury exposure may also cause a decrease in the amount of nutrients that the placenta is able to transport, stunting fetal development (Boadi, 1992).

A highly publicized example of methylmercury poisoning occurred near Minamata Bay in Japan, where villagers ate contaminated fish over a long period of time. The bay was polluted by mercury from 1953-1969, and in 1970, it was found that 121 people had suffered from mercury poisoning and 54 people died (OECD, 1974). The water contamination went relatively undiscovered, but became apparent after these deaths and after a large number of children were born with birth defects (Cote, 1990).

The Minamata Bay incident yet again shows the extremely harmful effects that mercury has on infants. Since their mothers had eaten fish from the mercury polluted water while pregnant with them, 23 babies were born with severe brain damage. (NRC, 1978). The mothers, on the other hand, showed no signs of methylmercury poisoning, except for mild paraesthesia, which is an unnatural "skin sensation such as burning, prickling, itching, or tingling" (NRC, 1978).

According to the 1978 National Research Council Report, the largest known epidemic of methylmercury poisoning occurred in Iraq during the winter of 1971-1972. More than 6000 contaminated people were hospitalized because they ate homemade bread made from seed wheat cultivated with methylmercury fungicide (NRC, 1978). Five hundred of these people died as a result of this poisoning.

Methylmercury affects genetic and reproductive processes as well. It has been shown to disrupt the mitotic spindle function (chromosome segregation) and cause c-mitosis at low concentration (NRC, 1978). After receiving an injection of methylmercury, male mice suffered fertility problems within a matter of weeks. It has not been adequately determined whether methylmercury causes cancer, or behavioral and intellectual problems (NRC, 1978). In adults, methylmercury often does cause neurological problems such as cerebral or peripheral nerve disease (Ajax, 1990). Toxic body burdens of methylmercury may accumulate because it has a long half-life in people (an average of 70 days) (Nriagu, 1990).

1.2.2. Cadmium

The potential health problems that may affect humans contaminated with cadmium have caused the United Nations' Food and Agriculture Organization (FAO) and the World Health Organization (WHO) Expert Committee on Food Additives to advise that "every effort should be made to limit, and even reduce the existing pollution of the environment with cadmium." (Oberdorster, 1986). Cadmium is a major component of recycleable nickel cadmium (nicad) batteries. These batteries are often used to power portable electronic goods such as laptop computers. Nickel cadmium batteries are also used in subways and airplanes as an emergency power source.

Since cadmium is toxic and causes numerous human health problems, efforts arc underway to find a less harmful replacement for nicad batteries. One of the alternatives to nickel cadmium batteries as a power source arc nickel metal-hydride batteries, but these arc still a threat to the environment since nickel is known to cause cancer. Although nickel cadmium batteries only contribute 0.1 percent of the total U.S. wastestream by weight, they account for 54 percent of cadmium in the waste stream (Damian, 1991). Thus, nicad batteries pose major environmental hazards because of the nickel and cadmium that compose them. Elimination of cadmium for nickel cadmium batteries is not viable since according to John Onuska of Inmetco in Ellwood City, PA, the amount of cadmium in nicad batteries cannot decrease as the amount of mercury in alkaline batteries has decreased since the batteries are already produced with the minimum amount of cadmium. Ten or twelve states have also threatened to restrict or control the disposal of cadmium. (Damian, 1991). The proposed legislation is not intended to ban the use of cadmium in batteries (as is the intent in legislation against use of mercury in batteries), but to "ensure that products using it are designed so consumers can easily remove their battery packs for safe disposal," since in 80% of the products which use nickel cadmium batteries as a power source, the batteries are sealed inside the product and are not easily accessible (Damian, 1991).

Cadmium accumulation in humans occurs mostly through intestinal and respiratory absorption, with the liver and kidneys being the organs that collect the greatest amount of cadmium (Nriagu, 1980). The kidneys are the most affected by cadmium as they hold the highest concentration of cadmium and often fail with high cadmium contaimination (Nriagu, 1980).

Occupational exposure guidelines for cadmium have been *m* by various health organizations and have become more stringent as continued research on cadmium's effects on humans is completed and more evidence that cadmium is dangerous to one's health is found. These limits sometimes depend upon the form in which one is exposed to the cadmium. For example, the U.S. Occupational Safety and Health Administration **(OSHA)** has set current guidelines of 100 (ig/nw^3 for cadmium exposure from fumes and 200 (ig/m^ for cadmium exposure from dust (Oberdorster, 1992). OSHA has proposed to lower the maximum cadmium exposure in all forms to 1 or 5 (ig/m^- The American Conference of Governmental and Industrial Hygienists (ACGIH) currently has a limit of 50 (ig/m^ for **all** forms of cadmium exposure, though it plans to lower the levels to 10 (ig/m^ for cadmium dust exposure and 2 (ig/m^ for respiratory exposure to cadmium (Oberdorster, 1992). The World Health Organization has set a limit of 10 (ig/m^ for all forms of occupational exposure to cadmium. Occupational exposure to cadmium has been thought to cause lung cancer and renal disorders.

It has been reported in numerous medical journals that cadmium may cause cancer, although questions still remain about whether a generalization that cadmium exposure definitely causes cancer can be made. It seems that cadmium may cause lung cancer when people are exposed to it through inhalation, especially when exposed in the workplace. A multitude of tests has been administered to animals, the results of which are quite confusing since it was found that cadmium inhalation caused cancer in rats, while it does not cause cancer in mice or hamsters (Oberdorster, 1992). Thus, it appears that certain species may be more vulnerable to cancer because of differences in lung cell interactions with cadmium.

Results from studies on workers exposed to cadmium seem to contradict each other. In case studies summarized in a paper by Gunter Oberdorster, there are incidents where no excess amount of lung cancer was found in exposed workers (with cadmium dosages from below 1 mg/m^3 to as high as 24 mg/m^3), yet other incidents occurred where workers were exposed to similar or even lower dosages of cadmium, and it was inferred that cadmium may have caused lung cancer (0.3 mg/m^3 to 1 mg/m^3 of cadmium exposed to workers) (Oberdorster, 1986). Researchers who found increased incidence of lung cancer were unsure of whether this cancer was caused only by cadmium exposure or by smoking, exposure to arsenic or nickel, or a combination of these (Oberdorster, 1986).

In a study published in the British Journal of Industrial Medicine, it was reported that workers exposed to a zinc-lead-cadmium smelter had an increased incidence of lung cancer but "the increasing risk of lung cancer associated with increasing duration of employment could not be accounted for by cadmium and did not appear to be restricted to any particular process or department." (Eades, 1988). Even with the lack of information on cadmium's connection with cancer, it has been estimated that exposure to the EPA's upper bound unit risk for cadmium of 1.8 x 10"^{3} cases/|ig/m^3 causes more than 100,000 lifetime excess cases of lung cancers (Peters, 1986). The estimators admit, however, that cadmium inhalation cannot be generalized as a cause of lung cancer (Peters, 1986).

Cadmium may cause cancer in part of the body other than the lungs and through means other than inhalation, although only limited research on this has been conducted. When injected subcutaneously (under the skin), water-soluble cadmium salts have been found to cause injection site tumors and tumors in other spots such as the testes and pancreas (Peters, 1986). Cadmium has not yet been found to cause cancer after oral exposure (Oberdorster, 1986).

Numerous studies have been completed to find the correspondence between cadmium and kidney damage. A specific study on Swedish battery factory workers was detailed in the British Journal of Industrial Medicine in which it was proven that workers exposed to cadmium do have a greater incidence of kidney stones (Jarup, 1993). Of the 868 workers who responded to the survey, 146 were women and only 3 of them (2.1%) had developed kidney stones, so gender may also play a role in the development of kidney damage. Of the 619 male workers, 87 (14.1%) developed kidney stones and of these 14 had stones before they were hired by the battery factory. In these workers, incidence of kidney stones increased with age and cumulative exposure. Other risk factors affecting one's probability of contracting kidney stones include heredity and diet (Jarup, 1993). Climate is also a significant factor in kidney stone formation due to the **increased** manufacture of vitamin D in skin exposed **to sunlight (Jarup,** 1993). Kidney **damage from** cadmium exposure may cause urolithiasis (urinary calculi or stones) and tubular proteinuria (Jarup, 1993). This kidney damage may cause glomerular impairment, which can lead to uraemia (an excess of urea in the blood and sometimes accompanied by headaches, **nausea,** and comas) and even death (Jarup, 1993).

Scientists have different opinions on how cadmium affects the developing fetus. In Cadmium in the Environment (Part I), it is said that the placenta stops cadmium **from** entering the fetus and that the mammary glands filter the chemical out of breast milk so that the infant is not exposed to cadmium (Nriagu, 1980). However, in Toxicology and Applied Pharmacology, cadmium is said to cause damage to the fetus. The amount of damage is in proportion to the level of exposure to the mother (Boadi, 1992). In rats, a single injection of cadmium into the fetus causes fetal death and placental necrosis, even though fetal concentrations of cadmium may be low (Boadi, 1992). Cadmium also has a significant effect on placental cell membrane: this could contribute to the metal's adverse effects on the fetus (Boadi, 1992).

1.2.3. Lead

Lead is a main component of lead-acid batteries, which are used to power cars and other electronic goods. Their shape is thin, and their power is twice that of nicad batteries, so they may seem like an ideal choice to use as a power source. However, lead is very toxic and under the U.S. Federal Resource Conservation and Recovery Act (RCRA), used lead-acid batteries are considered to be a hazardous waste and must be disposed of in a designated treatment center.

Lead is especially harmful to the brain and can cause a multitude of neurological problems. Even in adults with lead concentrations less than those normally associated **with** lead intoxication (70 (ig/dL), deficits in **attention** span, psychomotor function, short **term** memory, visuospatial capabilities, and speaking skills **are** normal (White, 1993). **It has been supposed that an international decline in intellectual functioning has been caused by low lead exposure, as intelligence tests scores have been steadily decreasing, although** many dispute this claim (White, 1993). Nonetheless, infants and children "moderately[11] exposed to lead have suffered inadequacies in neurological, behavioral, and neuropsychological functions (White, 1993). Lead's toxic effects **to** the brain are **detailed** in the following two case studies.

Children from Taiwan who were schooled near lead smelters were studied to **see** whether or not lead had caused a decrease in the child's potential intelligence. **The** researchers used tooth lead levels to determine the amount of lead intoxication that **the** children were afflicted by (Rabinowitz, 1992). Children who had a lead level at or above 3.5 |ig/g suffered an IQ deficit in comparison with those with lower lead levels and similar backgrounds (Rabinowitz, 1992). The students with higher lead levels were 1.3 times more likely to score two units lower on the CPM (Colored Progressive Matrices) test that gauges intelligence (Rabinowitz, 1992).

Another test was completed on humans who were exposed to lead before their fourth birthday, but are now adults. Those who had been contaminated with lead had deficits in "attention, reasoning, memory, motor speed, and current mood" as compared to those not experiencing lead intoxication (White, 1993). The group that had been contaminated with lead also had a "lower" occupational status as compared to the control group, even though both groups finished the same amount of school (White, 1993). The scientists who were involved in the experiment concluded that those exposed to lead as children suffered from acute encephalopathy (disease of the brain) in their youth, which developed into a chronic subclinical encephaioDathy which affected their adult lives (White, 1993).

The National Research Council (NRC) has recently published a report on the effects that lead may have on humans — Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations. In this report, the NRC reported that both the U.S. Environmental Protection Agency (EPA) and the U.S. Centers for Disease Control and Prevention (CDC) have lowered the lead-exposure guideline to 10 |ig/dL, with a possibility of lowering this guideline even more because of confirmation that very small exposures to lead may be burdensome to the human body (NRC, 1993). Even if only exposed to the current blood lead concentration guideline of 10 |ig/dL, the human body may still suffer health problems. At this level, the exposed fetus may have an impaired central nervous system and suffer other organ development problems (NRC, 1993). Young children contaminated with lead at this level may have damaged cognitive function and may develop behavioral disorders. Adults may have increased blood pressure as a result of this lead exposure. In infants, children, and pregnant women, the group identified by the NRC as most "sensitive" to lead exposure, lead contamination of about 10 |ig/dL may cause problems in calcium function and homeostasis (equilibrium produced by a balance of function and of chemical composition) (NRC, 1993).

According to the NRC, children's central nervous system (especially the brain), kidneys, and blood-forming organs are most adversely affected by lead intoxication. Children exposed to lead levels of 100-150 |J.g/dL often develop lead encephalopathy (disease of the brain), which is most often not fatal, although it may have "permanent neurologic sequelae, including retardation and severe behavioral disorders." (NRC, 1993). Kidney damage in children most often occurs with lead exposure ranging between 40-120 |ig/dL and consists of aminoaciduria. With blood lead concentrations of at least 70 (ig/dL, anemia often occurs, and the possibility that the level of concentration needed to cause anemia is less than this exists.

In adults, the most likely result of lead contamination is "peripheral polyneuritis involving sensory or motor nerves." (NRC, 1993). To develop encephalopathy, lead exposure must be great (greater than 150 |ig/dL) and it may begin with irritability, headaches, and hallucinations, and may advance to convulsions, paralysis, and death (NRC, 1993). Lead poisoning in adults has been proven to cause tubular nephrotoxicity after both short and long-term exposure and usually causes tubular proteinuria (NRC, 1993). Impairment of heme biosysthesis **and** increased erythrocyte destruction have **also** been seen in lead workers exposed to lead.

Lead may also adversely affect male fertility. In lead battery workers, an increased occurrence of oligospermia, asthenospermia, and teratospermia was found **(Gennart,** 1992). These problems may lead to hypothalamic and pituitary disturbances if there is **a** long period of exposure (Gennart, 1992). Lead also has a direct effect on the seminiferous tubules. As the period of lead exposure increase, the level of fertility decreases as compared to the control group of people with similar characteristics.

Lead has been proven to cause spontaneous abortion and the birth of stillborn children in pregnant women exposed to it in the workplace (NRC, 1993). Lead may lead to gameototoxic, embryotoxic, fetotoxic, and teratogenic effects in human offspring. In a study on Boston women with lead concentrations of at least 15 |LLg/dL, it was found that their children had more of a chance of intrauterine growth retardation, low birthweight, and were comparatively smaller than those of the same gestational age (NRC, 1993). Lead has also been found to cause the premature birth of children (NRC, 1993).

Even though it is most feared for its potential damage to the nervous system, lead is also thought to be a carcinogen. For example, rats that are fed high amounts of lead have been found to develop kidney cancer (NRC, 1993). Although no specific dose-response results have been found, the National Research Council has concluded that "lead can act

both as a renal carcinogen in rodents and as a promoter of renal carcinogenesis caused by other organic renal carcinogens" based upon animal testing.

Kidney damage due to lead contamination has also been documented. Problems stem from the kidneys' difficulty in lead absorption. In short-term exposure, reversible proximal tubular damage is known to occur, while reduced glomerular filtration occurs slowly and progressively (EPA, 1980). In addition, high amounts of lead exposure may cause "cerebrovascular disease, heart failure, electrocardiographic abnormalities, impaired liver function, impaired thyroid function, and intestinal colic." (EPA, 1980).

Following is the dose-response results for both children and adults. These results detail the Lowest-Observed-Effect Levels (LOEL) for each group, summarizing the effects that may come about as a result of the following dose levels. Note that neurological disorders may affect children who are exposed to level of lead as low as 10 |ig/dL. As a rule, the severity of harmful effects increases as dosages increase.

"Lowest-Observed-Effect Levels (LOEL) of Blood Lead for Effects in Children"

LOEL (uff/dL)	Neurological Effects	Other Effects
<10 to 15 (prenatal and postnatal)	deficits in neurological behavior, clectrophysiolgic changes, lower IQ	reduced gestational age and birthweight, reduced size up to age 7 - 8 years
15-20		impaired vitamin D metabolism
<25	longer reaction time	
30	slower nerve conduction	
70	peripheral diseases or abnormalities	
80-100	encephalopathy	colic, other gastrointestinal effects, kidney effects

(Jata courtesy of National Research Council, 1993)

"Lowest-Observed-Effect Levels (LOEL) of Blood Lead for Effects in Adults"

LOEL rtif/rii;)	Neurological Effects	Renal Effects	Reproductive Effects	Cardiovascular Effects
10 - 15				increased blood pressure
40	peripheral nerve dysfunction (slower nerve conduction)			
50	overt suben-cephalopathic neurologic symptoms		altered testicular function	
60			female reproductive effects	
100-120	encephalopaihic signs and symptoms	chronic nephropathy (kidney disease)		

(data courtesy of National Research Council, 1993)

1.2.4. Nickel

When considering the toxicity of batteries, mercury, cadmium, and lead are the main metals that are discussed in terms of harmful ecological effects. Nickel is somewhat ignored in comparison, especially when the environmental safety of nickel cadmium and nickel metal-hydride batteries is considered. Most of the environmental concerns with nicad batteries are with the cadmium in them and nickel metal-hydride batteries are widely believed to be environmentally safe.

Interestingly, it has been found that although cadmium pretreated with nickel has a lower toxicity, nickel's nephro- and hepatotoxicity (kidney and liver problems) is enhanced by cadmium (IARC, 1984). A test group consisting of 48 female albino rats was injected with nickel sulfate after being periodically injected with either cadmium chloride or normal saline. In the rats that were pretreated with cadmium, the additional administration of nickel caused more toxic forms of enzymuria, proteinuria, and aminoaciduria, while also causing increased kidney uptake of nickel (IARC, 1984). This leaves questions about the combination of nickel and cadmium in nicad batteries and whether their toxicity is caused not only by the metals' individual potential damage, but also by the possible hazards that they may cause in combination.

Most of the nickel that is consumed as pan of a person's food intake is not absorbed within the gastrointestinal tract since there seems to be a bodily mechanism that limits the amount of nickel that is absorbed (NAS, 1975). This is very important since humans take in a large amount of nickel through seafoods, vegetables, and wheat products.

Even though extreme exposure to it may cause hazards to one's health, scientists believe that nickel may be essential to human life, although the amount of nickel necessary for the health of humans is so small that its deficiency is not important in light of its toxicity (Nieboer, 1992). One reason that researchers believe that nickel may be essential to life is that it is present in the fetus in the same amounts as in its mother, leading scientists to believe that nickel can cross the placenta, but leaving them to wonder whether nickel helps the fetus to grow (NAS. 1975). Although questions remain about whether nickel is ever helpful to the developing fetus, it is known that nickel may be harmful to the embryo (early to mid gestation) and the last gestation of the fetus in different ways. The embryo can be delayed in development and even be seriously malformed by nickel exposure while the fetus is not deformed by nickel, but may experience delayed development or even fatal results (Nieboer, 1992). It has been found that women are more sensitive to nickel during pregnancy, due to physiological changes or disproportionate distribution of the metal in the body (Nieboer, 1992). Uneven distribution will most likely harm the woman and she will receive a higher dose of nickel, perhaps resulting in hyperglycemia (Nieboer, 1992).

Nickel carbonyl is thought to be the most toxic nickel compound and it is often emitted from refinery plants. Nickel cadmium batteries are made from two water insoluble compounds: nickel and nickel hydroxide. Few studies have been made on nickel hydroxide and the specific health problems that it may cause and thus additional research on the effects that it may cause on the body should be completed.

There are numerous documented cases of people who acquired lung cancer and cancer of the nasal passages because of working in nickel refineries. In these cases, the metal was often nickel carbonyl and the method of contamination was inhalation, neither of which relate to the possibilities that may exist when nickel seeps out of landfills into the soil and ground water. Tests have been done on animals to explore nickel's possible cancer-causing nature and they will be described in further detail in section 1.3.4.

Cancer is not the only health problem that nickel may cause to adults. For example, nickel causes skin disorders and those who work in the production of nickel cadmium batteries are at additional risk since they experience occupational exposure (NAS, 1975). The resulting nickel dermatitis begins with itching and burning sensations and the skin tends to lichenify (become dry and scaly), while affecting not only the area in direct contact with the metal, but also often affecting other areas of the body (NAS, 1975).

Nickel may present health problems to the kidneys as well. For example, one report details a group of people who often drank water from a nickel-contaminated well and developed symptoms of kidney damage such as proteinuria, or protein in the urine, although its effects are not as toxic as those that cadmium presents (Nieboer, 1992). Other tests on factory workers exposed to nickel show no signs of serious kidney damage and it thus considered to be a "minimal" health hazard in comparison with cadmium (Nieboer, 1992).

Recently, it has been discovered that immunological problems may also come with nickel exposure. Nickel intoxication can decrease host resistance to viral and infectious agents, as well as "depress antibody responses to T-phages, inhibit gamma-interferon production, and suppress the phagocytic capacity of microphages." (Nieboer, 1992).

1.2.5. Zinc

Zinc-air batteries present an option for growth in rechargeable battery technology. Zinc-air batteries are inexpensive, lightweight, and have a long life potential. One producer (AER Energy Resources) claims that its batteries can run for up to 20 hours at a time without failure. Small primary zinc-air batteries are in use in hearing aids and pagers, while larger batteries are used in such devices as ocean buoys, railroad signals, and remote communications applications (PSMA, 1992). But, as most metals, zinc does present potential health threats to humanity.

Zinc can be toxic in at least three different situations: when its fumes are inhaled, when it is ingested, and when it enters water (a specific example involves a patient who suffered kidney failure after the water for his hemodialysis was stored in a galvanized tank) (Nriagu, 1980a). Zinc contamination may cause "dehydration, electrolyte imbalance, abdominal pain, nausea, vomiting, lethargy, dizziness, and muscular incoordination," and has been known to cause kidney failure as well (Nriagu, 1980a).

The dosage of zinc is very important in determining its effect on the human body. For example, two grams of zinc sulfate may be used safely as an emetic, while a 45 gram dosage may cause death (the human body needs about 15 to 20 mg/day of zinc). Zinc is "noncumulative" and the amount that the body absorbs is inversely proportional to the amount taken in (Nriagu, 1980a).

Zinc is believed to cause cancer in humans, although this is not a proven fact. In England, it was found that the logarithm of the zinc/copper ration was much higher at the homes of people who had died of stomach cancer than those who died of other causes (Nriagu, 1980a). A similar relationship between extreme zinc intake and stomach cancer was found in Japan. In Africa, a connection between zinc intake and cancer of the esophagus was discovered (Nriagu, 1980a). Injection of zinc sulfate has been found to speed the growth of experimental sarcomas. Zinc-induced cancer in animals is further discussed in section 1.3.5.

Pregnant women often take vitamin supplements with zinc added, so **doctors** wonder whether this will affect fetus growth. In one study, it was found that when levels five to six times the normal dosage were administered to pregnant rats, the fetus showed an increased rate of resorption (Nriagu, 1980a). Studies were completed by the same set of scientists on humans in which 100 mg supplements of zinc sulfate were dispensed to women in the third trimester of pregnancy. **Out** of the four women in the experiment, **three had premature births and one had a stillborn child (Nriagu, 1980a). However, in other experiments, no adverse effects were found in mother or child and the pregnant women** who routinely take these drugs do **not seem to have problems with their pregnancies** (Nriagu, 1980a).

Of all of the different health **problems that** may **come** as a result of **zinc** contamination, anemia, a deficiency in the oxygen-carrying material in the blood, **is the** most common (Nriagu, 1980a). Zinc **has been known to cause gastrointestinal bleeding to** a patient taking 440 mg/day of zinc sulfate and hypocupremia in sickle-cell anemia **patients.**

1.2.6. Lithium

Lithium-ion and lithium polymer batteries have been billed as two hopeful replacements for the nickel cadmium rechargeable battery. The power potential of lithium-ion batteries triples that of nicad batteries, although they are highly reactive. In fact, because of the volatile nature of lithium when it is exposed to moisture, the amount of metallic lithium allowable in each battery cell has been limited to 0.5 grams, as set by federal regulations (Krause, 1993). A cellular phone produced by Japan's Nippon Telegraph & Telephone had to be recalled since its lithium battery overheated and injured its user (Neff, 1993). Lithium polymer batteries are less reactive, double the power of lithium-ion batteries and can be cut into any shape. Although lithium is billed as "environmentally friendly/[1] it may cause problems if dumped into landfills in large quantities. Lithium batteries and their research and development, as well as an assessment of the potential risk that they present to the ecosystem, will be further detailed in section 2.

Lithium is often used as a drug to treat people who suffer from problems related to manic-depressive psychosis. Lately, studies have been done to determine its potential side effects which may include diarrhea, nausea, drowsiness, coordination problems, and vertigo. Patients have suffered from delirium, convulsions, or seizures for weeks after lithium treatment has been discontinued. Lithium may cause a major disturbance in water balance (Walker, 1993). Lithium can also block synthesis of thyroid hormone and is thus a goitrogen (Yasumura, 1990).

The neurotoxic effects that lithium may have on the human body are documented in numerous medical journals. The reference dose statistics are available mainly because of studies of the neurological side effects that lithium salts cause to people who are treated with them for psychological problems. One sign of these problems is found in **the** abnormal EEG (test of the electrical activity of the brain) results of people treated with lithium (Messiha, 1993). Following is a compilation of case studies of lithium intoxicated patients, with their recorded dosages of lithium and the corresponding health problems **that** followed.

A man who was diagnosed with manic psychosis was treated with a combination of drugs, including a 1.8 gram/day dosage of lithium carbonate (Uchigata, 1981). A week after the treatment was started, he became drowsy and suffered from dysarthria (speech disorder), tremors, unsteady gait, muscle twitching, increased muscle tone, sweating and a fever (Uchigata, 1981). He then lapsed a coma, which he was quickly brought out of. Three months after these developments, he still had impaired speech, mild weakness of the extremities, and decreased vibratory sense in his feet.

Similar types of consequences coming from lithium treatment have been reported. Dr. Joseph Green describes his findings in the Annals of Neurology. A woman that he treated was given a lesser dosage of lithium (1.2 gram/day) and experienced serious neurological damage. Maculopapular rash, weakness, incapability to walk, and impaired speech plagued the woman after only three weeks of drug administration. Eleven months after the treatments were initiated, she still needed assistance to walk and had continued slurred and problematic speech.

Often, lithium intoxication is not detected, even when lithium serum levels testing is conducted, and thus the neurological damage is allowed to continue since lithium administration is not connected with the problems that are occurring. This type of situation could easily occur with environmental lithium contamination since it is not easy to evaluate the amount of lithium that one intakes through polluted ground water and other types of contaminated sites. An example of both undetected lithium intoxication and smaller dosages adversely effecting patients is described in a report by Dr. Donald A. Lewis in the Journal of the American Medical Association. Specifically, a man who was given two doses of 300 mg lithium carbonate per day was allowed to continue lithium therapy for over six months before administration was discontinued because it then was finally realized that lithium was the cause of the neurological problems that he was experiencing (Lewis, 1983). During the period that he was undergoing lithium treatment, he suffered from impaired coordination, cerebellar dysfunction, decreased intelligence level, ataxia (impaired muscular coordination), and speech problems, all of which ceased after lithium administration was stopped. These side effects occurred even though the patient's serum lithium levels were in the acceptable therapeutic range, thus indicating difficulty in correlating lithium contamination and neurological damage.

Lithium causes not only neuropathy, but peripheral- and poly-neuropathy as well. A man who was given 900 mg of lithium carbonate per day became comatose and suffered from hypertonia (extreme muscular tension) and right-sided hemiparesis (Vanhooren, 1990). Two months after he broke from the coma, the patient still could not walk and had global arethexia, slight proximal paraparesis, and distal paresis (slight paralysis), of the left arm. After a year, his muscle strength returned, but he still had weak tendon reflexes and impaired muscular coordination. This type of peripheral neuropathy caused by lithium intoxication usually involves encephalopathy (brain disease) developing into a coma and hyperthermia (Vanhooren, 1990).

The different neurological effects that lithium may have on the human body have been described in the summarized case studies. Many more studies on patients who have been adversely affected by lithium administration have been conducted and a chart summarizing the dose-response results is below. Note that dosages as low as 438 mg/day have been found to cause cerebellar and corticospinal damage, as well as dementia (irreversible damage to the intellect with additional emotional problems) and that this damage may not come to light for years after treatment (Donaldson, 1983). Thus, those contaminated with lithium through environmental pollution may not experience these side effects until years after lithium exposure and may not know that lithium is the cause of their neurological damage.

Reported Cases of **Neurological Damage Due to Lithium Ion Intoxication**

Source	Dosaize (mii/day)	Time passage before symDtoms were found	Permanent neurological damage
Goldwater and Pollock	**438**	**2 years**	**cerebellar, dementia, corticospinal**
Hanscn and Amidscn	**885**	**10 years**	**cerebellar, dementia**
Juul-Jcnscn and Schou	**900**	**N/A**	**cerebcllar**
Donaldson	**1000**	**5 weeks**	**cerebcllar, corticospinal, brain stem**
Donaldson	**1000**	**2 years**	**cerebcllar**
Julicn ci al	**1000**	**2 years**	**cerebcllar**
Cohen and Cohen	**1165**	**13 days**	**choreoathetosis, parkinsonian**
Hansen and Amidscn	**1184**	**9 years**	**dementia**
Cohen and Cohen	**1500**	**11 days**	**ccrebcllar, corticospinal, parkinsonian**
Von Huru/ch	**1600**	**4 weeks**	**ccrebcllar, choreoathetosis, corticospinal**

(data from Donaldson, 1983)

Children are thought to experience less serious health problems from lithium contamination than adults because they have a higher kidney clearance (Campbell, 1991). That is not to say that children are not adversely affected by lithium exposure. On the contrary, when 48 children with behavioral disorders were given different dosages of lithium carbonate, they suffered from a variety of health problems and many of the children had multiple side effects. Through the four to six week lithium administration period, 46% of these children (ages ranging from five to twelve) had three to eight episodes of side effects, while 10% had more than ten episodes of side effects (Campbell, 1991), Effects included weight gain (77%), vomiting (39.6%), headache and nausea (27.1%), **and** tremors (25%). Younger and autistic children were found to have more side effects (Campbell, 1991). A list of some of the dose-response results is given below. Note **that** the children may be affected by one or more of these conditions, thus compounding **the** adverse effects associated with lithium administration.

Side Effects Associated **With Lithium Administration in Children**

Side Effects	Percent of patients affected	Dose (mfȝ/day)
weight gain	**77**	250-2100
vomiting	39.6	600-2100
headache	27.1	500-1800
nausea	27.1	750-1500
tremor	**25**	600-1800
cmurcsis	18.8	250-1250
sedation	10.4	750-1750
anorexia	10.4	500-1800
aiaxia (muscle coordination prob.)	**6.3**	900-1500

(data from Campbell, 1991)

In a recent report published in Kidney International, the nephrotoxic effects of lithium are discussed. Lithium salts have been known to cause polyuria and nocturia; Mendelsohn even recommended that it be used as a diuretic (Walker, 1993). Lithium may also cause impairment of distal urinary acidification. Even after its use has been discontinued in the treatment of patients, case studies show that lithium has caused nephrogenic diabetes insipidus (Walker, 1993). Thus, just as it is possible that lithium has caused neurological damage years after environmental contamination and the connection between lithium and these problems may never be made, this may occur with lithium-caused kidney damage as well. That lithium intoxication may go undetected heightens **its** degree of toxicity.

Often, what may seem to be minor urinary concentrating ability may actually be a symptom of major kidney damage. It has been found in studies on patients given lithium for over a period of two years that up to 26% of these patients will develop successive impairment of urinary concentrating ability, which is a symptom of chronic focal interstitial nephritis (Walker, 1993). In more than half of the patients reported in other studies, a direct relationship between the urinary concentrating ability and the amount of lithium administered was shown. Lithium induced chronic nephrotoxicity is not always reversible and thus these effects may be permanent.

Lithium may cause both acute and chronic renal (kidney) failure. In acute kidney deterioration, changes in the tubules were found, including "distal tubular flattening, proximal tubular necrosis, cytoplasmic vacuolation, cellular polymorphism of the distal nephron, and nuclear polymorphism." (Walker, 1993). Chronic kidney lesions such as interstitial fibrosis, tubular atrophy, and glomerulosclerosis have been known to develop in 13 out of 14 patients *on* lithium for more than a year, as described by Hestech (Walker, 1993).

Pregnant women who are contaminated by large amounts of lithium salts may put the fetus that they carry at risk. Lithium crosses the placenta and also enters the breast milk through blood circulation, so the fetus and newborn infant are easily exposed to lithium (Messiha, 1993). Lithium influences neonatal cardiac toxicity and in turn may also affect heart lactate dehydrogenase (H-LDH) (Messiha, 1993). Other effects to the lithium contaminated fetus include abnormalities of the external ear, ureters, central nervous system, and endocrine system (Chapman, 1989). Lithium-infected infants may experience shallow breathing, hypotonia (low muscle tone), lethargy, cyanosis (blueish discoloration of skin due to lack of oxygenation in blood), and bradycardia (abnormally slow heartbeat) (Chapman, 1989). Other possible health problems that may be caused to the fetus, newborn, or to children through lithium contamination are explored more thoroughly in section 1.3.6 where tests on infant mice and rats are detailed.

1.3* Ecological risks that materials in batteries present to other members of the ecosystem: animals, land, water

Jerome O. Nriagu states in the September, 1990 issue of Environment magazine that "inevitably, a buildup of toxic metals in the food chain has resulted from the massive quantities of metals being discharged into various environmental media." This human-induced metal contamination has a harmful effect not only on human life, but on animal and plant life as well. Just as the exposure to toxic chemicals stunts the growth of young human life and alters that of adults, young plant and animal life is adversely affected by this pollution. The problems that the toxins in batteries cause for plants and animals also have a direct effect on human life since we depend upon plants and animals as food sources.

There is special concern about the effects that batteries may have on the environment since tests have shown that dry and bulk metals are less soluble (Nriagu, 1986). Since they are dry and often are dumped in large quantities, batteries can be described as less soluble. With this in mind, studies have shown that "acidification of unfiltered samples (of metals have) artificially released metals from insoluble panicles." (Nriagu, 1986). This translates to the battery problem when acid rain hits a landfill where batteries are dumped and the toxic metals are discharged into the environment unnaturally.

Once the metals are dispersed throughout the soil, they do not biodegrade and they cannot be recovered from the ground (Nriagu, 1990). This is compounded by the fact that unless they come in contact with acid rain, metals remain stationary in soil and thus the metal pollution gathers in the surface layers and will then reach the crops that grow in the soil (Nriagu, 1990). Nriagu states that "any environmental effects of trace metal pollution, therefore, tend to be permanent." These environmental problems most often occur in cities since most pollution originates from industrial facilities and urban refuse (Nriagu, 1990).

1.3.1. Mercury

Depending upon their habitat, animals are exposed to mercury in various ways and amounts. Animals that reside in waterways are more easily contaminated than land animals since they cannot escape the polluted waters that they live in (NCR, 1978). As in humans, the larva (developing, infant animal) are most affected by mercury poisoning (NRC, 1978). Marine invertebrates are one group that is especially at risk since they seem to accumulate large amounts of mercury. In unpolluted waters, oysters had mercury levels between 0.003 and 0.017 |ig/g while they contained 5.61 |ig/g at contaminated Minamata Bay, Japan (NRC, 1978). When comparing invertebrates and plants, it seems that invertebrates are much more effected by mercury pollution. When a single deposit of methylmercury hydroxide was put into a pond, invertebrates had the highest recorded level of concentration factors of mercury. Submerged parts of water plants had a range of mercury concentration factors from 34 - 3200 depending on the type of plant, while the parts of the plants out of water had mercury concentration factors ranging from 8 - 25 (NRC, 1978). Moss and sediment had concentration factors of 5900 and 6100, respectively (NRC, 1978). Invertebrates, however, had mercury concentration factors that ranged from 3290 - 8470 (NRC, 1978). Thus, invertebrates have the capacity to take in huge amounts of mercury, in comparison with plant life.

According to the 1978 report published by the National Research Council on the harmful effects of mercury contamination, fish's response to mercury exposure may depend on a wide variety of factors, including age, weight, length, species, metabolic rate, degree of pollution, location, and sometimes gender. Methylmercury is the leading mercury contaminant in fish (NRC, 1978). The main ways that mercury enters the bodies of fish are through absorbing the water that come through their gills or through the food chain, although fish can also absorb mercury through their skin as well (NRC, 1978).

It has been found that the fish's metabolic rate and the mercury contamination in the water play the most imponant role in determining the amount of mercury that a fish accumulates and the rate at which it eliminates the mercury (NRC, 1978). The metabolic rate of fish is controlled by the temperature of the water, so fish become more contaminated with mercury during the summer than in the winter (NRC, 1978). Once they come in contact with methylmercury, fish suffer lasting effects. When contaminated, a fish's brain and nerve tissues keep at least that amount of methylmercury in the body, with the possibility of further accumulation even if the fish has no more contact with the toxin.

Although it is difficult to determine the effects that mercury may have on aquatic birds because of their sporatic migration, it is known that eating habits and their migration are two of the main causes of mercury contamination (NRC, 1978). It is also known that, just as fish do, birds can concentrate very high levels of methylmercury (NRC, 1978). Birds that eat plants have the least contamination of methylmercury while birds that eat fish have higher mercury levels. Also, if birds leave their polluted home and migrate to one that is unpolluted, mercury can and will leave their systems, although they may face pollution all year if they migrate to a place that is contaminated (NRC, 1978). As in humans and other animals, mercury poisoning affects the young of the species. Mercury poisoning in bird's feathers has been known to halt the growth of eggs and cause them not to hatch (NCR, 1978). Birds that live primarily on land may also experience mercury poisoning through eating seeds that have been exposed to mercury. These birds carry their highest levels of mercury in the kidneys and liver, as fish do (NRC, 1978).

Terrestrial mammals usually have low mercury concentrations when compared **with marine** mammals and their main source of mercury exposure is through the food that **they** eat (NRC, 1978). Plant eating animals usually have the lowest mercury levels, **while meat** eating animals (especially those that eat fish) have the highest concentrations (NRC, 1978).

Plants in water are much more apt **to be polluted by** mercury than land plants. In waterways such as rivers, lakes and **oceans, higher plants are actually able** to **remove mercury** from the water (NRC, 1978). **Mercury usually settles in the sediment. The amount** of mercury in land plants **depends upon the type** of **plant, location, and form of mercury** it is polluted with. Rooted **plants do not absorb inorganic or methylmercury as** easily as it does other types of mercury (NRC, 1978).

1.3.2, Cadmium

Cadmium may enter the **ecosystem in various manners, one of which is through** waste disposal and landfilling in **particular. One problem with cadmium entering the environment** through landfills is that **the concentration of cadmium** in them is **great in** comparison with other sources of cadmium contamination. Cadmium makes up a **very** small portion of the atmosphere (Nriagu, 1980). Thus, cadmium contamination is **usually** caused by human activities. The average cadmium concentration in fresh water is 2.0 μg/g, in oceans is 4.0 μg/g, and on continents is 0.3 μg/g when considering biological uptake (Nriagu, 1980). In comparison, the average concentration in sewage on lands and in oceans is 23 μg/g (Nriagu, 1980). This means that waste disposal is often a source of cadmium pollution.

In test cases where animals have been fed cadmium, it has been found that their kidneys and livers absorbed most of the toxin (as in humans) and that their tissues absorbed very little cadmium. The kidneys are more adversely affected by cadmium and this is due to a greater inducibility of cadmium in renal (kidney) tissues and because cadmium may have to compete with other dietary metals in the liver (Nriagu, 1980). Cadmium added to the diets of hens, chickens, and lambs in different experiments found that the kidney levels of cadmium often close to doubled those of the liver while the animals[1] tissue was relatively unaffected (Nriagu, 1980).

In an experiment on mice in which their drinking water was contaminated by cadmium, it was found that the liver and kidneys had accumulated most of the cadmium. However, after the cadmium was taken away from the water supply, the amount of cadmium in the liver decreased by half in six months while the level of contamination in the kidney remained constant over that period (Nriagu, 1980). Thus, just as the kidneys accumulate a greater amount of cadmium, they also may keep the original concentration of the metal, instead of losing it with time as the liver did. The decrease of cadmium in the liver over time does not always occur and, in fact, the level of cadmium there may increase in time, even after the cadmium exposure is ceased (Nriagu, 1980).

Next to atmospheric fallout and coal fly and bottom ash, urban refuse is the largest contributor of cadmium pollution into soil, with 4200 tons of cadmium entering the soil through landfills annually (Nriagu, 1990). With the average cadmium concentration in soils ranging from 0.3 - 0.6 |ig/g and the soil density estimated at 2.5 g/cm^, the amount of cadmium in soil will most likely double every 50 - 80 years if the current rate of pollution exists (Nriagu, 1990). The biggest problem with this pollution is that once the soil is contaminated, there is no way to clean it of the toxins. Even when small amounts of cadmium are added to the soil, the plants have no protection from cadmium, especially when the pH in the soil is reduced (Nriagu, 1990). Thus, any cadmium contamination in soil may stifle plant life and there is no known amount of cadmium pollution that is considered to be "safe" (Nriagu, 1990).

1.3.3. Lead

Lead has been found to cause a variety of different health disorders in humans and causes similar disorders in animals. When exposed to lead in the fetus or through oral lead administration in high doses, malignant and benign "renal neoplasms" (tumors in the kidney) are known to develop in mice and rats (Gerhardsson, 1986). In hamsters, exposure to lead oxide with benzo(a)pyrene leads to lung tumors, while lead subacetate contamination causes lung adenomas (tumor of glandular origin) in mice and cerebral gliomas in rats (Gerhardsson, 1986).

Industrial lead contamination has disastrous effects on the environment and animals in their natural habitats, as seen in California sea otters. California sea otters have had **a** much smaller rate of population increase in comparison with sea otters from the Pacific Northwest and Aleutian archipelago, and it is believed that this is due to excess industrial lead contamination (Smith, 1992). Industrial lead emissions into the atmosphere **are** considered to be a major contributor to environmental pollution, especially **when** considering that "industrial lead inputs to aquatic ecosystems are derived primarily from atmospheric (1x10** kg/year) and point (4xlO^{7} kg/year) sources that together exceed natural inputs by nearly two orders of magnitude.'^{1} (Smith, 1992). Natural lead levels in **marine** waters and the surrounding ecosystem have increased by one to three orders of magnitude because of these industrial lead emissions (Smith, 1992). Lead increases nonlinearly through marine food webs and thus relative increases in environmental lead will increase lead intoxication throughout the food chain (Smith, 1992).

1.3.4. Nickel

As aforementioned, concern for cadmium in the environment has often overshadowed the potential hazards that nickel presents. For example, in a 1975 report published by the National Academy of Sciences (NAS), it was reported that in 1948, large air concentrations of nickel dust for an alkali-storage-battery plant were found but were ignored because of the cadmium exposure that occurred at the same time. The NAS calls for increased testing of the nickel pollution that is caused in the manufacturing process of nicad batteries since its adverse effects are not adequately known. What is known is that the nickel that is dumped into the environment via landfills cannot be recovered, so any nickel pollution is permanent (NAS, 1975). Nickel exposure to plants may cause chlorosis, which is distinguished by the deficiency of green pigment and has effects similar to iron-deficiency in humans (NAS, 1975).

Animals have often been used in experiments to find the potential effects that nickel may have on humans. Even with the multitude of tests that have been completed, no clear cuts answers about these hazards come to the surface. In particular, many studies have been done to find which nickel compounds are cancer causing. Testing of oral exposure to nickel and its consequences is not very thorough, although in the tests given, no orally-caused cancer was detected (Nieboer, 1992). When nickel hydroxide was dispensed intramuscularly in 40 Wistar rats, 19 of them developed local sarcomas (tumors) (Nieboer, 1992). In another more recent experiment with Wistar rats, low numbers of local sarcomas were found and it seems that a colloidal preparation did not yield any tumors while crystalline preparations caused tumors in eight of 40 rats (Nieboer, 1992). In this, it must be kept in mind that the exposure through landfills would be through oral means instead of through muscular.

Tests have also been done to determine what other types of health problems arc caused to animals due to nickel contamination. Metallic nickel seemed to cause no problems to dogs and cats when given daily doses of 4 - 12 mg/kg for 200 days, although oral doses of as little as 5 mg/kg can be toxic to guinea pigs (NAS, 1975). However, when fed intravenously in single doses, 10-20 mg/kg of colloidal nickel was fatal to dogs (NAS, 1975). In other tests done on rats via muscular injection with nickel dust, 13 out of 20 rats developed local sarcomas and only four out of 20 survived over two years (IARC, 1984).

1.3.5. Zinc

Studies and experiments have been completed to determine the effects that zinc has on animals to better determine its effects on people since it is still difficult to determine what health risks come from zinc exposure. For example, from tests on rats who ingested 0.5 to 1.0% zinc, it was found that zinc contamination may cause stunted growth, anemia (inadequacy in oxygen-carrying material of the blood), a reduction in the activity of liver catalase and cytochrome oxidase, and a decrease in reproduction (Nriagu, 1980a).

Of special concern to scientists is the possible carcinogenic properties of zinc. Animal testing is one way to aid in the discovery of what types of cancer may be caused by zinc and the manners in which zinc administration may cause cancer (ingestion or inhalation, for example). The first discovery of zinc-caused cancer came from an intratesticular injection of zinc chloride, which led to testicular teratomas in cockerels (Nriagu, 1980a). In one report, it was found that the same administration did not cause tumors in Wistar rats, while in yet another, the injections caused seminomas, interstitial cell tumors, and teratomas in rats (Nriagu, 1980a). It is not proven whether zinc chloride in drinking water causes cancerous tumors. One study claimed that this did cause mammary carcinomas in rodents while this was later disputed by other scientists. The only proven way in which zinc has been shown to cause cancer in animals is through intratesticular injection (Nriagu, 1980a).

1.3.6. Lithium

Lithium has been reported to have detrimental effects on the fetus, as shown in recent tests on rodents. In mice, the fetus and the breast-fed infant suffered from problematic organ development when its mother was exposed to lithium while the problems were not as serious when young rats (developed past newborn state) were contaminated with lithium through direct exposure (Messiha, 1993). Also, female mice were more severely harmed than males, leading to the thought that there are "developmental gender-linked sensitivities to lithium toxicity" (Messiha, 1993). The lithium contamination may cause interferences in carbohydrate metabolism and some endocrine functions such as changes in growth hormone and proiactin (pituitary hormone that stimulates the secretion of milk) secretions. Further, it was found that mice whose mothers were infected with lithium and were breast fed had lower brain weights, in both the cerebrum and cerebellum, and had continued stunted growth of the brain even after the exposure had been stopped (Messiha,

1993). The spleens (organ which filters **and stores blood)** of **children whose mothers were** exposed to lithium during pregnancy **or nursing** also **tend to be enlarged, leading to physiological** and/or immunological **irregularities which could leave them more vulnerable to** infectious diseases (Messiha, 1993). **Other birth defects that have been seen in lithium-contaminated** mice include cleft palates, **skeletal anomalies, and exencephaly (Klug, 1992). Changes** in **the** kidney may come as a **result of the lithium-caused decreases in its weight, as seen in developing mice (Messiha, 1993).**

In other tests on rats, birth defects were also seen to be caused by lithium exposure. As reported in **the** Archives of **Toxicology, even at the lowest concentration tested (50 |ig/ml),** a notable decline of the **growth and development of the embryo occurred. At concentrations of 150 M-g/ml, more pronounced effects, such as "absence of the eye cup, kink in the** spinal anlage, and **'blebs' (retractions) at the nostral head region," were seen (Klug, 1992). Developmental problems were also found in the limb buds, ear vesicles, tailbud, and heart, and conditions such as the cleft palate, brain and digital defects, and skeletal** abnormalities also developed **(Klug, 1992).**

1.4. Suggested improvements in toxicity studies

There are many questions about the definite effects that metals may have on humans. To further determine these effects, experiments on animals are often completed. Researchers also may resort to studying the health of people who have already **been** contaminated by metals through occupational or environmental exposure. Even with **the** variety of tests that have been done by many **different** research groups, there is still **much** that needs to be learned about the illnesses that may be caused by exposure to heavy metals.

For example, many questions still remain about which metals are carcinogens. Lead is thought to cause cancer, based upon results from animal testing, although no specific dosage of lead has been said to have caused cancer and researchers are still unsure of whether or not methylmercury causes cancer. Specific testing has been done on cadmium and zinc to determine their cancer-causing status, and although it does appear **that** they are carcinogenic, this is not a proven fact. Questions also remain about how cadmium causes cancer, whether it does so only through inhalation and injections, or whether it also may be carried through oral administration.

Sometimes, as in the studies of cadmium as a carcinogen and cadmium's effects on the developing fetus, there are questions about how results from tests should be evaluated and different researchers look at these statistics in various ways. For example, some researchers doubted that cadmium exposure to workers was cancer-causing and instead blamed smoking or exposure to arsenic or nickel for cancers that had developed. However, in some cases, inadequate amounts of testing is the reason for questions on how a metal may adversely affect the human body and the rest of the ecosystem. For example, nickel hydroxide is a major component of nickel cadmium batteries, and although a multitude of tests on nickel's effects on humans have been conducted, few tests have been completed on the specific potential health risk that nickel hydroxide may present. Thus, it is difficult to consider the true hazards that nickel cadmium and nickel metal-hydride batteries may yield until additional testing on nickel hydroxide is completed. Questions of nickel's environmental effects were also posed by the National Academy of Sciences since they had recognized that exposure to cadmium was highlighted in research, while the effects of nickel contamination were ignored. To know the definite adverse effects that nickel and nickel hydroxide may pose to the ecosystem, additional testing must be completed.

Through the continuation of research on the toxic metals that compose batteries, additional information on their potential hazardous effects is found. Also with this research comes the realization that there is still much more information that must be found to know the true effects of these metals. Continued animal testing may be unethical, but is one way to find answers to many *of* the unanswered questions that remain. Since the definite amounts *of* battery remains that enter the waste stream is still unclear and will probably never be known, it is difficult to connect direct adverse health conditions to toxic battery exposure. In the future, perhaps increased testing of soil and water near landfills will be completed to find a clear correlation between battery disposal and possible environmental pollution and the indirect human contamination that follows.

1.5. Comparison of materials' potential threat to **the** ecosystem

Now that some of the potential dangers that common battery metal components present to the ecosystem are known, it is necessary to find which metals are most harmful and should be avoided in battery manufacture. Below is a compiled chart of the possible health effects that may come as a result of metal contamination, the most common of these being neurological or kidney damage, birth defects, and cancer, four very serious health conditions.

COMPARISON of METALS and THEIR HEALTH EFFECTS

Metal	**Potential Health Effects**
Mercury	death, birth defects, neurological damage, impaired vision, reproductive and genetic problems
Cadmium	carcinogen, kidney stones, birth defects
Lead	neurological damage, *IQ* deficits, kidney damage, carcinogen, reproductive problems
Nickel	carcinogen, kidney damage, liver damage, skin disorders, immunological disorders
Zinc	carcinogen, birth defects, anemia, kidney damage
Lithium	neurological damage, adverse effects to children, kidney damage, birth defects

Each of these metals has a multitude of dangerous side effects that may come as a result of intoxication. As mentioned before, kidney damage seems to be a common result of poisoning. Four of these metals (cadmium, lead, nickel, and zinc) are thought to be carcinogens while mercury, cadmium, zinc, and lithium are also thought to cause birth defects. Neurological damage is caused by extreme exposure to mercury, lead, and lithium. If these effects happen in combination, the health condition of the person affected becomes more severe and thus exposure is more dangerous than once expected.

It is difficult to say which metal is the most volatile and causes the most potential adverse effects to the human body since the amount of the metal dumped into the environment must also be considered. Mercury is a highly toxic metal and perhaps the most dangerous of all of the described metals, but the amount of mercury in batteries has been steadily decreasing, and with the threat of legislation to ban mercury from battery manufacture altogether, it will continue to drop. Zinc-air batteries are not widely used and are thus as not as large a threat to environment as lead-acid or nickel-cadmium batteries, especially when considering the especially toxic effects of lead, cadmium, and nickel. In comparison with these metals, zinc is not as potentially harmful to the ecosystem.

Lead is especially harmful because of the permanent neurological damage that it causes to young children who must face a lifetime with these defects. With the development of the electric car industry and the potential use of lead-acid batteries as a power source, lead has the possibility of entering the waste stream at a greater rate, so increased recycling of the batteries should become a priority. Recycling of nickel cadmium batteries should also continue because of the combined toxicity of nickel and cadmium. Nickel metal-hydride batteries should continue to be the new choice in battery technology since they are more green than nickel cadmium batteries since they do not contain cadmium. Lithium's potential neurotoxicity also makes it harmful to the ecosystem and the potential contamination that lithium battery disposal poses is explored in the next section.

2. An assessment of the extent of **lithium contamination in humans**

The lithium-based battery industry, especially lithium-ion battery technology, is quickly growing as companies put increased time and money into battery development. By the year 2000, the primary lithium battery market should grow from the 1992 value of 75 million dollars to 120 million dollars, while the market for secondary (rechargeable) lithium batteries should reach 10 million dollars by that time (PSMA, 1992). The development process of lithium batteries, the uses of these batteries, and other applications of lithium will be discussed in this section. The amounts of lithium mined and consumed will also be documented, with the scarce available information.

Lithium can cause damage to the ecosystem in a variety of ways, as detailed in sections 1.2.6 and 1.3.6. The specific doses which may cause these damages to humans were outlined. Using estimates on how many lithium batteries are dumped per year, predictions on how much lithium is ingested by Americans due to lithium-based battery landfilling will be made. These numbers will take the fact that lithium battery industry is still growing, and the potential for more batteries to be used and in turn dumped will be taken into account. Then, the effects that humans may suffer from this lithium contamination can be inferred based upon the established dose-response relationships.

2.1. Lithium battery development

The development of new battery technology tends to be costly and time consuming, as emphasized by Moli Iinergy Ltd. president Boris Sawicky in his statement that "unfortunately, there aren't a lot of people who appreciate how much time, effort, and money is needed to bring a new technology to market" (Smith, 1993). In its development of lithium-ion battery technology, Moli has spent at least $30 million and plans to invest even more time, energy, and capital into the development of this product. This type of effort is not uncommon in lithium-based battery development, where the research is in fairly early stages as compared to other batteries such as alkaline, lead-acid, and nickel cadmium. With increased commercialization efforts of lithium-ion batteries and continued research on lithium polymer batteries, lithium batteries seem to be the emerging battery technology.

In 1986, the Eastman Kodak Company introduced its Ultralife lithium battery and in 1990 was forced to halt manufacture of it due to lack of consumer interest (Ansberry, 1990). Ultralife was the "first mass-market lithium cell" and seemed to conquer the combustibility of lithium through Kodak's patented safety mechanism that would shut the cell down in case of a short circuit (Ansberry, 1990). However, there were plenty of problems with the Ultralife battery. The **fact that** the battery was the infrequently **used nine-volt** size was considered to be part **of the sales problem,** although material **buildup** also seemed to alter the expected ten year shelf life. Although Kodak no longer produces the Ultralife battery, the Ultralife label and technology has been purchased and batteries **are** still produced under this label. These batteries are sold to companies such as First **Alert** and Honeywell who include them in their product manufacture.

At least six companies are actively attempting to market lithium batteries. In 1992, a lithium-ion battery for camcorders was introduced by the Sony Corporation of Tokyo, although Sony has not yet introduced a battery for general use in all goods (Patton, 1993). The TR-1 camcorder weighs 1.5 pounds and can recharge the battery when the camera (with battery pack inside) is set on a "handycam station." (Neff, 1993). Sony has also been producing 1 00.000 rechargeable lithium batteries a month for use in cellular telephones, with plans to increase production so that its batteries can be used to power laptop computer as well (Anonymous, 1992). Sony subsidiary Sony Energyttec has sent 600,000 batteries a month to Japanese electronic companies for use in their appliances, with plans to increase this number. A & T Battery, a group venture by Asahi Chemical Industry Co. and Toshiba, .shipped 200,000 batteries a month in early 1993 and planned to increase distribution to 1.000.000 by late 1993, while Matsushita also planned to begin sample battery shipping in 1993, after investing S80 million in lithium-ion battery development (Neff. 1993).

Sanyo Electric Company Ltd. of Osaka is also attempting to introduce its own line of rechargeable lithium-ion batteries, while planning to double their monthly battery output from 0.5 million to 1 million batteries (Patton, 1993). These batteries should be the first lithium-ion batteries marketed to suit a multitude of applications since Kodak's Ultralife battery. According to Dr. Toshiako Saito of Sanyo, their "lithium-ion batteries will have greater capacity than others because we use graphite as an anode material." (Patton, 1993). The lithium-ion battery technology has been in development stages for at least five years, and Dr. Saito says that although Sanyo is researching lithium polymer battery technology, it will not be ready for practical applications for at least another five to ten years (Patton, 1993). Other industry representatives agree that lithium polymer technology is still in developmental stages, although Valence Technologies claims that its battery is in late research stages. Valence maintains that its lithium polymer batteries cost a small fraction of the per-watt-hour production of lithium-ion batteries, although Chemical Engineer Elton J. Cairns of Lawrence Berkeley Laboratories claims that they may cost the same per energy output (Neff, 1993).

Eveready also plans to market its lithium-ion battery in England. These new batteries will cost almost four times as much as typical consumer alkaline batteries with a less of an increase in power iCoghlan, 1994). Eveready claims that its battery will not cause any hazards to the environment. Technical sales manager Dave Gilham states that "even if you hammered a nail through it, or exposed it to rainwater for months and allowed it to corrode, it would not pose any hazards or cause any environmental problems. It can be disposed of in normal domestic waste" (Coghlan, 1994). Eveready claims that this is because of the safety features that it has added that prevent leakages. Eveready also claims that its battery is safe to use in the "rechargers" that add power to nonrechargeable batteries (Coghlan, 1994).

Red Bank. New Jersey's Bellcore also plans to market its solid lithium-ion battery in one to three years (Taninecz, 1994). Bellcore's battery is said to have power capabilities of batteries twice its weight. According to Bellcore, the battery is leakproof since the elements are "permanently bonded together, then covered by a moisture-proof-barrier coating...it looks like a solid, but acts like a lithium-ion battery" (Taninecz, 1994). Bellcore battery team leader Jean-Marie Tarascon also claims that the battery materials are "totally recyclable" (Taninecz, 1994).

2.2. Applications of lithium batteries

Lithium-based batteries are used to power a variety of electronic goods. Currently, Valence Technology, Inc. of San Jose, California and the Delco Remy Division of **General** Motors are collaborating on the development of lithium batteries for use in automobiles (Dawson, 1993). Valence has also received financial support from Motorola ($100 million) for use in the development of rechargeable lithium polymer batteries (Young, 1993). Although Valence is a forerunner in lithium-based battery development, they are not the only company making advancements in this technology for use in powering consumer products. 3M is under contract with the United States Department of Energy and the Big 3 automakers (Chrysler, Ford, General Motors) to develop a lithium polymer battery for use in cars as well (Marcotty, 1993). Working with Hydro-Quebec and Argonne National Laboratory, two expert battery research organizations, the proposed battery will be one-eighth the weight of the current lead-acid batteries, with added features of durability and low volume, coming from the fact that the battery will be made from flexible thin cells and solid material (Marcotty, 1993).

A new lithium iron rechargeable battery has been developed by Bell Communications Research (Bellcore) for use in portable telephones and laptop computers (Holusha, 1994). The battery is thin and flexible (like a credit card) and will not leak. Mine Safety Appliances Co. (MSA) manufactures lithium iodine batteries, which are used in a variety of products, including heart pacemakers and the machines which measure oxygen levels (Gaynor. 1992). In conjunction with Measurement Specialties Incorporated (MSI), Health-o-Meter has begun to power their scales with lithium batteries (Murphy, 1993). This change of energy source from alkaline to lithium batteries increases **battery** lifetime from one year to thirty years.

2.3. Other applications of lithium

Lithium is used in applications **other than battery manufacture. As mentioned before, lithium** salts are used to **treat people with manic-depressive disorders. The Aluminum** Company of America **(Alcoa) produces an aluminum-lithium alloy which aerospace** companies such as **McDonnell Douglas use because it is lightweight, although it is still** fairly expensive since it is in **its development stages (Kandebo, 1991). Lithium-based** greases are also commonly used **(Runyon, 1990). The Navy's MK50 torpedoes are powered** by lithium boilers and **must be disposed of carefully due to environmental concerns** (Southwell, 1992). Dallas **Semiconductor Corporation uses a lithium power source** in combination with its electronic **chips to power equipment (Radwan,** 1992). **The specific** percentages of lithium that each **industry consumers will be listed in section 2.4.**

2.4. International lithium production and consumption

Lithium is produced and consumed in industrial countries throughout the **world.** The leading producer and consumer of lithium continues to be the United States, as it has been for many years, while Chile attempts to maintain its role as a low cost producer and become the foremost lithium producer in the world (Ober, 1992). Only two companies produce lithium in the U.S.. Cyprus Foote Mineral and FMC Corp., Lithium Division, and their production numbers and stock data are kept secret "to avoid disclosing company proprietary data.' (Ober. 1992). Nationally, a lithium-aluminum-silicate material (spodumene) is mined from large hard-rock deposits in North Carolina by both national lithium production companies, while it is also found in geothermal brine deposits in Nevada (Ober. 1992).

In 1992. total U.S. exports of lithium compounds were 12% lower than those in 1991, with most of the exports going to Germany, Japan, and the United Kingdom (Ober, 1992). This decrease in exports occurred with a 31% increase imports (Ober, 1992). This differs from the situation outlined in the 1988 Lithium Materials Yearbook, when both imports and exports increased greatly (Ober, 1988). In 1988, estimated consumption and world production rates increased (Ober, 1988). The prices of lithium set by both of the U.S. lithium producers continue to rise, as they have for the past six years, rising 3% from 1991 to 1992 (Ober, 1992).

Developing lithium battery technology continues to be a "growth area for lithium consumption," while the estimated domestic consumption of lithium decreased by 12% in 1992 (Ober, 1992). In 1992, batteries consumed 7% of the lithium used in the United States. The other consumers of lithium are the ceramics and glass production industry (20%), aluminum smelters (18%), synthetic rubber and Pharmaceuticals (13%), chemical manufacturing (13%), miscellaneous chemicals (12%), lubricants (11%), and air treatment (4%).

Confusion arises in the lithium production statistics that are reported, as explained in the Bureau of Mines report on lithium:

> Lithium presents special problems when compiling estimates of production capacities different operations. Ore concentrate products arc not comparable to lithium carbonate. Lithium carbonate was the primary compound produced at lithium chemical plants and the compound from which all other lithium chemicals were produced. Because even high-grade ore products usually contain almost 20% lithium, production capacities reported in tons per year represent large differences in the actual lithium content of the product. For thai reason, capacities were reported based on the lithium content of the produds also known as contained (salient) lithium.

In this report, the statistics that are given will be those on salient or contained lithium since these are the figures that most accurately describe the lithium content that is mined and consumed by industry in the manufacture of products.

As mentioned before, information about the specific amount of lithium production in the United States per year is held confidential because the two companies involved consider it to be proprietary information. Apparent consumption numbers of lithium are also withheld, although the amount of lithium consumed per year is estimated by the Bureau of Mines. Below is a summary of the available statistics on the amounts of salient (or contained) lithium produced or consumed in the United States. Note that import and export results are available. The estimated consumption of salient lithium in America has dropped from 2,600 to 2,300 between 1991 and 1992. It can also be inferred that the two lithium producers in the United States produced at least 2,100 metric tons of lithium **in** 1992 since that amount was exported.

Information on Salient Lithium Production and Consumption in the U.S.
(in metric tons)

United States	1<>88	1989	1990	1991	1992
Imports	1,000	630	790	590	770
Exports	2,300	2,600	2,600	2,400	2,100
Estimated Consumption	2,700	2,700	2,700	2,600	2,300
Rest of world: Production	4.S00	5,400	5,400	5,200	5,200

(data taken from Table 1, Obcr, 1992)

2.5. Risk assessment of lithium in the ecosystem

In assessing the risks that **are associated with lithium exposure, there are three steps to** consider, as detailed in **Calabrese and Baldwin's** Performing Ecological Risk Assessments. First, the physical and **chemical properties of the agent must be identified, including** the amount of the pollutant. **Then, estimation of the quantities and areas of substances may** he completed and **finally, prediction of the concentrations may take place.**

In sections 1.2.6 and **1.3.6, the hazards that lithium may present to the ecosystem were** outlined and dose-response **results were given so as to give a general idea of how** much lithium is nccc.s.viry to cause **intoxication and adverse health effects. These will be used** to help determine whether or not **the amount of lithium that enters the environment**

through battery disposal is harmful to humanity and if the possibility for intoxication exists. Now that the chemical properties and risks of lithium have been identified and detailed, the quantity of lithium that enters the environment must be estimated.

Difficulty comes in the estimation of how much lithium is disposed of in landfills yearly. Since there is no available data on how much lithium is produced per year and only estimated data on American consumption of lithium exists, there are many questions on where the lithium produced in America goes after industrial consumption. Lithium-ion batteries are often part of the product as it is purchased and consumers may dispose of these products without knowing that they are dumping lithium simply because they do not know that they are there since they came with the product. For example, Ultralife lithium power cells are used in such marketed products as First Alert Smoke and Fire Detectors, ADEMCO Wireless Security Console, Escort's SOLO Radar Detector, and Honeywell's Hand Held Transmitter. The company makes the decision on the power source, not the consumer, leaving consumers virtually unaware of the disposal possibilities that exist with lithium batteries.

Another problem in the estimation of the amount of lithium that enters the waste stream yearly comes from the fact that it is not know how quickly these batteries are replaced and thus how often they are disposed of (how many reach landfills per year). It also has to he considered that lithium-ion battery use is just beginning and with the further introduction of commercialized lithium-ion batteries, more and more of the batteries will enter the waste stream per year. Thus, the effects that may come from the potential increase in commercial sales of these batteries must also be considered to see if some sort of policy on lithium-based battery disposal should be established as the industry continues to grow and consumers begin to use these products on a regular basis. The opportunity exists for lithium-ion batteries to replace alkaline batteries as the main power source for consumers and this should be considered when estimating the adverse effects that may arise from lithium disposal in landfills. One obvious good point for using lithium-based batteries over alkaline batteries is that lithium batteries have a longer lifetime and are thus disposed of less often. Lithium-based batteries also do not use extremely toxic mercury, which is another reason why it may be replace alkaline batteries. Although lithium batteries cost more than alkaline cells now, in time these costs may fall since these batteries are still in developmental stages.

Assumptions must be stated before estimations of the concentrations of lithium in humans due to its disposal in landfills are made. Since lithium battery recycling is relatively non-existent at this time, it will be assumed that it plays no role in the disposal of lithium batteries. Thus, in this assessment, disposal of batteries in landfills or incinerators are the only possibilities for lithium batteries after their usage is over. Susan Knight of Ultralife Batteries reported that they incinerate their batteries in quantities of hundreds to thousands at a time, so incineration is a viable disposal possibility for these batteries and must be considered. At this time, it will be assumed that 90% of the lithium batteries that are consumed are disposed of in landfills and that the remaining 10% are incinerated. This assumption comes from figures from the EPA's The Solid Waste Dilemma: An Agenda for Action, where it is said that 80% of municipal waste goes to landfills, 10% goes to incinerators, and 10% is recycled. Since it is assumed that no lithium batteries are recycled, the amount that would be recycled will be supposed to have been dumped in landfills as a worst case scenario.

In the calculation of how much lithium from batteries is dumped per year, it is assumed that all of the lithium that is consumed through battery usage is disposed of. In reality, the amount of lithium which is disposed of is probably much less than this since lithium batteries have a long lifetime, but this assumption presents a another worst case scenario of battery dumping.

The final assessment of lithium concentrations in humans will be a very rough estimate because the data used is estimated itself. The population of the United States is estimated at 250,000.000. The Bureau of Mines estimated the consumption of contained lithium in the United States to be 2,300 metric tons (2,530 short tons) in 1992. The **battery** industry consumes *17c* of the total lithium consumption in the United States and thus **the** estimated amount *of* lithium used in battery production is 161 metric tons (177.1 **short** tons). This number is bound to rise in time since the amount of lithium batteries **being** produced is slowly rising, so that fact will **be** considered in **the** analysis. The **suggested** reference dose will be taken to be 250 mg **since this** is **the smallest dosage that causes any sort** of hazardous effects (weight gain) **to children. The smallest dosage found to cause** neurological damage to adults is 438 mg. **This reference dose is thus very conservative, again** with the objective of using a **worst case scenario.**

As mentioned above, the formula **used to calculate this exposure is very rough and this** is appropriate since the numbers used **are estimated.** To find **the** total intake of **metal per** person per clay, the following **calculation will be used:**

TOTAL INTAKK = umouru ol lithium dumped in landfills in 1992 (AMT) / (US population * 365 **days)**

where AMT = .9 (percent l;indrilled)*amouru consumed (in short tons)* 907029.5 (convert from tons to g)

In this case, where the amount of lithium dumped in landfills is 177.1 short tons and **the** above calculation is used, the total intake of lithium per day is 0.001584 g (1.58 mg). **This** number is *0.6327c of* the suggested reference dose and thus is a very small fraction of **the** reference dose. Even when considering the potential increase in lithium battery production, the amount of lithium that would enter the waste stream due to battery disposal is **very** small and thus, at this time, can be disregarded. Lithium may enter the waste stream through sources other than the battery industry (through its use in aluminum production, for example) and these may prove to cause more *of* a threat to the environment.

3. Environmental policies regarding **battery disposal**

Growing public awareness about environmental hazards has brought green issues into the forefront in both legislative and industrial arenas. In this section, the programs and legislation introduced by the United States Environmental Protection Agency (EPA) will be outlined and the specific regulations that affecting the disposal of waste into landfills will be detailed. The policies of the Clinton Administration on environmental issues, including its apparent efforts to appease industry, will also be explored. Problems also exist in the newly formed European Community (EC), with twelve countries with different views on the importance of environmental protection coming together to create legislation. The way in which industry has joined the environmental bandwagon in creating "greener[11] products, initiating recycling programs, and cleaning up their production facilities will also be explored.

3.1. Existing environmental **regulations in the United States**

In 1970, the Environmental Protection Agency (EPA) was added as an independent agency in the executive branch of the United States government (Anonymous, 1990). Its function is "to permit coordinated and effective government action on behalf of the environment" (Anonymous, 1990). This means that the EPA is responsible for controlling all types of pollution, including contamination caused by solid wastes, toxic substances, and noise.

There are various regulations that the EPA has set forth in order to control the potential contamination of the environment. One that directly deals with the governing of landfills is the Supcrfund program, which was passed by Congress in 1980 under its formal name: the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Mukherjee. 1992). The enactment of CERCLA provided for the creation of a fund (the Superfund) whose emphasis was to clean up hazardous waste at sites that were called "uncontrollable" or were deserted (Howson, 1992). Under this plan, the EPA also has the right to find former landfill owners, operators, and waste contributors when seeking compensation for cleanup costs at hazardous sites (Howson, 1992). HI first, the program was allotted SI.6 billion, but was then given $8.5 billion more in 1986 when it was obvious that the initial funding was not enough to cover the adequate expenses. It is not clear where this money has been spent, leaving for many questions from state officials whose programs have almost no power in forcing businesses to clean their sites and not enough money to clean up hazardous sites. "It was a good idea that went bad," said North Carolina assistant secretary of environmental protection Edythe McKinney. "The federal program is so slow...It is too cumbersome and bureaucratic" (Mukherjee, 1992). McKinney continues that "what we are not getting from the EPA is money to actually go out and clean the sites" (Mukherjee, 1992).

Initially passed in 1976 and later amended in 1980 and 1984, the Resources Conservation and Recovery Act (RCRA) governs the "generation, transportation, storage, and final disposal" *of* all wastes (including hazardous) in all stages of the waste's lifetime. (Howson, 1992). Through this act, hazardous wastes are characterized into four different types of waste: reactive or explosive, corrosive, ignitable, or extraction procedure (EP) toxic (Hartsfickl, 1992). In the case of batteries dumped in landfills, the EP toxicity is especially significant since it applies to the toxins that may "leach out" of batteries, thus characterizing them as hazardous wastes (Hartsfield, 1992).

The EPA has a multitude of < ?-ier programs aimed at guarding the American people from environmental hazards, a few of which will be summarized here. The Toxic Substances Control Act rules the wa\ · dustry handles and disposes of potentially harmful chemicals, such as mercury and lead (Howson, 1992). The Clean Water Act controls the level of chemicals that may enter the ground water and the Clean Air Act sets limits on air pollution levels (Howson. 1992). The Emergency Planning and Community Right to Know Act (ΓiPCRA) gives citizens the right to information about potential hazards in their area, makes businesses responsible for informing the government and the American people about hazards that they may have created, and outlines a plan to follow when an emergency hazardous situation may occur (Howson, 1992).

Lately, questions have been raised about whether the EPA is protecting the environment or protecting industry's interests. For example, the EPA emissions trading program allows companies that have emissions below EPA standards to earn credits that will allow them to have higher emissions at another plant or sell their credits to a firm **that** has emissions above EPA accepted levels. The government says that this procedure will encourage businesses to meet EPA standards since they will be forced to buy emissions or pay fines if they don't. This policy does not seem to be based on protecting **the** environment since any number of plants could legally be above EPA standard emissions and this could adversely affect the people living near the plant. These plants with bought or earned emissions could theoretically have emissions any amount above these set limits, again creating a potentially dangerous situation for nearby residents since they are **being** exposed to levels of contamination which exceed those which are considered **safe.** Through this, it seems that the EPA is sending a message to industry that money can buy your way out of environmental protection.

The types *ot* environmental regulations that our current administration plans to implement are still unclear. Vice President Al Gore is quite outspoken on environmental issues and has even written a hook on his environmental views called Earth in the Balance. How devoted he and President Clinton will remain to these issues is another matter. The administration seems very willing to compromise with industry on environmental issues. President Bill Clinton himself has said that he would like to steer environmental protection away from the present "command and control regulatory system" to a less expensive program which would use market incentives as a way to regulate businesses. (Ching, 1993). One way of doing this is the above mentioned emissions trading plan, which has been used as a means of regulation for years. He will allow continuation of many current

EPA programs such as the Superfund, RCRA, and the Clean Water Act, but will also seek generation of new jobs with environmental reform. (Ching, 1993).

Since its goal is the creation of new jobs, the administration will continue to appease industry, as shown through its handling of the Waste Technologies Industries (WTI) testburn of its hazardous waste incinerator. Vice President Gore promised the people of Liverpool, Ohio (where the plant is located) that he would stop burning at the facility, stating that "we'll be on your side for a change instead of the side of the garbage generators" (Hopey, 1993). President Clinton backed this claim up with his statement **that** "the federal government should not permit permitting incinerators where you are going to have on-site storage of garbage in a flood plain" (Hopey, 1993). After these promises were made, the U.S. Supreme Court rules that it would not block commercial burning at WTI's incinerator. Clinton claims that he has "no legal basis" to stop the burns since the Bush administration approved the trial burn before he took office (Hopey, 1993), yet it still does not appear that Clinton intends to keep his promises to protect the environment and **the** people who reside in it.

EPA Administrator Carol Browner has voiced her concerns over what she calls "gross problems" with the Superfund, calling attention to "inconsistency in application of law and regulation by regional offices" (Ching, 1993). On February 1, 1993, the **EPA** issued a memorandum discussing the eight major Superfund priorities for 1993, which include accelerated cleanup *o(* hazardous sites, fairness in enforcement policy, innovative technologies, and effective contract management (Ching, 1993). Browner also says that she plans to revise laws "to make them less cumbersome and more reasonable" for businesses (Raian, 1993). Under tier leadership, the Superfund program may change its focus from cleaning up all sites that border on becoming a hazard to cleaning only the most hazardous waste sites (Ratan. 1993). This type *of* reform would definitely benefit industry, but it may ;uu necessarily be the best plan for the environment. Just because a site may not be one of the "most hazardous" sites when compared to other locations, it does not mean that the site cannot present a potential danger to those close to it. Other plans for the EPA include spending $446 million over a five year period on "recycling and other clean technology to supplement regulation" (Ratan, 1993). It remains to be seen whether these plans will improve the status of the current hazards that face the environment.

It is a common idea among industry leaders that the government tends to overregulate businesses where environmental issues are concerned, yet our ecosystem continues to suffer from various industrial abuses as a result of improper waste disposal. Overregulation may or may not be a problem, but enforcement of current rules definitely is. For example, in 1992, 83 sites in Triangle Research Park, Nonh Carolina were not cleaned to EPA standards and had not yet been cleaned or the companies had not yet paid penalties for the potential hazards that they created (Mukherjee, 1992). Costs for cleanup had been estimated at about $100 million, with the businesses to be held accountable for most of these costs. State officials tried to help to enforce these guidelines by hiring more lawyers and engineers, but they blame the enforcement problems on the EPA Superfund division. Nonh Carolina State Secretary of Environment, Health, and Natural Resources Bill Cobey claims that "It (the Superfund) is not set up correctly. All the time there are examinations going on but we don't know what's happening in the final analysis when it comes to panicular sites" (Mukherjee, 1992). Just as communication between state and federal officials is not as open as it should be, there is also a lack of communication between the EPA and the businesses involved. An anonymous North Carolina businessman says: "It is hard to keep up with the EPA changes in terms of regulation. It changes every year and suddenly we get a letter that we have made the (hazardous sites) list and no further communications after that. I don't think anybody knows what is going on" (Mukherjee, 1992).

When it comes to cleanup costs, the EPA may hold not only those who run landfills responsible for cleaning hazardous sites, but may also force those whose waste was dumped in the landfill to pay for cleanup costs. In Richmond, Virginia, C & R Battery Co.

Inc. was cited for hazardous landfilling by the EPA and was to be regulated for cleanup under the Superfund program (Martz, 1992). However, in 1985, C & R Battery owner Charles Guyton closed the site and disappeared, and left behind other polluted sites in Indiana and Georgia (Martz, 1992). With Guyton gone and no one left to take responsibility for the land polluted with battery materials such as cadmium, lead, and zinc, the EPA held all companies whose batteries accounted for at least 1% of the waste responsible for the SI4.3 million dollar cleanup costs. The Chesapeake and Potomac Telephone Co. (C & P), a subsidiary of the Bell Atlantic Corporation, agreed to pay **the** EPA for the cleanup since none of the other 17 responsible companies was willing to **pay,** and then seek compensation from the other companies whose batteries were found in **the** landfill (Martz, 1992). Kimberly A. Hummel, head of the Superfund section for Virginia and West Virginia, said that the EPA found no indication of polluted ground water in **the** area. Cleanup will consist *o*\' "removal, treatment, and disposal of an estimated 36,800 cubic yards of contaminated din" according to Hummel (Martz, 1992).

One reason why the EPA may deal more harshly with those who landfill their waste incorrectly is because the agency feels very wrongly about the potential harm that landfilling may cause. According to Jonathan H. Adler xr the Competitive Enterprise Institute, federal officials believe that "landfilling is the least desirable option for disposing of hazardous waste," based upon ihc effects that this pollution may have on the environment. Industry often prefers to use landfills tor their garbage disposal since other forms of disposal such as incineration are more strictly regulated (Adler, 1993). Adler claims that incineration may be more environmentally friendly, although this is just an idea and has not yet been proven.

Although landfills are considered to be a less desirable option for hazardous waste, 67% of the 195 million tons <t municipal solid waste was sent to landfills in 1990, with the amount of waste expected to grow to 220 million tons by the year 2000 (EPA, 1993). In the EPA's Safer Disposal For Solid Waste: the Federal Regulations for Landfills and Criteria for Solid Waste Disposal Facilities: A Guide for Owners/Operators, guidelines for

the operation of landfills are outlined. **It** is **up to the landfill owner or operator to develop a program to** keep regulated hazardous **wastes out of their landfill. This program must include** for random inspections, **adequate training of employees to recognize hazardous waste, thorough book keeping, and notification of the proper authorites if hazardous waste is discovered at their waste facility. Since batteries are considered to be hazardous waste and are often disposed on in the municipal solid waste stream with other household garbage, this type of regulation is especially pertinent to battery disposal. These demands will hopefully encourage increased recycling efforts.**

The methane gas that is often produced from the waste must closely monitored. The gas emissions must be checked every three months, and if they surpass the limits specified in the regulations, the operator must inform the state director so that "immediate steps to protect human health and the environment" may be taken (EPA, 1993). To protect the ground water, the landfill must have a control system to prevent storm waters from coming in contact with the **active portion of the landfill. Landfills are also governed by the Clean** Water Act and must be sure **not to release pollutants which not in accordance with it. By** October 9, 1994, any landfill **that** is **less than one mile in any direction from a drinking water** intake (including surface or **groundwater) must have a ground-water monitoring** system installed and all sites more than two **miles from** a **drinking water intakes must have** a system installed by October 9, 1996. **The EPA** has also **set Maximum Contaminant** Levels (MCLs) to ensure that landfills **perform to** a **certain level of pollution prevention. Cadmium,** lead, and mercury have **MCLs** of **0.01 mg/L, 0.05 mg/L, and ().002mg/L** respectively. These levels arc set especially for landfills that **do** not correspond with **the** EPA-designed composite liner and leachate collection system.

3.2. European Regulations

Creating a uniform set of environmental regulations for the 12 countries that are members of the European Community (EC) proves to be a daunting task considering that each country has its own idea of the importance of the environment. A goal for establishing a single, internal trade market for the EC was set for 1992, with environmentalists wondering how green issues fit into the economic decisions to be made- One such policy involves the potential banning of nickel cadmium batteries in the EC (Mackay, 1992). These batteries are often used as a power source in such electronic products as portable computer and are a significant part of the economy, while these batteries do present a hazard to the environment.

The legislation most often used by the EC consists of either regulations or directives (Laurence, 1989). Used mostly for commercial trade and agricultural policy, regulations are directly binding on all member states. Directives, on the other hand, must be executed by the member states through their own legislation (Laurence, 1989). Environmental policy is most often carried out with directives instead of through regulations.

As of 1989. the European Community had issued two important directives concerning waste disposal. These were issued with economic issues in mind; the legislation was not to interfere with trade between EC countries. The directive on waste disposal was put into effect in 1975 and in 1978, the directive on toxic and dangerous waste was implemented (Laurence, 1989). These directives gave each member state control over what regulations were actually enacted and how they were implemented. Each state could also decide which substances were wastes and how to control them (Laurence, 1989). Waste disposal facilities such as landfills had no specific standard rules for their regulation, and the only rule regarding incinerators was that they must not endanger human health or the environment (Laurence, 1989).

It is difficult to determine how new environmental decisions will be made since each country already has its own sets of rules and, even with EC membership, is still entitled to make most of its own environmental decisions since these issues are most often dealt with using directives. For example, environmentally concerned countries such as Holland and Germany require that their industries dump wastes in landfills close to industry sites or in expensive state-run incinerators, while other European countries allow their trash to be shipped to poorer, developing countries (Anonymous, 1989). In this case, the difficulty arises in finding rules that agree with all of the countries involved, especially when economic issues are considered. Under the Single European Act, an EC country may enact stricter environmental regulations than other member countries if these standards do not create a barrier to inter-EC trade (Anonymous, 1989).

It may not seem that environmental regulations would have much to do with the economy, but they could easily play a role in trade relations. For instance, a country with lax standards on waste disposal could be giving its industries an edge over countries **that** have stricter rules on disposal by allowing its businesses to have lower costs and thus sell its products at a lower price (Anonymous, 1989). Another example of environmental issues affecting economics is when one country has rules that products used there must meet specific environmental guidelines, preventing goods from other EC countries that do not meet these guidelines from entering the country (Anonymous, 1989). A specific case of this involves Germany, who has prohibited batteries containing mercury from being used there. If another EC country produced batteries with mercury, they would not be permitted to he sold in Germany, creating trade barriers. It will be interesting to see how the European Committee resolves these environmental issues in light of economic concerns.

3.3. Industry's efforts in improving environmental relations

Sparked by the public's increasing concern over the environment and by new state regulations regarding batteries, battery companies are developing more environmentally friendly batteries. For a start, they are producing batteries with no added mercury. As **of** 1992, six states had already passed laws stating that by 1996, all batteries sold there **must** be mercury free (Liesse, 1992). At that time, **twenty** other states were considering **similar legislation.** The National Electrical **Manufacturers has also ruled that by 1996, no mercury** may be added to its batteries (Soviero, 1992). **Batteries can never be completely "mercury free"** because mercury traces can be found **in other material components of batteries, such** as zinc (Soviero, 1992).

As each major battery company **attempts to market their "environmentally correct" battery,** it hopes that the potential **decrease in power as compared to typical alkaline batteries** will not discourage customers. **Eveready Battery Company is already test-**marketing its alkaline Green Power battery that **has** "no mercury added" with the **slogan that** Green Power "may not save the world, but it's a step in the right direction." (Liesse, 1992). However, it tears that since this battery has only 90-92% of the average lifetime that its Energizer battery has. consumers will be weary of buying the Green Power battery. Eveready Vice President of Marketing Sue Foley says that "For consumers, the name of **the** game in batteries has been long life...We want to see not only what a pure environmental claim will do but also what consumers' level of concern and interest is when it comes **to** batteries and environmental issues." (Liesse, 1992).

Other battery companies have followed suit in introducing these "green" batteries, with Matsushita Battery Industrial Company leading the development of this technology. Matsushita has developed the batteries to be marketed under Panasonic's name and the technology which Rayovac is licensing (Liesse, 1992). Likewise, Eastern Kodak Company sells batteries manufactured in a mutual ireement with Matsushita (Liesse, 1992). Kodak claims that us batteries are "99.999% mercury free" (Anonymous, 1992).

Matsushita will also work with China's Shanghai Battery Factory to sell no-mercury-added batteries in China starting in 1995 (Anonymous, 1993). Duracell Inc. also planned to begin marketing of its mercury-free battery in 1992, at the same prices that it sells its other alkaline batteries (Anonymous, 1992).

Companies give varied claims on their green batteries potential battery life, since losses in power come with the decrease of mercury in the batteries is that mercury prevents the gassing that causes leaks (Soviero, 1992). As mentioned before, Eveready's **Green** Power battery has only about 90% of the lifetime of the Energizer battery, but **both** Panasonic and Kodak maintain that their batteries can perform as well as their **other** household batteries. European-produced batteries with low amounts of mercury perform about 85% as well as batteries with normal mercury levels (Soviero, 1992).

Companies are not only changing their products to please consumers, but are also changing their manufacturing practices for the good of the environment. The Duracell USA plant in Lancaster, South Carolina has installed a filter press to treat their waste water so that it is no longer considered a hazardous waste (Anonymous, 1993). Duracell estimates that this use of technology keeps 650,000 lbs of waste from entering landfills. This improvement, along with their Mercury Elimination Project which has made all Duracell products produced in the Lancaster plant mercury-free, has caused Duracell to be named the 1993 winner of the South Carolina Governor's Pollution Prevention Award (Anonymous, 1993).

Influenced by environmental concerns, some companies whose products use batteries offer consumers the option of returning their used batteries so that they may be recycled instead *ot* thrown away. One company that offers this option is Compaq Computer Corporation, as reported in the February 17, 1992, issue of Computerworld (Fitzgerald, 1992). To participate in the "Backpack" program, users call an 800 number and are then sent a postage-paid package addressed to an EPA approved dump, namely the Inmetco recycling facility in Ellwood City, PA. Inmetco is the only plant in North America which recycles nickel-containing batteries. After the facility receives the batteries, it then sells the reusable metals from the batteries to other companies for use in the production of new products. Both nickel cadmium and nickel metal-hydride batteries are recycled through this program. The consumer may also exchange these spent batteries for new ones at an authorized Compaq reseller and then Compaq will send the batteries to a recycling facility. This program is of no cost to consumers. Other companies also sponsor similar programs. Sanyo rechargeable batteries come in a tube which can be mailed back to Sanyo for recycling (Cornell, 1991). Black & Decker also has a program to recycle nickel cadmium and lead-acid batteries (Jones, 1992). Batteries can be left at any authorized service center and Black & Decker will recycle them. Linda Biagioni, Director of Environmental Affairs for Black & Decker, says "Nicad batteries are an excellent source of portable power and can be recharged over and over again. Also, used Nicad batteries can be recycled; thus the nickel and cadmium need not enter the waste stream." SAFT America also has a recycling program for its rechargeable batteries (Soviero, 1992). Their nickel cadmium "Again & Again" batteries can be mailed back to the company's recycling center in Greensville. NC. Then, the cadmium in them is used to produce new batteries and consumers will receive a new battery at no cost (Soviero, 1992). Hopefully, more manufacturers of electronic goods and batteries will encourage their consumers to recycle by sponsoring programs such as these.

4. Recommendations

It is difficult io assess the exact amount of ecological damage that the metals in batteries cause to the ecosystem. From the multitude of tests conducted on the people and animals who have been contaminated by these metals, it is known that each of the six metals detailed in this report (mercury, cadmium, lead, nickel, zinc, and lithium) has potentially hazardous effects to each member of the ecosystem. It also known that batteries manufactured with these metals are dumped in landfills and that they can leach into the environment, thus affecting not only the soil and ground water, but also the animals and people who rely on these environmental components as a source of food and a place to live. Although the risk assessment of lithium showed that lithium is not an imminent danger to humanity, with increased usage of these batteries and disposal in landfills, it could become a health hazard in the future. People could easily contract illnesses from this sort of contamination and be unaware of it because of the nature of these sicknesses. Battery recycling is essential for complete environmental protection, to ensure the safety and preservation of the entire ecosystem. With the legislative push to ban batteries with added mercury, it is apparent that the American people are aware of the dangers that may come with the dumping of toxic chemicals. It is also apparent that dumping of batteries is a problem, as seen from the aforementioned fact that nickel cadmium batteries make up 0.1% of the waste stream, yet contribute 54% of the amount of cadmium dumped in the environment. Recycling must become more of a priority if this number is to decrease and environmental purity is to be maintained. This type of pollution tends to be permanent and thus once the environment is contaminated, it is very difficult to restore it to its prior condition.

Recycling is one way that the battery industry can improve its environmental standing. Another is to further develop new rechargeable battery technologies such as the lithium-based and nickel metal-hydride batteries that seem to be more environmentally friendly than the commonly used nickel cadmium and lead-acid batteries. Additional testing on the effects that batteries dumped in landfills have on the environment need to be completed so that these effects may be further understood and safety to the ecosystem may be ensured.

For these types of additional tests and reforms to occur, the government needs to become more involved and set regulations on mandatory battery recycling. Current policies encourage industry growth, yet seem to put environmental issues in the background, concentrating on the economic issues involved. While these economic issues are important, environmental contamination has permanent effects and attempts to clean up sites that are polluted are quite expensive. Much money has been spent through the Superfund program to rectify these sites contaminated by industry, and yet it seems mat these problems seem to exist *on* the same scale as they did prior to this legislation. Hopefully, the Clinton administration will not continue to bow to industry's requests and will enforce these policies, forcing industry to pay for their mistakes and giving them incentives to keep their sites clean. On their part, industry should continue their efforts in developing and marketing "green" batteries with no additional mercury. They should also sponsor battery recycling programs at no cost to the customer to encourage consumer participation. These types of programs pertain not only to battery manufacturers, but also includes industries such as those that produce portable computers, that use toxic batteries such as nickel cadmium and lead-acid. These companies should inform their buyers of **the** recycling options available, and include information on battery type and toxicity so **that** consumers are fully aware of the battery toxicity.

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