NOTRE DAME UNIVERSITY-LOUAIZE

ENVIRONMENTAL AND ECONOMIC BENEFITS OF RECYCLING DEAD LEAD-ACID BATTERIES

BY

AZADOUHI TASHJIAN

A Project
Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Business Administration
to the Faculty of Business Administration and Economics

Beirut, Lebanon
February 1998

NOTRE DAME UNIVERSITY-
LOUAIZE

ENVIRONMENTAL AND ECONOMIC BENEFITS OF RECYCLING DEAD LEAD - ACID BATTERIES

by

Azadouhi Tashjian

Approved:

Dr. H. Hadjetian
First Reader

Dr. A.El-Tannir
Second Reader

Dr. Ph. Zgheib
Chairman of the Committee

Dr. H. Hadjetian
Dean,Faculty of Business Administration & Economics

ACKNOWLEDGEMENT

This project was undertaken at Notre Dame University - Louaize' under the supervision of Dr. Hratch Hadjetian. I am indebted to Dr. Hadjetian for his keen interest and invaluable guidance, without which this study would not have been taken its present shape.

I am also thankful to Dr. Akram El-Tannir, second reader of my project, and Dr. Philippe Zgheib, the chairman of the research project committee, for their useful comments and suggestions.

Finally, I thank to Mr. Manuelian, my brother-in-law, for his support and help throughout my research.

Azadouhi Tashjian

TABLE OF CONTENTS

List of Tables

List of Figures

Abstract

ENVIRONMENTAL AND ECONOMIC BENEFITS OF RECYCLING DEAD LEAD-ACID BATTERIES

By:

Azadouhi Tashjian, Master of Business Administration
Notre Dame University, 1998.

Major Professor: Hratch Hadjetian, Ph.D.
Faculty: Business Administration and Economics.

This project presents the study of environmental and economic benefits of recycling dead lead-acid batteries. Its first objective is to examine the impacts of recycling on resource recovery, physical environment and health. The second objective is to examine the impacts of recycling on employment, foreign exchange earnings or savings, price of lead, and profit.

(94 pages)

CHAPTER ONE

INTRODUCTION

Recycling is as old as life itself, for in nature there is no such thing as unusable waste. Living organisms use materials from their environment and return those materials, in a different form, to the environment. Thus, materials continually cycle through the ecosystem.

The decomposition of organic materials into their constituent compounds, which makes them available for reuse by other organisms, is one of the most fundamental biological processes. Natural systems are cyclic: decomposers breakdown organic materials (both wastes, and dead plants and animals) into their constituent compounds. These compounds are then used by other organisms, which give off wastes and eventually die. The wastes and dead matter are again recycled by decomposers. In contrast, human systems tend to be linear: manufacturers produce objects from raw materials, consumers use these objects, and then they dispose them. But according to the law of conservation, materials can neither be created nor destroyed. Therefore, when we "dispose" of our wastes, we do not get rid of them; we simply move them from one place to another.

Were it not for the law of conservation of matter, there would be no solid waste crisis. If we could destroy matter (and create more when we needed it), landfills would never become full, toxic and hazardous wastes would pose no problem, and the environmental and economic costs of waste disposal would be minimal. But since materials cannot be destroyed, society faces problems associated with solid wastes. The most promising solution to these problems is to imitate natural systems by reusing and recycling materials as much as possible (Franz and Kaufman,1993,p.425).

Recycling and waste minimization, both in industry and at home, can limit the use of materials which will only be thrown away. Reducing the production of wastes conserves resources and reduces the need for disposal. Recycling can also help to conserve natural resources and reduce the harmful effects on our environment. Accordingly, recycling should be the first option of any waste management system (Franz and Kaufman, 1993, p.438).

Waste management is a major problem in Lebanon. Tons of wastes are produced daily in Lebanon in the form of glass, tin bottles, paper, cartoon, household garbage, dead batteries, old refrigerators, washing machines, cars, and so on. These garbages are thrown in the landfields, rivers or left in the open air. These wastes constitute hazards to our health, make our environment dirty and ugly, while they can be easily transformed into wealth. Today, we have the technology to recycle efficiently a large part of these wastes, and it is an imperative to manage our waste efficiently for the sake of present and future generations.

The purpose of this research project is to study the environmental and economic benefits of recycling dead lead-acid batteries in Lebanon, though they constitute a small percentage of waste in Lebanon. There are several reasons for choosing this topic:

(1) Lead, though a toxic metal, is widely used. It is a well established fact that the use of high doses of lead is harmful to human beings. Frequent and even close exposure to lead constitutes a hazard to health. Batteries left in the plain air constitute a health hazard.

(2) Lead is one of those very rare matters that is 100 percent recyclable.

(3) Lebanese environment is getting deteriorated at a frigthening rate and recycling will reduce that rate.

(4) Recycling would benefit the economy by generating jobs, and reducing outflow of foreign exchange as lead used in Lebanon is all imported.

Concerning about sources of data, most of the secondary data required for our study were collected from books, periodicals, documents and previous research related to our topic. As for the primary data, they were collected through interviews with experts and the owner of International Metal Company, the major lead recycling firm in Lebanon.

However, due to scarcity of data about lead recycling industry in Lebanon, we have relied heavily on the data provided by International Metal Company. It is clearly understood that the results of our analysis should not be hastily generalized. Further research would be necessary to confirm or modify them.

In the present chapter we have expressed the background of the problem, the purpose of the study, sources of data and the limitations of the study.

In Chapter Two we have presented an overview of lead, batteries and recycling industries. Part I describes the origin of lead; part II describes the origin and background of batteries; and part III describes the lead recycling processes in a Lebanese firm.

Chapter Three presents the objectives and methodology of this research.

In Chapter Four we have shown the environmental and economic benefits of recycling dead batteries.

Chapter Five presesnts our conclusion of the research project.

CHAPTER TWO

Overview of Lead, Battery, and Lead Recycling

I. Origin and Background of Lead

A. Origin of Lead

Lead is an ancient metal. It was probably first used by Egyptians as early as 5000 B.C. along with copper, gold and silver. There is evidence that the Phoenicians have developed the lead deposits at Rio Tinto, in Spain, in 2300 B.C., and the use of lead water pipes by Romans is well known. These water pipes were made by hammering lead into sheet before forming it into tubes and welding the joints with molten lead. The Rammelsberg mine of Preussag AG at Goslar, in the Unterharz of Germany, has been in operation for over 1000 years.

The extraction of lead from oxide and sulphide ores is very simple. This simple extraction process, along with the many outcrops of lead sulphide and lead oxide ores, account for the fact that lead was one of the first metals used by man.

The main deposits of lead were formed volcanogenically. However, lead does occur in zinc deposits that were formed by marine sediments. The earth's crust contains a relatively small quantity of lead, though a large amount is concentrated into fairly rich deposits. It has been claimed that deposits with 2% lead can be economically recovered but this is unlikely today without considerable credit from other minerals such as zinc, silver and gold. Today, there are a number of virgin lead mines. The most famous ones are: the mines at Broken Hill in Australia, the Missouri lead belt in the USA, and the new Aggeneys mine in South Africa. Other lead concentrates productions are by-products of zinc, copper, silver and fluorspar mining. As a result, it is very difficult to assess world reserves (Patten,1973, p.93).

B. Mining of Lead

Mining of lead ore is made of small firms. Although there are a few outcrops and deposits close to the surface that have been worked in the past, the current lead mines are underground operations. The ore is broken with explosives, crushed in jaw crushers and further reduced in cone crushers underground. This crushed ore is used as feed to a concentrator at the mine site which differentially floats the lead mineral and seperates it from the zinc, copper and iron sulphide minerals found in the ore. The zinc and copper concentrates have a commercial value but, in general, the iron does not. The lead mineral mined is called galena. This is a crystal of almost pure lead sulphide contaminated with silver, zinc, antimony and tin. The impurities have to be removed during refining of lead but form useful by-products for the mine.

The lead concentrate that is recovered at zinc, copper and silver mines is also the mineral galena. These concentrates contain more impurities than the concentrates from lead mines and their removal requires more elaborate refinery treatment than the purer lead concentrates. Lead scrap arises from most lead uses, and as it represents about 60% of world consumption, it is, and will remain, a major factor in world supply (Patten,1973, p.94).

C. Production of Lead

As indicated above, lead production is a simple operation. The recovery of the mineral galena (lead sulphide) means that the sulpher has to be removed so that oxide can be obtained and treated with carbon in a blast furnace to produce lead bullion. The release of sulphur in the form of sulphur dioxide into the atmosphere is now very carefully controlled because of its detrimental effect upon the environment. The high cost of collecting this waste product has been the cause of closing down of many small lead smelters and the growth of modern large plants. These large plants can control the emission of SO2 according to the limits set by legislation. Most of the world's lead smelters are integrated with zinc smelters and their sulphur goes into the company's fertilizer outlets. The lead bullion produced by the blast furnace contains impurities such as gold, silver and copper, while the slag from the furnace can contain recoverable quantities of zinc, antimony, arsenic, etc.

The refining of bullion is a specialised activity as it contains different types of impurities. There are two types of refining. The first technique is pyrometallurgical and relies on the reaction of the impurities with oxygen, chlorine, sodium, zinc, and other elements. The second technique, called the Betts process, is electrolytic and was first developed in North America in about 1920. The latter process produces very pure lead having low bismuth and tin concentrations which are difficult to obtain by pyrometallurgical means alone. Scrap lead from the demolition of buildings and from sulphuric acid plants is easily remelted in reverberatory or rotary furnaces. The smelted lead is generally quite impure and a refining stage is necessary since the tin content, mainly derived from solders in the scrap, can be quite high in the remelted lead. It is often not removed but used to produce new tin containing alloys. For the same reasons, antimony is another impurity that is often not completely removed in the refining stage.

The sharp fall in antimony content of battery alloys in recent years, especially in the USA, has greatly taxed the ingenuity of recyclers as it is difficult to extract and recover economically. Lead drosses, arising from the remelting of lead, consist of pure lead trapped in the complex and mixed oxides of lead. These are normally treated in a blast furnace to reduce oxides back to lead. Battery scrap, which consists of lead alloy grids coated with lead oxide and lead sulphates are recovered. In the past, these grids and their paste had to be seperated from the battery case by hand sorting. Today, however, shredding techniques linked with differential flotation equipment (the seperation of particals of a mass of ore according to their relative capacity for floating on a given liquid) are available to do this automatically. Another approach, the Bergsoe Process, is to charge the whole battery into the furnace, using the case as fuel (Patten, 1973, p.95).

D. Properties and Uses of Lead

Lead is a dark, grey, soft, heavy metal with a melting point of 327.3 degrees centigrade, a boiling point of 1740 degrees centigrade, and a specific gravity of 11.34 . It has a body centered cubic lattice that can be strengthened by both interstitial and precipitation hardening.

The use of organo-lead compounds to improve the octane rating of petrol has been an important factor in the increase in the demand for lead. This is diminishing in importance, however, due to legislation to control lead emissions.

The protection of underground electric power and telephone cables from damage by moisture was at one time exclusively done by shielding the cable in lead. This task has now been almost completely taken over by aluminium and synthetic materials.

The use of lead as a bearing material when alloyed with tin and antimony has been long established. However, improved bearings have been developed and this use remains relatively small.

The lead-tin alloys have had a traditional use as solder. Although the tin content and use of many solders have been reduced, an important market still exists.

Lead is an alloying addition to free machining steel and brass, and a constituent of Britannia metal and many other alloys. The tonnage involved is modest but steady. It has in the past been added to pewter; however in recent years it has been only present as an impurity (Patten, 1973, p.96).

E. Trade of Lead

Canada, Australia and South Africa are the major lead concentrate producers and exporters, while Europe, Japan and the USA are the main users.

There is a considerable trade in lead concentrates because large quantities are produced by mining companies who do not have lead smelting facilities. Ore and concentrate metal merchants, centered in New York, are very active in purchasing lead concentrates in small and large quantities. The big mining companies of the world do their own concentrate marketing. Long-term contracts with lead smelters are often important in the initial financing of lead and zinc mines.

Europe is self - sufficient in lead metal because it has modernised its smelters. It has large quantities of scrap and lead producing countries have been prepared to let the smelting of what is normally a by-product concentrate go abroad. As a result of this, the principal ocean movements for lead metal are in 99.99% grade material, so as to be sold in the London Metal Exchange warehouse.

The London Metal Exchange (LME) has been an outlet for the USA for both primary and secondary lead at times of recession and price controls. It has also been the only source of metal at times of shortage. As a result, considerable quantities of lead have from time to time moved between Europe and America, mainly in order to arbitrage availability and demand.

All lead smelters have sales departments who market their product on a long term basis. They occasionally sell their production to merchants, particularly when they are let down by their traditional customers. The merchants that trade in lead metal generally obtain their supplies on this opportunistic basis or enter into tolling contracts with the smelters for the refining of bullion or the smelting of concentrates.

The use of LME by the merchants for hedging their purchases and sales is universal. The essence of the traders' businesses is to have regular contracts for purchase and sale, thus enabling a flexible trading position to be established.

Speculators, both trade and non-trade, use the LME for establishing long and short positions and for trading with options on an LME basis. The lack of a hedging and option market with quotations in US cents per 1b, means that traders dealing on the basis of the US producer quotation need to obtain foreign exchange cover for their hedges and options placed on the LME (Patten,1973,p.98).

F. Price Quotation of Lead

There are two main prices for lead. In North America, it is the producers' quotation in U.S. cents per 1b. Although the pricing point can change, i.e. stock exchange, it usually relates to a delivered plant basis as distinct from ex-works price. For the rest of the world, it is the LME quotation. Concentrate contracts, although based upon a LME sterling price, rarely have their treatment charges quoted in sterling; although a US dollar basis is common, it is sometimes negotiated in buyer's local currency.

Outside the American continent and self sufficient areas, the price, although based on the LME sterling quotation, is invariably converted to local currency.

When producers of 99.99% lead export to countries where there is import duty, they call upon the buyer to purchase on a cif basis, the duty to be paid by the buyer. Local producers of 99.97% lead sell on an ex-works basis linked to the cost of delivery to the nearest LME warehouse, or on a delivered basis linked to the cost of the delivery from a LME warehouse. Metal Bulletin quotes the LME and the US producer prices of lead. It also quotes in the currencies of the following countries: Australia, Canada, France, West Germany, Italy, and Japan (Patten, 1973, p. 100).

G. London Metal Exchange Warehouse (LME)

Almost all European and Middle Eastern countries that deal with lead ingots use the prices recieved daily by LME.
LME has thirteen warehouses in Europe: England , Italy , France , Spain , Germany, Sweden , Holland , Belgium , and others .
The commercial grade of lead should be minimum of 99.97 % purity and above . If the purity of lead ingot is below 99.97 %, then the

firm can not sell its product to the LME warehouse except after refining it (Worell,1982, p.129).

The stock of lead ingot in the LME warehouses is around 200,000 tons. When the amount of lead ingot in the LME stock warehouses falls below 200,000 levels, then the price of lead ingots increases and vice versa. Therefore, 200,000 tons of lead ingots in the LME stock warehouses is the balance of the lead market. On an average, the daily turnover of lead ingots in the LME stock market is between 6,000 to 7,000 tons (Financial Time,1995,p.4).

II. Origin and Background of Battery

A. History of Battery

In 1791 Luigi Galvani, an Italian professor of anatomy at the University of Bologna, accidentally discovered that it was possible to cause a direct or continuous flow of current along an electrical conductor by bringing two dissimilar metals into contact with a moist substance. About 1800, acting upon Galvani's discovery, Alessandro Volta, professor of natural philosophy at the neihgbouring University of Pavia, created the first battery, the epoch-making "voltaic pile". Volta assembled a series of silver and zinc disks in pairs, seperating each pair with a sheet of pasteboard soaked in a conducting liquid (salt water). When the top disk of silver was connected by an external wire to the bottom disk of zinc, a current was produced. Volta believed that the current was generated by the contact of silver with zinc, whereas it was actually developed across the salt-soaked pasteboard, which was an electrolyte. Volta constructed piles with as many as 60 pairs of disks, but in use the pile dried out and ceased to operate, forcing him finally to make a modification that he called a "crown of cups". This device consisted of a series of cups filled with a salt solution, each cup containing a piece of zinc and silver. The zinc in each cup was connected electrically to the silver of an adjacent cup or cell and the cups were arranged in the form of a circle. He measured the strength of his battery simply by placing his fingers across the end terminals.

In 1836, a professor of chemistry in London developed the classic form of primary cell: a battery that is nonchargeable, and once used up could not be used again. In this cell, known as the Daniell cell, the positive electrode, or anode, was a rod of pure zinc, immersed in sulfuric acid (the electrolyte). A coating of mercury protected the zinc from attack by the acid. The negative electrode, or cathode, consisted of a copper canister, containing sulfuric acid saturated with copper sulfate (The New Encyclopedia Britanica, 1974, p. 764).

B. Definition of Battery

Battery is a device that produces electricity by means of chemical reaction. A battery consists of one or more units called electric cells. Each cell has all the chemicals and parts needed to produce an electric current. The word "battery" actually means a group of connected cells. However, the term is generally used to refer to single cells, such as those that serve to operate flashlights and toys.

Batteries serve as a convenient source of electricity. They power such portable equipments as radios, tape recorders, and television sets. In automobiles, batteries provide power to start the engine. Batteries also supply electricity in spacecrafts and submarines. During power failures, batteries provide an emergency supply of electricity for telephones, fire alarms, hospitals and other essential buildings (Collier's Encyclopedia,1994,p.168).

C. Kinds of Batteries

Manufacturers produce a wide variety of batteries, which may be classified according to their basic design. The design of a battery determines the amount of electricity provided. Some batteries, called primary batteries, stop working when one of their chemicals has been used up and must be discharged. Other batteries can be recharged and used again after they have discharged their electric energy. They are called secondary or storage batteries. Batteries can also be classified according to the general makeup of their electrolyte, the chemical substance that conducts electric current inside a cell.

Many primary batteries have a jellylike or pastelike electrolyte. Batteries that contain such nonspillable material are known as dry cells. A few types of primary batteries, called wet cells, contain liquid chemicals. Most secondary batteries have a liquid electrolyte.

Battaries are manufactured in a wide range of sizes. For example, the tiny batteries used in electronic or battery- operated watches weigh only about 1/20 of an ounce (1.4 grams). The huge batteries that power submarines weigh up to 1 short ton (0.91 metric ton). However, manufacturers produce most batteries in certain standard sizes. Therefore, batteries made by different manufacturers can be used in the same clock, radio, or other devices.

Batteries also differ in voltage. A primary cell of the type used in a flashlight has 1 1/2 volts. Most secondary batteries for automobiles are 12-volt battteries consisting of six 2-volt cells connected in a series (Collier's Encyclopedia, 1994, p. 168).

Since the concern of this research project is about secondary batteries, we will elaborate more about secondary batteries.

Secondary batteries are so made that their chemical reactions can be reversed. This feature enables them to be recharged efficiently after they have delivered their electric energy. The most common types of secondary batteries are (1) lead-acid storage batteries and (2) nickel-cadium storage batteries (Collier's Encyclopedia,1994,p.170).

Nickel-cadium storage batteries are beyond the scope of this research, since there are no nickel-cadium recycling plants in Lebanon. Nickel-cadium batteries are used in drills, garden tools, and other portable equipments. Most space sattelites use these sorts of batteries.

Lead-acid storage batteries consist of a plastic or hard-rubber container that holds three or six cells. Each cell has two sets of latticelike electrodes or plates. The frames of these structures, called grids, are made of a lead-antimony alloy. The meshes (open spaces) of the negative electrode are filled with a mass of pure lead in spongy form. The meshes of the positive electrode contain lead dioxide, a compound of lead and oxygen. An electrolyte of sulfuric acid and water surrounds the electrodes.

During the discharge process, chemical reactions take place between the electrode materials and the electrolyte. At the negative electrode, atoms of pure lead (Pb) react with negative sulfate ions (SO4 --) of the electolyte. The negative sulfate ions, along with positive hydrogen ions (H+), form sulfuric acid (H2SO4) when they dissolve in water. As the lead atom looses two electrons, it becomes a molecule of lead sulfate (PbSO4). This chemical reaction at the negative electrode can be written as:

$$Pb + SO4^{--} \Longrightarrow PbSO4 + 2e^{-}$$

The electrons lost by the lead atoms flow from the negative electrode to the positive electrode through a device using the electric current. At the positive electrode, they are captured by molecules of lead dioxide (PbO2), which in turn combine with the hydrogen and sulfate ions of the electrolyte. This reaction produces lead sulfate and water:

$$PbO_2 + 4H^+ + SO_4^{--} + 2e^- \Longrightarrow PbSO_4 + 2H_2O$$

Adding together the positive and negative electrode reactions yields a combined discharge reaction:

$$Pb + PbO_2 + 2H_2SO_4 \Longrightarrow 2PbSO_4 + 2H_2O$$

Thus, sulfuric acid is consumed and water is produced during battery use. Eventually the sulfuric acid becomes so diluted that the necessary chemical reactions can no longer occur.

After a lead-acid battery looses its ability to supply electricity, it can be recharged by means of a battery charger. The battery charger forces electrons through the battery in a direction opposite to that of the discharge process. This action reverses the chemical reactions that occur when a battery discharges. The reversed reactions of the charging process restore the electrode materials to their original form. They also increase the amount of sulfuric acid in the electrolyte to a satisfactory level (Collier's Encyclopedia, 1994, p.171).

D. Composition of Lead - Acid Battery

Lead - acid battery consists of lead plates in the form of grid filled , when charged , with lead peroxide at the positive plate and sponge lead at the negative plate . The plates are insulated from each other by means of seperators made of microporous materials : ployvinyl chloride , polyester , polypropylene , rubber , or glass . The battery is filled with diluted sulfuric acid (Duecker,1971,p.320).

It is very difficult to believe that a very active chemical such as sulfuric acid is at the same time one of the most widely used and most important technical product . It is the agent for sulfate formation and for sulfonation. It is frequently used because it is a rather strong and cheaply priced inorganic acid (Austin,1984,p.325).

The origin of the first sulfuric acid is unknown , but it was mentioned as far back as the tenth century . Its preparation by burning sulfur with saltpeter was first described by Valentinus in the fifteenth century . In 1946 , Roebuck of Birmingham , England , introduced the lead chamber process . The molecular form of sulfuric acid is H2SO4 . Sulfuric acid is prepared by sulfur (Duecker,1971,p.327).

An ordinary battery consists of 13 to 15 plates per cell and has several cells in series. It delivers 2V per cell (Duecker, 1971, p.336).

III. Lead Recycling Process

Lead recycling industry is relatively small. Even in a big country like the U.S., there are only twenty two smelters (Cheremisinoff and Cheremisinoff, 1993,p. 152).

Before we go into the actual process of recycling of lead, it should be mentioned that there are actually two substances that are recycled in the case of dead battery, namely lead and plastic.

Dead batteries are unloaded in a battery- crusher, which seperates them into three basic components: lead, plastic, and acid. The plastic is removed by a gravity seperator, where it is floated out as its density is less than that of the liquid it is in. The acid is drained off and sent through a treatment process, since it contains lead impurities. The lead plates are sent through a pyrometallurgical process. First, they go to a furnace, where they are melted down. The impurities in the lead are driven off by the heat of the furnace in the form of fumes and dust. These by-products are sent to a cooling chamber, then to a baghouse, and finally to a wet scrubber before the clean gas is released to the atmosphere via a stack. The molten lead is then passed into kettles, which hold the liquid material. Finally, the metal is cast into ingots, ready for resale. Approximately 90 percent of the refined lead is purchased back by battery manufacturies.

It is also important to talk briefly about scrap lead. It can exist in a variety of forms. Aside from batteries, metal sludges, soils, and paint debris, the major forms of scrap lead are: lead baghouse filtrate, cable sheathing, solder drosses, counterweights, scrap ballast, babbitt and type metals, lead pipe, fittings and coils, lead solder, lead crystal, wheel weights, printed circuit boards, lead sheeting and flashing, lead slag, radiation shielding materials, lead-bearing ceramic scrap, lead anodes , lead casting scrap , lead pigments , and used lead ammunition.

While scrap lead can find its way to landfills as a component in bulk wastes, recycled scrap lead is an important source of supply to smelters and refiners. Unlike the recycling of many other metals, refined lead produced in secondary recovery plants has metallurgical properties equivalent to those of the refined lead produced directly from ore in primary plants. Lead produced in primary and secondary plants compete in the same markets, and each is influenced by the amount of lead produced by the other.

The price paid by recyclers for scrap lead varies with geographical area, scrap type, and supply/demand conditions (Cheremisinoff and Cheremisinoff,1993,pp.152-153).

A. Lead - Recycling Process in Lebanon [1]

There are only four lead recycling firms operating in Lebanon. They are:

a. Aaraibi Company
b. International Metal Company (IMC)
c. Keshishian Company
d. Yasine Company

Aaraibi Company is located in the Bekaa region. Though it is the largest lead recycling plant in Lebanon in terms of production, all the processes are done manually.

International Metal Company is located in Beirut, Dora region, near the seashore. Though its production is smaller than that of Aaraibi Company, it has some advantages over the others: it has an Automatic Scrap Processing Machinery, and its Smelting is endowed with an air pollutant filteration.

---

(1) All information in this section are collected from Mr. Manuelian, the general manager of IMC.

It is worthy of mentioning that this filtration reduces the air pollutant resulting from the process of smelting the lead to 0.15 % , whereas the other factories do not have such filteration. The filtration machine was installed in 1994 and it has costed U.S. $ 300,000.

Keshishian Company is also located in Beirut , Dora region . This is a small factory , and all the operations are done manually .

Yasine Company is located in Tripoli. This factory is the smallest one , and again all the operations are done manually .

B. Lead Recycling at IMC (2)

Since IMC uses the most advanced processes in Lebanon, we will describe the lead recycling processes used there.

Scrap batteries are dead-batteries of cars, trucks, boats, etc, that cannot be used anymore. These are purchased by IMC from wholesalers and stocked in a large place in order to be broken down (see Fig. 2-1).

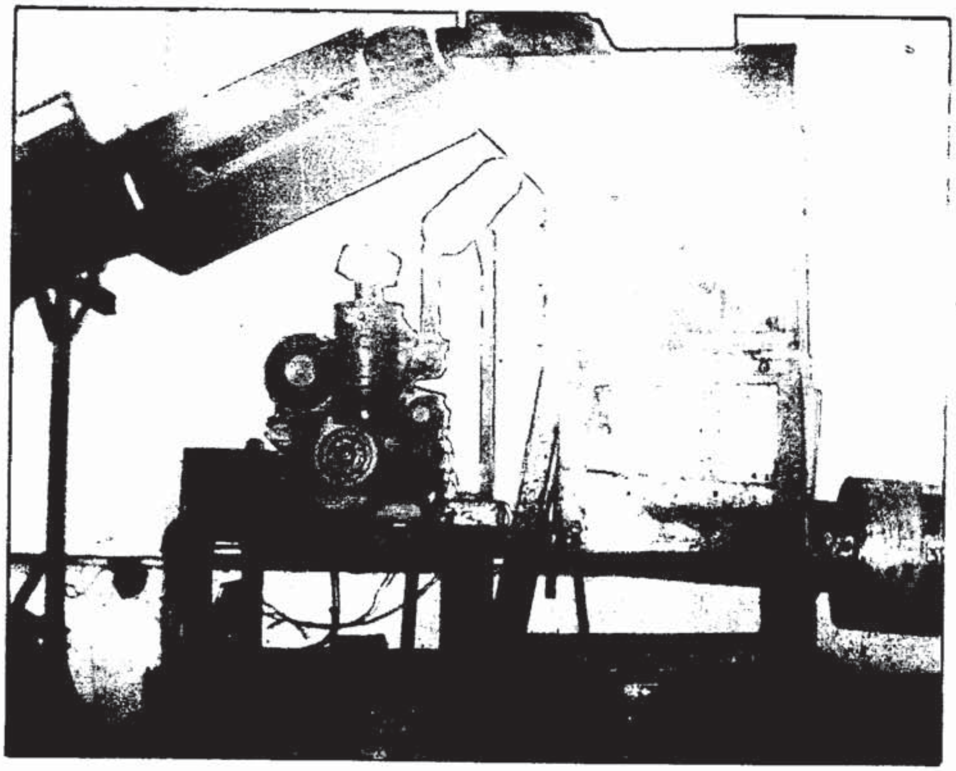
---

(2) All information and pictures in this section are provided by Mr Manuelian, general manager of IMC.

Figure 2-1 Stocks of Scrap Batteries

Workers put scrap batteries in the breaking machine (see Fig. 2-2).

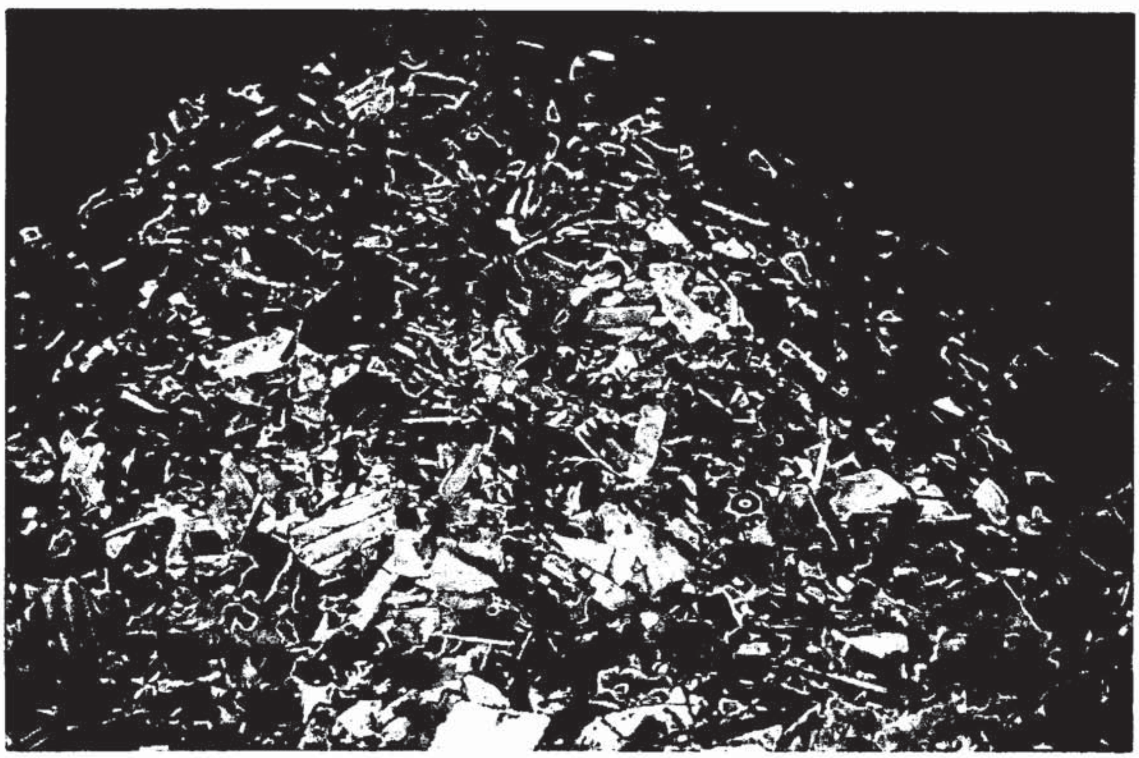
Figure 2-2 Battery Breaking Machine



The job of this highly automatic and efficient breaking machine is to wash down the dead-lead acid batteries and to separate the broken down plastic from the lead oxides. Moreover, it crushes complete, undrained lead acid storage batteries, and seperates all the components. Outflow streams are lead, lead oxide, plastic, and waste organic metals.

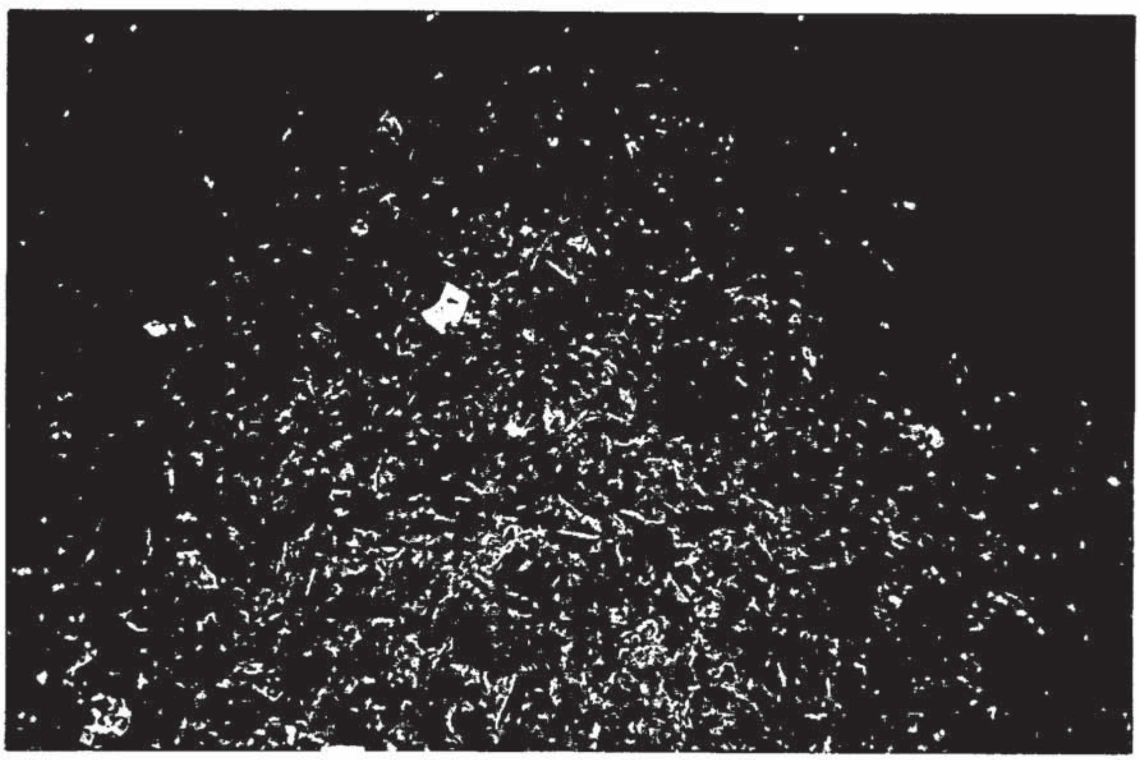
Figure 3 shows how the breaking machine seperates the plastic from the lead oxide. This plastic is sold at a price of U.S. $ 350 per ton to plastic plants where they are used to produce plastic vases for plants.

Figure 2-3 Seperaton of Plastic from Lead Oxide



After the whole, undrained batteries are crushed, a water stream washes most of the finely divided lead oxide from the lead metal organics. These oxides are washed through a screen conveyor into a wet removal classifier. Once settled, the oxides are removed by a flat wire drag conveyor to an oxide collecting auger for dewatering and densifying (see Fig. 2-4).

Figure 2-4 Seperation of Lead Oxides



After seperating the lead oxides from the plastic through the process of breaking machine, the lead oxides are loaded into the smelting furnace. The process of smelting needs 850 degrees centigrade to melt the metal (see Fig. 2-5a and 2-5b).

Figure 2-5a Smelting Furnace

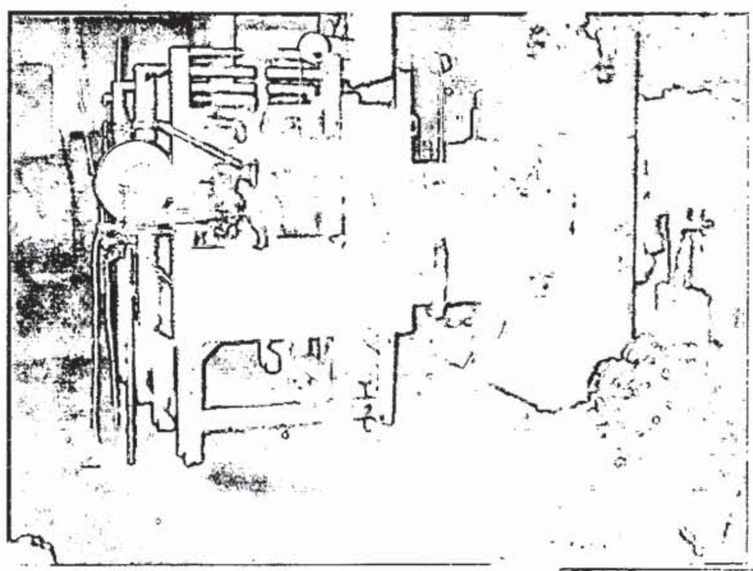


Figure 2-5b Smelting Furnace

Once the lead oxides are melted, they are poured into a mould (see Fig. 2-6), and are formed into lead ingots. This process is called "crude lead production." Crude lead has less than 99.97% purity. It still needs to be refined so as be able to be sold in the LME (London Metal Exchange) warehouses.

Figure 2-6 Mould to Form Lead Ingots

Then the crude lead is loaded into the refining furnace (see Fig. 2-7). The refining process is the process through which the crude lead is refined and transformed into 99.97% purity. After refining they are once again poured into the mould (see Fig. 2-6) to have refined lead ingots with a purity of 99.97 % or above (see Fig. 2-8 and 2-9).

Figure 2-7 Refining Process

This lead ingot having 99.97 % purity or above is called "virgin lead". (see Fig. 2-8 and 2-9). Now the virgin lead is ready and could be sold in the international market, such as the London Metal Exchange warehouse (LME).

Figure 2-8 Ingots

Figure 2-9 Refined Ingots of 99.97% Purity

CHAPTER THREE

Objectives and Research Methodology

This chapter describes the steps undertaken to conduct this research project and pinpoints its limitations.

The study has two objectives:

I. Examination of the environmental benefits of dead battery recycling.

This objective has three sub-objectives: examination of recycling on resource recovery, physical environment and health.

Due to the nature of their objective, all data collected for its examination were from secondary sources, such as books, journals, and encyclopedia.

II. Examination of the economic benefits of dead battery recycling.

This objective has two sub-objectives: macroeconomic and microeconomic benefits. Under macroeconomic benefits, we have studied the benefits of recycling on employment and foreign exchange earnings or savings.

Our original plan was to visit all the dead battery recycling firms and get actual employment figures. However, we were refused, in a polite way, to get employment figures. We couldn't get figures from government sources as they didn't have any. The only firm which was willing to give us information about employment was IMC.

Regarding data about foreign exchange savings, we couldn't get any official government statistics. Thus, it was planned to visit each firm and get their yearly production of lead. In this case, too, the only firm which was willing to provide us with data was IMC. We took the annual production of lead from 1985 - 1996, and by multiplying with the average price of lead, we got the annual savings of foreign exchange.

Under microeconomic benefits, we showed theoretically, with the help of demand and supply curves, the benefits of recycling on the price of lead. We first assumed that demand for lead was fixed and supply was decreasing. Then we took a more realistic case, where the supply was decreasing and the demand was increasing. Finally, we took the case where demand was increasing but because of recycling the decrease in supply was somewhat offset, and showed the effect on the price.

To examine wether or not recycling is profitable, the plan was to calculate the profit of lead recycling industry in Lebanon. Our first step was to gather information about each firm's revenue and cost. But all the interview attempts were failed. The only firm that cooperated with us was IMC. Thus, we were obliged to calculate the profit of lead recycling industry in Lebanon by choosing IMC as our sample. By simple total revenue and total cost method, we calculated the gross profit of the company, then its profit, after subtracting taxes.

Because of no official government statistics and limited data about lead recycling industry, we were obliged to rely on the sources provided by IMC only. Thus, the results of this research project should not be generalized. It is studied and concluded according to the given data. Of course, more informations could have lead to much more reliable results.

CHAPTER FOUR

Environmental and Economic Benefits of Recycling Dead Lead-Acid Battery

In Chapter Two we provided with a detailed description of the process of recycling dead lead-acid batteries in a leading firm in Lebanon. In this chapter we will examine the advantages of recycling dead batteries.

I. Environmental Benefits of Dead Battery Recycling

A. Resource Recovery

Although lead-acid batteries are widely used, most people might not be aware that they can also be a source of raw material, such as plastic and lead. Every year, millions of automobile batteries are replaced by new ones. In the United States alone, for example, more than 175 million batteries were used between 1980 and 1991 (Croom,1995,p.123). What would happen to the supply of lead if dead batteries were not recycled?

Before we proceed, it is important to define the term "resource".

A resource is anything that serves a need; it is useful and available at a particular cost. All organisms consume resources (another way of saying that all living things live at the expense of their environment). They produce wastes, which then become resources for other organisms. Some resources are renewable. They can be replaced by the environment, and as long as they are not used up faster than they can be restored, supplies are not depleted. In contrast, nonrenewable resources exist in finite supply or are replaced by the environment so slowly (in human terms) that, for all practical purposes, the supply might as well be finite.

All organisms exploit the environment to the best of their ability. Humans, however, are most successful of all species at doing so (Franz and Kaufman, 1993,p.15). The technologies we have developed, the fact that we tend to satisfy wants rather than needs, and our sheer number have resulted in an environmental impact much greater than that exerted by any other single species. Human demand for renewable resources appears to be growing faster than the biosphere can renew them. We are, so to speak, living on the capital of our environment rather than on its interest. The World Resources

Institute, in its 1990-1991 report on the global environment has already warned us : "The earth cannot produce its bounty if we continue to damage its productive capacity" (Franz and Kaufman, 1993, p.16).

A debate rages regarding the actual cause of resource abuse and depletion. Some people contend that growing population is consuming resources faster than the earth's living systems can replace them. Others argue that enough resources are available to support the world's population, if we could find the means to distribute the resources more evenly and to stop their wasteful use. They point out that 20 percent of the world's population living in developed countries (especially Western Europe, the United States, Canada, Australia, the former Soviet republics, and Japan) use nearly 80 percent of the resources consumed each year. The remaining 80 percent of the world's population - 4 billion human beings - consume just 20 percent of resources. The United States alone, with just 5 percent of the world's population, uses 35 percent of the world's raw materials and about 35 percent of the world's energy. Further, the United States wastes about 50 percent of the materials and energy it uses (Franz and Kaufman, 1993, p. 16).

Irrespective of the causes, the fact remains that resources are scarce, and they will be scarcer and scarcer. If we add to these the fact that resources will rise sharply in the next 20 to 30 years by both industrialized and developing countries, we get a better picture of the situation of resources (Franz and Kaufman, 1993, p. 16).

Resource recovery is an umbrella term that refers to the taking of useful materials or energy out of the waste stream at any stage before ultimate disposal. Recycling and composting remove useful materials from the waste stream in order to yield new products. Recycling is the collection, processing, and marketing of waste material for use in new products. Problems with the way we currently manage our wastes is that all materials are simply mixed together. Mixing wastes greatly reduces the value of recycable materials. Hence, efficient and effective collection and sorting are critical to a successful recycling effort (Franz and Kaufman, 1993, p.434).

The economic analysis of scarcity emphasises that increasing scarcity leads to increases in the rate of resource price appreciation, (such as lead price), which then induces greater substitution with other materials and increased waste recycling. "Materials-balance" and "production and consumption" are not precise terms and they should not be taken to imply that matter simply disappears through use. The term "waste" is also a misnomer since in nature nothing is wasted; everything is a part of a continuous cycle. More property, wastes should be re-termed as "residuals" and placed in an economic context. The term "resource recovery" has evolved into a general concept referring to any productive use of what would otherwise be a residual requiring disposal.

The outputs of the resource recovery are what can be labelled "secondary materials" in order to distinguish them from "primary (virgin) material" (the original natural resources) and from end- use products. Resources are inputs to the economic system. Adding resources will produce a linear system:

R -----> p -----> C

where R is the resource,
P is the production, and
C is the consumer good.

The system , however, captures the first function on natural environments, namely, the provision of resource inputs to the productive system.

Waste arises at each stage of the production process. The production of resources creates waste, like with overburden tips at coal mines; production of final goods creates waste in the form of industrial effluent, air pollutants and solid waste; final consumers also create waste by generating sewage, litter, and municipal refuse. So, we can take the linear system and expand it a bit further:

Table 4-1 Expansion of Linear System

```
R -----> P -----> C
:        :        :
:        :        :
V        V        V
Wr       Wp       Wc
```

It is important to explain that there is a difference between production waste (Wp) and consumer waste (Wc). For the consumers, wastes are the wastes of their consumption. On the other hand, producers use wastes as the resources of their production.

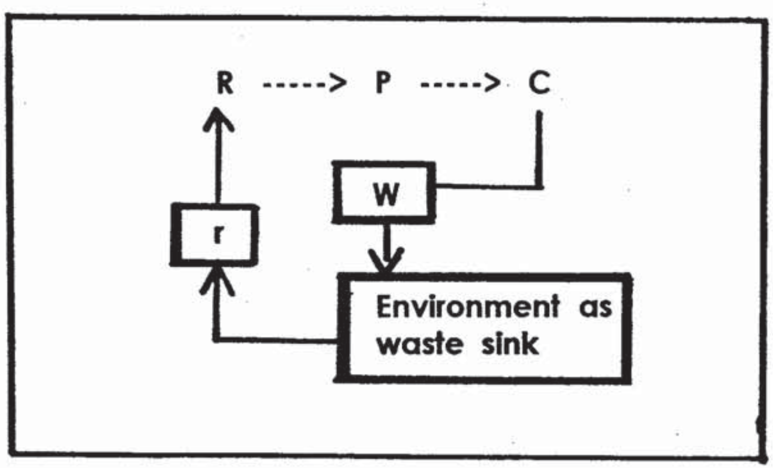
Now, there is an interesting relationship between R and the sum of the waste flows generated in any period of time. If we forget for a moment about production of capital stock, then the total mass of waste created, Wt, in any period is equal to the amount of natural resources used up. That is:

$$R = Wt = Wr + Wp + Wc$$

The reason for this equivalence is the First Law of Thermodynamics. This law essentially states that we cannot create or destroy mass. Whatever we use up by way of resources must end up somewhere in the environmental system. It cannot be destroyed or thrown away, yet it can be converted to something useful through recycling. For example, coal consumption in any year must be equal to the amount of waste gases and solids produced by coal consumption. Some of it will appear as slag, some as carbon dioxide and so on. Each of these "wastes" can be used as input for the production of something else after being recycled. This equivalence is not a hard and fast one if we consider capital goods where resource flows become 'embodied' in the capital equipment. But even in this case, capital equipments constructed in the past will be wearing out, so they will appear as waste flow.

The linear system can now be converted to a circular system. We now have:

Table 4-2 Circular System



The box r is recycling. We can take some of the waste and convert it back to resources. We are all familiar with bottle banks for recycling glass bottles. The lead in dead car batteries is generally recycled. Many other metals are recycled.
By looking at this circular flow, sometimes called "materials balance model", are able to identify clearly three economic functions of the environment : resource supplier, waste assimilator, and direct source of utility. They are economic functions because they all have a positive economic value, if we bought and sold these functions in the market - place. The dangers arise from the mistreatment of natural environments because we do not recognise the value of these economic functions. This is not the fault of economics or economists. Indeed, environmental economists have been at considerable pain to point out these economic functions and to demonstrate their positive price. Ignorance of economic functions lies elsewhere, namely, in the personal and social aims of individuals, groups, communities, pressure groups and politicians (Pearce and Turner,1994, pp.35-41).

B. Physical Environmental Benefits

The harmfull effects of toxic gases and dusts generated by mines on the surrounding animal and vegetable life, the aesthetic costs of strip mining, the acids leached into streams from mine operations, loss of nature's beauty, and water and air pollution, etc., are all examples of environmental and social costs. Unfortunately these costs are not internalized, and hence they do not affect the decision of the volume of extraction of resources and the consumption of goods using these resources. Substituting secondary resources for virgin resources can yield substantial environmental benefits.
These potential benefits, however, go largely unrealized, as long as the market price of raw materials does not also reflect the social costs of supplying them (Franz and Kaufman, 1993, p.436).

As minerals become increasingly scarce, and their demand increase, new resource exploration and mining activities will cause further (and sometimes irreversible) damages to the environment. Wild and semi-wild (national parks) areas are especially at risk from such activities. Because of the multifunctionality of such environmental assets, resource extraction can, for example, mean the direct loss of landscape quality and both direct and indirect ecological damage via pollution (Pearce and Turner,1994,p.302). For example, Russia has lead deposits in Angara that lie beneath the riverbed. However, to exploit these resources, a large dam is to be constructed to mine these deposits - a costly and ecologically risky undertaking. On the other hand, Russia has potentially rich seam of lead scrap from batteries but as yet there is little infrastructure in place to collect and process used batteries (Metal Bulletin,1993, "Base Metals", p.6).

One of the most pressing issues of the 1990s is what to do with the millions of tons of "stuff" we throw away each year. In rethinking the ways we manage our solid wastes, it is helpful to focus on measures that prevent resource overuse through conservation - reusing and recycling materials - to protect the environment and preserve living systems. Any form of waste disposal poses a potential harm to human health and/or the environment. The less waste produced and disposed of, the less is the damage on both the living systems and the environment. Thus, although society is increasingly turning to resource reduction and resource recovery as economic necessities, these activities can also help minimize environmental degradation and to cut costs associated with the mitigation of environmental damage. Wastes should be diverted to landfills or incinarators only if they cannot be recycled or composted.

How we manage solid wastes affects other resources - air, soil, wilderness, and biological diversity. Mimicking living systems through the recycling of wastes and the consequent conservation of materials and energy can help alleviate many environmental problems and help to preserve living systems. In a direct way, resource recovery affords us the opportunity to build a sustainable and sustaining society (Franz and Kaufman, 1993, p. 438).

In Lebanon, in the absence of dead- battery recycling, thousands of them would be thrown in the forests or open fields. These would make our beautiful environment look ugly and damage vegetable life. Thus recycling dead batteries reduces the degradation of our environment.

The presence of environmental costs are not only empirically important, they are also conceptually important, since they form one of the bridges between traditionally separate fields of environmental economics and natural resource economics.

Thus, an efficient economic system will orchestrate a balance between the consumption of depletable and recycled materials, between disposing of used products and recycling, and between imports and domestic production (Tietenberg,1992, p. 194).

Furthermore, we must consider the relationship between the marginal cost of disposing and the efficient level of recycling. Suppose, for example, it costs a community $20 per ton to recycle a particular waste product which could ultimately be sold to a local manufacturer for $10 per ton. Can we conclude that this is an inefficient recycling venture because it is losing money? No, we can't! In addition to earning the $10 per ton from selling the recycled product, the town is avoiding the cost of disposing of the waste. This avoided marginal cost is appropriately considered a marginal benefit from recycling. If the marginal avoided disposal cost were $20 per ton, the benefits to the town from recycling would be $30 per ton ($20 per ton avoided cost plus $10 per ton resale value) and the cost would be $20 per ton; this would be an efficient recycling venture. Both marginal disposal costs and the prices of recycled materials directly affect the efficient level of recycling (Tietenberg,1992, p.201).

C. Human Environmental Benefits (health)

Today, the major concern about the degradation of the environment is its impact on our health.

Extensive research has shown that lead causes several health problems. One of the biochemical aspects of lead is that large soft cations are prone to react with the sulfhydryl group in proteins, and inhibit the enzyme responsible for catalytic biosynthesis of heme. This causes impairment of hemoglobin, oxygen starvation and finally leads to anemia.

It has also been confirmed that the biochemical activity of lead is responsible for increased hyperactive and delinquent behavior among children, adults, and animals, since there is a direct relationship between the activities of blood and brain enzymes.

Human beings are exposed to lead from numerous sources, such as paints, pigments, automobile and industrial emissions, surface and groundwater, and some forms of solder. Fetuses, infants, and children under the age of seven, pregnant women and women of child-bearing age are also categorized as high-risk groups, since fetuses are at risk due to high level of lead in blood.

Many scientists believe that lead exhibits a "continuum of toxicity"- that is, the slightest exposure to lead has an adverse effect on some organs in the body.

Human health is effected by chronic toxicity. Everyone takes in lead from the environment, which accumulates slowly and unnoticeably. Chronic toxicity refers to health problems resulting from excessive accumulation of lead.

Children who absorb lead usually show no symptoms of lead poisoning, but over time they can develop the following problems:

* Subtle behavior changes
* Irritability
* Appetite suppression
* Weight loss
* Sleep disturbance
* Hyperactivity
* Shortened attention span and
* Hearing impairement

Children with even moderate exposures to lead are at greater risk of requiring special education, dropping out of school, and reading disabilities.

Lead poisoning in children also results in serious damage to the brain and central nervous system. Furthermore, it causes hearing disabilities, mental retardation, convulsion, coma, and death. Unfortunately, children may be poisoned by lead without having specific symptoms; thus the best way to detect lead poisoning is to have blood screening test.

Exposure to lead also effects the health of adults. Lead poisoning and high level of lead in the blood causes high blood pressure in adults. A large dose of lead over a short period of time results in acute toxicity. This may cause cancer after many years. The health consequences of excessive exposures to lead can be immediate and severe. High-level symptomatic lead poisoning from acute exposures is rare today, but they might occur.

Health effects due to exposure to lead include:

* Blidness
* Kidney damage or failure
* Seizures
* Coma
* Encephalopathy (degenerative disease of the brain)
* Death

Table 4-3 provides a summary of physiological and health effects associated with overexposure to lead.

Table 4-3 Summary of Health Problems Due to Lead

(a) Health Effects of Adult Lead Poisoning

Acute (Short-term)	Chronic (Long-term)
Tend to be non specific • **Irritability** • **Fatigue** • **Depression** • **Headaches** • **Loss of appetite** • **Hard to concentrate** • **Sleeping problems** • **Pains in muscles and joints** • **Stomach cramps (colic)** • **Reproductive problems**	**Some effects may be reversible such as high blood pressure, but it can cause permenant damage to:** * **Nerves of hands and feet** * **Brain** * **Kidneys** * **Reproductive System**

(b) Possible Reproductive Health Effects of Lead

Men	**Women**
• **Decreased sex drive** • **Problems having an erection** • **Decreased fertility** • **Birth defects and miscarriages in partners**	* **Decreased fertility** * **Miscarriages** * **Premature births** * **Stillbirths** * **Learning and behavioral problems in offspring**

Recycling lead will increase the supply of lead. However, it will not eliminate all the negative effects of exposure to lead, but it will definitely reduce them.

It is a fact that workers working in the lead mine are more exposed to lead than workers working in the lead recycling firms. Lead mining not only damages health, but also environment. On the other hand, workers working in recycling firms are less exposed to lead due to strict restrictions imposed by the Ministry of Environment and Ministry of Industry to protect the health of workers. All recycling firms are obliged to have a filteration machine which filters more than 90 % of the pollutants generated during recycling. In this way, workers protect themselves from the exposure of lead through the use of engineering controls and good work practices. Respirators are not relied upon as the sole method of protection. Engineering controls, where feasable, and good work practices are used to minimize employee exposure to lead. Engineering controls and good work practices help to protect the environment and occupants of adjacent units, and they make cleaning an easier task. Some examples of good engineering and work - practice controls are:

* Prohibiting unacceptable methods of abatement such as open burning and machine sanding without attached refined filteration.
* Providing on-site washing facilities and segregated areas free from active abatement of lead for changing clothes.
* Shutting down of forced-air systems and sealing of all intake and exhaust points in the work area and providing alternate sources of heat, if necessary.
* Daily clean up procedures
* Spray misting of dry debris before cleanup, and prohibition of dry sweeping.

Moreover, good industrial hygiene practice requires the employer to provide and assure that employees use protective clothing and equipment. Use of protective clothing and equipment helps to reduce employee exposure to lead dust and prevents the transfer of such dust from the abatement work area to other work areas or environments (for example, homes and vehicles).

Protective clothing and equipment are used whenever the potential for lead exposure is present. The following are protective work - clothing and equipments:

- Protective coveralls
- Disposable shoe covers
- Gloves
- Vented goggles and face shields
- Respirators and cartridges
- Hats or other hair protection

II. Economic Benefits of Battery Recycling

In addition to its beneficial effects on resource preservation, ecology and human health, recycling of batteries can have substantial economic benefits.

A. Macroeconomic Effects

1. Effect on employment

Generating employment is one of the macroeconomic targets of any economy. As employment increases, national production increases and the standard of living of the population goes up too. Employment also reduces social and health problems, like crime, theft, prostitution, alcoholism, etc.

In order to know how much employment the battery recycling industry generate in Lebanon, it is important to examine the different stages of recycling.

Collectors go around and collect dead bateries. These batteries are sold to recycling firms . Dead batteries are also sold to recycling firms by car battery sellers. These batteries go through several stages before they are transformed into lead. These stages were described in Chapter Two.

This lead is sold to different manufacturing industries: battery manufacturing, hunting products manufacturers, sea-weight products manufacturers, and others. The rest of the lead produced is sold to LME.

At each stage of dead battery recycling several jobs are created. It is also important to mention that because of recycling, many other jobs are created in an indirect way, like trucks transporting the lead to manufacturers.

We tried to get exact figures regarding the number of people who are involved in collecting dead batteries. Whenever we made our inquiry, we were told that " Hundreds of people were involved in collecting batteries".

Despite all our efforts to collect data on employment in the recycling industry in Lebanon, it was impossible. Firms were neither willing to reveal their number of employees nor allow us to visit their premises. The only firm which gave us information about the number of employees was IMC. There were 50 regular and part-time workers. According to the manager of IMC, the total number of employment in the industry should be around 300.

2. Effect on foreign exchange savings

In Lebanon there is no official statistics about production, export and import of Lead. That is why we had to visit the four factories to collect data on production. But as previously mentioned, only IMC was kind enough to give us information about lead production. Hence, we had the opportunity to collect the yearly production of lead only from IMC. We took the lead production of IMC from 1985 to 1996. By multiplying these figures by the average price of lead, we got the value of lead produced over these years (see Table 4-4). As all lead used in Lebanon is imported, the value of lead produced is equivalent to the value of foreign exchange saved.

Table 4-4

Foreign Exchange Saving due to Recycling

	(1)	(2)	(1)x(2)
Year	(a) Average Price ($/ton)	(b) Quantity Produced (ton/year)	Total Value of Lead Produced($/year)
1985	434.34	264.472	114,870.7684
1986	491.06	267.280	131,250.5168
1987	793.42	261.248	207,279.3881
1988	860.73	235.976	203,111.6224
1989	686.60	208.624	143,241.2384
1990	634.95	226.720	143,955.8640
1991	512.02	217.360	111,292.6672
1992	539.39	218.400	117,802.7760
1993	517.10	205.920	106,481.2320
1994	549.54	200.200	110,017.9080
1995	631.20	249.080	157,219.2960
1996	695.65	266.240	185,209.8560

(a) See appendix 2 for the transformation of lead price fluctuation from cents/pound to $/ton
(b) Source: IMC

According to the manager of IMC, Lebanon does not import lead. In fact, it even exports a small quantity.

B. Microeconomic Effects

1. Effect of Recycling on the price of lead

There is virtually universal agreement among analysts that the immediate prospects for lead prices are very bullish. Consumers are being warned that the lead market is heading for a period of supply tightness that might last untill 1998. Let us see the views of some experts. Mr. Jim Lennon at Macquarie Equities, part of an Australian banking group, sums up the mood: "The dramatic fall in London Metal Exchange stocks in 1995 and in the first quarter of 1996 means that overall market stocks remain uncomfortably low. With the seasonal upturn in demand rapidly approaching, market stocks are likely to begin to fall again and lead prices appear well placed to stage a strong rally" (Financial Time, Friday August 9,1996,p.20).

The above analysis can be shown with the help of diagrams. Let So and Do be the current supply curve and demand curve for lead respectively. Assuming that the demand for lead remained the same, but the supply of lead resources fell, the price of lead would increase from Po to P1 (see Fig. 4-1).

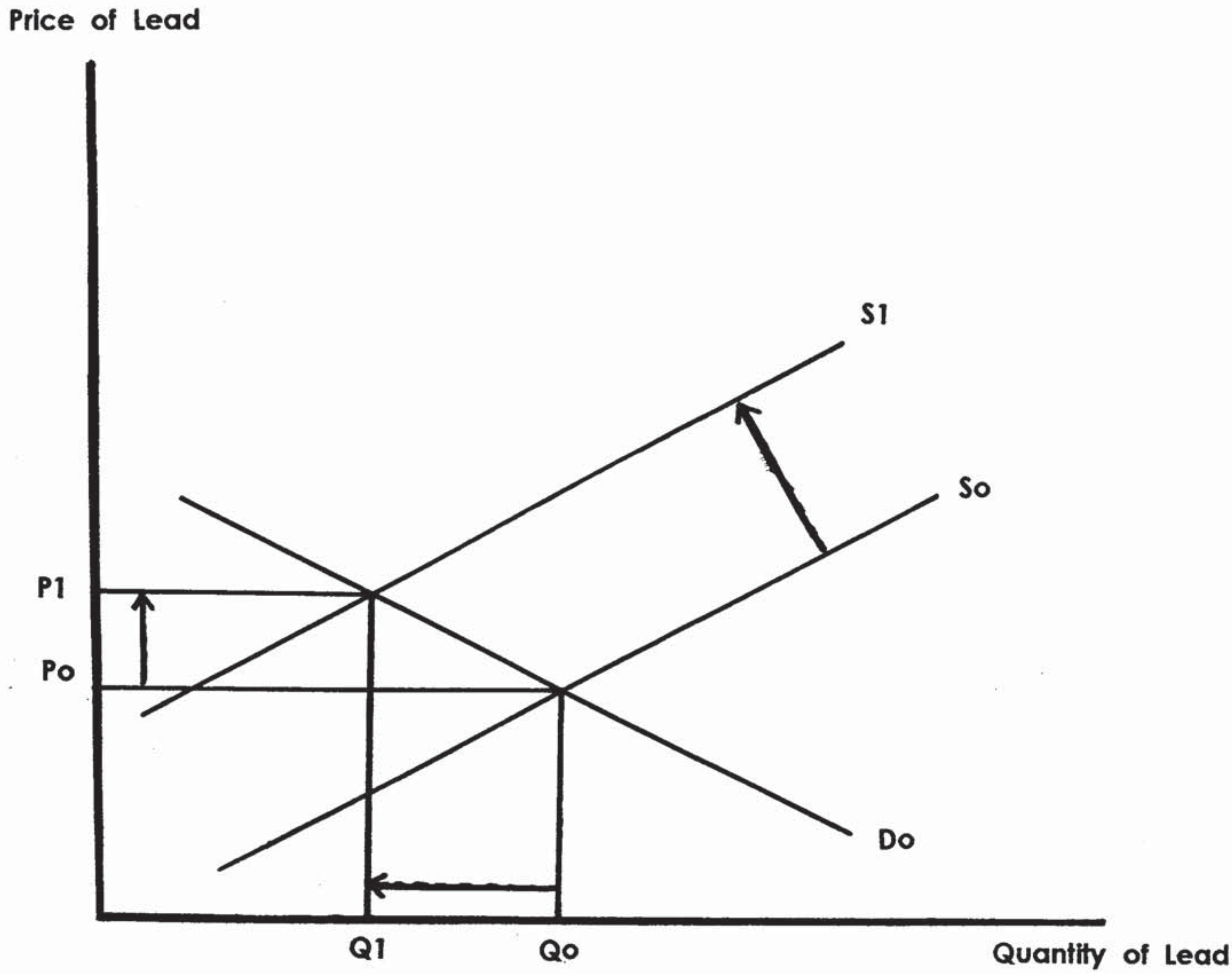


Figure 4-1 The effect of a decrease in supply of lead on the price and quantity of lead.

Mr. Angus MacMillan, research manager at Biliton Metals, part of the Gencor mining group, has revised upwards his lead price of forecasts recently. He is looking for average prices of 38 cents a pound this year and 39 cents in 1997. "We take the view that the lead market will remain in supply deficit both this year and next, although as 1997 wears on we expect to see the market returning to near balance" (Financial Time, Friday August 9,1996,p.20).

At Bain & Company, a Deutche Bank subsidiary, Mr. Wilktor Bielski says it is not surprising that lead, together with zinc, were the metals that first shook off the impact of the Sumitomo crisis that dragged down all LME prices in the middle of June and have returned to the price levels that existed before.
He says: "The lead market remains in structural deficit, with stocks being run down in order to meet consumption.
LME stocks have fallen by more than 25 percent since the start of this year and look set to continue falling as consumption recovers from the traditional second quarter slump. Already demand is rising with the advent of the replacement battery season. With stocks below the critical five weeks, consumption

level, further price rises are inevitable" (Financial Time, Friday August 9, 1996, p.20).

According to the International and Zinc Study Group, an intergovernmental organisation, the present tightness in the lead market can be traced mainly to big falls in output last year in China and Kazakhstan, which coincided with record demand by battery producers, the biggest consumers of the metal. Priliminary statistics from the ILZSG show that Chinese production fell by 12.4 per cent or 58,000 tons compared with 1994, while the drop in Kazakhstan was 29 per cent or 47,000 tons (Financial Time, Friday August 9,1996,p.20).

This resulted in a big drop in exports from eastern Europe. The CRU, International metals consultancy, estimates net exports fell 36 per cent, from a record 253,000 tons in 1994 to 161,000 tons. This was the main reason lead consumption in the western world exceeding supply by 172,000 tons last year compared with a 38,000 tons surplus in 1994 (Financial Time, Friday August 9 1996, p.20).

If, however, we add to this the fact that, year after year the demand for lead also increases, that is the demand curve shifts from Do to D1, the effect of decrease in the supply of lead on price would be much higher. It would increase from Po to P2, rather than to P1 (see Fig. 4-2).

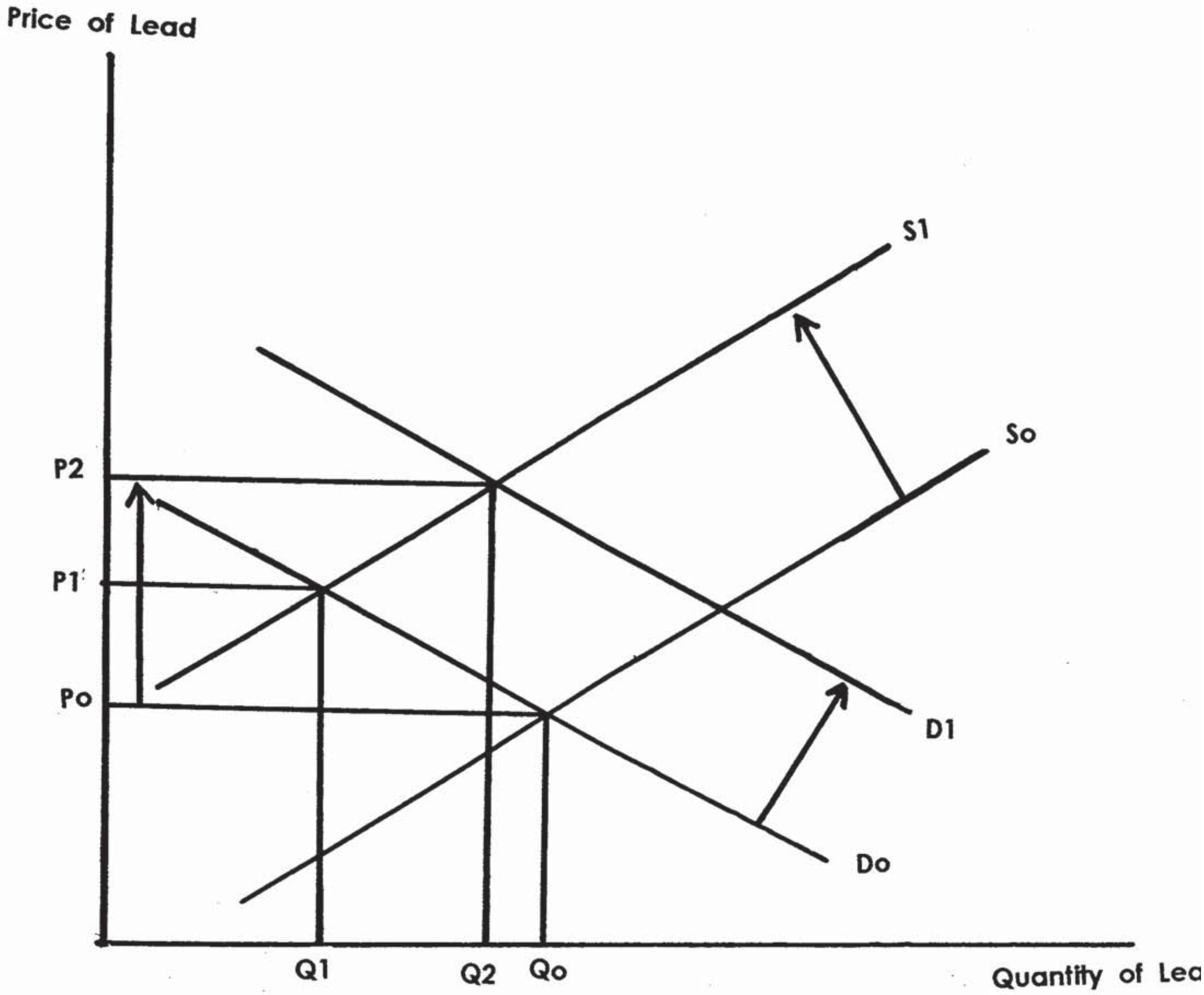


Figure 4-2 The effect of a decrease in supply and an increase in demand on the price and quantity of lead.

However, recycling shifts the supply curve of lead to the right. Now, if S1 shifts back to So, then the price will still increase from Po to P3, but not much. In case the supply curve shifts to the right somewhere between So and S1, like S2, the price will increase from Po to P4 (see Fig. 4-3). All these show that recycling will not let the price of lead to increase as much as it would in the absence of recycling.

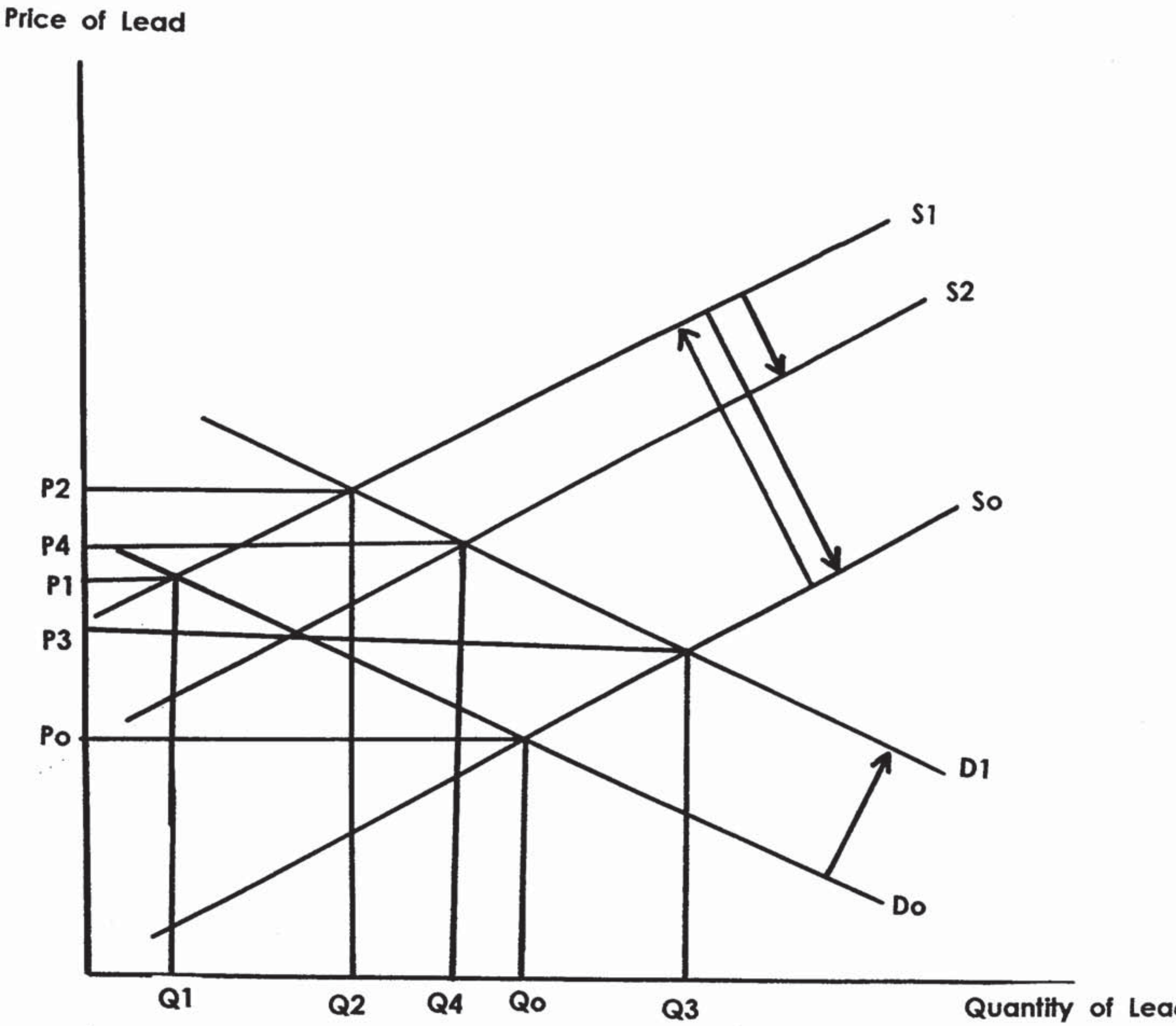


Figure 4-3 The effect of a decrease in supply, an increase in demand and recycling on the price and quantity of lead.

As recycling becomes cost competetive, rather dramatic changes occur in the manufacturing process. Not only do manufacturers rely more heavily on recycled inputs, they also begin to design their products to facilitate recycling. Facilitating recycling through product design is already important in industries, where the connection between the manufacturer and disposal agent is particularly close (Tietenberg,1992, p.192).

2. Effect on profit

In order to show whether dead battery recycling is or is not a profitable business, we calculated the total cost of processing one ton of dead battery, and then we compared it with the total revenue derived from refined lead and plastic. These calculations are summarized in Table 4-5.

Table 4-5

Calculation of Net Profit

	Lead ($/ton)	Plastic ($/ton)	Total ($/ton)
Revenue	312	15	327
Less: Cost			297
Gross profit			30
Less: Tax (15 %)			4.5
Net profit			25.5
Net profit / year			66,300

Let us see the details of net profit calculation.

Table 4-6 shows the composition of 18kg of dead battery before and after recycling.

Table 4-6

Composition of 18kg of Dead Battery

Before Processing	**kg**	**After Processing**	**kg**
*Metallic Lead	3.75	*Refined Lead	9.50
*Lead Oxide	7.50	*Polypropylene (plastic)	1.40
*Polypropylene (plastic)	1.50	*Slag Waster(iron sulfate)	2.10
*PVC Rubber (seperator)	1.25	*Other Wastes	1.00
*Spent Electolyte (acid)	4.00	*Recycled water	4.00
Total	18.00kg	Total	18.00kg

Source: IMC

Table 4-7 shows detailed explanation about the calculation of revenue.

Table 4-7

Calculation of Revenue

* From 18kg of dead battery we get 9.5kg of lead.

* Thus from 1 ton of scrap battery we get:
$\frac{9.5 \times 1000}{18}$ = 520kg of lead.

* The selling price of 1 ton of lead being $ 600, the total revenue received from 1 ton of scrap battery will be:
$520 \times \frac{600}{1000}$ = $ 312.

* From 1 ton of dead battery we get 60kg of plastic. The price of plastic being $15 per 60kg, the revenue received from plastic will be: $60 \times \frac{15}{60}$ = $15.

* Total revenue received from 1 ton of scrap battery will be:
$312 + $15 = $327.

Source: IMC

Table 4-8 on page 72, shows the cost of processing one ton of scrap batteries.

Table 4-8

Calculation of the costs of processing one ton of of scrap batttery

Labor	$25.00
Fuel	30.00
Generator Fuel	5.00
Electricity Bill	4.00
Rent	1.00
Fire Breaks	3.00
Breaker Machine	2.00
Furnace	1.50
Filteration Unit	2.00
Casting Machine	0.75
Refining Kettle	0.75
Chemical Cost	20.00
Administration & Other	2.00
Purchase of Scrap Battery	$ 200.00
Total Cost	$297.00

Source: IMC

Therefore, the gross profit made from 1 ton of scrap battery will be $30. As the government charges 15% profit tax, the net profit will be: $30 - (30 x 0.15) = $25.5 .

Given that, on an average, the company recycles 2600 tons per year, the net annual profit will be: 2600 x 25.5 = $66,300.

These calculation show that scrap battery recycling is a profitable business. And as attitutes towards environment will be more rational in the future, recycling will be a more and more profitable business (Amer,1988, p.27).

CHAPTER FIVE

CONCLUSION

The purpose of this research was to study the environmental and economic benefits of recycling dead lead-acid batteries.

The discussion on environmental benefits included resource recovery, environmental (physical) benefits, and health. The discussion on economic benefits included macroeconomic and microeconomic benefits, like employment, foreign exchange earnings, and pricing.

Our study shows that, in general, Lebanese are not aware of the fact that many "wastes" are recycable. They can be converted to something useful and they can be used agian and again. As resources are getting scarcer and scarcer, recycling should be a must. It preserves resources, keeps our physical environment clean and more beautiful. This is true not only in the case of dead lead-acid battery, but also for other "wastes".

Our study also shows that recycling dead lead-acid battery has beneficial effects on the health of human beings. It is true that workers working in recycling firms are also exposed to some hazards, but it is less than the hazards in the lead mines. This is due to the fact that there are very strict rules and regulations to eliminate or minimize pollution in lead recycling firms.

Regarding the second objective, our study shows that recycling dead lead-acid battery generates microeconomic and macroeconomic benefits. It does not allow lead price to increase as much as it would in the absence of recycling. It also generates additional income, output and employment to Lebanese. It further saves and earns foreign exchange. These benefits are not substantial because we did not have data for the whole industry. It was based on data gathered from one firm.

To sum up, our study supports the view that recycling has beneficial economic and environmental effects.

APPENDIX I

LEAD PRICE FLUCTUATIONS (1)

Annual low, high and average prices of pig lead (common corroding) in New York.

Year	Low	High	Average (cents/pound)
1904..........	4.10	4.60	4.32
1905..........	4.45	6.25	4.70
1906..........	5.35	6.35	5.66
1907..........	3.50	6.35	5.35
1908..........	3.65	4.60	4.23
1909..........	3.95	4.75	4.30
1910..........	4.37 1/2	4.75	4.49
1911..........	4.25 1/2	4.60	4.46
1912..........	4.00	5.15	4.48
1913..........	4.00	4.85	4.40
1914..........	3.50	4.15	3.87
1915..........	3.70	7.62 1/2	4.67
1916..........	5.50	8.25	6.83
1917..........	5.50	12.25	8.71
1918..........	6.25	8.05	7.46
1919..........	4.80	8.00	5.81
1920..........	4.45	9.50	8.08
1921..........	4.00	5.37 1/2	4.55
1922..........	4.70	7.45	5.71
1923..........	6.00	8.75	7.25
1924..........	7.00	10.30	8.08
1925..........	7.65	10.80	9.02
1926..........	7.65	9.50	8.42
1927..........	6.20	7.80	6.75

(1) Compiled from quotations published in American Metal Market.

Year	Low	High	Average
1928..........	6.00	6.50	6.31
1929..........	6.25	8.25	6.83
1930..........	5.10	6.25	5.52
1931..........	3.75	5.10	4.24
1932..........	2.65	3.75	3.18
1933..........	3.00	4.50	3.87
1934..........	3.50	4.25	3.86
1935..........	3.50	4.65	4.06
1936..........	4.50	6.05	4.71
1937..........	4.75	7.80	6.01
1938..........	4.00	5.15	4.74
1939..........	4.75	5.50	5.05
1940..........	4.75	5.80	5.18
1941..........	5.50	5.85	5.79
1942..........	5.85	6.50	6.48
1943..........	6.50	6.50	6.50
1944..........	6.50	6.50	6.50
1945..........	6.50	6.50	6.50
1946..........	6.50	12.55	8.11
1947..........	12.55	15.00	14.67
1948..........	15.00	21.50	18.04
1949..........	12.00	21.50	15.36
1950..........	12.00	17.00	13.30
1951..........	17.00	19.00	17.49
1952..........	13.50	19.00	16.47
1953..........	12.00	14.75	13.48
1954..........	12.50	15.00	14.05
1955..........	15.00	16.00	15.14
1956..........	16.00	16.50	16.01
1957..........	13.00	16.00	14.66
1958..........	10.75	13.00	12.11
1959..........	11.00	13.00	12.21
1960..........	11.00	12.00	11.95
1961..........	10.00	11.00	10.87
1962..........	9.50	10.25	9.63
1963..........	11.00	12.50	11.14
1964..........	13.00	16.00	13.62
1965..........	16.00	16.00	16.00
1966..........	14.00	16.00	15.12
1967..........	14.00	14.00	14.00

Year	Low	High	Average
1968..........	12.50	14.00	13.21
1969..........	13.00	16.50	14.93
1970..........	13.50	16.50	15.69
1971..........	13.50	14.50	13.89
1972..........	14.00	16.00	15.34
1973..........	15.25	19.00	16.31
1974..........	18.50	24.50	22.49
1975..........	19.00	24.50	21.52
1976..........	19.00	25.75	23.02
1977..........	26.99	32.86	30.74
1978..........	31.00	38.18	33.68
1979..........	40.64	60.74	53.03
1980..........	34.19	51.06	42.91
1981..........	30.63	44.64	37.10
1982..........	20.12	29.90	26.03
1983..........	19.30	26.00	21.80
1984..........	23.11	32.14	26.91
1985..........	19.05	20.50	19.68
1986..........	18.41	28.37	22.25
1987..........	26.00	42.00	35.95
1988..........	32.33	45.67	39.00
1989..........	22.79	39.43	31.11
1990..........	20.71	36.83	28.77
1991..........	18.43	27.97	23.20
1992..........	19.26	29.63	24.44
1993..........	18.80	28.06	23.43
1994..........	19.43	30.37	24.90
1995..........	22.28	34.92	28.60
1996..........	25.18	37.86	31.52 (2)

(2) Forcasts made at LME seminar for the year 1996, (US cents / lb).

APPENDIX II

Transformation of lead price fluctuation from cents per pound to dollar per ton

Note: 100 cents = $1 | Let X = 100 cents | Z = 1 / 100 = 0.01
Let Y = 1 $ | Z = 0.01
1 pound = 453 gr = 0.4539 kg | 1 kg = 2.207 pounds
1 kg = 1000 gr | So, 1 Ton = 2,207 pounds
T = 2,207
W = 0.01*2207
W = 22.07

Note: Annual low, high and average prices of pig lead (common corroding) in dollars per ton, after they have been transformed from cents per pound.

Year	Low	High	Average
1904	90.487	101.52	95.342
1905	98.2115	137.94	103.729
1906	118.0745	140.14	124.916
1907	77.245	140.14	118.075
1908	80.5555	101.52	93.356
1909	87.1765	104.83	94.901
1910	107.4809	104.83	99.094
1911	104.8325	101.52	98.432
1912	88.28	113.66	98.874
1913	88.28	107.04	97.108
1914	77.245	91.59	85.411
1915	81.659	179.21	103.067
1916	121.385	182.08	150.738
1917	121.385	270.36	192.230
1918	137.9375	177.66	164.642
1919	105.936	176.56	128.227

								80
	1920		98.2115		209.67		178.326	
	1921		88.28		129.55		100.419	
	1922		103.729		164.42		126.020	
	1923		132.42		193.11		160.008	
	1924		154.49		227.32		178.326	
	1925		168.8355		238.36		199.071	
	1926		168.8355		209.67		185.829	
	1927		136.834		172.15		148.973	
	1928		132.42		143.46		139.262	
	1929		137.9375		182.08		150.738	
	1930		112.557		137.94		121.826	
	1931		82.7625		112.56		93.577	
	1932		58.4855		82.76		70.183	
	1933		66.21		99.32		85.411	
	1934		77.245		93.80		85.190	
	1935		77.245		102.63		89.604	
	1936		99.315		133.52		103.950	
	1937		104.8325		172.15		132.641	
	1938		88.28		113.66		104.612	
	1939		104.8325		121.39		111.454	
	1940		104.8325		128.01		114.323	
	1941		121.385		129.11		127.785	
	1942		129.1095		143.46		143.014	
	1943		143.455		143.46		143.455	
	1944		143.455		143.46		143.455	
	1945		143.455		143.46		143.455	
	1946		143.455		276.98		178.988	
	1947		276.9785		331.05		323.767	
	1948		331.05		474.51		398.143	
	1949		264.84		474.51		338.995	
	1950		264.84		375.19		293.531	
	1951		375.19		419.33		386.004	
	1952		297.945		419.33		363.493	
	1953		264.84		325.53		297.504	
	1954		275.875		331.05		310.084	
	1955		331.05		353.12		334.140	
	1956		353.12		364.16		353.341	
	1957		286.91		353.12		323.546	
	1958		237.2525		286.91		267.268	

1959	242.77	286.91	269.475
1960	242.77	264.84	263.737
1961	220.7	242.77	239.901
1962	209.665	226.22	212.534
1963	242.77	275.88	245.860
1964	286.91	353.12	300.593
1965	353.12	353.12	353.120
1966	308.98	353.12	333.698
1967	308.98	308.98	308.980
1968	275.875	308.98	291.545
1969	286.91	364.16	329.505
1970	297.945	364.16	346.278
1971	297.945	320.02	306.552
1972	308.98	353.12	338.554
1973	336.5675	419.33	359.962
1974	408.295	540.72	496.354
1975	419.33	540.72	474.946
1976	419.33	568.30	508.051
1977	595.6693	725.22	678.432
1978	684.17	842.63	743.318
1979	896.9248	1340.53	1170.372
1980	754.5733	1126.89	947.024
1981	676.0041	985.20	818.797
1982	444.0484	659.89	574.482
1983	425.951	573.82	481.126
1984	510.0377	709.33	593.904
1985	420.4335	452.44	434.338
1986	406.3087	626.13	491.058
1987	573.82	926.94	793.4165
1988	713.5231	1007.94	860.7300
1989	502.9753	870.22	686.5977
1990	457.0697	812.84	634.9539
1991	406.7501	617.30	512.0240
1992	425.0682	653.93	539.3908
1993	414.916	619.28	517.1001
1994	428.8201	670.27	549.5430
1995	491.7196	770.68	631.2020
1996	555.7226	835.57	695.6464

BIBLIOGRAPHY

Austin , George T . Shreve's Chemical Process Industries . 5th ed. United States. Ed.McGraw-Hill Inc., 1984.

Amer, Barry. "National Solid Waste Management Association." American Metal Market. Boston: Massachusetts, April 29, 1988, p. 27.

Baucus, Max. "The present tightness in the lead market." Financial Time. Friday August 9, 1996, p. 20.

Bielski, Wilktor. "Supply tightness lifts lead prices." Financial Time. Friday August 9, 1996, p. 20.

Chereminisoff, Paul N., and Nicolas P. Chereminisoff. Lead. New Jersey. Ed. Prentice - Hall Inc., 1993.

Corwin , Devitt , and Taft Worrell . International Technology for the Nonferrous Smelting Industry . New Jersey: U.S.A. Ed. PEDCO Environmental Inc. , 1982.

Croom , Miles L . 1995. Filter - Dust Collectors . New York. Ed. McGraw-Hill Inc., 1982.

Duecker and West . "Manufacture of Sulfuric Acid." Chemical Engineering Progress Technical Manual. New York. Ed. Collier MacMillan Ltd., 1971.

Franz, Cecilia M., and Donald G. Kaufman. Biosphere 2000. Protecting Our Global Environment. New York. Pub. Harper Collins, 1993.

Harley, William D., and Emanuel Freidman. Colliers Encyclopedia. Vol. 3. New York. Ed. Macmillan Educational Co., 1994.

Interview with Ohan Manuelian, general manager of IMC, International Metal Co. Dora-Beirut, Lebanon, May 27, 1996.

International Metal Consultancy. Financial Time. Friday August 9, 1996, p. 20.

Lennon, Jim. "Analysts Bullish on Lead Market Prospects." Metal Bulletin. August 9, 1996, p. 20.

London Metal Exchange. "Lead Price Fluctuations." American Metal Market- Metal Statistics." September 3,1996, p. 4.

MacMillan, Angus. "Lead prices jump to 5-year highs as stocks fall again." Metal Bulletin. November 22, 1995, p. 27.

McConnel Campbell R. "Russian lead output declines by a third." Metal Bulletin. December 31, 1993, p.6.

Mooney, Richard. "Lead & Zinc supply deficit seen continuing." Base Metal. November 1, 1995, p.25.

Moore, Nick. "Supply shortages forcast to drive lead prices higher." Metal Bulletin. December 16, 1996, p. 20.

The New Encyclopedia Britanica. 15th ed. Vol. 2. London, Encyclopedia Britanica Inc. , 1973-1974.

Patten, Keith. "Base Metal Trading." 6th Ed., United Kingdom, Comico Ltd., 1973.

Pearce, John A., and Barry R. Turner. A Cleaner Environment. Atlanta: Goergia, Lake Engineering Inc., 1994.

Tietenberg, Tom. Environmental and Natural Resource Economics. New York, Harper Collins Inc., 1992.

Worell, Harold L. 1982. Industrial Society and Social Welfare. London, Pub. Collier - MacMillan Ltd., 1982.