Transactions of the Materials Research Society of Japan 29[5] 1905-1908 (2004)

Material Flow of Lead and Used Lead-acid Battery Recycling System in Japan

Tsuyoshi Masuda, Takahiko Okura*, Takashi Nakamura**

*Metals Research Dept., Nippon Mining Research & Technology, 10-1Toranomon, 2-Chome, Minato-Ku, Tokyo, Japan
Fax: 81-3-5573-7397, e-mail: masuda@shinnikko-tr.co.jp
**Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Katahira, Sendai, Japan
Fax: 81-22-217-5213, e-mail: ntakashi@sda.att.ne.jp

Abstract: Although lead is very useful metal for battery and solder, it has toxicity. Thus, the environmental regulations are very severe in the world. Important point is how to prevent its diffusion into the living environment. So, lead recycling is meaningful, especially for used lead-acid batteries. Material flow and stock of lead in Japan is precisely investigated in the present paper. The 3/4 of the lead consumption in Japan is used for lead-acid batteries and more than 95% of used lead-acid batteries have been recycled. Battery Association of Japan established the present recycling system in Japan in 1994. However, it is becoming impossible to maintain economically the present collecting recycling system of used lead-acid batteries for cars because of the burden of battery producers, primary and secondary lead producers concerning of such problems, as the "free rider" problem and low lead price. We propose, "The deposit-refund system combined with the charging of collecting expenses" based on the concept of "material lease."

Keyword: lead, lead-acid battery, recycle, material flow, material lease, deposit-refund system

1. INTRODUCTION

Lead-acid batteries are used as automobile batteries mainly because : (1) the ion exchange current density of lead is larger than that of other metals and (2) lead-acid batteries are cheaper than other types of battery.
Because of the fact (1) above, it is unlikely they will be substituted by other materials that can procure large current density needed for starter batteries for cars. On the other hand, lead is subject to severe environmental regulations because of its hazardous property. This is also the case with used lead-acid batteries which were once called "the honor student of recycling". Sufficient attention should be paid not only to the management of lead itself but to the landfill of the sludge and the wastewater produced in the treatment of used batteries. We investigated the material flow and stock of lead in Japan and pointed out that it was required to improve the rate of reuse of lead contained in lead-acid batteries in order for the lead recycling in general to improve considering the demand for lead while the demands are sharply declining due to Environmental regulations.
It is becoming impossible to maintain economically the present collecting - recycling system of used lead-acid batteries for cars only at the burden of battery producers, primary lead producers, secondary lead producers, and etc. because of such problems, as the "free rider" problem and low lead price.
In order for us to be able to continue to use lead-acid batteries, we should promptly develop new technology for the recycling of lead-acid batteries, and build a social system that can prevent diffusion of lead.
We believe that carrying out circulation use of lead within a social system based on the concept of material lease is of significant profit to us.
We propose "the deposit-refund system combined with the charging of collecting expenses" based on the concept of "material lease."

2. MATERIAL FLOW OF LEAD

The material flow of lead in Japan in 2000 is shown in Fig. 1. The material flows of lead are created based on what was reported by the Metal Economics Research Institute (MERI), Japan. The present material flow, compiled based on the material flow of lead reported by MERI, takes into account the export and import of products contained large amount of lead (for example, cathode-ray tube type televisions and lead-acid batteries), and the amount of market and social accumulation in Japan.

2-1 Domestic production and import of metallic lead

The rate for which a recycling lead accounts among domestic production and import of a metal lead reaches to 54%. Lead produced by the ISP zinc smelting process accounts for 25% of metallic lead, with lead produced by lead smelting accounting for only 21%.
As for the cathode-ray tube type televisions that used to be produced in Japan until several years ago, 90% or more in the amount of sale are imported.
Furthermore, imports of manufactured goods including lead-acid batteries are expected to rise in the future following the anticipated transfers of manufacturing plants to overseas bases. On the other hand, although lead contained in the exported products, at 75kt/y, comprising cathode-ray tube type televisions and
lead-acid batteries is almost equal to lead contained in the imported manufactured goods the import of lead are expected to exceed the export, signaling that the amount of lead circulating in Japan will increase.

2-2 Lead consumption

The largest use of lead, at 76% of all used amount, is by lead-acid batteries, followed by inorganic chemicals and solder, moves for lead-free products are gaining ground in the fields

other than lead-acid batteries, and it is expected that the amount of lead used in these fields will decline in the future, with a result that the rate of lead-acid batteries to the total lead usage is expected to rise further. Lead is used for anode and cathode plates in a lead-acid battery. It is difficult for secondary lead producers to manufacture lead with the purity that meets the requirement of a cathode plate (4N), and it is particularly difficult to meet the requirements by the Japanese battery producers , which excel in the quality control and require higher quality.

Therefore, electric lead accounts for 81 % of the lead used in a lead-acid battery because of its high purity and easiness to produce 4N lead. If the use of maintenance-free type storage batteries expands in the future, it is expected that the tendency for higher purity becomes stronger.

2-3 Consideration about a non-collected amount of lead

The lead consumption in 2000 is 347kt, and the amount of collected lead is 158kt, which account for 46% of the consumption. Other flows of lead are in market accumulation (18kt); lead contained in the exported products. Landfill and unknowns, despite severe environmental regulations, amount to 120kt (30%) according to the reference 2.

Hereafter, consideration is on the non-collected lead.

According to data by the Battery Association of Japan, the collecting rate of used lead-acid batteries in 2000 is 95%, and the non-collected amount of lead is 8kt.

The collecting rate of used lead-acid batteries has been 90% or more. Accumulation of uncollected lead in Japan increased early in the 1990s when the collecting rate fell, although some amount was exported. It has gradually increased and is estimated to have reached about 200kt now.

That is, although the collecting rate of lead-acid batteries is about 100% now, it is thought that there is a lot of accumulation. Moreover, battery producers are collecting not only automobile batteries, but, voluntarily, industrial use batteries and small sealed batteries, and the collecting rate is expected to become higher in the future.

However, if the collecting rate increases under current lead price and recycling system, collecting expenses increase, and the collection becomes less profitable, which will require reexamination of the system. This issue will be revisited later.

On the other hand, lead contained in inorganic chemicals and solder which account for a major portion of the uncollected lead is expected to decrease with the anticipated increase of non-leaded products. In addition, the following two are mentioned as problems of lead collecting and recycling.

(1) Reuse of cathode-ray tube glass containing lead is becoming impossible, as the result of the recent rapid transfer of cathode-ray tube manufacturers to overseas.

Exports of cullet containing lead to overseas cathode-ray tube makers as raw materials are under study but it has not been established yet.

(2) Most of the lead contained in incineration ashes can be explained by mixing of small seal lead-acid batteries and other batteries into common garbage.

3. Present Condition of Automobile Lead-acid Battery Recycling System

3-1 Outline of the present system

The collecting rate of automobile lead-acid batteries has been about 100%, and has been the recycling model for metals. Lead-acid batteries including ones for industrial-use were collected almost 100% as "valuables", when the lead price was high. The collecting rate fell sharply at the time of the fall in the price of lead in 1993 - 1994, illegal disposal increased, and it became a social problem. At this time, the Battery Association of Japan worked out " lead recycling program" by request of the Ministry of Health and Welfare and the Ministry

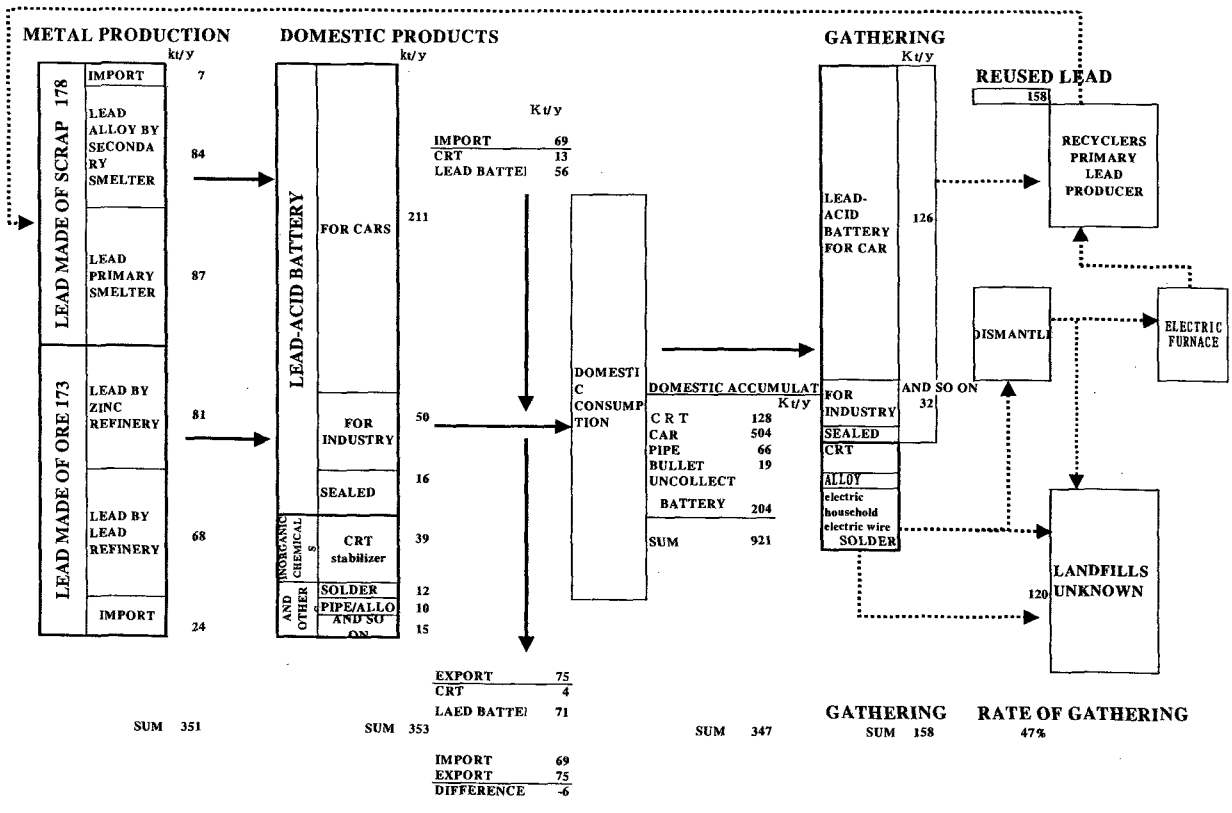

Fig. 1 Lead Material flow in Japan (2000 base) (unit: k tons / year)

of International Trade and Industry, and it was implemented in 1994. Consequently, the collection rate has recovered to about 100%. A concrete scheme is shown in Fig. 2.
The system, based upon the continuous use of conventional collectors, consists of

① recovering, free of charge, used lead-acid batteries at the times of car maintenance at retailers, volume retailers, gas stations and so on and making battery producers buy the secondary lead from Secondary Lead Producers at a price including collecting expenses.
② making primary lead producers and other treating facilities actively collect recycled lead.

3-2 Problems of the present system
The present system was built in a way that existing systems could be preserved as much as possible, based on the price and the manufacture costs in Japan prevailing at the time of its introduction. Some problems have already surfaced and it has now become difficult to maintain the system. Problems of the present system are shown below.

3-2-1 Scale of the secondary-lead industry
The secondary lead and primary lead producers registered with the Battery Association of Japan can be divided roughly into a group of four non-ferrous metal smelters that have been producing lead from ores and a group of 15 secondary lead producers that specialize in recycling. In addition, there are about 80 secondary lead producers in Japan. The number of relatively small producers in the secondary lead market of 160kt/y is very high and the rationalization of the re-treatment process by scale merit is difficult to be realized. Consequently, re-treatment prices tend to remain high.

3-2-2 Fluctuation of international lead prices of lead
The price of lead, as an international commodity is determined at LME (London Metal Exchange), and domestic prices are determined as LME price X exchange rate + (distribution costs, customs duty, etc.). That means that lead prices in Japan fluctuate depending on the international market and exchange rates.
Moreover, the competitive power of domestic lead-acid batteries has declined due to the strong yen, and 12% or more of lead-acid batteries for cars sold for domestic repair uses are now imported .
We presume that the current situation of the present system is as follows.

(1) The amount of secondary-lead that a battery producer should purchase is determined based on the percentage of its share of domestic sales of lead-acid batteries in 1996 when the "lead recycling program" was worked out. The share figure has now moved away from the reality.
(2) Battery producers purchase secondary lead at the price equal to the aggregate amount, for example, of collecting expenses of 10 yen /kg (120 yen per lead-acid battery; 20 yen/kg lead equivalent) and the costs of recyclers ((demolition expenses + secondary-lead processing expenses+ waste processing expenses+ environmental measure expenses etc.).
The level on which a secondary lead producer is in a break-even level is presumed to be +20 - 30 yen/kg over Japan-domestic price (85 yen/kg).
3-2-3 Free riders
Currently 158kt of lead per year is collected from used lead-acid batteries, with used lead-acid batteries for cars accounting for 80% and other used lead-acid batteries (industrial use etc.) for 20% .
However, the used lead-acid batteries for cars include discarded imported lead-acid batteries produced by overseas battery producers, with their collecting and reprocessing costs borne by the present system, the so-called "free rider" problem. The problem may lead to a collapse of the present system.

3-2-4 Regulations
Permit of work concerning the management of special industrial waste. The present system uses the contractors and systems existing at the time of its introduction, and there are contractors without the permit of work.
Because of this, it is said that there is a possibility that environmental measures are not properly taken and processing is not suitably conducted. Moreover, it is expected that there will surface inconveniences with respect to the handling of cross border processing of lead-acid batteries because each prefecture has different specifications as to lead-acid batteries for qualifying contractors as the "special management industrial waste collection transport industry" or the "special management industrial waste disposal business", a practice born from the necessity to meet the reality of local existing contractors. To avoid such situation, unified regulation that is applied to all domestic areas is required.

3-2-5 Cost sharing as to the expenses of collection and freight and the collecting expense of illegal dumping
In the present system, the higher the collecting rate, the higher

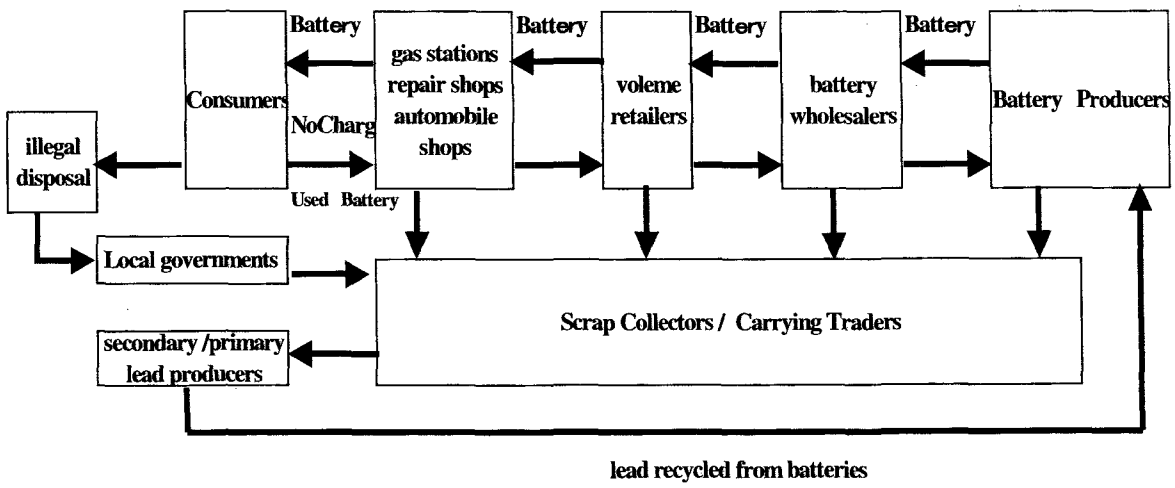

Fig. 2 Current recycling system of used lead-acid batteries (source; Battery Association of Japan)

will become the recycling costs such as collecting, transporting, and reprocessing and the costs that battery producers have to bear increase.
Moreover, local governments defray the collecting expenses of illegal disposals from the tax.
If the above situation continues, it is expected that the current system will not be able to cope with the recycling of lead-acid batteries. A new system requiring costs sharing by producers and consumers is needed in order to prevent diffusion of lead contained in lead-acid batteries by illegal disposals, and to promote proper processing of sulfuric acid contained in lead acid batteries.

4. Proposal of a New Lead-acid-Battery Recycling System for Cars

Several systems were examined in order to find out a new social system that can allow the continuous use of useful lead-acid batteries, without increasing the burden on the environment.
These are (1) the deposit-refund system combined with charging of the collecting expenses, (2) the product lease system, and (3) The recycling ticket system in which collecting expenses are paid at the time of disposal.
Comparison of the deposit-refund system, the lease system and the recycling ticket system is summarized in Table 1.

In the above three systems, the lease system of batteries is very unlikely to be implemented because of the high costs for development and maintenance of the system that manage dumping and re-treatment of leased batteries and psychological resistance to "leasing". Therefore, the ticket system or the deposit system is thought to have a possibility to be introduced as the new system.
With the deposit system it is highly possible that there will be increased collection of non-collected batteries. The system is more effective than other systems in collecting illegally abandoned batteries. In either system, there is a risk that the principle of free competition does not work if expenses such as collecting expenses are fixed. If so, the system may remain a comparatively high-priced system. This is a difficult point of the new system. The transparency of NPO that manages the fund in the case of the deposit system becomes very important, consequently.

5. Conclusion

The material flow of lead in Japan was investigated and a new system of recycling was proposed as to the lead-acid batteries to replace the current collecting system that is now becoming difficult to maintain under the current low lead prices. The deposit system with charging of collecting expenses, which is based on the concept of material lease, is believed to be the best system in order for the collection rate to increase or to eliminate illegally dumped batteries completely. We would be pleased if it could be helpful in establishing a new circulation system of lead and lead-acid batteries.

References

[1] Takashi Nakamura, Kohmei Harada, "A Prospect of The Material Lease society", MTERE2,41 (11) pp.744-749 (2002)
[2] Metal Economics Research Institute, Japan, "copper, zinc, and lead of domestic material flow investigation (II)"(1997)
[3] Yasufumi Suzuki, Hiroshi Takatsuki,Shin-ichi Sakai, "Presumption of Origin of Lead Using Lead Concentration Distribution of Incineration Ashes", Collection of 5th Research Presentation Meeting Lecture Papers of Japan Society of Waste Management Experts, pp525- 527, (1994)

(Received October 10, 2003; Accepted October 31, 2003)

Table 1 Comparison of the deposit-refund system combined with charging of collecting expenses, the lease system and the ticket system (o= improvement, x= aggravation)

	Present problems	Deposit system *	product lease system	ticket system **
Consumers	Illegal Disposal	O	O	×
Local governments	Cost burden of collecting illegally disposal batteries	O	O	×
Battery Producers	Change in Rate of secondary-lead use	O	O	×
	Producer responsibility	O	O	O
Scrap Collectors Carrying Traders	Unsuitable collection	O	O	O
Lead secondary producers	Costs	O	O	O
	Unsuitable processing	O	O	O

*collecting expenses charged
**charged at time of disposal