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Material Flow Analysis of Metals in Japan

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The need of sustainable society arose from the realization that there is a limit in the supply of natural resources and that development and production can cause serious environmental problems. To cope with these problems materials should be designed to be cycled in natural environments, and at least not to destroy natural cycling systems of the earth. Environmental loads consist of two different factors: energy consumption and toxicity. For the materials produced with intensive energy consumption, recycling saves much energy and therefore diminishes environmental load. For the materials having high toxicity in production and discarding, the complete recycling is essential to avoid fatal damages to humans and ecological systems. There is a need for increased understanding the material flow of such materials in detail. As an integrated part of many types of metal production, the recycling of metal scrap needs to be increased for both economic and environmental reasons. Reprocessing and reuse of materials are effective in reducing energy consumption. Material flow analysis of lead, cadmium and mercury has been studied in this work. Resource and environmental issues of these metals have caught much attention in recent years. The generation of waste is thought socially incorrect. The more a product can be recycled, the more socially acceptable it will be.
Key words: diffusion materials/ material flow/ metal recycling/lead/cadmium/mercury

1. INTRODUCTION

Progress of science and technology has much changed living conditions in modern countries. However the ecological consequences of technological progress are threatening our common future. The need of sustainable society arose from the realization that there is a limit in the supply of natural resources and that development and production can cause serious environmental problems. At this point sustainable society is no longer just an option but an imperative.

Materials may come from either renewable or non-renewable sources. The traditional primary renewable resources are agricultural, forest and wildlife products. Primary non-renewable resources are those created in geologic time, namely minerals, and organic materials such as coal, petroleum and natural gas. This distinction is blurred by the practice of recycling materials, whereby feedstock supply can be satisfied with reduced use of primary inputs. After either a long or a short life, the raw materials are discarded and are returned to the environment. Thus ecological and economic circulations are in constant interplay. All such activities on the earth are entropy increasing process. The crucial problem which human beings face now lies, therefore, not in the increasing entropy, but in the increasing difficulty of its disposal due to grossly accumulating waste with underground origins (resources).

In the man-aided recycling system, there are materials whose quantity for the particular use and recycling is not clear in material flow. We called these "diffusion materials" in material flow. Some of the diffusion materials are dissipated to the environment during use and are unavailable for recycling. The other problem of diffusion materials takes place during recycling. Some elements go to slag or dust during the secondary metal production. Furthermore, scrap contaminated with tramp elements is almost impossible to recycle. The problem that radioactive materials are mixed and smelted appears in recent years.

2. MATERIAL FLOW

The material flow in Japan in the fiscal year of 2000 [1] indicated that the total in resources from nature, both domestic and imported from overseas, is about 2.1 billion tons. The amount of waste disposal is 800 million tons. The amount of recycling is 230 million tons which corresponds to 11 % of total material consumption. Sands and rocks for construction and other uses amount to about 1.15 billion tons, accounting for 55 % of total material consumption.

Primary materials consist of raw materials as well as masses that are moved to get use of the raw materials but are not further use for processing (like overburden in mining). The latter was called "ecological rucksacks" of raw materials [2]. This term in general refers to the sum of primary materials that are moved by man in order to produce a certain product minus the mass of the product itself. The quantity of the ecological rucksacks is estimated at 150% of that of resources from nature in

Japan in the fiscal year of 1997 [3]. The rucksacks of imports are huge. This means that the corresponding environmental impact has been shifted abroad.

The need for a strategy of sustainable society arises from the realization that there is a limit in the supply of natural resources, and that development and production can cause serious environmental problems. To cope with these problems materials should be designed to be cycled in natural environments, and at least not to destroy natural cycling systems of the earth. Environmental loads consist of two different factors: energy consumption and toxicity. For the materials produced with intensive energy consumption, recycling saves much energy and therefore diminishes environmental load. For the materials having high toxicity in production and discarding, the complete recycling is essential to avoid fatal damages to humans and ecological systems. There is a need for increased understanding the material flow of such materials in detail.

3. DIFFUSION MATERIALS IN MATERIAL FLOW

In man-aided recycling system of materials, entropy production accompanied with material circulation is necessarily compensated by the negative entropy transfer supplied by energy resources such as oil, coal and natural gases. Consumption of these resources in turn produces materials with high entropy such as CO_2 gas and waste heat. Therefore, in order to reduce the environmental impact in man-aided recycling system, reduction of resources is most effective. As an integrated part of many types of metal production, the recycling of metal scrap needs to be increased for both economic and environmental reasons. Reprocessing and reuse of materials are effective in reducing energy consumption.

In the man-aided recycling system, there are materials whose quantity for the particular use and recycling is not clear in material flow. We call these "diffusion materials" in material flow. Some of diffusion materials are dissipated to the environment during use and are unavailable for recycling. The other problem of diffusion materials takes place during recycling. Some elements go to slag or dust during the secondary metal production. Furthermore, scraps contaminated with tramp elements are almost impossible to recycle. The problem that radioactive materials are mixed and smelted happed frequently. A few examples of diffusion materials will be presented below, although the material flow of diffusion materials is not well comprehended.

4. THE CASE OF LEAD

Lead has widespread usages. Resource and environmental issues of this metal has attracted much attention in recent years. The generation of waste is thought to be socially incorrect. The more a product can be recycled, the more socially acceptable it will be.

Figure 1 shows the shipment of lead batteries used in major products such as automobiles, industrial goods, motor bikes and seals. Automobiles clearly use the most amounts of lead batteries. This lead is almost always recycled.

Table 1 shows the production and importation of lead in Japan. Twenty seven thousand tons of lead was used in 2001. Table 2 shows the changes in lead usage. The consumption of lead in Japan was 293 thousand tons in 2001. Lead is used for batteries (about 76%), inorganic chemicals (about 10%), solder (3%), wire cable (2 %) and others (8%). The reclamation of lead from batteries is one success story, with 95% being typically recovered.

Figures 2 and 3 show the material flow of lead. The total amount of recycled lead is estimated at 168 thousand tons and the land filling including unknown is estimated at 100 thousand tons. 63 % of all lead is currently being recycled. The remaining 37 % appears unrecoverable in any practical sense. Lead is still recognized as one of diffusion materials.

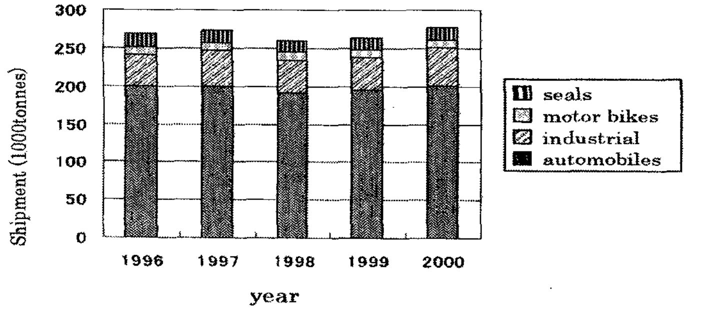

Fig. 1 Shipment of lead batteries used in major products

Table 1 Production and importation of lead metal in Japan (unit : ton)

year	1996	1997	1998	1999	2000	2001
production	224,729	227,953	227,571	227,122	239,384	236,042
importation	33,334	32,634	27,342	13,815	24,455	37,153
total	258,063	260,587	254,913	240,937	263,839	273,195

(Year book of minerals and non-ferrous metals statistics)

Table 2 Changes in lead usage (ton) (without importation)

fields \ year	1994	1995	1996	1997	1998	1999	2000	2001
batteries	250,917	244,484	244,588	248,321	236,056	221,408	229,435	223,227
Inorganic chemicals	50,657	45,828	40,997	38,418	32,325	33,139	38,302	29,325
solder	14,585	14,104	13,258	13,041	10,680	11,360	11,996	10,106
Lead tubes and plates	9,929	10,924	11,916	12,085	11,491	-	3,284	-
Wire cable	4,529	3,836	6,173	4,079	2,871	2,378	4,588	6,440
plating	456	332	351	657	664	766	-	-
tubes	409	433	361	337	309	305	-	-
Antifriction alloys	107	62	55	59	72	-	-	-
others	31,401	30,182	28,012	30,704	31,821	69,588	27,654	23,996
total	362,990	350,185	345,711	347,701	326,289	338,944	315,259	293,094

(Year book of minerals and non-ferrous metals statistics)

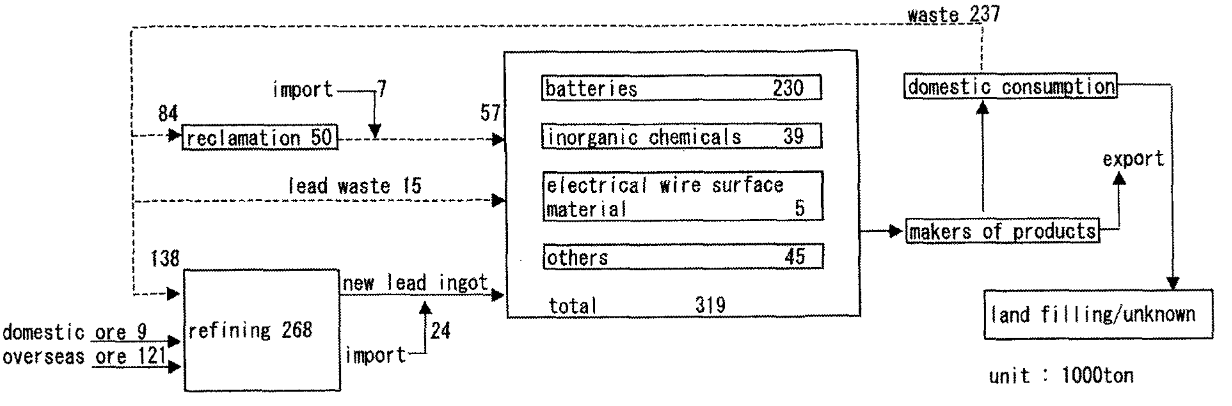

Fig.2 Material flow of lead

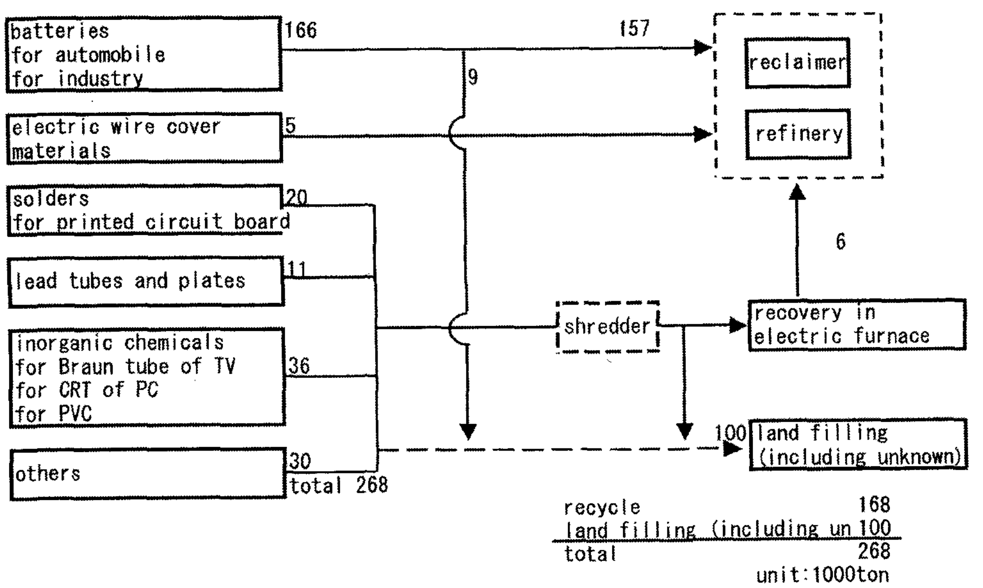

Fig. 3 Material flow of lead

5. THE CASE OF CADMIUM

Figures 4 and 5 show the supply and demand of cadmium respectively. The main use of cadmium is as Ni-Cd batteries. The total production of cadmium in Japan is estimated at 70 % of the total world production. The batteries itself and the batteries included in electric and electronic equipments are exported. The rest are the pigments and alloy elements.

The changes in the number of batteries produced are shown in Fig. 6. With the increase of Li and Ni-H batteries, Ni-Cd batteries have decreased. Table 3 shows changes in cadmium usage in Japan.

Figure 7 shows the material flow of cadmium in 1999. There is a recycling system for Ni-Cd batteries, in Japan. Cadmium contained in batteries is recycled. Cadmium is collected in the dust of an electric furnace in the steel industry. Cadmium is thought to come from Zn coated steel sheets or Ni-Cd batteries.

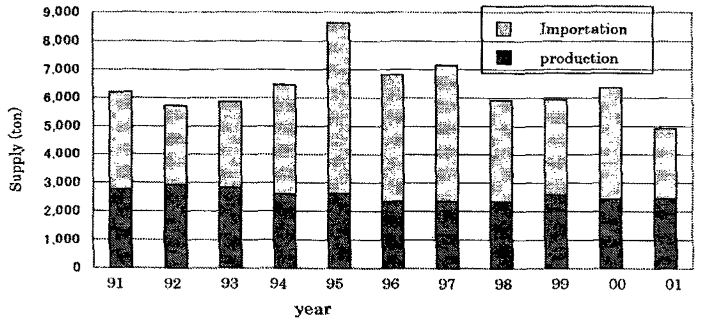

Fig.4 Cadmium supply

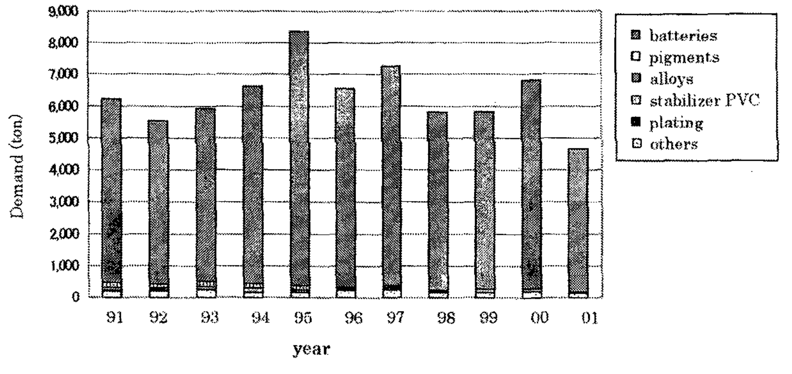

Fig.5 Cadmium demand

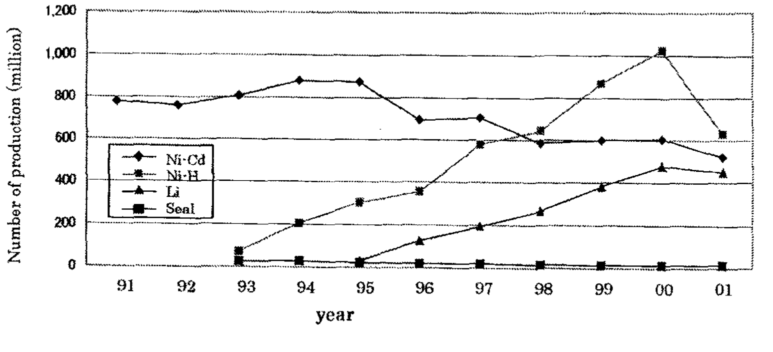

Fig.6 Change of number of production in batteries

Table 3 Changes in cadmium usage in Japan (ton)

year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
batteries	5,771	5,120	5,416	6,173	7,979	6,219	6,874	5,578	5,563	6,520	4,468
pigments	147	123	160	142	143	54	69	20	4	23	3
alloys	94	69	83	132	70	58	64	52	113	72	40
Stabilizer of PVC	24	24	14	9	0	0	0	0	0	0	0
plating	6	4	3	11	0	0	1	1	0	0	1
others	187	202	245	162	171	226	249	163	157	195	139
total	6,231	5,542	5,921	6,630	8,363	6,557	7,257	5,813	5,838	6,810	4,650

(Bulletin of Japan Mining Industry Association)

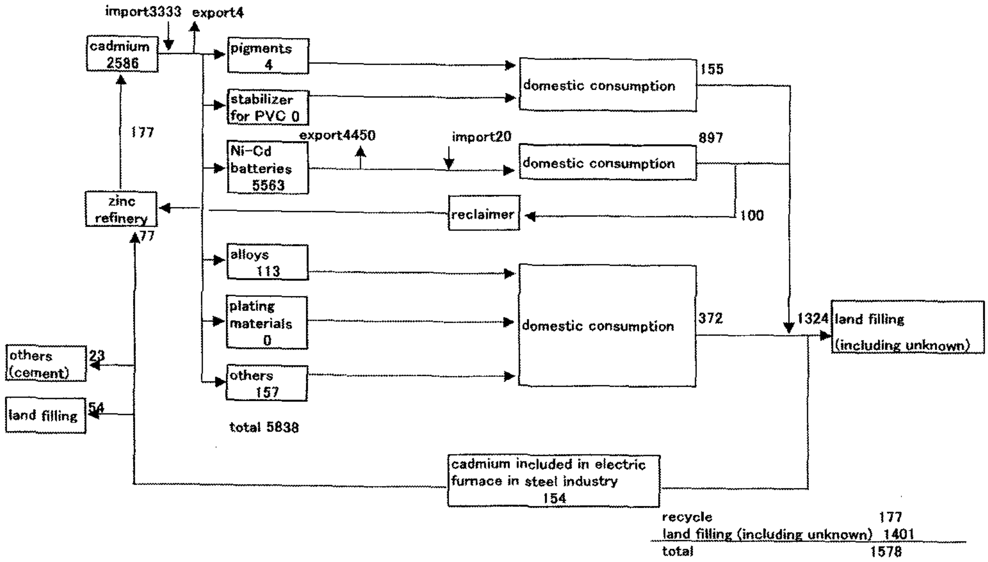

Fig.7 Material flow of cadmium

6. THE CASE OF MERCURY

Table 4 shows the changes in mercury supply in Japan. The supply, stocks, reclamation/collection and imports of mercury decrease every year, however at its highest this figure was more than 1400 tones one year.

Table 5 shows mercury demand in Japan. About 10 tons of mercury is used in Japan. The uses of mercury are inorganic chemicals, electrical instruments, measuring instruments, batteries and others. The domestic supply and demand of mercury is understood, but the discharge of mercury from the waste equipments is not certain.

Due to the recent growing environmental consciousness, coupled with low regulation, the collection of batteries and fluorescent lights have begun.

Table 4 Changes in mercury supply in Japan (ton)

year	1980	1985	1990	1995	1996	1997	1998	1999	2000*	2001*
supply	1439	1095	340	133	164	107	101	81	79	77
stock	1007	401	186	86	96	95	77	69	71	65
reclamation/collection	366	677	128	44	56	8	17	1	1	1
imports	66	17	26	3	12	4	7	10	7	11

*2000 and 2001 are calendar years

(Year book of minerals and non-ferrous metals statistics)

Table 5 Mercury demand in Japan (calendar year) unit: kg

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
caustic soda	—	—	—	—	—	—	—	—	—	—
amalgam	2,175	1,700	1,456	503	516	139	66	55	0	0
inorganic chemicals	8,196	3,707	4,251	5,111	5,054	6,945	4,323	459	1,760	1,477
electrical instruments	6,735	6,048	6,032	3,971	2,627	2,679	3,358	2,196	2,453	2,289
measuring instruments	16,197	15,268	11,186	8,766	9,500	5,771	4,923	1,953	5,275	3,335
batteries	46,889	35,177	27,020	16,470	4,637	4,881	3,856	3,199	3,438	2,058
others	6,885	2,104	3,608	3,583	3,275	3,862	2,703	3,886	175	1,208
total	87,077	64,004	53,553	38,404	25,609	24,277	19,229	11,748	13,101	10,367

(Bulletin of Japan Mining Industry Association)

7. CONCLUSION

The material flow of lead, cadmium and mercury has been studied in this work. The resource and environmental issues of these metals have attracted great attention in recent years. However, the need for more detailed material flow analysis is paramount.

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