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News and commentary

Information technology waste problems in Japan

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1 Discarded IT products: assault on the environment

The use of cellular phones in Japan is growing so fast that an estimated 70000 used cell phones are discarded each day (Tsuhan Seikatsu 1999). Most of them are not discarded because of physical breakage, making them unable to function; users are merely "done with them" and toss the appliances for new ones or later models.

It is not only cell phones, however, as over the last few years the production and consumption of personal computers and other information technology (IT) products has skyrocketed, with new products frequently emerging. What is more, even though products are still useful, they are discarded because of social obsolescence-Discarded IT equipment amounts to about 140000 tons annually (2001statistics).' Here I focus mainly on computers and telecommunication equipment. Although in terms of quantity this seems small in comparison with 400 million tons of industrial waste and 50 million tons of municipal waste, qualitatively IT products are potential hazardous wastes because of the heavy metals and plastics they contain. These wastes cannot be disregarded in view of the need for environmental protection and resource management.

1.1 Hazardous substances in IT products

I use the example of personal computers to show the hazardous substances IT products contain (Table 1). When using computers we are usually looking at the cathode ray tube (CRT) monitor, which includes glass and solder, which in turn contain lead. Each CRT shields users from its radiation by using about 2 kg of lead, an element that damages human central and peripheral nerves and has deleterious effects on the growth and development of children. Lead is also an endocrine disruptor. For these reasons it must be used with care.

Table 1. Materials used in desktop computers

Substance	Content (wt%)
Plastics'	22.9
Lead	6.9
Aluminum	14.1
Iron	20.4
Tin	1.0
Copper	6.9
Zinc	***22***
Cadmium	**0.009**
Mercury	**0.002**
Gold	**0.001**

Source: Electronics Industry Environmental Roadmap 1996

'Plastics contain polybrominated flame retardants

Dismantling a computer shows that plastic is used in the printed circuit board, connectors, enclosure, cables, and other parts. Flame retardants are added to plastic to prevent fires. Brominated flame retardants may produce bromide dioxins and brominated furans. Especially significant problems are the flame retardants polybrominated diphenyl ethers (PBDEs) themselves plus the highly toxic polybrominated dibenzofurans (PBDFs) and polybrominated dibenzo-p-dioxins (PBDDs), which are formed when burning and recycling plastics (Commission of European Communities 20(X)). In fact, PBDEs, which are suspected endocrine disruptors, have been detected in the blood of recycling plant workers in high concentrations. In Sweden the concentrations of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in human breast milk have been declining over the last few decades, but concentrations of the PBDEs have been rapidly climbing (Sjodin et al. 1999; Noren et al. 2(KK)). Flame retardants are used not only in IT products but also in curtains and a wide variety of other products, and they are widely dispersed, as shown by their detection in Arctic seals.

In Japan Dr. Shin'ichi Sakai, director of the Waste Research Division at the National Institute for Environmental Studies, has shown that plastic television parts using brominated flame retardants also contain bromide dioxins as impurities. He pointed out the possibility that dioxins can be formed even without burning the plastic (Sakai 2000).

The flame retardant triphenyl phosphate, which is used in video displays, is an indoor air pollutant and a known allergen (Carlsson 2000). A cautious attitude is also needed toward the toxicity (causing headaches, nausea, diarrhea, nervous system disorders) of antimony oxide, which is also used in large quantities as a flame retardant.

Persona] computers and other portable IT products are powered by a variety of batteries, and those containing cadmium and mercury require caution. Cadmium is found in not only nickel-cadmium batteries but also in printed circuit boards and semiconductors. It enters the body via inhalation or food and accumulates there because of a long half-life; it causes symptoms of poisoning. As seen from itai-itai disease, the element also damages kidneys.

Japan consumes more cadmium than any other country (Hata 2001) (in 1997 it consumed about 7200 tons, or 44% of worldwide use); about 6000 tons a year are used in NiCd batteries, about 20% of which are discarded in landfills. This amount corresponds to about 190 tons of cadmium. About 20% of NiCd batteries are recovered, and the rest are either kept in storage or incinerated, scattering the cadmium. Tests of rice paddies near waste incinerators in Chiba and Ibaraki prefectures have found the rice and soil to be contaminated with cadmium. In 1985 cadmium spread from a NiCd battery disassembly facility into the Koide River watershed, causing the worst soil contamination in Japan, at 3304 ppm(Matsuzaki et al. 1987).

Mercury is found in dry cells and circuit resistors. As with Minamata disease, methyl mercury travels through the food chain and accumulates in the body. It causes chronic toxicity and damages the brain. Worldwide, 22% of mercury is used in electric and electronic products, including fluorescent lights and batteries.

1.2 IT waste disposal

It is clear from the foregoing discussion that improper disposal of discarded IT products can make them into hazardous wastes. Careful consideration is required regarding the environmental cautions needed, but here we broadly examine what environmental problems might arise when discarded IT products are incinerated, when they are landfilled, and when they are recycled.

When IT products are incinerated with municipal wastes, they substantially increase the heavy metals' levels and those of compounds of chlorine, bromine, and other elements over the levels usually found in municipal wastes. When burning brominated flame retardants at low temperatures (600°-800°C), the copper in other wastes catalyzes the formation of bromide dioxins and brominated furans. Although improving the incineration method is important, it is vital that discarded IT products containing heavy metals and compounds with chlorine, bromine, and other elements be separated from municipal wastes. Until now the discarded consumer appliances recovered by municipalities have been shredded and separated, with most of the plastic being incinerated, but this method should be reconsidered.

When disposing of IT products in a landfill, it is impossible to prevent heavy metals from leaking outside the site. Especially, disposal in uncontrolled landfills almost certainly has an undesirable environmental impact. Of particular concern are the leaching and vaporization of hazardous substances. For example, breaking circuit resistors allows the mercury to leach out, and polychlorinated biphenyls (PCBs) leach out of capacitors. If brominated flame-retardant plastics and plastics with cadmium are put in landfills, PBDEs and cadmium leach into the soil and groundwater. Much lead leaches out of CRTs, and unintended fires at landfill sites cause dioxins to form.

What happens when IT products are recycled? There is no doubt that recycling provides resource conservation and extends the life of landfill sites. Recycling also can be polluting, however, unless wastes are properly treated because, unlike reuse, recycling involves the reprocessing of materials. As we have seen, recycling the plastic parts of discarded IT products requires that the plastic be heated, which could generate dioxins and furans. These are not the only problems arising from recycHng. Air pollution by heavy metals can occur when recycled products contain lead, cadmium, or other heavy metals. PCBs and other substances come from transformers, and pollution also arises from shredding processes.

Therefore, it is possible to reduce substantially the many health and environmental impacts of discarded IT products if landfills and incineration are avoided, and separate collection programs are instituted. At present only about 40% of IT products are collected (JEITA 2002), and in that hght it would perhaps be best if these products did not use hazardous substances in the flrst place. At the very least, manufacturers must restrict the use of hazardous substances and quickly find substitutes. The European Union (EU), as a matter of fact, is working on prohibiting the use of substances that include lead, cadmium, mercury, hexavalent chrome, and brominated flame retardants (Commission of European Communities 2(X)2).

2 Problems of discarded IT products in Japan

2.1 Amount of IT waste generated in Japan

There are no data from studies on the volume of scrapped computers in Japan, but there are estimates. *The Report on the Takeback, Disposal, and Recycling of Discarded IT and Computers* (JEITA 2002) provides the following estimates. The total number of discarded IT products including general-purpose computers, mid-range computers, workstations, PCs, and printers during 2000 reached 140000 tons. The total number of discarded computers, including personal computers, increased year by year until peaking in 2001 at 80000 tons. It is predicted to level off at around this figure because computers are getting smaller and lighter. Figure 1 shows that in 2000 the amount of discarded personal computers was 72000 tons (business use 64000 tons; consumer use 8(XK) tons). Whereas the amount tended to increase slightly until 1998, it soared from then until 2001, and since that time it has hovered around 80000 tons annually. This is because although the number of discarded computers increased their weight did not increase much owing to the greater ownership of notebook computers.

2.2 Takeback, disposal, and recycling by computer makers

Let us examine the management of discarded computers (Fig. 2). Even the same computer gets different treatment depending on whether it was used in a business or a private home. Only about 25% (17000/64000 tons) of business computers and 12% (1000/8000 tons) of consumer computers are recovered.

Fig. 1. Estimated information technology (IT) waste. Source: JEITA 2002

Products Collection Treatment

(Municipalities)

Fig. 2. Takeback and treatment of used personal computers (PCs) in Japan, t, 10000 tons.
Source: JEITA 2002

The above-cited JEITA report estimated that 72000 tons of computers were discarded in 2000, and the computers taken back by manufacturers accounted for about 25% of them. All the recovered computers were from businesses. Although there is a fee-based system under which manufacturers recycle computers from business users, there are in fact not that many manufacturers that can properly manage and recycle them, which is causing a trend toward exporting discarded computers. Consumers get rid of their computers by selling them to used product dealers, by having their municipalities collect them as bulky waste at low cost or no charge, or by sending them for shredding and separation. Using the 1998 discarded computer collection data for Metropolitan Tokyo's 23 wards to estimate the amount of discarded consumer computers recovered by all Japan's municipalities yields a figure of about 7000 tons, or about 350000 computers. Both the percentage and the number of units are low. It is believed that only about 12% of discarded consumer computers are recovered. The rest are put away in closets or disposed of by municipalities. Computer collection and management in Japan is inadequate because, unlike the EU, no takeback obligation was imposed on computer makers, and there were no reuse or recycling systems that gave the environment top priority.

Finally, the government required that discarded computers be recovered beginning in April 2001. This was not done under the Home Electrical Appliance Recycling Law because computers are also used by businesses. Instead, computers became "specified products for resource recovery" under the Law for the Promotion of Utilization of Recycled Resources (Revised Recycling Law). This law requires that business-use computers be properly recycled when discarded, at which time users pay a fee. The program is already in operation. After collection, personal computers are dismantled, separated into the chassis, printed circuit boards, and waste plastics and then recycled. The resource recovery targets are 50% for desktop computers and 20% for notebook computers. On the other hand, the law requires that used consumer computers be recycled with advance fee payment made at purchase time. This program is not yet enacted.

2.3 Environmental problems of computer recycling

From an environmental perspective, when recycling personal computers caution is needed for handling circuit boards and monitors. Displays come in two types: CRTs and liquid crystal displays (LCDs). CRTs are basically the same thing as a television picture tube and present the same environmental challenges because both contain lead.

Tanaka and Sekito of Hokkaido University Graduate School Engineering have performed detailed research on lead contamination caused by consumer electronics (Sekito and Tanaka 2000). They calculated that the lead concentration for household bulky waste overall is 2048g/ton and found that 90% of that comes from televisions. Almost all the lead in televisions is in the lead glass of picture tubes.

For this reason the concern when recycling CRT monitors is what to do with the lead. Currently, the idea is to reuse the lead glass as is instead of separating the lead from the glass. Japan's Household Appliance Recycling Law, which took effect in April 2001, stipulates that four categories of appliances including televisions must be recovered when discarded, and it also sets recycling rates.

Now let us examine LCD recycling. Computers are currently switching from CRTs to LCDs, but the latter also present a problem because in some LCDs the glass contains arsenic. A vital technique called "clarification" is used to remove bubbles that form during the manufacturing process for liquid crystal glass, and arsenious acid is often used because it has the best clarification effect. As a result, the glass has about 1% residual arsenic by weight. Some health effects that arise from arsenic poisoning are general physical debility, neuralgia, skin damage, anemia, liver tumors, and leukopenia. Although clarification processes that do not use arsenic have been developed, al present only about 30% of liquid crystal glass is produced using this method.^ The main ingredients of liquid crystals are iridium and tin compounds, and caution is needed against the toxicity of iridium. This has been a survey of computer recycling. In terms of technology, trends are leading toward designing computers to make them recyclable, thereby accommodating improvements in component performance, and toward developing substitutes for hazardous substances. In terms of social institutions, it is necessary to create a system by which manufacturers take back their products and to create regulations governing incineration, landfilling, and recycling that might cause pollution.

2.4 Problem with 35% cell phone recovery

In Japan more than 60 million cellular telephones are now in use, and the number keeps climbing (Fig. 3). There is no other consumer electronics product like cell phones, which sell nearly 100 million units around the world in 3 months. People use cell phones for less than 2 years on average, and new products are developed quickly. Already cell phones have broken out of the "telephone" mold and are evolving as mobile multimedia. New functions are continually being added, such as the NTT Docomo's "i-Mode." Even though a cell phone might be perfectly usable, the lack of new features make it "behind the times."

Although accurate data are lacking, as mentioned at the beginning of this article, it is said that 70000 cell phones are discarded in Japan in 1 day. Because cell phones weigh less than 100 g each, it is possible that they find their way into household trash. When cell phones are discarded, the gallium arsenide and heavy raetals used in their electronic components could leach out and pollute. In addition to these environmental problems, throwing cell phones away loses scarce metals such as palladium. Research by Dr. Yukio Yanagisawa at the University of Tokyo predicts that by 2010 the Japanese will have discarded a total of 600 million cell. These data are from an interview with a liquid crystal glass manufacturer.

Fig. 3. Cell phone sales units: 10000. Source: Japan Association of Telecommunications

Industry 2000 phones, and that the arsenic contained in their semiconductors will total 93 kg (Yomiuri Shimbun 2001). Deadly poisonous beryllium is used (as an alloy with copper) in the spring material of electronic components. Cell phones were originally rented to users, but since 1994 users have purchased their phones. Nevertheless, it is often the case that users do not directly pay the price of their phones, which is 20000 yen or more. Many readers have no doubt seen advertisements in the cities proclaiming something such as "Buy your cell phone now and pay only 1 yen." Cell phone companies subsequently recover the price of the phones through the call fees paid by users. Because users therefore do not sense much of an economic burden from purchasing their phones, they tend to lose them easily or discard them for newer models. Telecommunication carriers are voluntarily beginning to recover cell phones and batteries because even though phones are sold to users the carriers maintain their link with users through number changing and other services. In 1999 NTT Docomo recovered about 5.9 million cell phones, automobile phones, and personal handyphone system (PHS) phones as well as about 4.9 million batteries, but even that is estimated to be a recovery rate of only about 40%.

A report by the Clean Japan Center says that the apparent number of discarded cell phones (the annual number of phones produced minus the increase in subscribers) in 1998 was 26.5 million (Clean Japan Center 2000), which agrees with the theory of 70000 phones discarded daily. About 35% of them are recovered by dealers (Table 2), but it is estimated that of the remaining 65% half are discarded and half are put in storage. According to the report, at the beginning of 2001 the parts inventory of portable terminal makers and unsold distributor stocks together possibly totaled almost 100 million units.

Table 2. Recovery of used cell phones, 1998
Source: Japan Association of Telecommunications Industry 2000

Fig. 4, Recycling of cell phones. Source: Nikkei Communications 2000

2.5 Cell phone collection system

The postcollection process involves, for NTT Docomo, accepting used appliances from customers, removing the batteries, sorting by type, then passing the items on to intermediate processing contractors for separation and disassembly. Nonferrous metal companies and others then recover the metals (Fig. 4). Even if used cell phones could be sold for recycling, the costs of collection and transport would outweigh the sale price, apparently making for a loss of about 100 yen. However, considering that cell phones whose actual unit cost is at least 20000 yen 2ire being sold at substantial discounts, one expects that a small collection fee could be paid. Cell phones contain gold, silver, palladium, and other precious metals, and their gold content per unit weight is higher than that of gold ore. In fact, Yokohama Metals Company in Sagamihara City buys discarded cell phones for 120-150 yen per kilogram and extracts precious metals including gold and silver (cell phones are only a small part of its business). However, because cell phones have such resource value only after being recovered and transported, the major focus is on this collection and transport system and its cost. The next-generation cell phones appeared in 2001. So long as one has a memory card, it is possible to continue using the same service even when changing phones, but losing the link between the carrier and the customer makes it difficult to recover discarded phones. If carriers ever stop directly selling phones, consumers will buy them from manufacturers; and if by this means consumers start paying the real costs of their cell phones themselves, it will lead to a market for used phones. Furthermore, if it becomes possible to use cell phones abroad, it could spell the end of the current recycling scheme under which telecommunication carriers recover the appHances. It is therefore important to set up a collection system with the cooperation of carriers, phone makers, and users.

There are still no plans for recycling cell phones under the Household Appliance Recycling Law, but northern European countries, where cell phones have a high penetration rate, are setting up organizations that recover and recycle all cell phones no matter which carrier one uses and no matter which company has manufactured the phone. Under this arrangement, which provides useful ideas for Japan, cell phone makers later pay the costs for their phones. It is necessary to work on setting up a system for a cell phone collection and transport system while combining technological improvements for reuse and recycling.

An example of how to facilitate reuse would be to standardize battery shape and attachment mechanisms. This would make it possible to reduce waste by 30% merely by removing the battery when a cell phone is recovered. Recycling could be facilitated by adopting phone configurations, making it easy to remove the plastic casing and electronic components, and by standardizing the type of plastic. There are already practical technologies for recovering valuable metals.

3 Computer waste exported to China

The United States exports discarded computers. Exports to China and Taiwan are especially large, but information is difficult to come by because even when computers are sold to domestic recyclers there is no telhng where they will end up.

Making money exporting discarded computers requires that the destination countries have cheap labor and lax regulations. According to an electroscrap collection pilot program in San Jose, CA, it costs 10 times as much to recycle CRT displays in the United States as it does to export them to China. Under the 1989 Basel Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal, discarded computers are regarded as hazardous waste because they contain lead, mercury, cadmium, and other substances. In 1998 the convention began to restrict their export for the purpose of recovery. The United States, however, has not ratified the Basel Convention, and it will likely continue exporting under bilateral agreements.

Let us examine how discarded computers are managed after arriving in China from abroad. A study by Professor Eiji Hosoda at Keio University found that overseas Chinese groups have created import channels along the Chinese coast near places including Guangzhou to bring computers from the United States, Japan, and other countries. Processors bum the electronic circuit boards and recover lead and other metals (BAN and SVTC 2001). Labor is cheap in China, and there is great demand for metals and recycled items. In 1998 Japanese businesses applied for permits to export 32400 tons of discarded computers and peripherals to China as "metal and electronic appliance scrap," but it appears that since that time such export perniits have not been granted because of Basel Convention restrictions.

In 2000 approximately 96% of the television sets, 14% of the personal computers, and 32% of the refrigerators manufactured in other Asian countries were exported to Japan. At the same time, Japan exported 38% of its used television sets and 33% of its used air conditioners to other Asian countries (Ministry of Economy, Trade and Industry 2002). These statistics show the transboundary movements of IT products in particular Asian countries. Therefore, it is urgent to set up a safe, environmentally friendly recycling system among Asian countries.

4 Conclusions

This article has been a survey on the problems of discarded computers and cell phones. I conclude with three observations. Technological innovation in these IT products is rapid. What is more, cell phones by nature tend to be mass consumer goods, so the consequence of their mass production and mass consumption is mass disposal; hence the problem of dealing with discarded phones is an integral part of our modern social system. Therefore, my first observation is that basically the only way to keep "used" cell phones from becoming waste is to avoid such fast social obsolescence and to set up a takeback and recycling system. Second, making effective use of resources while providing for environmental protection should be of primary importance with respect to discarded IT products.

To begin with, it is crucial that we institute changes in production by reducing the use of hazardous substances and developing substitutes. Manufacturers must at the same time design their IT products to facilitate reuse and recycling.

Third is the challenge of setting up systems to collect discarded products. The Organisation for Economic Cooperation and Development (OECD) is proposing extended producer responsibility, and the EU is trying to create a system that imposes a product takeback obligation on producers. Japan too should quickly incorporate provisions such as these into its system.

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