J Mater Cycles Waste Manag (2006) 8:1–12
DOI 10.1007/s10163-005-0147-0

SPECIAL FEATURE: REVIEW ARTICLE

E-waste

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Current status and research on E-waste issues in Asia

Received: November 4, 2005 / Accepted: November 14, 2005

Abstract Rapid economic growth in Asia and the increasing transboundary movement of secondary resources will increasingly require both 3R endeavors (reduce, reuse, recycle) in each country and appropriate control of international material cycles. Recently, managing electrical and electronic waste (E-waste) has become an important target for domestic and international material cycles from the viewpoints of environmental preservation and resource utilization efficiency. To understand the current status of E-waste issues in the context of international material cycles and to discuss the future tasks related to achieving 3R in the region, we organized the National Institute for Environmental Studies (NIES) E-waste Workshop in December 2004. This article reviews past studies on E-waste and briefly describes the topics presented and discussions held at the workshop. The topics at the workshop included E-waste generation, recycling systems, international trade, and environmental impacts. In addition, we discussed various issues such as terminology, current environmental concerns, and possible solutions. Transboundary shipments of E-waste should be conducted taking into consideration the concept of sustainable development. The direction of future research and possible collaborations are also discussed.

Key words E-waste · Asia · Recycling systems · Material cycles · Environmental preservation

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Introduction

Rapid economic growth in Asia and the increasing transboundary movement of secondary resources will increasingly require both 3R endeavors (reduce, reuse, recycle) in each country and appropriate control of international material cycles. To meet these needs, the prevention of environmental pollution and efficient utilization of resources will both be important.

In this context, Japan's National Institute for Environmental Studies (NIES) launched a research project (Structural Analysis of Material Cycles and Waste Management in Asia) in cooperation with the United Nations University/Institute for Advanced Studies (UNU/IAS, FY2002 to FY2003), the University of Tokyo (FY2003 to FY2004), and the Institute of Developing Economies (IDE/JETRO, FY2004), with funding by the Ministry of the Environment of Japan from FY2002 to FY2004. The objectives were to identify the structure of material cycles in Asia, focusing

mainly on material exported from Japan, to understand the current waste management situation in Asia and to identify the tasks needed to improve the situation.

NIES invited 42 Asian experts to the Workshop on Material Cycles and Waste Management in Asia, held at NIES, for three consecutive years (2002–2004). The workshops focused on waste management and material flow analysis (2002) and the international flow of recyclable resources and waste management, mainly on landfill issues (2003).

Recently, electrical and electronic waste (E-waste) has become an important target in managing domestic and international material cycles from the viewpoint of environmental preservation and resource utilization. To understand the current status of E-waste issues in the context of international material cycles and to discuss the future tasks required to achieve 3R in each region, we organized the third workshop (renamed the NIES E-waste Workshop) in December 2004. This paper reviews past studies on E-waste and describes the topics presented at the workshop and the ensuing discussions.

Review of past studies

Literature review: past studies of domestic and international waste movements

The fact that limited information is available on the quantities of waste material that moves between countries has made it popular to investigate specific products or waste flows within a country or flows of wastes or used products between countries. Matsuto et al.,[1] Terazono et al.,[2] Stevel et al.,[3] and Macauley et al.[4] used this approach. A second type of study focuses on hazardous substance emissions associated with the recycling process, the international movement of hazardous wastes, or both. Reports by the Basel Action Network (BAN) and the Silicon Valley Toxics Coalition (SVTC),[5] Alter,[6] and Sakai[7] are examples of this type of study. By its nature, hazardous waste needs special care and treatment, whether it is exported or processed domestically. The transboundary movement of hazardous waste is particularly contentious when the waste is exported from developed countries to developing countries. For example, BAN and SVTC, both active nongovernmental organizations (NGOs), warn that the current recycling system in China for imported E-waste causes significant environmental harm, partly because many electronic products contain hazardous materials or parts. A third type of study deals with the responsibility of producers for the collection and recycling of postconsumer or end-of-life products[8] or discusses the relationship between economic development and importation of secondhand products and materials.[9] This section reviews some of the key articles in this area.

Matsuto et al.[1] examined domestic efforts to recycle used home appliances in Japan, focusing on recent legislation (the Home Appliance Recycling Law) that requires appliance producers to take responsibility for the collection and recycling of end-of-life products. The authors surveyed recycling plants to investigate operational data such as the material content in each type of designated product, the material balance, the recovery rate of heavy metals, and the configurations of the recycling processes. They concluded that waste generation and emissions of heavy metals were reduced by implementation of the law, although the extent varied in four scenarios.

Terazono et al.[2] provided a broad perspective of material flows between Japan and China. First, they referred to the definition of recyclable resources under Japan's Fundamental Law for Establishing a Sound Material-Cycle Society and argued that whether or not a product is valuable does not correspond exactly to whether recyclable resources will be recycled. Similarly, whether products are valuable or not depends on the buyers and sellers: that is, the market decides prices. The article provides an overview of international material flows for products such as plastics and used home appliances.

Exporting Harm[5] is one of the reports most frequently cited, because of its stark portrayal of informal E-waste recycling in China as environmentally harmful. It criticizes the United States for exporting E-waste under the name of "recycling" without bearing responsibility for the cost, and states that this process is harmful to the poor and vulnerable in Asian countries, such as women and children. BAN and SVTC also state that because most collected E-waste is not treated domestically and is instead exported, the current E-waste management system does not function properly; the solution is to strengthen producers' responsibility for eliminating toxic substances from their products and for collecting end-of-life products. To accomplish this, BAN and SVTC strongly recommend examining the legislative actions taken in the EU.

Stevels et al.[3] studied consumer electronics products produced by Phillips in the Netherlands, and listed the main areas related to the organization and operation of "take back" and recycling of discarded consumer appliances: the party responsible for the issues, the financial aspects of the system (i.e., cost-sharing mechanisms), and the organizational structure of the take-back and recycling system.

When we consider the actual motivation to properly dispose of an electronic product, the costs and benefits are obviously influential. Macauley et al.[4] provided important insights on this issue. For example, the glass in cathode ray tubes (CRTs) contains a large amount of lead, which can adversely affect human health and soil and water quality. They examined the costs and benefits associated with several policy scenarios for the disposal of the CRTs used with computers.

Workshops on transboundary waste management

Many materials and wastes are currently traded internationally, but E-waste has drawn particular attention from government officials, NGOs, researchers, and practitioners

Table 1. Brief list of some workshops on E-waste management

Workshop	Date/place	Organizers	Participants from
The Third Workshop on Material Cycles and Waste Management in Asia (NIES E-waste Workshop)	December 14–15, 2004,	National Institute for Environmental Studies, Japan	China, Hong Kong SAR, Korea, India, The Philippines, Taiwan, Japan
Kick-off Workshop for Capacity Building for Recycling-based Economy in APEC	August 30 to September 1, 2004, Gotemba, Japan	Institute for International Studies and Training, Japan	China, Indonesia, Korea, Malaysia, Mexico, New Zealand, The Philippines, Taiwan, Japan
Regional Expert Group Meeting on E-waste in Asia–Pacific	June 22–23, 2004, Bangkok, Thailand (UNEP)	UNEP Regional Resource Center, Bangkok	Thailand, Switzerland, China, USA, India, Nepal, Japan
International Conference on Electric Waste and Producers' Environmental Responsibilities in China	April 21–22, 2004, Beijing, China	Greenpeace China and the Chinese Society of Environmental Science	Greenpeace International/China, Basel Action Network, China, Switzerland, India, UNU, Lund University, Silicon Valley Toxics Coalition
Asia–Pacific Regional Scoping Workshop on Environmentally Sound Management (ESM) of Electronic and Electrical Wastes	November 19–22, 2002, Tianjin, China	The Basel Convention Regional Centre in China	China, India, Malaysia, The Philippines, Singapore, Sri Lanka, Thailand, Vietnam, Japan

NIES, National Institute for Environmental Studies

at both the domestic and international levels.[5,8,10] For example, at least four international workshops on E-waste or international waste flow management were held in 2004. The transboundary nature of this issue requires discussion and exchange of opinions among developing and developed countries. Table 1 summarizes recent workshops that have focused mainly on transboundary waste movement in Asian countries. Clearly, E-waste management is becoming a central issue in Asia.

The discussions that occurred during these workshops covered aspects such as environmental impacts, health concerns, legal frameworks, international cooperation, and economic development, and reflected the complicated dimensions of the E-waste problem and the international movement of wastes. For instance, in a workshop organized by Greenpeace, Bo et al.[11] reported the work environment and health issues of workers engaged in the demanufacturing of E-waste in Guiyu (China). At the same workshop, Eugster[12] discussed the international partnership between Switzerland and developing and transitional countries to achieve proper E-waste recycling.

Collectively, these workshops reveal the growing presence of NGOs such as Greenpeace China. As Table 1 shows, Greenpeace China organized a workshop that brought together a number of other NGOs. BAN and SVTC, which also participated in the workshop, published a report[5] that is often cited by NGOs and researchers, implying that the impacts of their activities are becoming effective and explicit.

As seen in this section, much effort has been made to clarify some profiles such as material flow, environmental impacts, legal frameworks, and other social aspects associated with transboundary movements of E-waste. Continuous intellectual exchange and cooperation is required as well as more involvement from exporting countries such as Japan.

Individual topics at the Workshop

At the NIES E-waste Workshop (hereafter referred to as the Workshop), E-waste issues were presented from various viewpoints. In this section, we have divided these issues into four categories: E-waste generation, recycling systems, international trade, and environmental impacts.

E-waste generation

Most countries lack reliable data on E-waste generation. Williams[13] discussed E-waste generation by selected countries from a review of studies from the E-waste project based at Eidgenössische Materialprüfungs und Forschungsanstalt (EMPA)[14] in Switzerland (Table 2). Comparison of the figures in Table 2 is difficult because there is no standard definition of E-waste, and the methods used to estimate E-waste generation are not compatible among countries. Thus, although these figures provide an indication of the magnitude of the problem, it is important to question their reliability.

Sample data on E-waste generation in Asia are shown in Table 3, which is based on the presentations by each speaker at the Workshop. Because these countries have different target items of E-waste and different urban populations, it is difficult to compare any two countries. Nonetheless, it is clear that most Asian countries are generating increasing amounts of E-waste because of their rapid economic growth.[15,16,17]

These data are based primarily on sales data from each country, but are partially estimated using material flow models. Peralta et al.[15] used the end-of-life model of Matthews et al.[16] and accounted for the relationships among reuse, storage, recycling, and landfills. Yang et al.[17] and Jain

Table 2. E-waste generation in selected countries by EMPA project

Country	Total E-waste generated (tonnes/ year)	Categories of appliances counted as E-waste	Year
Switzerland	66042	Office and telecommunications equipment, consumer entertainment electronics, large and small domestic appliances, refrigerators, fractions	2003
Germany	1100000	Office and telecommunications equipment, consumer entertainment electronics, large and small domestic appliances, refrigerators, fractions	2005
UK	915000	Office and telecommunications equipment, consumer entertainment electronics, large and small domestic appliances, refrigerators, fractions	1998
USA	2158490	Video products, audio products, computers and telecommunications equipment	2000
Taiwan	14036	Computers, home electrical appliances (TVs, washing machines, air conditioners, refrigerators)	2003
Thailand	60000	Refrigerators, air conditioners, televisions, washing machines, computers	2003
Denmark	118000	Electronic and electrical appliances including refrigerators	1997
Canada	67000	Computer equipment (computers, printers, etc) and consumer electronics (TVs)	2005

Table 3. E-waste generation in Asia

Country	Home appliances[a]	Personal computers	Year
China	51480000	4480000	2003
India	Unknown	Unknown	
Japan	18625000	Approx. 80000 tonnes	2003
Korea	Unknown	1710000	2003
Philippines	2379142	Unknown	2004
Taiwan	53800 tonnes	21100 tonnes	2004
Thailand	Approx. 2400000[b]	Approx. 300000	2001

Data are number of units unless otherwise stated
[a] TV sets, refrigerators, washing machines, and air conditioners
[b] TV sets, refrigerators, and air conditioners

et al.[18] calculated E-waste generation by using sales data for each year and assumed product lifetimes. In addition, the Weibull distribution is often used for such modeling in Japan,[19,20] although a detailed description was not introduced at the Workshop.

Recycling systems in each country

Table 4 summarizes the existing E-waste management regulations in each country. In 2001, Japan implemented a recycling system for TV sets, refrigerators, washing machines, and air conditioners under the Home Appliance Recycling Law. Figure 1 shows the conceptual framework of material and monetary flows in the recycling of Japanese home appliances, and was originally provided by Sakai.[7] Recycling and transportation fees are paid by consumers, and discarded appliances are sent to recycling facilities. Tasaki[19] and Terazono[21] report that the appliances collected under this framework represent only about half of the estimated production, suggesting that the remaining half is either exported and/or disposed of domestically.

In 2003, Korea enacted a Recycling Law[22] legislating that TV sets, refrigerators, washing machines, air conditioners, and personal computers must be recycled under their extended producer responsibility (EPR) principle. Audio equipment and mobile phones followed in 2005. Taiwan has also identified TV sets, refrigerators, washing machines, air conditioners, and information technology (IT) wastes such as computers, monitors, and printers as "due recycled waste."[23]

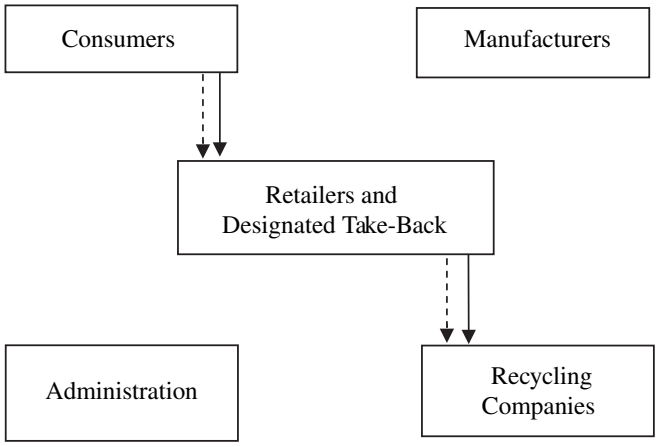

Fig. 1. Material (*solid lines*) and monetary (*dashed lines*) flows in Japanese home appliances recycling

In both Korea and Taiwan, manufacturers must pay recycling fees to recycling management bodies, and the work of recycling facilities is subsidized by these bodies. Figure 2 shows the material and monetary flows of E-waste

Table 4. E-waste management regulation in each country

Country	Items	Regulation	Brief explanation
Cambodia		No regulation for E-waste	
China	TV sets, refrigerators, washing machines, air conditioners, personal computers	Management of Recycling of Home Appliances and Electronic Equipment regulation was drafted in 2004	Distributors (retailers) have responsibility for collection and then transiting to recyclers. Recyclers should organize reuse, disassembling, or disposal. Consumers should send E-waste to collectors. Special national funding will be launched for E-waste recycling. Part of the funding will be from manufacturers
India		No regulation for E-waste	
Japan	TV sets, refrigerators, washing machines, air conditioners	Home Appliances Recycling Law (enacted 1998, enforced 2001)	Retailers are obliged to accept appliances discarded by consumers. Manufacturers are obliged to take these from retailers and to implement measures for reuse and recycling. Retailers and manufacturers can charge consumers for collecting, transporting, and recycling their discarded appliances
	Personal computers (both for business and household use)	Law for Promotion of Effective Utilization of Resources (2001 for business PCs, 2003 for household PCs)	Manufacturers are obliged to accept discarded PCs for recycling. Recycling fees are added to the sales prices.
Korea	TV sets, refrigerators, washing machines, air conditioners, personal computers (2003), audio equipment, mobile phones (2005)	EPR in Recycling Law (2003)	Government allocates mandatory quantity for recycling every year. Manufacturers must pay the standard expenses to the recycling bodies by item
Malaysia		No regulation for E-waste. In Environmental Quality (Scheduled Wastes) Regulations, 1989, discarded or off-specification batteries containing lead, mercury, nickel, or lithium from battery manufacturing plants are Scheduled Waste S271	
Taiwan	Waste home appliances (TV sets, refrigerators, washing machines, air conditioners) and waste IT products (personal computers, monitors, printers, notebook computers) as Due Recycled Waste	Waste Disposal Act (amended 1998)	Producers should take financial responsibility only (not physical responsibility). Producers shall submit recycling–clearance disposal fees to the recycling management bodies (RMF)
Philippines	Consumer electronics (radios, stereos, TV sets, etc.), white goods (stoves, refrigerators, dishwashers, washing machines, dryers, etc.)	Ecological Solid Waste Management Act of 2000 (RA 9003)	Consumer electronics and white goods are classified as special wastes requiring separate handling from other residential and commercial wastes
Thailand	Unknown	National Strategic Plan for the environmentally sound management of E-waste was recently drafted and submitted by the Thai government	

in the Korean and Taiwanese recycling systems. Because consumers do not directly pay the recycling fees when discarding appliances (unlike in Japan), they are presumably more likely to send discarded appliances to recyclers. However, Kim[22] and Lin and Lin[23] described the difficulties in collection under the laws and the responsibility of manufacturers. As for the collection, discarded items can be easily sent to recycling facilities that are not covered by Korean and Taiwanese laws because of the low recycling fees paid by manufacturers and the high economic value of the items, even after they have been discarded. Recycling fees paid by manufacturers and consumers are compared in Table 5. As for where the responsibility lies, there has been discussion about the limited responsibility of manufacturers compared with that specified in the European waste electrical and electronic equipment (WEEE) directive that requires manufacturers to take back their products.

Table 5. Recycling fees paid by either manufacturers or consumers in three regions

	Korea (won/kg)	Taiwan (NT$/unit)	Japan (JPY/unit)
Fees paid by	Manufacturers	Manufacturers	Consumers
TV sets	165	278–412	2835
Refrigerators	131	441–662	4830
Washing machines	122	352	3675
Air conditioners	89	282	2520

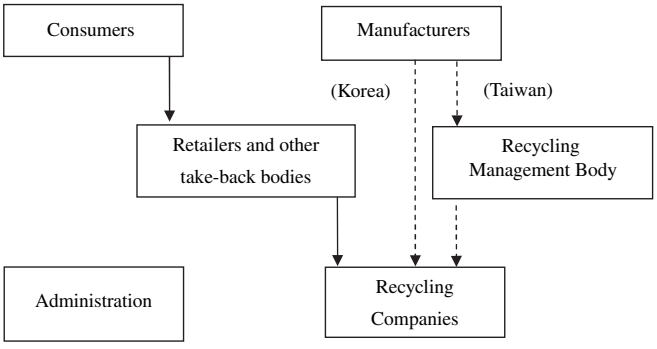

Fig. 2. Material and monetary flows in the E-waste recycling system in Korea and Taiwan

The Chinese policies and regulations for controlling the environmental problems from E-waste management are in the process of being drafted.[17] Currently, three regulations govern E-waste management. The National Development and Reform Commission (NDRC) enacted the Management of Recycling of Home Appliance and Electronic Equipment regulations in November 2004 to increase resource utilization efficiency. The State Environmental Protection Administration (SEPA) is drafting the Technical Policy of WEEE Pollution Prevention and Control regulations to govern pollution releases at the end of a product's life. The Ministry of Information Industry (MII) is drafting the Pollution Control and Management of IT Products regulations to prevent pollution at the source. Under the NDRC's policy, E-waste categories include TVs, refrigerators, washing machines, air conditioners, and personal computers. A special national funding will be launched for WEEE recycling. Partial funding will also be collected from producers.

In the Philippines, the Ecological Solid Waste Management Act of 2000 was signed into law in January 2001. Under the law, consumer electronics and white goods (major household appliances, such as stoves and refrigerators, that are typically finished in white enamels) are classified as special wastes that must be handled separately from other residential and commercial wastes. Although the law recognizes these types of wastes, no clear guidelines specify how to handle them.[15]

Other countries, such as Cambodia, India, and Malaysia, have no specific regulations for management of E-wastes, with the exception of batteries.[18,24] In these countries, informal sectors (including scavengers) play a large role in collecting and recycling valuable parts.[18,25] These sectors also account for a large share of the total waste collection in Korea, Taiwan, and Japan, where formal legal recycling systems already exist.[22,23]

International trade

In addition to the BAN/SVTC report,[5] Yoshida et al.,[26] Kojima and Yoshida,[27] and Leung et al.[28] have reported the problem of inappropriate recycling of E-waste in Guiyu, southern China. Part of the E-waste treated in Guiyu is imported from countries such as the United States, Japan, and Korea.

Transboundary movement of hazardous waste is controlled by the Basel Convention, which entered into force in 1992. The convention lists hazardous wastes in Annex VIII (list A) and nonhazardous wastes in Annex IX (list B), as shown in Table 6. Some types of E-waste, such as batteries, electronic assemblies or cables containing lead, and CRT glass, are listed in A. International trade in such waste requires prior notification between exporting and importing nations. There is also a proposed amendment, the "Basel Ban," which prohibits international trade in waste classified as hazardous in the list. Although this has not been ratified, the European Union is voluntarily abiding by the ban. It should also be mentioned that products destined for reuse are excluded from classification as waste.

Some countries have regulations in addition to those of the Basel Convention. For instance, China's SEPA issued the Regulations on the List of Goods Prohibited to be Imported, which included 21 categories of E-waste. However, Kojima and Yoshida[27] report inadequate control of secondhand electronic products. One problem is that the definitions to distinguish secondhand electronics and E-waste are not clear. Another is that international trade in secondhand goods is not controlled by the Basel Convention. Table 7 shows current regulations that affect trade in secondhand electronic products.

It is difficult to accurately and consistently identify the amounts of secondhand electronic products because most national systems tracking trade do not have specific codes distinguishing new and secondhand goods under the Harmonized Commodity Description and Coding System (HS). Terazono et al.[2] and Terazono[21] have tried to distinguish between the trades in new and secondhand TV sets among Japan, China, and Hong Kong, using the unit prices reported in Japanese trade statistics.

The handling of metal scrap after the dismantling of E-waste is also complicated. For example, the export of this

Table 6. E-waste listed in the Basel Convention

Annex VIII	List A	Annex IX	List B
A1170	Unsorted waste batteries, excluding mixtures of only list B batteries. Waste batteries not specified on list B containing Annex I constituents to an extent to render them hazardous	B1090	Waste batteries conforming to a specification, excluding those made with lead, cadmium, or mercury
A1180	Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included on list A, mercury switches, glass from cathode ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B B1110)	B1110	Electrical and electronic assemblies: electronic assemblies consisting only of metals or alloys. Waste electrical and electronic assemblies or scrap (including printed circuit boards) not containing components such as accumulators and other batteries included on list A, mercury switches, glass from cathode ray tubes and other activated glass and PCB-capacitors, or not contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III (note the related entry on list A A1180). Electrical and electronic assemblies (including printed circuit boards, electronic components and wires) destined for direct reuse, and not for recycling or final disposal
A1190	Waste metal cables coated or insulated with plastics containing or contaminated with coal tar, PCB, lead, cadmium, other organohalogen compounds, or other Annex I constituents to an extent that they exhibit Annex III characteristics	B1115	Waste metal cables coated or insulated with plastics, not included in list AA1190, excluding those destined for Annex IVA operations or any other disposal operations involving, at any stage, uncontrolled thermal processes, such as open burning
A2010	Glass waste from cathode ray tubes and other activated glasses	B2020	Glass waste in nondispersible form

Table 7. Trade regulation of secondhand electronic products in selected countries

Country/ region	Content
China	In 1998, import of secondhand home appliances was prohibited. In 2000, import of E-waste was also prohibited. In 2002, import of crushed E-waste was also prohibited
Hong Kong	International trade of secondhand items is not under control, but a notice on distinction of secondhand and waste was issued by the Environmental Protection Department, such as testing before shipment and proper packaging
Japan	International secondhand electrical products are not under control
Korea	Export of collected E-waste is not prohibited, regardless of whether dismantled or not
Philippines	Prior notice and consent is requested, even for secondhand items
Thailand	Copying machines less than 5 years old or other electronic products less than 3 years old can be imported

scrap is not regulated by the Japanese Home Appliance Recycling Law. Figure 3 shows the relationship between the scrap's economic value and the role of the recycling law. Home appliance recycling facilities extract from the used appliances a wide variety of valuable parts and raw materials, such as steel and nonferrous metal scrap, as well as some valueless materials such as CFCs and dust. Japan and other countries such as China have different standards for valuable and valueless resources, while strong foreign demand is directed at valuable resources in Japan. As a result, the volume of valuable resources sent to domestic recyclers is declining in Japan, and valueless resources are undoubtedly being left to disposal facilities in Japan.

In Korea, the export of collected E-waste is not prohibited, regardless of whether the waste is dismantled. Kim[22] noted that crushed E-waste is categorized as scrap that is needed to be recycled overseas. This E-waste is exported under the name of mixed metal scrap.

Environmental impacts

Leung et al.[28] focused on the adverse effects of the hazardous substances, such as persistent organic pollutants (POPs) and heavy metals, that are contained in electrical and electronic products. The emission of these harmful substances is mainly the result of the primitive techniques used in extracting metals from used products, such as open burning of the E-wastes. Citing the examples of Guiyu (Guangdong Province, China) and Taizhou (Zhejiang Province), Leung et al. reviewed the potential environmental and health risk of these hazardous substances.

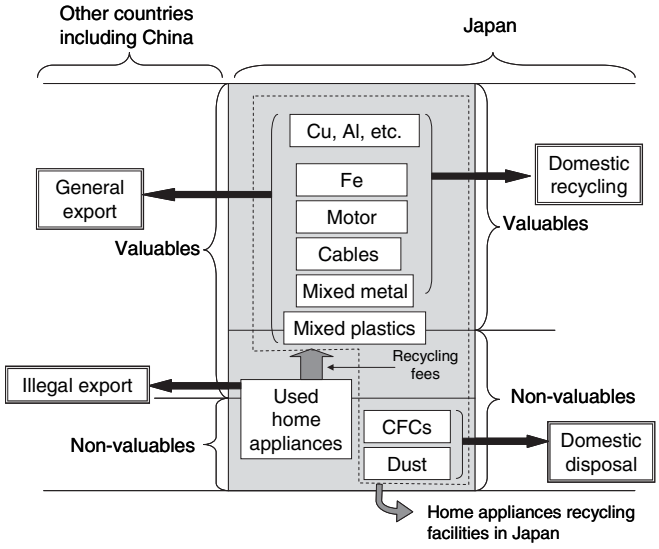

Fig. 3. Relationship between economic value and the role of recycling law in the case of home appliances

Sakai[7] also reported that hazardous polybrominated diphenyl ethers (PBDEs) are likely to be released into the environment during the recycling of used home appliances if there is no appropriate control system. The Japanese Home and Appliance Recycling Law does not specifically address PBDEs, and thus may not reduce PBDE loads in recycled materials or prevent their emission into the environment. Thus, he recommended implementing dust control during recycling (because PBDEs are found in dust) and suggested that a globally harmonized scheme, such as the European Union Directives for restriction of certain hazardous substances (RoHS), is necessary to control hazardous substances in recycled materials.

Inanc[29] reported the potential pollution caused by E-waste in landfills and dumps in Asia. After the useful components have been recovered, most of the remaining materials are dumped and thus create significant potential health and environmental risks. Electronic products contain heavy metals such as lead, mercury, cadmium, and arsenic, as well as organic chemicals such as polychlorinated biphenyls and brominated flame retardants (BFR). The compositions of municipal solid waste (MSW) in developing Asian countries differ greatly from those in the Western industrialized world and Japan. Asian waste (except in Japan) is dominated by biowaste. In the relatively warm climates that are common in the region, leachate produced by precipitation generally increases rapidly. The majority of the heavy metals found in landfill leachates may originate from E-waste.

Discussion at the Workshop

In this section, we summarize the discussions at the Workshop. First, we focused on four issues: unifying terminology, screening current concerns from the environmental viewpoint, the positive and negative aspects of international trade, and others. We closed the discussion with the potential solutions for the problems recognized.

Terminology

Issues related to the word "waste" were discussed. The word is controversial, since its original meaning did not include secondhand goods that could be reused. But secondhand electrical appliances and electronics cannot be neglected when discussing E-waste. In this context, the Japanese experience was discussed. Because waste usually means valueless items, illegal disposals, such as those that occurred in the Teshima Island Industrial Waste Case,[30] have occurred whereby certain business sectors insisted that their wastes were valuable. In response, new terminologys "waste, etc." was introduced under the Fundamental Law for Establishing a Sound Material-Cycle Society, established in 2000, which defined more clearly whether something was valuable. Another new term, "recyclable resources (materials to be used cyclically)" (*jyunkan-shigen* in Japanese) was also introduced, since most items classified as "waste, etc." should be recycled.

Waste or "recyclable resources" can be either valuable or valueless. Thus, it is necessary to clarify whether these categories include "secondhand" or "used" goods. Similarly, "reuse" is sometimes included in "recycling," and this can lead to confusion.

The term "E-waste" is easy to understand and is often used. However, few definitions or explanations appear, other than in existing regulations. The EU uses WEEE to describe these materials, but this definition does not resolve the above-mentioned problems related to the definition of waste. A clearer definition is needed to support regulation, and this definition should include secondhand goods and clarify whether materials and parts such as wires in E-waste are included.

Some alternative terms for E-waste were introduced:

- "E-waste for reuse" and "E-waste for recycling"
- "Discarded consumer electronics" (DCE)
- "Used recyclable electronic component application" (URECA)

As an example of specific words related to E-waste, participants discussed the two meanings of PCB: polychlorinated biphenyl and printed circuit board. To avoid confusion, participants proposed the following alternatives for printed circuit board: PC board, PWB (printed wiring board), and electronic circuit board.

Concerns from an environmental viewpoint

In terms of environmental pollution, inappropriate handling such as open burning must be addressed. Open burning, especially of wires and cables, apparently may create persistent organic pollutants (POPs). There may be resulting health effects from these pollutants. Occupational

effects have already been reported and include diseases of the skin, stomach, and other organs. These health problems arise mainly as a result of metal recovery using low-cost techniques that fail to protect workers. Workers at landfill sites are affected through dust inhalation (including brominated flame retardants) and exposure to leachate. In contrast, the effects on residents living near these sites are unclear and are currently under investigation.

Wires and cables are of particular concern. Open burning of these items is still carried out, but it is not clear whether this represents more than a small proportion of the total handling of these materials. Primitive recyclers are gradually being gathered together in designated recycling parks in China; however, mechanical processing with grinders and separators is gradually prevailing.

Any recycling activities generate residues, and these are an important concern. The rate of residue production is usually unclear. These residues may have effects on future generations.

Positive and negative aspects of the international trade in E-waste

We should recognize that there are also positive aspects of the international trade in E-waste. For example, the positive aspects include the following:

- US of the unfulfilled potential of the resources, such as recoverable copper in wires, becomes possible.
- The working lives of products, through reuse, can be extended.
- Cheap secondhand goods can still be used in many recipient countries, even if the goods are considered obsolete in the exporting countries. This not only increases resource utilization efficiency, but also provides benefits for people in the importing countries.
- Employment of local people, local economic growth, and a profitable businesses may be generated, in the especially for informal sector.
- Export of some E-waste may be a solution where treatment techniques are inadequate in exporting countries, such as the Philippines.

At the same time, there can be negative effects caused by the international trade of E-waste; for example:

- Inappropriate technologies are still being applied in recipient countries.
- The imported secondhanded products will necessarily become waste sooner or later in the importing countries.
- Often, related industries in recipient countries, especially in the informal sectors, do not consider externalities such as environmental effects. Market price alone does not reflect the true economic value of a material.
- Transactions in secondhand goods are hard to control.
- Recycling facilities in exporting countries face difficulties in collecting E-waste.

Other issues

Additional aspects should be examined to cope with ongoing E-waste issues. For example, EcoDesign and cleaner production techniques should be emphasized more, rather than relying on end-of-pipe technology. Another example is to choose materials during design and manufacture that make E-waste recycling easier. However, implementing this approach will require long lead times. Until the effects of the EcoDesign concept are felt, wastes will remain the same and will have to be sorted well.

A second aspect is to examine the supply chain of electrical and electronic products. The upstream supply chain is already global. Thus, when we consider the downstream flow in the form of E-waste, we cannot neglect the global upstream aspects. Moreover, we cannot depend exclusively on domestic recycling.

Possible solutions for the concerns raised

Our proposals

We proposed several solutions to the concerns raised above, especially concerns associated with international trade in E-waste. The following, we feel, are the most important solutions:

- Minimum standards and improved awareness are needed for recycling in Asia, especially in the receiving countries.
- Alternatives for recycling technologies and materials must be developed.
- Harmonization is needed among governments concerning environmental issues and trade in Asia.
- Enforcement and regulation policies must be included in any discussions.
- The informal sectors that are deeply involved in materials cycling must evolve into more formal sectors, especially in developing countries. This is a big issue for all downstream businesses.
- All costs must be internalized rather than ignored as externalities.
- Generation of E-wastes must be reduced. This could be accompanied by the promotion of appropriate reuse.

All of these solutions are equally important; however, because the last three are considered difficult to implement, we discussed them in further detail. The discussion will be summarized in the following section.

Formalization of the recycling sector in developing countries

In many developing countries, informal sectors play significant roles in recycling E-wastes. Although some people suggest that these informal activities should not necessarily be formalized, formalization remains an important issue. As an example of formalization, the Japanese experience in

recycling lead batteries in the 1970s was presented, based on Kojima's analysis.[31] Participants at the Workshop learned that:

- Pollution control regulations were imposed by the local government of the area where each recycler was located, not by the central government.
- Recyclers formed an association to share information and improve compliance with the regulations. This association also helped fund the activities of recyclers.
- The first stage of the formalization involved registration of all recycling facilities. To encourage registration, heavy obligations were not imposed.
- After registration, the next stage involved tightening of the regulations. However, the standards remained reasonable and enforceable.
- At this stage, it was also better to set a time limit for adoption of the standards.
- A notification system should be formalized to improve information sharing.

In addition to the previous points, on the basis of the Japanese experience, the following points were raised as policy options to accelerate formalization:

- Tax reductions/incentives for recycling industries could be provided.
- Low-interest loans for the installation of pollution-control equipment would be useful.
- More information concerning the potential for cleaner production could help to implement appropriate technologies.
- Factories can be relocated to industrial parks to upgrade facilities for the reduction of pollution.
- Environmental awareness should be increased.

The first four points represent incentive programs. The last point does not directly provide incentives to recycling industries, but is beneficial in the broader sense.

Two difficulties with incentive systems were pointed out. First, when the profit generated by remaining informal is larger than the incentive to become formal, the incentive system does not work. In addition, if illegally imported wastes are sufficiently profitable, there is no need to collect domestic wastes. This means that international material cycles could create obstacles to the proper management of domestic E-waste. Despite these difficulties, subsidization seems to be a strong candidate solution, and all participants agreed that proper subsidies should be provided.

Internalizing the costs

To internalize the recycling costs (formerly considered to be externalities), two key questions must be answered. Responsibility is the first one. One sound proposal was the "profit-maker pays principle." However, the following drawbacks were noted:

- Both importers and exporters could be considered profit-makers, so identifying which one should pay seems difficult.
- In practice, it is easier to control exporters than importers.
- The trade in E-waste is relatively small, so that sufficiently detailed customs inspections seem difficult.

Reexporting E-wastes was another concern. In some countries, computers are dismantled and then the CRT glass is exported to other countries. Potential reasons for this reexporting include:

- There is a desire to satisfy demand in the importing countries.
- Better technology in importing countries makes it economical to import these materials from countries with less-suitable technologies.
- Industries established in a free-trade zone, designed to export all products, should be expected to export these goods.

The greater the number of countries involved in the recycling process, the more the responsibility becomes dispersed during both the recycling stages and the manufacturing stages. For example, if parts are produced in one country and assembled in another country, it is difficult to apply the polluter pays principle (PPP). This principle offers some incentives to producers, but is difficult to apply in this case.

A second question involves how much each agent should pay and what scheme should be applied for the payment. Once again, source control (i.e., exporter control) seems more practical, although there is currently almost no control of secondhand exporters. One possible system for transboundary movement of E-wastes would be to require exporters to deposit money in an international recycling fund. A recycling industry in the importing country could then be subsidized by withdrawals from this fund. In the existing trade of general merchandise some countries have already implemented bilateral treaties on tariffs. This type of treaty could also be applied to control the trade in secondhand goods.

Promotion of "reduce" and "reuse"

If E-waste causes problems, the first priority should be to reduce its generation. In this regard, consumers in exporting countries should change their lifestyles. For example, consumers in developed countries often purchase new computers to obtain a newer model, not because their current computer is broken. If the lifespan of the PC could be prolonged, less E-waste would be generated.

In addition, reuse should be promoted; however, noneconomic obstacles interfere with the market in secondhand materials. For example, software license agreements could interfere with the trade of secondhand computers because of the unsophisticated secondhand market system. This obstacle increases the amount of recycling rather than reuse. Therefore, a broader sense of "design for reuse" is required.

International collaboration among companies seems to be an interesting idea for promoting reuse. If the introduc-

tion of common parts becomes possible at an international level, more components of imported E-waste could be more easily reused. In addition, the dismantling process would become easier and safer.

Another factor that discourages reuse is the difficulty in differentiating reusable E-waste from nonreusable E-waste. For example, excess stock could be exported as secondhand goods that are obviously different from real end-of-life goods. Appropriate differentiation could thus help to promote reuse.

Concluding remarks

Transboundary shipments of E-waste should be conducted taking into consideration the concept of sustainable development. Because the value of products and even waste and their transboundary movement can be explained by the differences of various socioeconomic conditions in importing and exporting countries, transboundary shipments could contribute to increase the utilization of limited natural resources. However, negative impacts associated with the shipments are likely to coexist if no actions are taken to control them. One challenge for such control is to determine the appropriate spatial scale of international and/or domestic recycling.

At the Workshop, the direction of future research and possible collaborations were discussed. First, we all agreed that information exchange is essential. This information includes both data and systems, mainly involving legislation. In addition, a future outlook on the demand and generation of E-waste is necessary.

Acknowledgments This article includes various discussion points that are not fully agreed by all the authors. The article also reflects contributions from many participants at the NIES E-waste Workshop and cooperators other than the authors. This support is greatly appreciated.

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