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# E-Waste Recycling: Where Does It Go from Here?

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E-waste recycling has become a hotly debated global issue. This study, using China as a case study, analyzes the environmental, economic, and social implications of e-waste recycling in the developing world. More practical approaches, taking into account local economic and social conditions and the principles of Extended Producer Responsibility, are recommended to alleviate the increasing environmental disruption from improper e-waste disposal.

## INTRODUCTION

Electronic and electrical products, such as refrigerators, washing machines, mobile phones, personal computers, printers, and television sets, are ubiquitous in the modern society. Along with economic growth, ownership of electronics has been rapidly increasing around the world. At the same time, continuing technological innovation has resulted in early obsolescence of many electronic/electrical products; e.g., the average lifespan (2 yr) of a new computer in 2005 was less than half of that (4.5 yr) in 2000, and has been continually declining.[1] A combination of increasing ownership and shortened lifespan has led to rapid growth in the amounts of unwanted and obsolete electronics (commonly known as e-waste). It was estimated that the rate of e-waste generation globally was approximately 40 million tons $yr^{-1}$.[2]

Management of e-waste has been recognized as a great challenge to the human society. Concerns focus not only on the volume of e-waste generated, but also on the list of e-waste-associated toxicants. Numerous studies have revealed that abundant toxicants, including, but not limited to, heavy metals, polychlororinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), could be leached into the ambient environment during e-waste disposal with primitive methods, posing serious risks to environmental and human health.[3−11] Well managed sanitary landfills have been demonstrated to be the most efficient option for preventing these toxicants from leaching.[8,12] On the other hand, electronics also contain valuable and/or rare materials such as gold, palladium, copper, and plastics, among others. A previous study found that e-waste contains more rare and noble metals than typical metal mines.[13] Clearly, e-waste recycling may be able to at least partially fulfill the global demand for metals, especially in regions enduring resource shortages. Reuse of secondhand electrical and electronic devices has also been encouraged to extend their lifespan.[8,14] Applications of Life Cycle Assessment and Multi Criteria Analysis on e-waste management also have pointed to recycling as the most appropriate strategy for e-waste disposal.[15,16]

The relatively high cost for e-waste disposal in developed countries has driven recycling operations to developing countries such as China, India, and Pakistan (Figure 1, left).[17] It is


**Figure 1.** Map of (left) the main routes of transboundary transport of e-waste (adapted from Basel Action Network, Silicon Valley Toxics Coalition, Toxics Link India, SCOPE (Pakistan), Greenpeace China) and (right) e-waste processing regions in China (e = e-waste recycling site).

estimated that nearly 80% of all e-waste generated in developed countries is exported elsewhere.[18] This trans-boundary trade turns e-waste recycling, a net cost activity in developed

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**Figure 2.** Primitive e-waste disposal in Longtang (one of the global largest e-waste recycling sites in Guangdong Province of China; Figure 1, right): (A) sorting recyclable plastics and aluminum without any gloves or protection; (B) dismantling wires for copper; (C) acid stripping; (D) stove for incineration of e-waste; (E–G) imported e-waste from Japan and North America; and (H) transport of e-waste for local e-waste recycling operations in Longtang. (Note: One of the authors took these photos on May 19, 2012).

countries, into a profitable business in the developing world.[19] Moreover, low labor cost and strong demand for raw materials in the developing world[20] have also encouraged small operators, without proper pollution control equipment and technology, to recover valuable materials from e-waste, further stimulating the trans-boundary flow of e-waste. In response to this situation, an international treaty, the *Basel Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal*, was enacted to ban the international trade of hazardous wastes including e-waste. Correspondingly, China, India, and some other Asian countries have recently amended their laws and regulations to limit e-waste importation and primitive recycling.[1,21] Yet the situation has not been satisfactorily improved, partly because major e-waste exporters such as the United States have not strictly enforced or even ratified the Basel Convention and e-waste has been generated at alarming rates in developing countries. Ineffective enforcement of laws and regulations is an additional negative factor.[21]

In the rest of this article, we will use China as a case study to analyze the economic, social, and environmental implications of e-waste recycling in the developing world. We will then make some recommendations with the hope of improving the management of e-waste recycling activities. As China has long been the largest global importer and recycler of e-waste and, in fact, is home to the world's largest e-waste recycling operation, the experiences learned from China would be beneficial for other developing nations that attempt to alleviate the increasing environmental disruption from e-waste disposal.

## ■ STATE OF E-WASTE IMPORTATION AND RECYCLING IN CHINA

Presently, approximately 70% of e-waste generated worldwide is processed in China every year,[22] i.e., 28 million tons $yr^{-1}$ based on the estimated amount of 40 million tons $yr^{-1}$ produced globally.[2] Guangdong Province of South China and Zhejiang Province of East China (Figure 1, right) are two regions with the most intensive e-waste recycling activity, mainly due to their convenient locations for importation.[23] Importation of e-waste has increased in coastal China, almost coincidental with the rapid expansion of the regions' electronics industry during the last few decades. Electronics manufacturers are also concentrated in these regions, which provides a market for use of recycled materials from e-waste. On the other hand, government-promoted exports have stimulated domestic manufacturers to respond quickly to technological advances,[23] further increasing the demand for materials.

Domestic generation of e-waste has become increasingly significant due to the increasing popularity of modern electronics in China with a huge consumer base. A report by the United Nations Environment Programme estimated that the amounts of e-waste generated domestically from obsolete computers, cell phones, and televisions in China will be approximately 4, 7, and 1.5 times greater by 2020 than in 2007.[17] By then, China would become the world's second largest producer of e-waste (2.3 million tons $yr^{-1}$), just behind the United States (~3 million tons $yr^{-1}$).[17]

To deal with the worsening e-waste situation, China has established a few regulated management systems for e-waste. By 2002, China's Environmental Protection Administration had licensed 509 enterprises as importers and processors of waste, in an attempt to curb the growing illegal activities of recycling imported e-waste in coastal China.[23] As pointed out previously,[24,25] and further confirmed by our own experience in Longtang of Guangdong Province (one of the largest e-waste recycling centers in China; Figure 1, right), most e-waste recycling methods in China have remained primitive. For example, dismantling of e-waste often takes place without any gloves or protection, kneeling in dust and debris, and sorting through copper wires, capacitors, recyclable plastics, and aluminum (Figure 2A and 2B. Other unsafe practices include cathode-ray tube cracking and dumping, acid stripping of chips (Figure 2C), printed circuit board recycling (Figure 2D), plastic chipping and melting, and dumping of waste residues.[25] To recover copper from e-waste, for instance, wires are pulled out, piled up, and burned, while printed circuit boards are baked and dismantled. These processes can emit organic pollutants such as dioxins, as well as toxic cyanide and acids used to remove gold from printed circuit boards.[24]

Because of all these negative consequences, primitive e-waste recycling operations are deemed illegal and therefore supposedly prohibited by domestic laws and regulations. Unfortunately, administrative and statutory interventions have largely become ineffective on the local level. We hypothesize that current legislation, mainly focusing on environmental issues, is inadequate to address the economic and social implications of e-waste recycling operations for local residents. The following section is intended to address these issues.

## ■ ECONOMIC AND SOCIAL IMPLICATIONS OF E-WASTE RECYCLING

**Economic Benefits.** E-waste contains considerable quantities of valuable and reusable materials such as precious metals and plastics. For example, a typical printed circuit board is composed of ~16% copper, ~4% solder, ~3% iron and ferrite, ~2% nickel, and ~0.05% silver by weight.[26] In addition, the combined number of mobile phones and personal computers sold worldwide in 2007 alone may constitute up to 3% of gold and silver, 13% of palladium, and 15% of cobalt supplied by the world's mines.[17] E-waste recycling may potentially be an attractive business, because metals contained in e-waste are more abundant than those in ores. For instance, concentrations of gold in gold ores are typically 0.5−15 ppm,[27] while those in printed circuit boards can be 10 times greater (e.g., 150 ppm in expansion cards and higher than 10 000 ppm in central processing units).[28] By recycling 70% of e-waste generated globally (28 million tons), China would potentially recover 5.6 million tons of copper each year, which is ~19% of its known copper reserve and more than 10 times the volume of imported copper in 2009 (0.53 million tons).[29] China is often considered a resource-scarce country, because the per capita amount of natural resources is only 58% of the global average.[18] In addition, China's rapidly growing manufacturing sector demands large amounts of materials and components. Recycled materials are hence favorable and have become a profit-generating driver for manufacturers.

**Social Impacts.** E-waste recycling has played a significant role in industrializing some of China's rural areas, and has become an important revenue source for local governments and residents because it creates additional employment opportunities for unskilled locals and migrants.[30] Thirty large unauthorized e-waste recycling enterprises without import licenses have been founded during the past decade in Luqiao and three other adjacent towns (within a total area of less than 40 $km^2$) of Taizhou (one of the global largest e-waste recycling centers; Figure 1, right) in Zhejiang Province. As many as 13 000 local and migrant workers are employed by over 1500 family based firms.[23] The per capita net income for rural residents in Qingyuan of Guangdong, where one of the largest e-waste recycling centers (Longtang; Figure 1, right) is located, was ~¥6400 $yr^{-1}$ (~$1000 USD $yr^{-1}$),[29] not quite enough to support a family. By comparison, our personal conversation with local residents indicated that a wire-stripping worker employed by a small business of Longtang could earn ¥500 (~$80 USD) for recovering 1000 kg of copper (worth ~$7600 USD at the most recent price[31]) from wires, which takes approximately 5 d for an experienced worker to accomplish.

Despite potential health hazards from exposure to toxicants in e-waste, some workers seemed happy with their jobs, partly because these workers may not realize the risk. During a recent field trip to Longtang, we chatted with the owner of a small business about his future. The owner indicated that he knew the operation would not last long as the government will eventually shut down all primitive e-waste recycling businesses. When the owner was asked what he would do if his e-waste recycling business was closed, he smiled and said "Maybe I will get a few pigs and become a farmer". It is lamentable that local residents may not realize that they will probably not make decent profits by raising livestock or growing crops in the aftermath, because the area has already been contaminated with toxic metals and persistent organic pollutants that will persist for an unpredictable long duration.

## ■ ENVIRONMENTAL EFFECTS OF E-WASTE RECYCLING

**Positive Effects.** As mentioned above, e-waste is a rich source of plastics and rare metals. Plastics, mostly non-degradable in the environment, are pollutants themselves if improperly handled. Primary production of metals from mining ores consumes considerable land and energy, and releases huge amounts of wastewater, sulfur dioxide, and carbon dioxide. For example, the amount of carbon dioxide emitted is ~10 000 tons for primary production of 1 ton of gold, palladium, or platinum, and is 3.4 tons for 1 ton of copper.[17] By comparison, retrieval of metals from e-waste generates only a fraction of these carbon dioxide emissions and is also advantageous in terms of land and energy use.[13] For 1 kg of aluminum retrieved from e-waste recycling, the amount of energy used is 1/10 or less of that required for primary production, and e-waste recycling also reduces emissions of 1.3 kg of bauxite residues, 2 kg of carbon dioxide, and 0.011 kg of sulfur dioxide.[13] In addition, recycling 75 000 tons of metals (including 70 000 tons of copper/lead/nickel, 1100 tons of silver, 32 tons of gold, and 4100 tons of other precious metals) from 300 000 tons of recyclables and smelter byproduct by Umicore Precious Metals Refining, Belgium reduced emissions of carbon dioxide by 1 million tons in 2006 (0.28 million tons from recycling and 1.28 million tons from assumed primary production).[13] China recycles 28 million tons of e-waste each year, resulting in a reduction of carbon dioxide emissions by more than 90 million tons $yr^{-1}$, which is more than 1.2% of the total amount of carbon dioxide emitted by the entire country in 2009 (7710.5 million tons[32]).

**Negative Effects.** Primitive recycling operations can release large amounts of toxins, subjecting local workers to health hazards.[33] Numerous studies have reported greater levels of heavy metals and persistent halogenated compounds in regions impacted by e-waste recycling (Table 1).

*Air.* Atmospheric PBDE concentration in Guiyu (21.5 ng $m^{-3}$; Table 1 and Figure 1, right) was approximately 140 and 70 times higher than those in Hong Kong (0.15 ng $m^{-3}$) and Guangzhou (0.29 ng $m^{-3}$), respectively.[34] Similarly, the highest level of atmospheric PCDD/Fs (65−2760 pg $m^{-3}$; Table 1) in the world was reported in Guiyu.[35] In addition, significantly higher levels of chromium, zinc, copper, and lead at 1161, 1038, 483, and 444 ng $m^{-3}$, respectively, were found in airborne particles of Guiyu (Table 1), compared to those in other Asian countries.[36]

*Soil.* Greater levels of PBDEs were found in soils from areas influenced by e-waste disposal, such as acid leaching (2720−4250 ng $g^{-1}$; Table 1) and dump (893−2890 ng $g^{-1}$; Table 1),

**Table 1. Concentrations of Polybrominated Diphenyl Ethers (PBDEs), Polychlorinated Dibenzo-*p*-Dioxins and Dibenzofurans (PCDD/Fs), and Toxic Elements in Air, Soil, and Sediment from Areas Impacted by E-Waste Recycling in China**

| | air (ng m$^{-3}$) | soil ($\mu$g g$^{-1}$) | sediment ($\mu$g g$^{-1}$) |
|---|---|---|---|
| PBDEs | 21.5[a] | 2.72–4.25[d,e], 0.89–2.89[d,e] | 6–30[h] |
| PCDD/Fs | 0.065–2.76[b] | 0.85–10.2 × 10$^{-3}$[f] | 35 200[i] |
| nickel | | 85.2–722[g] | 151[j] |
| lead | 444[c] | 856–7040[g] | 448[j] |
| cadmium | | 5.51–42.9[g] | 7.48[j] |
| mercury | | | 307[j] |
| arsenic | | | 1000[j] |
| chromium | 1161[c] | 137–477[g] | 5800[j] |
| zinc | 1038[c] | 546–5300[g] | 1.81[j] |
| copper | 483[c] | 1370–14 200[g] | 13[j] |

[a]Guiyu.[34] [b]Guiyu.[35] [c]Guiyu.[36] [d,e]Soil impacted by acid leaching and dump, respectively.[37] [f]Surface soil near an e-waste recycling site of Taizhou.[7] [g]Soil from an e-waste recycling site in Guiyu.[25] [h]Lianjiang River of Guiyu.[38] [i]pg WHO-TEQ/g dry weight, Lianjiang River of Guiyu.[39] [j]Nanguan River of Taizhou.[40]

than those in soils from rice field (34.7–70.9 ng g$^{-1}$) and reservoir (2.0–6.2 ng g$^{-1}$) in Guiyu.[37] In Taizhou, levels of PCDD/Fs in surface soils near an e-waste recycling site (0.85–10.2 ng g$^{-1}$; Table 1) were significantly higher than those in soils from a reference site (0.073–0.456 ng g$^{-1}$) and in cultivated soils (0.0034–0.0338 ng g$^{-1}$) from several other provinces of China.[7] Similar results were also observed in Guiyu, i.e., levels of PCDDs/Fs in soils from areas influenced by e-waste recycling were significantly higher than those in soils from rice fields and reservoirs.[37] In addition, concentrations of cadmium (5.51–42.9 $\mu$g g$^{-1}$), chromium (137–477 $\mu$g g$^{-1}$), copper (1370–14 200 $\mu$g g$^{-1}$), nickel (85.2–722 $\mu$g g$^{-1}$), lead (856–7040 $\mu$g g$^{-1}$), and zinc (546–5300 $\mu$g g$^{-1}$) in soil from an e-waste recycling site in Guiyu (Table 1) were much higher than those in soil from reference sites.[25]

*Sediment.* The highest levels of PBDEs (6000–30 000 ng g$^{-1}$; Table 1) in river sediments reported so far were found in Lianjiang River of Guiyu, influenced by wastewater discharge from e-waste shredder workshops and acid processing.[38] Similarly, levels of PCDD/Fs in riverbank sediments from Liangjiang River (35 200 pg WHO-TEQ g$^{-1}$ dry weight; Table 1) influenced by e-waste recycling activities in Guiyu were much higher than those in sediments adjacent to residential areas (21.2–2690 pg WHO-TEQ g$^{-1}$ dry weight) and in downstream areas (1.69–3.49 pg WHO-TEQ g$^{-1}$ dry weight).[39] In addition, concentrations of nickel (151 $\mu$g g$^{-1}$), lead (448 $\mu$g g$^{-1}$), cadmium (7.48 $\mu$g g$^{-1}$), chromium (307 $\mu$g g$^{-1}$), zinc (1000 $\mu$g g$^{-1}$), copper (5800 $\mu$g g$^{-1}$), mercury (1.81 $\mu$g g$^{-1}$), and arsenic (13 $\mu$g g$^{-1}$) in surface sediment from Nanguan River draining through an e-waste recycling area of Taizhou (Table 1) were much higher than those for reference sites.[40]

*Human Exposure.* Levels of decabrominated diphenyl ether in serum of e-waste processing workers in Guiyu included the highest value reported so far at 3100 ng/g lipid, which was 50–200 fold higher than previously reported levels for occupational exposure.[41] The estimated daily intake of PCDD/Fs in six-month infants from around e-waste recycling sites of Taizhou was twice that from Hangzhou (the capital of Zhejiang Province).[42] Huo et al.[43] noticed blood levels of lead in children 1–6 years old from Guiyu (4.4–32.7 $\mu$g dL$^{-1}$ with an average of 15.3 $\mu$g dL$^{-1}$) were substantially higher than those in children from Chendian (without e-waste recycling activities). In summary, human health is seriously threatened by e-waste recycling via direct exposure routes such as inhalation, dust ingestion, and dietary ingestion.[4,10,44–46]

Although many previous studies have been conducted on the environmental occurrence of toxicants related to e-waste recycling, few have focused on the hereditary or biological effects and mechanisms, which is necessary to enhance the protection of the exposed environment and public health.[47,48]

## ■ STATE OF E-WASTE DISPOSAL MANAGEMENT IN CHINA AND RECOMMENDATIONS

Aiming to eliminate or mitigate contamination from e-waste recycling, China has ratified the *1992 Basel Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal* to ban e-waste importation. Several national and provincial laws, regulations, and rules have also been enacted to prohibit the collection, storage, transport, and disposal of e-waste in China.[18,21] National e-waste management-related legislation in China mainly includes the following: The Law on the Prevention of Environmental Pollution from Solid Waste, Notification on the Import of the Seventh Category of Wastes, and Notice on Strengthening the Environmental Management of Wasted Electrical and Electronic Equipment, Ordinance on the Management of Waste Household Electrical and Electronic Products Recycling and Disposal, and Management Measure for the Prevention of Pollution from Electronic Products, as summarized in a previous study.[18]

Besides legislative approaches, a more effective measure, i.e., setting up regional e-waste disposal centers with advanced technologies, has been recommended to reduce the harmful environmental consequences of backyard recycling operations.[21] Several international and national e-waste pilot projects have been built in China. Among them, a Swiss-Sino cooperation pilot project has been dedicated to establishing e-waste recycling facilities in four target cities across China since 2004.[17] Furthermore, DADI Environmental Protection based in Hangzhou was commissioned in 2003 to construct a centralized disposal center, making use of collection and recycling points throughout Zhejiang Province.[49] However, our recent field trip to a 5-km stretch of road in Longtang, crowded with numerous small e-waste recycling plants processing e-waste from North America and Japan (Figure 2E–G), indicated that the ongoing e-waste problems have not been effectively alleviated. We previously suggested that the lack of rigorous law enforcement and an ample supply of underclass laborers were the main reasons for the partial failure of laws and regulations regarding transboundary movement and disposal of e-waste in China.[21] This view, however, may require some amendments, amid the continuing growth of e-waste recycling businesses. Clearly, there are many barriers for effective implementation of current laws, regulations, and policies in China, considering the economic, social, and environmental driving forces.

First, laws and policies in China are inadequate in many aspects.[17] For instance, use of one standard policy to manage e-waste for different regions in China is problematic as "one size fits all" does not apply. Thus, policies for e-waste management should be flexible, considering the different economic and social conditions across the country. Meanwhile, several national government agencies (e.g., Ministry of Environmental Protection, National Development and Reform Commission, and National Ministry of Information Industry, etc.)[18] are simultaneously engaged in enacting regulations and management policies with their own agenda and territorial interests, resulting in overlapping jurisdictions and indistinct responsibility for stakeholders.[17] Therefore, a clear designation of the responsibilities for these government agencies is needed and an overall framework to synchronize the legislative process should be established. Moreover, government agencies at different levels lack a unified classification of e-waste. In some provinces, such as Guangdong, e-waste is regarded as hazardous materials, but it is considered as general solid waste in most other provinces.[50] In addition, not all types of e-waste were banned according to the Notification on Importation of the Seventh Category of Wastes, but only scrap computers, panel displays, television picture tubes, and similar electronic equipment.[23] This type of e-waste, however, may be disguised as scrap metal or secondhand electronic products which are legally allowed to enter China. Thus, stricter supervision of imported waste is needed.

Second, compared with government-authorized e-waste recycling operations possessing proper recycling technologies and receiving policy and financial support and/or subsidies from the government, unauthorized small businesses are more inclined to collect all possible e-waste from local communities besides buying imported e-waste. Domestically generated e-waste has become an increasingly important source for Chinese recycling business. High profits from primitive recycling allow unauthorized businesses to pay reasonable prices to consumers and professional collectors, which stimulates e-waste flow to these unauthorized recycling plants. On the other hand, unauthorized collection can result in a high collection rate of domestic e-waste and bears apparent economic and social benefits for the poor. In comparison, the two national experimental take-back systems for e-waste in Zhejiang Province and Qingdao City have had difficulty in obtaining sufficient e-waste to maintain normal operation.[23] Therefore, better cooperation between the government and unauthorized recycling businesses may be an alternative choice for enhancing the economic and social benefits of e-waste recycling, and at the same time minimize negative environmental consequences. The government should realize that maximizing profit should not be the top priority for e-waste recycling. They could collect and properly deal with hazardous materials from unauthorized plants, install best-practice landfills for hazardous wastes and incineration plants for specific waste streams at unauthorized plants, and/or offer them advanced equipment and technologies. In return, the government may charge these recyclers a higher tax on the basis of maintaining a stable market and price for recycled materials. Another strategy may be for the government to provide financial incentives for unauthorized businesses to resell e-waste to authorized operations.

Third, the economic stress of unskilled recyclers and the employment pressure of migrant laborers are major social barriers. The Chinese government has emphasized that primitive e-waste recycling has the potential to harm the environment and humans, and therefore declared it illegal.[21] However, the government has not implemented any stimulants for creating reasonable and safe jobs for the unskilled and underprivileged if primitive e-waste recycling is eliminated. Although it is unethical or unjust to expose powerless workers to toxicants unknowingly, it is equally unethical or unjust to deny them the opportunity to earn a decent salary for better living standards. Despite this contradiction, the challenge in finding appropriate employment and lack of education are the main motivation for unskilled laborers to work for primitive e-waste recycling businesses. It should be noted, however, that these problems may not disappear quickly under the current social and economic conditions. Therefore, it is important for the government to inform e-waste recyclers of the potential risk of primitive e-waste recycling and to increase their awareness of protective measures to minimize workers' exposure to toxins contained in e-waste.

In addition to the government's obligation of protecting the environment and people from threats by e-waste recycling, manufacturers should also assume the responsibility of reducing environmental hazards from their products. The principle of Extended Producer Responsibility (EPR),[51,52] which obliges producers to cover the cost of collection, recycling, and disposal, should be effectively and sufficiently implemented. Manufacturers should use designs beneficial to recycling, choose nontoxic, nonhazardous substances and recyclable materials, and provide information to aid recycling. Appliance retailers and service providers should also share the responsibility of collecting e-waste from consumers. The EPR does not obligate producers to physically take back and recover products, but requires producers to share the financial responsibility of authorized recycling activities.[53] With such financial support, authorized operations can compete with unauthorized businesses in collecting e-waste from the market,[53] resulting in reduced primitive recycling activities.

Implementation of EPR will surely elevate the cost of production. Therefore, governments may install certain incentive programs accordingly, such as tax incentives for companies practicing EPR. Currently, some developed countries which did not ratify the Basel Convention, such as the United States, have become the major source of e-waste illegally imported into the developing world. Rigorous enforcement of EPR, therefore, may be an effective way to reduce the negative environmental effects from primitive recycling of imported e-waste in the developing world. Although attributes of EPR have been embedded in some laws and regulations in China, many barriers remain.[53−55] Therein, smuggling is one of the most important, which evades the financial and physical responsibility for collection and recycling; therefore implementation of strengthened smuggling measures by the government has been called for.[53,56]

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### Notes

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