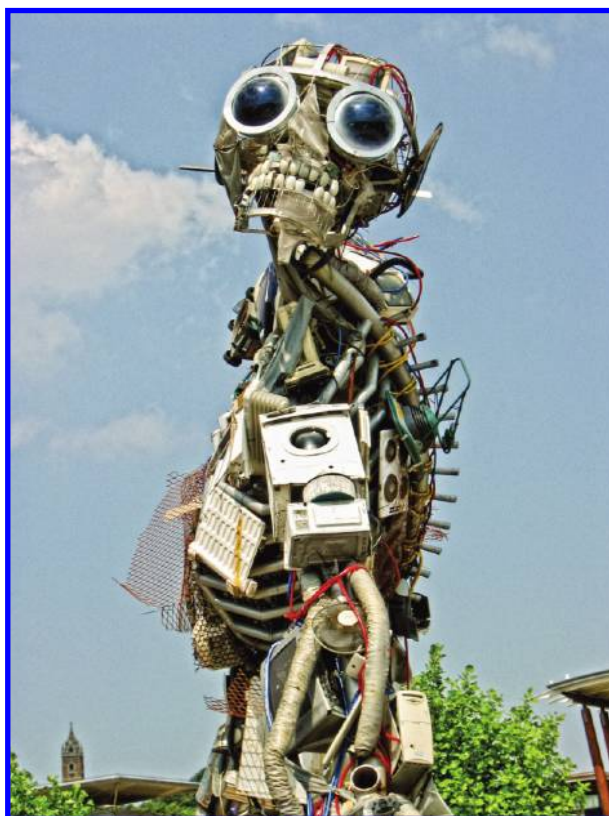


## Law Enforcement and Global Collaboration are the Keys to Containing E-Waste Tsunami in China

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Various levels of regulation are needed to stem the environmental health crisis due to e-waste importation and disposal in China.



SHUTTERSTOCK

Technological innovation and intense marketing strategies engender a rapid turnover of electrical and electronic devices. Consequently, large amounts of “e-waste” are constantly generated worldwide, posing an increasing global challenge for their disposal (1). The concern centers not only on the vast quantity of e-waste generated daily, but more importantly on the urgent need to deal with the large list of toxic ingredients associated with e-waste. Heavy metals and

polyhalogenated organics including PCBs can be released during e-waste disposal, posing extreme risk of harm to humans and the environment (2, 3).

As the world’s largest importer and recycler of e-waste, China experiences increasing pressure to alleviate the environmental consequences of e-waste handling. Additionally, that other Asian developing countries such as Cambodia, India, Indonesia, Pakistan, and Thailand, as well as African developing countries like Nigeria, also receive e-waste (1, 4), indicates that this problem is not just China’s. The difference is that while African countries mainly reuse disposed electronics, Asian countries simply dismantle them—in mostly unsafe manners (4). As the world begins to acknowledge the scope of the problem, it is notable that China, India, and other Asian countries have recently amended their laws to address e-waste imports (5). Further, some companies in developing countries have also attempted to safely dispose of e-waste with advanced technologies (4, 5).

Despite noble efforts, there has been extensive (international) media coverage reporting the serious environmental contamination and public health endangerment stemming from the improper disposal of e-waste in Asia and specifically China (6–8). The many underlying causal factors leading to China’s e-waste crisis have not been explored and evaluated. As a result, the global battle against illegal handling of e-waste continues to grow in a largely unabated fashion. In this article, we will describe China’s current state of disposing imported e-waste, summarize the existing Chinese laws and regulations concerning e-waste, then examine the motivations behind illegal handling of e-waste. Finally, we will present our thoughts and recommendations on how to curb illegal handling of e-waste in China.

### The Environmental Health Risk of E-Waste

The manufacturing process of computers and other electronic devices has them containing various high-risk chemicals such as lead, beryllium, mercury, cadmium, PCBs, and brominated flame retardants (BFRs) (2). (See Supporting Information [SI] for discussion of the possible sources of banned PCBs). These highly toxic chemicals are especially harmful to humans and the environment if not disposed of properly. Yet investigations revealed that the major e-waste recycling operations in China are primitive. These include toner sweeping, open burning, cathode ray tube cracking and dumping, circuit board recycling, acid stripping of chips, plastic fragmentation and melting, and dumping various waste residues (1, 4). The use of heat means that combustion-generated polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDDs/Fs) and polybrominated dibenzo-*p*-dioxins and dibenzofurans (PBDDs/Fs) can also be produced during the dismantling of e-waste (3). These activities liberate chemicals with exposure pathways that pose considerable occupational and environmental health hazards (9–12).

Indeed, a series of recent studies have found extremely high levels of PCDDs/Fs and PBDDs/Fs in soil (10) and air (11) around Guiyu, one of South China’s largest and best-known e-waste recycling sites (see below and Figure 1).



**FIGURE 1.** Localities of some e-waste dismantling and recycling sites in China (Beijing indicated for readers' geographic reference).

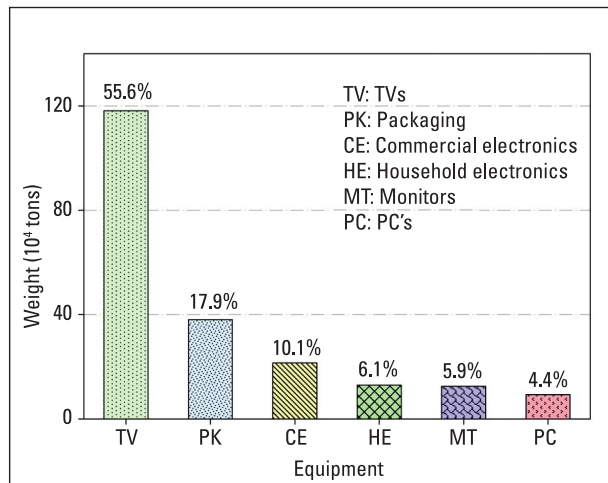
Additionally, very high levels of PBDEs (a type of BFR, manufactured as mixtures of penta-, octa-, and decabromodiphenyl ethers), have been detected in Guiyu residents (12), where ~80% of families work in the recycling and dismantling of e-waste. Blood sera levels of the "Deca PBDE" isomer, BDE-209, in Guiyu workers' exceed levels previously reported for occupationally exposed populations by a factor of 50–200: one worker in Guiyu had the highest blood serum level of Deca PBDE ever reported at 3100 ng/g lipid (6).

Such high levels in workers suggest that the problem is even more widespread than in the workplace. E-waste workers operating in confined spaces are likely to be exposed to PBDEs and may carry these and other hazardous materials home on their skin and clothing, thus unintentionally exposing their families to harm. Studies indicate that long-term exposure to PBDEs can lead to impaired learning and memory functions, as well as interfering with the thyroid and disrupting normal estrogen pathways (13). Further research strongly suggests that airborne pollution from e-waste disposal and recycling may be spreading toxic compounds to surrounding environments (6).

Although accurate statistics of e-waste sources in China are difficult to derive, inflows of e-waste are an important source of at least PBDE contamination in China (14). The Chinese domestic production of BFRs in 2000 was ~10,000 t compared to an average import of manufactured PBDEs on the order of 35,000 t/yr (14). Thus the majority of the PBDE inventory in China appears to have been accumulated from the importation of e-waste with only a small fraction coming from the use of commercial BFR-containing products. This further suggests that significant quantities of various other toxic substances (see above) have been deposited into the Chinese environment because of the importation of e-waste.

### Regulating E-Waste Importation and Disposal in China

E-waste is the fastest growing type of solid waste generated in the U.S. and other developed countries (1, 2, 5). It has been estimated that over 500 million computers became obsolete from 1997 to 2007 in the U.S. (14). China has been importing e-waste for over 10 years, receiving 50–80% of the U.S.' obsolete computers. As Figure 2 indicates, the problem is far larger than these numbers alone suggest, as computers comprise only 4.4% of e-waste totals (16). Additionally, the United Nations Environment Programme (UNEP) estimates that more than 50 million t of e-waste are annually generated worldwide, with ~70% being exported to China (14). Reports



**FIGURE 2.** Composition of e-waste generated in the U.S. (The most recent data available were compiled in 2000 (15)). Percentage of total is labeled on the top of each bar.

on these estimates do not indicate that the trend will be reversed any time soon.

**Geographical Distribution.** Published information from official Chinese sources confirms that the amount of e-waste imported to China has been increasing, with Guangdong Province as the main recipient. Subsequent to arrival in Guangdong, e-waste is then distributed to other provinces hosting processing centers such as Hunan, Jiangxi, Fujian, Zhejiang, Shanghai, Shandong, Tianjin, and Hebei (Figure 1). Guiyu, comprising several villages in the Chaozhou region of Guangdong ~250 km northeast of Hong Kong, has become a focal point of international attention because it houses perhaps the largest e-waste dismantling and recycling site in the world. Other municipalities that have large-scale e-waste processing facilities with typically hundreds of workers include Dali and Longtang in Guangdong Province, Taizhou in Zhejiang Province, and Huanghua City in Hebei Province (17).

**International and Domestic Regulations.** It has been widely perceived that a lack of laws and regulations in China is the main reason leading to the nearly out-of-control e-waste situation that exists today. Somewhat paradoxically however, China has in fact been one of the first global proponents for an international ban on the export of toxic waste from developed to developing countries (9). In 1996, based on the Basel Convention's agreement to ban the trade of hazardous waste between countries (i.e., the Basel Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal, sponsored by the Group of 77 [G-77] and China), China passed the Prevention and Mitigation of Environmental Pollution by Solid Wastes Act. Among other things, this Act (a) prohibits the import of solid waste that is unusable as raw material(s), and (b) strictly regulates the import of solid waste that can be used as raw material(s) (18). In February 2000, the Ministry of Environmental Protection (MEP) of the People's Republic of China made public regulation No. 19/2000 (of January 24, 2000), entitled *Notification on Importation of the Seventh Category of Wastes* (19). This regulation specifically states that the "seventh category of wastes" approved by the MEP for importation shall not include e-waste. This regulation was replaced in 2005 by the enactment of new and more specific legislation (19). Beginning April 1, 2000, the Customs Administration of China was directed to not allow the entry of abandoned electrical appliances (9). Also, an additional regulation, *Measures on the Administration of Business Certificate on Hazardous Materials* came into force on July 1, 2004. This regulation requires business licensing for the collection, storage, and



disposal of hazardous wastes (20). In 2005, the *Prevention and Mitigation of Environmental Pollution by Solid Wastes Act* was revised to strictly stipulate that the entry of solid waste into China for the purpose of dumping or disposal is forbidden (18).

In addition to these statutes and regulations, there are numerous other laws, regulations, and commandments regarding the collection, storage, transport, and disposal of e-waste in China. These include: the *Cleaner Production Promotion Law*, passed on June 29, 2002 and implemented on January 1, 2003 (21); the *Administrative Measures on Pollution Control of Electronic Products*, passed on February 28, 2006 and effected on March 1, 2007 (22); the *Administrative Measures for the Prevention and Control of Environmental Pollution by Electronic Waste*, promulgated by the MEP via Order No. 40 on September 27, 2007 and came into force on February 1, 2008 (23). The newest regulation is especially expected to play a key role in containing the e-waste crisis. These measures stipulate that operators of e-waste dismantling, utilization, and disposal factories must register with local government agencies. The measures further require that the pollution control techniques adopted in processing e-waste must comply with national standards. Violators will be fined ¥50,000–¥500,000 (~\$7300–\$73,000 USD [2008 exchange rate]). Order No. 40 also states that e-waste that has not been completely recycled or disposed of must not be transferred to any business that does not possess the required facilities to deal with the e-waste. Violators will be fined by local environmental agencies for up to ¥30,000 (~\$4400 USD). Readers interested in more information on these laws are directed to the China MEP's website (24).

The role of legislation and regulations governing e-waste in developed countries, and how they are actually implemented, is also extremely important to curb the occupational and environmental hazard threats. A popular opinion is that the reason trash ends up in China is because developed countries have more robust environmental laws, greater civic supervision, and more effective governmental enforcement. In reality, the situation is not so simple. For example, although the U.S. government requires disposal of e-waste at recycling centers, the waste itself is often collected and shipped abroad *legally* because the U.S. Congress has not yet ratified the Basel Convention—it is only a signatory (4, 25).

### Motives Behind Illegal Handling of E-Waste

Given the legislation passed in the last decade and before, it is clear that the Chinese government has long been aware of the severe environmental and human health consequences of inappropriate handling of e-waste and its importation from developed countries. But despite these attempts, the situation has remained grave due to widespread illegal activity. For example, according to various knowledgeable and long-time observers, although certain countries like those in the EU ban the export of e-waste, the number of illegal shipments of e-waste continues to rise (25). Information compiled by Greenpeace International indicates that vast amounts of e-waste are routinely and often illegally shipped from Europe, the U.S., and Japan to dismantling and recycling sites in China. Earlier in 2008, Greenpeace activists boarded the vessel *Yang Ming Success*, and prevented the offloading of an illegal container of e-waste from the Port of Oakland in California. The vessel was bound for the Sanshui district in Guangdong Province, via Hong Kong (26). Greenpeace also estimates that at present, as much as 4000 t of e-waste are discarded every hour in China (27).

The main motive behind illegal importation and handling of e-waste in China and other developing countries appears to be the significant financial windfall associated with the e-waste handling business (9). In developed countries, strict



**FIGURE 3. Workers unloading a truck of e-waste at an unspecified site in Guiyu.**

law enforcement has driven up the cost of e-waste disposal, making export of e-waste cheaper than disposal at home (2). This establishes a huge incentive for developed countries to export their e-waste to developing countries. Further, e-waste brokers can get paid twice for moving e-waste offshore: on the front end brokers receive payment for acquiring the e-waste, then they receive payment again for shipping the waste to Asia, most likely to China (9). Adding considerably to the problem is the fact that poor migrants from China's rural regions are exploited as cheap labor by profit-hungry e-waste entrepreneurs.

Clearly, the reason illegal importation and handling of e-waste in China has been able to escalate is not due to the lack of laws and regulations, but rather ineffective enforcement. Very often in China, laws or regulations are enacted without adequate resources allocated for enforcement. For example, numerous banners reading along the lines of "Dealing in imported used electronics is an act of smuggling" can be found in the streets of Guiyu, yet an illegal e-waste recycling business remains active in the region. In the absence of adequate enforcement, such nonchalance and disregard is commonplace: Figure 3 shows workers unloading a truck of e-waste intended to be processed in Guiyu. This photo aptly illustrates how little the laws and regulations have done to combat the ongoing illegal e-waste activities in China.

### Recommendations

Given our analysis, we present a set of recommendations to address China's e-waste crisis. A full length version can be found in the SI:

**1. Enhanced Law Enforcement.** The Chinese government must take steps to allocate sufficient resources to rigorously enforce existing environmental laws and regulations. Increasing the accountability of local government officials and establishing greater public awareness are likewise essential for enhanced law enforcement.

**2. Minimization or Elimination of Manufacturing-Related Pollution Sources.** China should adopt more appropriate models to deal with the e-waste problem. For example, Chinese manufacturers of electronic products should take the right steps and measures toward the reduction and prevention of e-waste problems during the manufacturing process. Additionally, the Chinese government should establish national or local e-waste disposal centers to minimize the possibility of e-waste pollution and speed up the development of its environmental protection industry and agencies.

**3. Increased International Collaboration.** International collaboration is one of the most effective ways to resolve the e-waste crisis. Disposal of e-waste to other countries, especially in an inappropriate manner, may temporarily seem

to alleviate a domestic problem. This sentiment is at best a narrow sense of the world by those who derive some economic benefit at either end of the process. China's e-waste crisis is a global problem due to its source and the nature of environmental pollution.

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## Supporting Information Available

Detailed discussion on some of the possible sources of PCBs in China's e-waste, a full-length description of our recommendations, and an additional figure. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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