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E-Waste Recycling: The Dirty Trade Between the United States and China

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TABLE OF CONTENTS

Preface:

China has been, and always will be, a very important part of my life. My mother and I moved to Shenzhen, a city in southern China, in 1999 when I was six years old. Over the next thirteen years, Shenzhen and I metamorphosed together; I grew into a young woman and she became a burgeoning metropolis of over 10 million people. During that time, I watched as Shenzhen became increasingly toxic. Incessant construction coated the urban landscape in heavy-metal-laden dust. Noxious sludge from innumerable factories leached into my beloved Shenzhen Bay. Brown smog from the exhaust pipes of 2.3 million vehicles shrouded the skyline. The city was choking, its vibrant colors turning dull. Economic development had boomed, but at the steep cost of self-poisoning.

My firsthand experience with the devastating effects of incautious, explosive urbanization and industrialization in China instilled in me the desire to pursue an education in environmental studies and is what ultimately motivated me to become an environmental analysis major at Pomona College. When it came time to choose a senior thesis topic, I knew I had to write about China.

Recycling has always been something I viewed as one of the simplest actions a person could take to protect the environment. Sure, I was aware that not everything dropped into the blue bin necessarily made it into the next 70% post-consumer material product, but I thought at least our recyclers were attempting to responsibly repurpose my waste. For this reason, when I learned that the US electronics recycling is dumping most of its collected goods on Chinese shores where it is then discarded in rural "e-

waste villages" and processed in ways incredibly harmful to human and ecological health, I was appalled and disappointed. How could an industry that was so integral to "saving the planet" be involved in such environmentally injurious and socially damaging practices? What dynamics were involved between the US and China that were allowing to happen? I hope that this thesis provides some answers to these questions, but more importantly offers viable suggestions for how the system might be changed so that poor communities in China are not bearing the burden of our "green" actions.

Introduction

Waste electrical and electronic equipment (also known as WEEE or e-waste) is the fastest growing sector in the global municipal waste stream. In 2005, the United Nations Environmental Program (UNEP) estimated that the total volume of e-waste generated worldwide would increase at a minimum rate of 3 – 5% per year, nearly three times as fast as the overall growth of the municipal waste stream. E-waste contains an amalgam of hazardous and valuable materials, distinguishing it from other forms of municipal waste and ranking it among the most complex and persistent types of waste generated. It is a potential source of precious reusable and recyclable resources, but requires special processing and recycling methods to avoid causing serious environmental contamination and damages to human health. This makes the proper management of e-waste a significant and pressing environmental and public health concern that will only continue to burgeon as increasing quantities of electronic equipment are discarded for the newest technologies.

The international trade and transport of e-waste has been steeped in contention over the potential economic benefits of recycling e-waste versus the potential harm to environmental and human health, particularly in developing countries that lack the sophisticated technology and rigorous safety standards to properly manage such hazardous materials. Some argue that the international trade in recyclable electronics presents a significant business opportunity for developing countries to advance a "green" industry while benefitting from an influx of valuable materials (Breivik et. al. 2014). There is also the claim that imports of used electrical and electronic equipment

to poorer nations will provide broader access to digital devices and could play an important role in bridging the "digital divide" between the Global North and Global South (Williams 2008).

On the other hand, there is an increasing body of scientific evidence confirming that the toxic emissions and contamination associated with informal e-waste recycling operations (such as are typical in many developing countries) indeed have serious environmental and human health repercussions. NGOs such as the Basel Action Network (BAN), the Silicon Valley Toxics Coalition, and Toxics Link have published multiple reports exposing the serious environmental health problems caused by e-waste recycling in places such as China, India, and Nigeria (*Puckett et. al. 2002; Agarwal et. al. 2003; Puckett et. al. 2005). For instance, measurements from river water samples in Guiyu, the largest e-waste recycling center in China, contained levels of toxins such as cadmium, nickel, and copper that exceeded EPA freshwater criteria by as much as 700% placing aquatic ecosystems at significant risk of extermination (Williams 2008). Another study from Guiyu revealed that children living in the e-waste village had blood lead levels ranging from 4.4 μg/dL to 33 μg/dL, with 80% exceeding 10 μg/dL (Huo et. al. 2007). The U.S. Center for Disease Control and Prevention considers blood lead levels of 5 μg/dL a serious cause for concern (Wheeler 2013). Some suggest that these studies indicate the damages linked with informal e-waste recycling may be the most significant of human health impacts associated with the lifecycle of electronic equipment (Williams 2008).

China plays a unique role on the global e-waste scene, as it is the largest importer and recycler of discarded electronic equipment (Breivik et. al. 2014). In many ways China's decision to accept much of the United States' collected electronic waste is in line with its willingness to be used by the US as a primary manufacturing platform. China has assumed this role fully aware that there are serious environmental and public health repercussions associated with industries such as steel production, textile production and lead-acid battery manufacturing. China also deliberately continues to derive most of the energy to power these industries from coal, the dirtiest of fossil fuels. Severe environmental degradation and extreme pollution is nothing new to China. Studies have found that 75% of China's rivers and lakes along with 90% of urban groundwater are highly contaminated with arsenic, untreated sewage, fertilizers, and pesticide runoff (Shapiro 2012). 20 of the world's 30 most polluted cities are in China (Shapiro 2012). Essentially, China's history over the past 30 years of rapidly increasing rates of desertification, erosion, acid rain, loss of arable land, salinization, and biodiversity loss places the contamination caused by e-waste in a context of widespread environmental destruction and diseased human bodies. Until very recent years, the Chinese government has done little enforce its environmental regulations (despite having some of the most rigorous environmental legislation of any country in the world) and has actively suppressed environmental groups who have attempted to draw attention to the severe environmental consequences linked with China's unbridled pursuit of economic growth (Shapiro 2012).

China has adopted a similar attitude towards e-waste. In theory, the Chinese government has taken significant steps to prevent the environmental degradation caused by e-waste recycling. Since 2000, the country has laid out a series of environmental protocols regulating e-waste, including a complete ban on e-waste imports (Feng et. al. 2013). China is also party to the Basel Convention Treaty on the transboundary movement of hazardous waste which prohibits transport of hazardous materials from developed to developing nations (Basel Convention 2011). Yet in practice, China did little to mitigate flows of e-waste into the country or to enforce controls on e-waste recycling operations until 2013. In February 2013, the Chinese Ministry of Commerce launched Operation Green Fence, a campaign to implement China's regulations on imports of recyclable materials, including e-waste.

As the world's largest exporter of waste and recyclable materials, the United States plays a significant role in China's e-waste problem. It is estimated that over 70% of all e-waste collected for recycling in the US is shipped to China (Puckett et. al. 2002). The economic benefits of doing so are significant. The cost of shipping e-waste to China are very low; shipping companies eager to avoid transporting empty shipping containers permit e-waste recyclers to ship their goods for a minimal price. The average wage per worker in Chinese e-waste recycling workshops is less than $3.63 per day (Li et. al. 2006), while according to the Bureau of Labor Statistics the median wage for a refuse and recyclable material collector in the United States in 2010 was $16.18 per hour (Bureau of Labor 2015). As with most manual-labor-intensive industries, it is simply cheaper to send e-waste to China. However, by outsourcing e-waste recycling

operations, the United States is also outsourcing the pollution and contamination associated with processing these toxic goods. Far from encouraging the development of a "green recycling industry" in China, the United States has simply dumped these hazardous materials on Chinese shores, allowing itself to conveniently avoid the environmental damages associated with electronics production and once again outsource the pollution associated with end-of-life electronics recycling.

Many of the solutions within the body of scholarly literature on China's e-waste problems call for strengthening China's regulatory framework and greater enforcement of its existing protocols. However, it is important to recognize the role of the United States in the issue. Without addressing the need for stricter regulations on US exports of hazardous waste and creating incentives for US recyclers to handle the waste domestically, solutions to China's e-waste recycling problem remain incomplete. Without a reexamination of US policies, the trend of e-waste exportation will continue—if not to China (should the country continue to enforce its import regulations as it did via the 2013 Operation Green Fence campaign) then to other developing nations with similarly lax enforcement of environmental safety protocols.

This thesis will attempt to provide an outline of the environmental and public health problems linked with e-waste recycling in China. The paper will then briefly examine the economic incentives for maintaining the e-waste trade between the US and China as well as provide an overview of the Chinese and American regulatory framework on e-waste leading up to the Chinese crackdown via the 2013 Operation Green Fence. Finally, this thesis will suggest a reexamination of existing US policies to prevent

outsourcing of e-waste pollution to disempowered communities in countries such as China.

Chapter 1: Case Studies on the Environmental Damage Caused by E-Waste Recycling in China

The majority of e-waste imported to China from foreign countries and collected from urban centers is deposited in rural "recycling villages" clustered along the southeastern coast of China near major shipping ports such as Hong Kong, Xiamen, Ningbo, and Tianjin (see Figure 3). The recycling operations are typically small, family-run workshops that use basic equipment such as hammers, screwdrivers, and saws to dismantle electronic scrap which is then either openly burned or soaked in acid baths, depending on the type of electronic component. All of this is done with little to no safety gear. Some of the myriad methods used to recycle electronic scraps and extract resources are summarized in Table 1.

Table 1: Typical recycling methods in e-waste recycling villages (adapted from Huo et. al. 2007).

Type of electronic waste	Primary recycling process used
Large electronic equipment	Dismantled into constituent parts (monitor, battery, hard drive, wires, plastic or metal frame, etc.) using drills, hammers, screwdrivers, and other basic tools.
Circuit boards	Cooked over coal fires to separate valuable parts from the solder such as microchips, diodes, and resistors
Microchips and other small computer components	Soaked in acid baths to obtain gold and other precious metals
Wires and plastic covered cables	Manually stripped and burnt to recover metals such as copper
Printer cartridges	Dismantled by hand and dusted for ink residues
Plastic scraps	Sorted by hand, sometimes burnt and classified by burning odor, some plastics are fed into grinders to create plastic pellets

These activities involve frequent direct human exposure to high doses of toxic substances contained in e-waste. Table 3 summarizes the types of hazardous substances linked to e-waste and their sources.

Table 3: Types of pollutants released by e-waste recycling (adapted from Wang et. al. 2012)

Persistant Organic Pollutants	**E-waste source**
Brominated flame retardants Polybrominated diphenyl ethers (PBDEs) Polybrominated biphenyls (PBBs)	Flame retardants in plastic resins
Polychlorinated biphenyls (PCBs)	Dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lights, ceiling fans, diishwashers, and electric motors
Dioxins	
Polychlorinated dibenzodioxins (PCDDs) and dibensofurans (PCDFs)	Released as combustion byproduct
Dioxin-like polychlorinated biphenyls	Released as combustion byproduct, also found dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lights, ceiling fans, diishwashers, and electric motors
Polyaromatic hydrocarbons (PAHs)	Released as combustion byproduct
Elements	
Lead (Pb)	Printed circuit boards, cathode ray tubes (CRTs), light bulbs, televisions, solder, and lead-acid batteries
Chromium (Cr)	Anticorrosion coatings, data tapes, floppy disks,
Cadmium (Cd)	Switches, springs, connectors, printed circuit boards, batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, CRTs, cell phones
Mercury (Hg)	Thermostats, sensors, monitors, printed circuit boards, liquid crystal display (LCD) backlights, fluorescent lamps
Zinc (Zn)	CRTs and metal coatings
Nickel (Ni)	Batteries
Lithium (Li)	Batteries
Barium (Ba)	CRTs and fluorescent lamps
Berylium (Be)	Power supply boxes, computers, x-ray machines, ceramic components of electronics

Lead, mercury, polychlorinated biphenyls, and cadmium are all ranked in the top ten of the US Agency for Toxic Substances and Disease Registry's "Priority List of Hazardous Substances" due to their known toxicity and significant potential threat to human health

(ATSDR 2013). Workers who engage in e-waste recycling typically do not wear so much as gloves or face masks to protect themselves from the hazardous chemicals released during these processes (Puckett et. al. 2002). This has led to serious public health consequences. There are also no enforced environmental regulations on the disposal of post-recycling toxic residue and other contaminated materials. The recycling villages regularly dump heavy-metal-laden ash and chemical-saturated effluents into the surrounding landscape (Puckett et. al. 2002). The widespread dumping of toxic e-waste into waterways as well as the release of chemicals into the atmosphere from the incomplete combustion and smelting of e-waste materials has led to significant ecological damage, poisoning bird and fish populations surrounding the villages (Xing 2008; Luo 2008). Unfortunately, the land encircling these villages continues to be cultivated for agricultural purposes and the rivers still fished. Many of the villagers are aware to some degree that their water sources are contaminated and buy imported water from neighboring cities (Gittings 2002). Some farmers nevertheless cultivate rice, which they refuse to eat themselves but sell to outside buyers (Watson 2013).

Following are two case studies from the largest recycling hubs in China that demonstrate the various negative environmental and health effects of these e-waste recycling operations. While there are many other affected recycling communities, these two recycling towns have received the most attention from scholars over the last decade. For this reason, the body of literature on the effects of e-waste in these municipalities is the most robust and examines the effects of e-waste pollution on both human and ecological health.

1.1 Guiyu

Figure 1: Map of China (Adapted from Wikimedia Commons image with permission of copyright owner Jowww 2008)

Figure 2: Map of e-waste village case studies and major cities of Guangzhou and Hong Kong (Adapted from Wikimedia Commons image with permission of copyright owner NordNordWest/Wikipedia 2010)

Guiyu is located in Guangdong province, 250 km northeast of Hong Kong and 300 km from Guangzhou (Google Maps 2015), both of which are primary entry points for e-waste in southern China (see Figure 1 and Figure 2). Historically a collection of 28 rice-growing hamlets (collectively referred to as Guiyu) with an agrarian economy, Guiyu's e-waste recycling industry was introduced to this collection of communities in 1995 (Puckett 2002). Since then, Guiyu has burgeoned to become China's largest e-waste recycling center, with approximately 150,000 workers employed in the informal electronics recycling industry comprising over 300 e-waste recycling companies with more than 3,000 individual workshops (Wong et. al. 2007). The village has a population of approximately 150,000 residents with 60 – 80% of families in Guiyu engaged in e-waste recycling operations (Zheng et. al. 2008).

In 2002, the Basel Action Network (BAN) in collaboration with Silicon Valley Toxics Coalition, Toxics Link India, and a few other NGOs prepared a report titled *Exporting Harm: The High-Tech Trashing of Asia*. The report and an accompanying documentary by the same name brought widespread attention to the informal recycling town of Guiyu. The watchdog groups exposed the complete lack of safety measures at the Guiyu recycling site and took soil and water samples which revealed high levels of heavy metal contamination, especially lead, copper, iron, and cadmium (Puckett et. al. 2002). The NGO report also exposed that large quantities of imported e-waste from the United States into China was finding its way to Guiyu (Puckett 2002). In 2008, the investigative television broadcast *60 Minutes* also brought Guiyu to US attention when it aired a segment examining the illegal importation of e-waste to China from US recyclers,

sending a team to Guiyu to film the hazardous e-waste recycling operations there (CBS 2008). Since 2002, the Shantou University Medical College and Hong Kong Baptist University have conducted a series of studies confirming that the human population of Guiyu as well as the surrounding ecosystem are being heavily poisoned by chemicals released during the processing of e-waste. This case study will focus on the research conducted on the blood lead levels of Guiyu children, cadmium concentrations in the umbilical cords of neonates born to Guiyu mothers, and accumulation of polychlorinated biphenyls (PCBs) in the bodies of fish populations surrounding Guiyu. Exposure to these substances have led to increased cases of lead poisoning, neurological damage, cancer, and genetic mutations (Robinson 2009).

Lead is a major contaminant released by the e-waste recycling processes in villages such as Guiyu. The heavy metal is found in many electronic parts from PVC cables to printed circuit boards to batteries (Puckett et. al. 2002). CRTs alone contain an average of 4 – 8 lb. of lead each (Huo et. al. 2007). The potential avenues for exposure are ubiquitous in Guiyu. The concentration of lead in dust samples from workshops in Guiyu were found to be hundreds of times higher than typical levels recorded for indoor dust in other parts of the world (Brigden et. al. 2005). Soil samples taken from an open burning site for circuit boards revealed lead concentrations ranging from 856 mg/kg to 7038 mg/kg, far exceeding the environmental pollutant reference value of 190 mg/kg set by the New Dutch List (Wong et. al. 2007). Water samples taken from rice fields and nearly rivers in Guiyu also showed elevated lead concentrations up to 2,400 times the World Health Guideline values for safe drinking water (Puckett et. al. 2002).

Children are much more sensitive to lead poisoning than adults. Lead is fat-soluble and readily absorbed by young digestive tracts and developing central nervous systems (Needleman 2003). It is also relatively easily absorbed by the skin. In Guiyu, lead inhalation is perhaps the most significant source of lead poisoning for children. Researchers found that lead contamination in the air from fly ash resulting from the open burning of e-waste was worst at around 75 – 100 cm above the ground, which is the typical height range for Chinese children aged 5 – 6 years (Wang and Zhang 2006).

One of the most widely cited toxicity reports on the Guiyu population is a study on the blood lead levels (BLLs) of Guiyu children conducted in 2004 by researchers from the Central Laboratory and Key Immunopathology Laboratory of Shantou University Medical College (Shantou is the county in which Guiyu is located). Children in Guiyu are regularly exposed to lead through direct contact with the skin, such as by stripping cables and through inhalation via breathing air contaminated by the open burning of circuit boards containing lead solder. Analyzing a population sample of 165 children (with a median age of five years old) from four of the Guiyu hamlets (in order to take into account differences in the types of e-waste processing conducted by each community), the Shantou researchers compared the BLLs of the Guiyu children to a control sample of 61 children from Chendian, a town located approximately 8 km from Guiyu that produces textiles (Huo et. al. 2007). The results showed that 81.8% of the Guiyu children had BLLs >10 μg/dL compared to 37.7% of the Chendian children showing BLLs >10 μg/dL (Huo et. al. 2007). Of the children with BLLs greater than 10 μg/dL, 27 of the Guiyu children had blood lead levels higher than 20 μg/dL (Huo et. al. 2007). The

average BLL for the Guiyu children was 15.30 µg/dL. Another study conducted by Shantou University scientists in 2007 corroborated these results. Testing the blood of 154 Guiyu children and 124 Chendian children younger than 8 years old, the results showed 70.8% of the Guiyu children had BLLs >10 µg/dL compared with 38.7% of the Chendian children (Zheng et. al. 2008). The mean BLL was 13.17 µg/dL.

To place these numbers in context, a study of 15 cities in China found the mean blood lead level of children ages 0 – 6 years old to be 5.95 µg/dL (Zhang et. al. 2005). Children living in neighboring Shantou City (about 50 km from Guiyu) had an average of 7.9 µg/dL (Luo et. al. 2003)—less than half of the average BLL of the Guiyu children. In the United States, the mean BLL of children ages 1 – 5 years is 1.3 µg/dL (*Wheeler 2013).

No safe blood lead level for children has been identified. Numerous studies have shown that lead is a powerful neurotoxin that adversely affects neurological development, cognitive functioning, and social behavior and that lead-associated impairments may be irreversible (*Lanphear et. al. 2000; Canfield et. al. 2003; Needleman 2003; Koller et. al. 2004; Jusko et. al. 2008). Studies have shown that children exposed to lead experience deficits in cognitive and academic skills at concentrations lower than 5 µg/dL (Lanphear et. al. 2000; Canfield et. al. 2003; Jusko et. al. 2008). A lifetime average blood lead concentration above 10 µg/dL (which was the acceptable BLL established for children by the U.S. Center for Disease Control and Prevention in 1991) may lead to a loss of up to 4.6 IQ points for each increase of 10

µg/dL (*Canfield et. al. 2003; Wheeler 2013).[1] The negative impacts of lead poisoning on social behavior are include attentional dysfunction, aggression, and delinquency (Needleman 2003). The economic implications in terms of income lost due to lowered IQs and behavioral problems are also potentially significant.

Lead is also linked to growth retardation and hormonal disruption. It is well-documented and studied that lead blocks the absorption of essential minerals such as calcium, iron, and other elements essential to physical development and hormone synthesis (Huseman et. al. 1992; Kim et. al. 1995; Needleman 2003). Multiple studies have shown a negative correlation between elevated BLLs and children's stature (Schwartz et. al. 1986; Kim et. al. 1995; Needleman 2003). In Guiyu, the mean height of the 154 children sampled by the second team of Shantou researchers was found to be significantly lower than Chendian children at 104.35 ± 6.93 cm compared to 105 ± 7.59 cm (Zheng et. al. 2008).

The results of these studies suggest that the Guiyu children's elevated lead levels are closely linked to the environmental lead contamination caused by e-waste processing in the village. Both lead studies on Guiyu children showed that BLL increased with age (Huo et. al. 2007; Zheng et. al. 2008). This is thought to be due to the tendency of older children to do more outdoor activities and bioaccumulation of lead through ingestion of contaminated vegetables and fish (Zheng et. al. 2008). Another important factor linked to higher BLLs were "father's engagement in the type of work related to e-

[1] In 2012 the CDC replaced the ≥10 μg/dL "level of concern" with an upper reference interval value of 5 μg/dL, in recognition that any level of lead in children's blood is cause for concern (Wheeler 2013).

waste." Children whose fathers work in the e-waste industry are thought to be exposed to higher amounts of lead because their fathers may bring back lead residue on their clothing, hair, and skin into the home (Zheng et. al. 2008).

Polybrominated diphenyl ethers (PBDEs), typically used as brominated flame retardants in electronic circuit boards and plastic resins, are another dangerous chemical toxin released by dismantling and burning e-waste (Wang et. al. 2011). PBDEs are easily inhaled by e-waste workers exposed to dust and fly ash in the electronics recycling workshops and may also be ingested through consumption of contaminated produce or drinking water. Extraordinarily high blood concentrations of PBDEs have been observed in Guiyu workers. For instance, one study found the median blood concentration for the PBDE congener BDE-209 in tested e-waste workers to be 83.5 ng/g while the median concentration for the two control groups[2] was 5.7 ng/g (Qu et. al. 2007). In other words, on average the e-waste workers had PBDE blood concentrations nearly 15 times those of the referent population samples. In fact, the highest blood concentrations of PBDEs ever recorded were found in an 18-year-old male worker in Guiyu; he was found to have a BDE-209 blood concentration of 3436 ng/g, or over 600 times the median concentration found in the control samples (Qu et. al. 2007). Overall, the Guiyu e-waste workers were found to have PBDE blood concentrations 11 – 20 times as high as the referents (Qu et. al. 2007). The study further compared the results from the Guiyu e-waste workers to previous research done on populations

[2] The control groups in this study were a group of subsistence farmers living approximately 50 km from Guiyu and a group of urban residents living in Guangzhou (Qu et. al. 2007).

occupationally exposed to PBDEs such as electronics dismantlers in Sweden and Norway and incinerator workers in Korea. Once again, the PBDE blood concentrations of the Guiyu e-waste workers were found to be significantly higher than these other exposed groups.

PBDEs have been found at extremely high levels in sediment and fish samples collected from rivers in Guiyu, which indicates that the open burning and dumping of e-waste is causing severe ecological damage. These findings also demonstrate the widespread avenues for human exposure beyond the workshops and village area. PBDE concentrations in river bank sediment samples from Guiyu were found to range from 4,434 to 16,088 ng/g which is several orders of magnitude higher than the 16.1 to 21.4 ng/g PBDE levels found in sediment at a wastewater discharge site for a vehicle repair shop in Hong Kong (Luo et. al. 2007). Compared to the results of a study done on river sediment from the Pearl River Delta in southern China, the PBDE levels in Guiyu were anywhere from 30 to 1400 times higher (Luo et. al. 2007). In comparison to areas in other countries such as the Tejo River basin in Portugal which has undergone industrial contamination from textile and paper production, the PBDE levels were 500 to 4000 times higher in Guiyu. Furthermore, the PBDE levels found in fish muscle from Guiyu samples were also anywhere from 10 to 1000 times higher than freshwater fish in markets in US and Taiwanese markets (Luo et. al. 2007). Unfortunately, these fish are still caught and eaten by Guiyu residents which has contributed to the bioaccumulation of PBDEs in the bodies of Guiyu villagers.

As with lead, the human body burden of PBDEs is greatest for children. The primary organs targeted by chronic exposure to PBDEs are the liver, kidney, and thyroid gland (Costa 2008). These chemicals are endocrine disruptors and are known to block estrogen, progesterone, and androgen receptors (Costa 2008). However, most worrying is the fact that elevated PBDE blood levels have been linked to developmental neurotoxicity. This is because thyroid hormones play a crucial role in brain development (Costa 2007). Studies have connected PBDE exposure and subsequent neurotoxicity with behavior changes and lowered cognitive function in infants and toddlers (Costa 2007).

Cadmium is another major public health threat released by e-waste recycling in Guiyu. Cadmium residue is ubiquitous in Guiyu as it is used in products such as rechargeable batteries, coatings in CRTs, and solder joints (Zheng et. al. 2008). The fumes released from solder smelting, workshop dust, and contaminated soil and water are the biggest sources of cadmium exposure (Brigden et. al. 2005). Research has also shown that mothers exposed to cadmium are passing the toxin on to embryos during pregnancy (Li 2010).

Cadmium is persistent in the body and does not degrade easily (Li 2010). It is an endocrine disruptor and interferes with the body's ability to balance metals such as calcium, iron, and magnesium (Li et. al. 2010). As a result, the principal targets of cadmium toxicity are the bones and kidneys. By inhibiting calcium uptake and increasing the rate of calcium leaching from bones, cadmium exposure can cause skeletal demineralization and increased risk of bone fractures (Moore and Satarug 2004). As a persistent toxin, cadmium may remain in the kidneys for up to 60 years and has been

associated with renal tubular dysfunction (Moore and Satarug 2004). Some experts believe that the renal tubular dysfunction associated with cadmium is irreversible (ATSDR 2011). The International Agency for Research on Cancer and the National Toxicology Program of the US Department of Health and Human Services have also identified cadmium as a human carcinogen, with particularly strong links to lung cancer following chronic inhalation (ATSDR 2013).

A study of 154 Guiyu children with a mean age of 5.1 years old revealed average blood cadmium levels (BCLs) of 1.58 μg/L. The average BCL of 124 children with a mean age of 4.6 years from the neighboring town of Chendian was .97 μg/L (Zheng et. al. 2008). According to the US Agency for Toxic Substances and Disease Registry (2012), normal BCLs for humans older than one year of age is .315 μg/L. According to the World Health Organization, however, even such low levels of cadmium causes adverse changes to the kidney in 10% of the population (ATSDR 2011).

Research conducted on 289 newborns born during the years 2004, 2005, and 2007 whose mothers live in Guiyu revealed high cadmium levels in umbilical cord and placenta samples. 25.61% of the Guiyu samples had cadmium concentrations exceeding 5 μg/L (Li 2010). Normally, newborns are born free of cadmium (WHO 2000), making these findings of high levels of cadmium in umbilical cord samples a serious cause for concern. Further tests on placenta samples revealed an average cadmium concentration 0.17 ± 0.48 μg/g in samples taken from Guiyu mothers, which was once again

significantly higher than the mean 0.10 ± 0.11 μg/g in samples from mothers living in Chaonan, a town located approximately 10 km from Guiyu (Li 2010).

Finally, polychlorinated biphenyls (PCBs) are another major contaminant released by the dismantling of e-waste. PCBs are commonly used in electronic fluids such as coolants, lubricants, hydraulic fluids and heat-exchange fluids (Puckett et. al. 2002). These chemicals are synthetic organochloride chemicals which have serious human health repercussions. Some of the ills that PCBs may cause include (Carpenter 2006):

- Suppression of the immune system and subsequent increased risk of contracting other diseases
- Promotion of tumor formation through enhancing the effects of other carcinogenic substances, such as cadmium
- Alteration of thyroid and reproductive function in both males and females
- Development of cardiovascular disease, liver disease, and diabetes

A study conducted by the Hong Kong Baptist Univesity in 2008 revealed elevated levels of PCBs in fish populations surrounding Guiyu (Xing et. al. 2008). The study results showed that the mean concentration of PCBs in freshwater fish samples taken from the river near Guiyu village was 17.27 ng/g (Xing et. al. 2008). The overall range was 1.95 – 58.43 ng/g (Xing et. al. 2008). Fish with a higher lipid content were also found to contain greater quantities of PCBs in their tissues, due to the fact that PCBs are fat-soluble (Xing et. al. 2008; Carpenter 2006). It appears overall that sediments were the primary source

of exposure for the fish populations to PCBs, although atmospheric deposition is thought to also be a potentially significant source of contamination (Xing et. al. 2008). Carnivorous fish were found to have higher concentrations of PCBs due to bioaccumulation within the food chain. This is a cause for concern, since humans eating contaminated fish experience the compounded effect of bioaccumulation.

These studies are indicative of the overall pattern of environmental degradation and human health damages caused by e-waste recycling in Guiyu. Unfortunately, this phenomena is not isolated. The villages of Qingyuan and Taizhou have experienced similar polluted conditions and health problems due to the e-waste recycling operations there.

1.2 Qingyuan

Although Guiyu is the largest e-waste recycling village in China and has garnered the most international attention primarily due to media coverage by groups such as the Basel Action Network and TV programs such as *60 Minutes*, the many other recycling villages dotted across the Chinese landscape have been subject to environmental damages very similar to Guiyu. Studies conducted on these villages serve to fill in the gaps in the body of research from the Guiyu case study.

Similar to Guiyu, Qingyuan village is located in rural Guangdong province. It lies approximately 80 km north of Guangzhou (Google Maps 2015a), another primary entry point for e-waste shipments, and is home to approximately 80,000 workers involved in e-waste recycling operations spread over 1300 dismantlilng and recycling workshops

(Zhang et. al. 2015). Several studies have been conducted in Qingyuan on the effects of toxins released by e-waste recycling on bird populations, which is an area of research not covered by the body of literature on Guiyu. Also, while multiple studies have been carried out on the concentrations of persistent toxic pollutants in sediment, dust, and water samples in Guiyu, little research has been conducted on the uptake and accumulation of these chemicals in the surrounding vegetation. Studies on Qingyuan investigating the contamination levels of vegetables grown in the area surrounding the e-waste village provide insight into this important avenue of toxic exposure (since many villagers both consume produce grown around e-waste villages as well as sell it to other cities).

Surveys of bird assemblages and samples collected from bird populations inhabiting the Qingyuan area have demonstrated the susceptibility of these bird species to e-waste contaminants. One study examined the changes in population abundance and species diversity surrounding the Qingyuan e-waste site, surveying a total of 8,216 individuals from 104 species over the course of four observational periods (Zhang et. al. 2015). The researchers found that the severity of contamination caused by e-waste recycling negatively affected total bird species richness, density, and diversity patterns of both migratory and resident species (Zhang et. al. 2015). The sharpest declines in species richness (the number of species present in a sample, or relative abundance of species) was observed in insectivore bird populations. Qingyuan had five species of babblers compared to natural farmland sites in Guangdong province (used as a reference to compare the e-waste site to) which contained five species of cuckoos, two

species of treepies, one woodpecker species, and one long-tailed tit species. Certain species of shrub and grassland specialist insectivores which were thought to typically inhabit the Qingyuan region such as partridges and pheasant species were not observed at all in the e-waste contaminated area.

There are several potential ways that e-waste contaminants may have contributed to this loss of species richness. Firstly, insectivorous birds require extra calcium during breeding and calcium-rich foods, such as snails, cannot survive in acid or metal polluted areas (effluent from acid leaching of computer chips is frequently dumped into waterways and fields surrounding Qingyuan) (Zhang et. al. 2015). This lack of calcium may result in thinner shells and fewer successful hatchings. An overall decline in suitable invertebrate food such as insects due to environmental pollution from e-waste and biomagnification in larger species such as frogs may also result in declines in bird species (Zhang et.al. 2015). Destruction of habitat for birds such as the Chinese Grassbird is especially concerning, since over the past decade this species has become near threated due to suffering substantial long-term losses of its native habitat in southern China to drainage and degradation of the land (Zhang et. al. 2015). While insectivorous bird species were observed to be the most affected by e-waste contaminants, granivorous species have also suffered decreased availability of food resources. The release of persistent organic pollutants from e-waste recycling sites into the environment reduce yearly seed production and lead to long-term depletion of seed banks in the soil (Zhang et. al. 2015).

Another study measuring the level of PCB contamination in waterbird species inhabiting the Qingyuan vicinity found high levels of PCBs in 90% of the birds tested. The median PCB concentration for piscivorous species was found to be .12 mg/g of lipid tissue which was higher compared to birds of similar tropic levels living in other regions (Luo 2008). Interestingly, however, Zhang et. al. (2015) did not find significant differences in total species density (the number of individuals of a certain species living in a given habitat) when comparing waterbird populations in natural farmland and the Qingyuan e-waste area. One possible explanation for this observation is that birds such as egrets and herons have a more diversified diet which and may be able to metabolize toxins more efficiently than other species (Zhang et. al. 2015). Nevertheless, continued monitoring will be necessary since PCBs are known endocrine disruptors and (as with other persistent chemicals found in pesticides) are linked to thinning egg shells which can devastate bird populations (Colborn 1993).

Another e-waste recycling pollutant that has affected the bird populations in Qingyuan is dechlorane plus (DP). Like PBDEs and PCBs, DP is used as an additive chlorinated flame retardant. It was originally introduced to substitute Mirex, which was banned from use in the United States during the 1970s (Mo 2012; Kaiser 1978). Samples of common kingfishers inhabiting the Qingyuan area were found to have been heavily contaminated with DP (Mo 2012). Another study compared DP soil concentrations in Guiyu, Qingyuan, and several other industrial areas in Southern China. The mean DP levels in Qingyuan and Guiyu were much higher than the five other industrial sites investigated, exceeding the mean DP concentrations of the industrial area samples by 8

to 10 times (Wang et. al. 2011). Unfortunately, there is little data on the ecotoxicology of DP on birds to date, however, it is clear that DP is accumulating within bird bodies and as a synthesized chemical will most likely inflict damage to the bird populations.

One of the areas that has not been thoroughly investigated in studies conducted on Guiyu is the levels of persistent organic pollutants in vegetables grown in e-waste village sites and consumed by local residents. However, most e-waste villages in China have agricultural fields where vegetables and rice are grown are locating within 500 m of the village perimeter (Wang et. al. 2011). This produce is eaten by the local community or sold to outsiders (who are of course uninformed of the contamination).[3] Not surprisingly, a study examining the top soil and vegetation of five different areas surrounding the Qingyuan e-waste recycling site, including an e-waste open burning site, vegetable field, paddy field, swath of deserted soil, and a pond, showed high levels of PCBs and PBDEs in the samples. The samples from the open burning site had average PBDE concentrations 10 times the concentration of samples from agricultural fields and paddy fields that were slightly more removed from the Qingyuan e-waste recycling workshops, with pollutant concentrations displaying an inverse relationship to the distance from the village. Some researchers have found that PBDE pollution can spread as far as a 74 km radius from the e-waste recycling area (Zhao et. al. 2009). Plant

[3] In 2002, the Chinese Ministry of Agriculture found that 10% of randomly tested rice samples contained excessive cadmium (Brigden et. al. 2014). A similar investigation conducted in 2013 found that 44% of tested rice samples had excessive cadmium (Brigden et. al. 2014). Little research has been done on the sources of the cadmium contamination. However, given that e-waste villagers are growing and selling rice from fields heavily polluted with cadmium and other heavy metals it is likely that the informal e-waste recycling sector was partially responsible for the scandal.

samples from the five tested sites had an average PBDE concentration of 32.2 ng/g, with the open burning site showing the highest PBDE levels (up to 217 ng/g), followed by the rice stalks and leafy vegetables. As of yet, no safety thresholds have been established for human PBDE exposure. However, given the fact that PBDEs are endocrine disruptors and have been linked with neurobehavioral changes in children the accumulation of these chemicals in the produce consumed by e-waste communities is cause for concern.

Another group of chemicals that was not extensively covered in the body of literature on Guiyu, but poses a significant risk to human health are polycylic aromatic hydrocarbons. PAHs are produced by incomplete combustion and are released in large quantities by the open burning of electrical components. PAHs are carcinogenic, mutagenic, and teratogenic (Yu et. al. 2006). Epidemiological evidence has shown that exposure to PAHs even in very small quantities results in significantly increased risk of lung, skin, and bladder cancers and can cause miscarriages and birth defects (Bosetti 2005). PAHs do not biodegrade easily due to their hydrophobic nature and low solubility; they tend to be readily stored in fatty tissue and are a persistent toxin that bioaccumulates through the food chain (Bosetti 2005). An air quality study conducted over the course of a year found that Qingyuan air exceeded China’s air safety standards for PAH concentrations by as much as 17.6 times (Wang et. al. 2012). In assessing and comparing the Qingyuan population’s risk of lung cancer compared to the population in Guangzhou, the researchers found that on average the lifetime inhalation cancer risk for Qingyuan residents was 160% higher compared to citizens living in the urban-industrial city of Guangzhou (Wang et. al. 2012). The researchers estimated that PAHs accounted

for nearly 20% of the total cancer risk in the e-waste recycling site. As an airborne contaminant, PAHs can travel long distances through the atmosphere, making the potential for environmental contamination and public health damages extremely high (Aamot et. al. 1996; Wilcke 2000).

Chapter 2: Economics of the E-waste Industry in China and the Trade in E-waste from the US to China

Despite the environmental degradation and human health harm caused by the informal e-waste recycling operations in villages such as Guiyu and Qingyuan, China has continued to allow e-waste across its borders (although officially the Chinese government has passed multiple pieces of legislation aimed at preventing imports of e-waste, as will be discussed in Chapter III). There are significant economic incentives China to maintain the e-waste trade. E-waste provides raw materials such copper, gold, and silver, as well as other metals while the collecting and recycling processes create thousands of jobs for unskilled laborers. Many scholars believe these incentives have played a significant role in preventing China from fully implementing its e-waste regulations.

For the United States, exporting e-waste permits the country to avoid the large expenses associated with funding the safe management of toxic residues produced by e-waste recycling, since handling the waste domestically would involve investing in sophisticated recycling technology and facilities. Since there is almost no federal regulation and minimal state-level control of e-waste collection and recycling, there is little incentive for private recyclers process the e-waste domestically when it is far cheaper to simply ship the electronic scraps to China.

2.1 US Imports of E-waste to China

Estimates of total e-waste imports to China from all countries are highly variable, primarily because imports of e-waste into China are illegal according to Chinese law as outlined in the *Catalogue of Solid Wastes Forbidden to Import in China* (MEP 2009). As a result, hundreds of thousands of tons of e-waste are falsely declared and imported as second-hand goods, mixed metal scrap, and mixed plastics (UNEP 2015). Currently, the best estimate of total annual imports (assembling data from multiple studies and approximations of China's e-waste flows) places the total annual imports of e-waste at approximately 3.6 million metric tons as of 2014 (Breivik et. al. 2014).

Even more difficult is determining the amount of e-waste imports originating from the United States. According to "Exporting Harm: The High-Tech Trashing of Asia," one of the most widely cited e-waste reports, an estimated 50 - 80% of collected recyclables in the United States will be shipped to Asia (Puckett et. al. 2002). Of those recyclables sent to Asia, 90% is thought to land in China (Puckett et. al. 2002). It is important to note, however, that from 2000 to 2010 only 10 - 20% of discarded electronics in the United States were even collected for recycling, with that number reaching nearly 30% most recently (see Figure 2 below) (EPA 2012). The remainder is either stored or trashed in domestic landfills. The EPA does not track e-waste exports exiting the United States since there are no regulations on such exports (EPA 2012). That said, assuming that 2002 estimate from Puckett et. al. is fairly accurate[4], this would

[4] This estimate is widely accepted in the body of peer-reviewed literature on e-waste.

suggest that up to 72% of the total amount of e-waste collected for recycling in the United States each year is exported to China. Looking at the e-waste generation estimates published by the EPA (see Figure 1). Therefore, the estimated amount of e-waste the United States has shipped to China could have increased from around 98,500 tons in 2000 to almost 720,000 tons in 2012 (EPA 2012). These numbers are predicted to continue to rise, creating an urgent need for definitive action to be taken by both the United States and China to solve the public health and environmental problems associated with e-waste processing.[5]

2.2 Employment in the Chinese Recycling Industry

The recycling industry in China is divided into two sectors: informal and formal. It is estimated that a total of 700,000 workers are employed in the informal e-waste collection and recycling industry in China, while only 16,000 people work in the formal industry (Duan and Eugster 2007). Of the total amount of e-waste claimed for recycling each year, approximately 60% is collected and processed by the massive informal e-waste recycling industry, 10% by the formal recycling industry, 20% by retailers through electronic trade-in programs (typically resold on the second-hand market), and the

[5] It is important to note that while the US e-waste imports contribute significantly to China's e-waste flow, China itself is a massive e-waste generator. Due to rising incomes and a burgeoning consumer population, China's domestically generated e-waste has risen significantly over the last several decades. The Chinese e-waste stream is thought to be increasing by approximately 13 – 15% each year (Lin and Liu 2012). The total volume of domestic e-waste generated is calculated to have risen from 50 million units in 2001 to approximately 225 million units in 2012 (Lu et. al. 2014). Currently, China is the second largest e-waste producer after the United States (StEP 2015). While this thesis primarily examines how the United States has been complicit in the environmental degradation and public health harm caused by the informal Chinese e-waste recycling industry through exporting its electronic scrap to China, the fact remains that China still bears the responsibility for the proper handling of its own mammoth flow of e-waste.

reminder directly reclaimed by the second-hand market (Wang et. al. 2011). The fact that the informal sector captures significantly more e-waste than the formal sector is problematic because the informal sector is much more difficult for the government to regulate. While attempts have been made at enlarging the formal sector, informal recyclers consistently outcompete their formal counterparts.

Most informal collection is carried out in urban areas by self-employed migrant workers who travel to individual residencies offering to purchase old electronic and electrical equipment (Wang et. al. 2011). These informal collectors (sometimes referred to as e-waste peddlers) offer to buy obsolete devices from consumers at varying prices according to the type of electronic (Feng et. al. 2013). A survey of 957 Beijing residents conducted by the Beijing Institute of Technology in 2010 illustrated that this system is the most successful at capturing e-waste because consumers highly value the convenience of selling their used electronics to a peddler at their doorstep and appreciate receiving a monetary reward for their obsolete electronic devices (Wang et. al. 2011). In fact, the study found that on average each household stored 1.93 broken or obsolete electronic products for three years rather than disposing of them immediately, primarily because they were still considered valuable goods that shouldn't be thrown away (Wang et. al. 2011). Moreover, 77% of the residents expressed that they would not be willing to voluntarily pay a fee to have their device recycled by a formal recovery facility and only 54% responded they would accept the charge if it were mandated by a law or regulation (Wang et. al. 2011). Interestingly, there were no significant differences found in willingness to pay between rich and poor residents (Wang et. al. 2011). Those

who were willing to pay a recycling fee in advance, still expressed a desire to get some money back for their electronic at the time of collection (Wang et. al. 2011).

Nevertheless, formal collectors typically offer consumers low prices (compared to informal peddlers) or nothing at all for their used electronic goods at the time of collection. Due to the high costs of investing in safety equipment and facilities that pass the government's eco-design standards for registered recycling enterprises, formal collectors offer at most a third of informal collector prices (Yu et. al. 2010). For instance, in 2006 the United Nations Environmental Programme (UNEP) launched a pilot recycling project in Suzhou, Jiangsu province, creating Suzhou Weixiang E-waste Recycling Ltd. in collaboration with Weixiang Ltd (Yu et. al. 2010). Using the latest technology in sophisticated air and water purification systems, the establishment was designed to safely recycle over 100,000 computers (5,000 tons of e-waste) (Yu et. al. 2010). However, the facility offered consumers very low prices for their electronics. For instance, a computer was priced at $7.35 in contrast to the $22 - $30 most informal Suzhou collectors were offering and consumers were also required to bring their e-waste to the recycling facility (Yu et. al. 2010). The project struggled to collect sufficient waste to maintain normal operations, even though over 400,000 computers were discarded in 2006 alone (Yu et. al. 2010). Another electronics take-back program offered consumers $.16 per kilogram of e-waste and managed to collect only 60 tons of e-waste (Yu et. al. 2010). Even a recycling facility with over 36 convenient collection points scattered across the city of Hangzhou could not collect enough electronic scrap to

remain in business, most likely because they didn't offer any monetary reward to consumers.

The observations of consumer perspectives on e-waste recycling suggest that the formal e-waste recycling industry needs to make itself more attractive to consumers through convenient collection services and monetary incentives. If not, the informal e-waste recycling sector will continue to dominate the market. As the 2013 United Nations University StEP (Solving the E-Waste Problem) Program report notes, "acknowledging and planning around consumer preferences regarding…the use of particular disposal channels might offer a key to increasing formal sector competitiveness."

Once e-waste is collected by informal recyclers they have the choice to either directly resell items in decent condition on the second-hand market or bring the goods to a recycling workshop to be refurbished or dismantled and stripped for the valuable components and materials. By selling used electronics directly to the second-hand market a peddler can make about three times the price they originally paid to consumers (Feng et. al. 2013). While this is a hefty profit, the greater economic benefits lay in recovering resources such as gold, silver and copper.

2.3 **Where the Big Money: Resource Extraction**

Although the formal e-waste recycling sector may be struggling to gather enough material to stay in business, the informal sector is booming, making the e-waste recycling industry highly lucrative as a whole. One study estimates that the recycling

center of Guiyu alone garners an annual revenue of 800 million RMB ($72 million) from the extraction of such precious materials (Hicks et. al. 2005). Some of the discarded electronic equipment some can be dismantled into individual parts to be used in manufacturing new products, such as electronic toys (Wang 2011). The remaining e-waste is disassembled to recover plastic and precious metals. Printed circuit boards are typically composed of 30% plastic, 30% inert oxide, and 40% metal, including high-grade precious metals (Lu et. al. 2014). CRTs contain an average of 4 – 8 lbs of lead (Huo et. al. 2007). The metals may be sold as raw material or directly reused to manufacture new products while the reinforced plastic resins can be pulverized for reuse as coatings, paving, and building material (Lu et. al. 2014).

The profits to be gained from selling the reclaimed raw materials are significant. Precious metals extracted from e-waste such as copper, aluminum, and gold all fetch hefty prices on both the domestic and global market. Early generation PCs contained up to 4g of gold each and modern computers still use small amounts of gold in their chips and circuit boards (Wang 2011). According to an interview with one e-waste recycler who had been in the business for eight years, for every 10 computer circuit boards a worker could usually extract 1 gram of gold, 10 grams of silver and 50 grams of copper (Xinzhen 2012). In 2005 the global market price for gold was $14.34 per gram and by 2012 had risen to $53.68 per gram (World Bank 2015). A pound of copper could be sold for $1.67 on the global market and by 2012 the price had risen to $3.61 (World Bank 2015).The International Criminal Police Organization (INTERPOL) estimates that on average one metric ton of e-waste is worth approximately $500 in salable commodities,

making e-waste imports to China worth several billion dollars annually. China is often characterized as a resource-poor country, with per capita distribution of natural resources at 58% of the world average (Hicks et. al. 2005), making the raw materials from e-waste all the more valuable. Due to the economic benefits from raw material extraction, the sizable profits linked to e-waste and the large number of unskilled workers employed by the e-waste recycling industry, it is not surprising that China's national government has been lenient for many years on the illegal imports of e-waste. At the local government level, attempts to control the informal recycling industry have also been feeble at best. In 2005, the head of the Guiyu township established a ban on burning computer parts or soaking them in acid yet the practice continues without abate (Chung 2011).

2.5 Economic Benefits for US Recyclers

China is not the only one benefitting economically from the trade in e-waste. E-waste exports are highly profitable for American recyclers as well. This is because gleaning materials from electronic components is a difficult and expensive process when done domestically, while shipping e-waste to China is low-cost and highly profitable.

Proper e-waste recycling in the United States is not a very lucrative business. In order to obtain reusable and recyclable metal and plastic scrap, the electronic waste must be stripped and sorted into its component parts which (if not done by hand as it is in China) requires multimillion-dollar machinery plus trained operators (Ezroj 2010). In the United States, facilities using such machinery must comply with government safety

standards plus pay their workers fair wages. Once the e-waste has been sorted into its constituent parts (e.g. CRTs separated into glass, plastic, and metal components) recyclers are often required to send the scrap to another facility equipped to handle that particular material. For instance, few recyclers are equipped to handle CRT glass. As a result, CRT glass must be sent to either a glass-to-glass recycler or a glass-to-lead recycler (Kang and Schoenung 2005). However, there are only a handful of facilities in the United States that are able and willing to process CRT glass because unlike glass bottles or window panes, CRT glass contains lead and copper which change the properties and quality of the output glass cullet. Most recyclers refuse to take on the added risk of processing CRT glass, since the wrong glass composition can contaminate an entire glass furnace and force operations to be shut down for three to four days to remedy the problem (Kang and Schoenung 2005). This means that to "properly recycle" CRT glass, an e-waste recycler must first seek out a recycler that will accept the glass and then deal with the costs of shipping it to that facility.

The costs of shipping e-waste to other US recyclers is much higher than the cost of simply sending the waste abroad. The price of shipping a container from Los Angeles to Chicago is approximately $2,400 while sending a container from Los Angeles to China is only around $600 (Royte 2013). One author found that the cost of shipping 40,000 pounds of e-waste from Los Angeles to Hong Kong was lower than the price of shipping just 50 computers from Los Angeles to San Francisco (Houghton 2009). This is largely due to the fact that recyclers are able to take advantage of discounted shipping rates for containers that would otherwise be sailing back to China empty (Royte 2013). Once the

e-waste arrives in China (and makes it through customs), the goods can be sold for a significant profit. According to existing sources, one container of CRT monitors can be sold in Hong Kong for $5,000 (UNODC 2013).

Despite the significant economic benefits to be gained for both the United States and China via the e-waste trade, in 2013 the Chinese government finally cracked down on e-waste imports. In a ten-month campaign called Operation Green Fence, the Chinese Ministry of Commerce (MOC) and Ministry of Environmental Protection (MEP) the government implemented China's long-standing (but historically unimplemented) ban on all imports of electronic and electrical waste and scraps, while also severely reducing the amount of contamination permitted for all other imported recyclables (1.5% contamination per bale of scrap) (Royte 2015). The next chapter will explore the series of legislative measures introduced leading up to Operation Green Fence and the reasons Operation Green Fence was implemented.

Chapter 3: A Brief Background on Chinese and US Legislation Regarding E-waste

In order to understand the political dynamics of waste electrical and electronic equipment (e-waste or WEEE) flows from the United States to China, it is helpful to explore the differences that exist between e-waste regulations (or lack thereof) in both countries. China and the US have developed two very distinct sets of regulatory policies on hazardous waste, yet these dissonances have not been given much attention within the body of scholarly literature on e-waste. Many authors have focused on China's domestic e-waste protocols, pointing out the gaps between China's stringent national laws and regulations on hazardous electronic materials and the widespread lack of enforcement of those standards. Certain authors have called the flow and handling of e-waste in China "administratively invisible" (Feng et. al. 2013), while others attribute the mishandling of e-waste to corruption at the local government level (Shapiro 2011) and loopholes within the e-waste regulations (Liu et. al. 2012). Not much has been written however, regarding the bilateral political and legislative dissonance created by the United States' failure to institute its own domestic regulations on e-waste disposal and its refusal to ratify the international Basel Convention treaty on the transboundary movement of hazardous materials (Basel Convention 2011). As a result, many of the solutions suggested for solving China's e-waste problem have been centered on strengthening the Chinese regulatory framework without addressing the need to simultaneous overhaul the US e-waste policies.

3.1 Easier Said than Done: China's E-waste Regulations

China has instituted an impressive body of legislature aimed at mitigating the amount of e-waste flowing across its borders and regulating e-waste processing. China joined 183 other countries in ratifying the 1989 Basel Convention Treaty, an international agreement aimed at controlling transboundary movement of hazardous waste (Basel Convention 2011). The Basel Convention was created against the backdrop of industrialized nations discarding toxic materials (including e-waste and other recyclables) in Eastern Europe and other developing nations to avoid increasingly stringent domestic regulations (Basel Convention 2011). As a result, the convention explicitly restricts transboundary movement of hazardous waste and demands that the amount of toxic materials generated by all parties first be reduced and second be dealt with "in accordance with the principles of environmentally sound management," regardless of the disposal location (Basel Convention, 2011). The convention outlines that transnational waste movement may occur if and only if all parties have given their written consent. In 1995, the Basel Convention was further strengthened with an amendment—known as the Ban Amendment—that prohibits all exports of hazardous waste from developed to developing nations. Developed countries are defined under the amendment as the 20 members of the Organization for Economic Cooperation and Development (OECD), the EU, and Liechtenstein, while developing nations constitute the non-OECD States (Basel Convention 2011). China, along with 82 other countries, ratified the Ban Amendment (Basel Convention 2011). By ratifying both the treaty and the amendment, China has emphasized its political commitment to protecting its lands

and citizens from foreign sources of hazardous waste. Despite these international agreements, e-waste imports to China from developed nations continue to rise. As the world's largest exporter of e-waste, the US has contributed (and continues to contribute) significantly to China's influx of toxic materials and remains the only OECD member that has refused to ratify the 1989 Basel Convention, much less the 1995 Ban Amendment (Basel Convention 2011).

At the domestic level, China has established significant national legislative measures to deter e-waste from entering its borders and to safely manage internally produced e-waste. Beginning in 2000, the Chinese government introduced increasingly strong controls on the importation, manufacturing, and disposal and recycling of electronic products. In 2000, the State Environmental Protection Agency (now the Ministry of Environmental Protection or MEP) released the first *Catalogue of Solid Wastes Forbidden to Import in China,* a comprehensive list of prohibited imports including a ban on all e-waste imports, including second-hand electronics (MEP 2009). Since 2000, this catalogue has been periodically updated with the latest version published in 2009 (MEP 2009).

In 2006 and 2007, the *Technical Policy on Pollution Prevention and Control of WEEE* and the *Measures for Administration of Pollution Control on Electronic Information Products* were introduced. The first focuses on the 3R principle (Reduce, Reuse, Recycle) and "Polluter Pays" guidelines. The 3R stipulations lay out general strategies for reducing the overall amount of domestically generated toxic electronic waste and encouraging reutilization of materials, refurbishing used electronics, and

recycling (Wang et. al. 2013). The Polluter Pays directive itemizes board standards for eco-design and stipulates that "the principal source of pollution would be responsible for the pollution" (Li et. al. 2008). However, as with previous legislation, this directive has been ineffective at significantly mitigating the environmental impact of e-waste in China since the document does not specify legal consequences for non-compliance (Li et. al. 2008). In 2007, the Ministry of Industry and Information Technology (MIIT) enacted the *Measures for Administration of Pollution Control on Electronic Information Products*. This regulation is considered by many scholars to be a counterpart to the EU Restriction of Hazardous Substances (RoHS) directive (which has been in force since 2003) in that it restricts the use of six hazardous substances: lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers (Liu et. al. 2006; Ministry of Commerce 2006). Mirroring the RoHS, the legislation also stipulates that when designing electronic products, producers "shall adopt the plan of non-toxin, harmless, or low-toxin, low-harm easy degradation and convenient for recycle" and will be punished for non-compliance (European Commission 2015; Ministry of Commerce 2006). In this way, the 2007 legislation strengthens the Polluter Pays concept introduced in 2006. However, while these measures perform the critical task of targeting hazardous waste at the source, they nevertheless fail to provide specific guidelines for dealing with e-waste disposal at the end of the manufacturing life cycle.

In 2008 and 2011, the MEP introduced three regulations on the end-of-lifecycle processing of e-waste. The 2008 *Measures for Administration of Pollution Prevention* introduced a licensing scheme by which Chinese electronics recyclers could apply for a

permit to recycle electronic waste according to set environmental standards. The 2008 *Technical Specifications of Pollution Control for Processing WEEE* provided further specific technical guidelines on e-waste storage, transport, dismantling, and waste handling (Wang et. al. 2013). In 2011, China introduced the *Regulation on Management of the Recycling and Disposal of Waste Electrical and Electronic Equipment*. Significantly more robust than all previous legislation on internal e-waste management, the policy made e-waste recycling mandatory and expanded upon the previous Polluter Pays directive by levying taxes on producers and importers of electronic goods to fund e-waste treatment subsidies (Wang et. al. 2013). The tax amounts vary by good, according to the estimated costs associated with treating the e-waste post-consumption. The regulation is modeled after the EU's WEEE Directive which introduced collection schemes aimed at increasing e-waste recycling (European Commission 2015). Minimal evaluation has been done as of yet to assess the effectiveness of China's e-waste recycling mandate and taxation system, nevertheless, the institution of this policy has been viewed as a pivotal stride towards creating a vigorous electronic waste control system.

With such a robust body of legislation in place to ensure the responsible management and recycling of e-waste, why is China struggling to properly regulate these materials? Some scholars claim that while the e-waste protocols may appear stringent, there are in fact significant loopholes in the legislature. For example, not all of the national Chinese environmental regulations apply to the special administrative regions of Hong Kong and Macau, which each have their own environmental protection

bureaus (Liu et. al. 2012). This is particularly problematic since Hong Kong is a primary entry point for electronic waste imports from other countries (Wang et. al. 2013). Another loophole exists in how "e-waste recycling" has been defined in Chinese legislature. Even the most robust policy introduced thus far, the 2011 *Regulation on Management of the Recycling and Disposal of Waste Electrical and Electronic Equipment*, does not include clear stipulations on the repair and refurbishing of e-waste, which can be just as dangerous to public health and the environment as recycling and resource extraction processes (Lin et. al. 2012).

Furthermore, multiple government agencies have responsibilities linked to e-waste, ranging from the Ministry of Industry and Information Technology (MIIT), National Development and Reform Commission (NDRC), the Ministry of Commerce (MOC), and the aforementioned Ministry of Environmental Protection (MEP) (Li et. al. 2008). The overlapping responsibilities of each of these agencies and, most importantly, the unclear delegation of authority with regard to e-waste policy implementation has directly contributed to the lack of enforcement of electronic recycling regulations. E-waste issues have often been transferred from agency to agency without any bureau taking primary responsibility for remediation (Shapiro 2012). While the 2008 *Measures for Administration of Pollution Prevention* dictate that "the MEP shall take responsibility for supervising efforts to prevent pollution from e-waste," the MEP is considered an infant institution and one of the weakest bodies within the Chinese government when

compared with other long-standing cabinet-level ministries (Shapiro 2012).[6] Hence, while the clarification of the MEP as the primary authority on e-waste management may be seen as a pivotal step towards a more effective monitoring system, it did little to change actual enforcement of the rules due to the MEP's lack of political clout within the Chinese government.

3.2 Operation Green Fence

Operation Green Fence was instituted during a time of major political changes within the Chinese government. President Xi Jinping had just assumed office in November 2012 and, in contrast to his predecessors, President Xi took a strong stance on environmental protection. Upon taking power, the President pledged that China would not sacrifice the environment for temporary economic growth (Xinhua 2013). In a May 2013 study session with members of the Political Bureau of the Community Party of China Central Committee, Xi asserted that the Chinese government set and strictly observe an ecological "red line" which requires all regions to optimize, prioritize, restrict or prohibit their industrial development (CCICED 2013). Those who cross the "red line" would be punished (CCICED 2013). At this same meeting, President Xi stated "A sound eco-environment is the basic foundation for the sustainable development of humans and society…our environmental protection and rehabilitation efforts should focus on solving obvious issues that harm people's health" (CCICED 2013). It is believed that

[6] The first environmental bureau, the State Environmental Protection Administration (SEPA), was formed in 1998. The institution only came a cabinet-level body after ten years in 2008 (the same year the *Measures for Administration of Pollution Prevention* policies were introduced) and its name was changed to the Ministry of Environmental Protection (Shapiro 2012).

Operation Green Fence was installed as a direct response to the growing awareness of the negative environmental and health impacts of small recycling enterprises, such as those in Guiyu and Qingyuan (Powell 2013).

The biggest crackdown on e-waste imports was spearheaded by the Ministry of Commerce. In 2013, the MOC collaborated with the MEP to launch Operation Green Fence, the first major Chinese campaign to severely restrict imports of contaminated recyclable materials, including e-waste (Velis 2012). While the campaign was a natural outgrowth of China's previous legislature, Operation Green Fence was highly unique in that it brought on an unprecedented wave of implementation of China's e-waste protocols and a major tightening of restrictions on other imported recyclable materials. It is speculated that during the ten-month campaign, Chinese customs officials turned away over one million tons of recyclable material including plastics, paper, and rubber that failed to meet the 1.5% limit[7] on contaminants such as metals, organics, and other non-recyclable materials. Any intercepted shipments of e-waste to China were rejected in accordance with the e-waste import ban outlined in the *Catalogue of Solid Wastes Forbidden to Import in China* (Earley 2013). Denied shipments were charged port demurrage fees until the containers could be sent back and many import-export licenses were rescinded during the campaign (Powell 2013). In fact, by the fifth month of Operation Green Fence, Chinese customs officials had suspended the licenses of 247

[7] The previous limit set by the MOC was 3 – 10% (Rooney 2014)

companies in violation of China's regulations (Earley 2013) and intercepted 337 cases of illegal smuggling of solid waste valued as $272 million (Martin 2013).

Operation Green Fence had two primary goals: to prevent the importation of contaminated goods and to crack down on violators of the recyclable licensing scheme. Shipping recyclables to China requires a recycling certification administered by the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ). Customs officials found that licenses were being sold under the table and that licensees were running illegal scrap auctions (Powell 2013), activities which both largely contributed to the problem of contaminated recyclables crossing Chinese borders. As part of Operation Green Fence, Li Shuyuan of China's MEP stated that companies caught using an AQSIQ license to import mixed wastes (such as e-waste) or using a license that does not belong to them would not only face cancellation of their licenses, but also face criminal charges (Taylor 2014).

Of course, the implementation of Operation Green Fence was not without flaw. Sometimes a shipment would be cleared by the China Certification and Inspection Group but ultimately rejected by Chinese customs (Holbrook 2013). Even containers of recyclable materials that met all the Green Fence regulations would at times be turned away. As Paula Felps commented, with enforcement of the Green Fence protocols, a shipment of recyclables found to have so much as a stowaway rodent or a single syringe was at risk of being turned away (Frost 2015).

As a result of these heightened inspections and enforcement of China's import policies, Operation Green Fence sent shockwaves throughout the US recycling market. Since China was no longer accepting dirty scrap, there was a concerted industry-wide effort to swiftly increase the quality of exported recyclable materials. Material recovery facilities (MRFs) began charging collectors to take recycled materials that they had previously been purchasing (Powell 2013). As municipalities searched for domestic recyclers that were able to properly process their low-grade scrap that had previously been shipping to China as is, some full-service US recyclers doubled their production in just six months (Holbrook 2013). In fact, for large-scale US recyclers that had invested in proper pollution control and high-tech recycling machinery, Operation Green Fence was a welcome mechanism to level the recycling playing field. Mike Bidddle, president of MBA Polymers, Inc., commented that legitimate, environmentally responsible recyclers such as his own company applauded the heightened Green Fence regulations since operating their high-cost recycling facilities became a more competitive enterprise in the recycling market (Holbrook 2013). MRFs fitted with the latest recycling equipment were easily able to accommodate the more stringent Chinese regulations. One such recycler, Maine Plastics, revealed that increased revenues due to the Green Fence campaign has allowed the company to invest in new equipment and technology to capture materials that were previously destined for landfills or export to China (Holbrook 2013). Saureen Naik, export sales manager of overseas operations for the Naik Group of Industries (a large recycling corporation), stated, "We see the Green Fence as an opportunity to grow domestically, to create new markets for our export

material, to create new jobs. Overall, we see this as an opportunity and not a threat" (Holdbrook 2013).

Of course, not all US recyclers welcomed the stringent Green Fence regulations with such open arms. Some recyclers producing low-grade scrap material that could not meet the Green Fence standards went completely out of business (Holbrook 2013) while others decided that the economics of sorting and baling mixed recyclables from the single-stream recycling flow would be so cost-negative that it was better to landfill rather than recycle (Frost 2015). Still other recyclers turned to alternative markets in Vietnam and Malaysia in order to continue exporting their scrap materials (Taylor 2014). As the 2013 China International Scrap Conference, Robert Stein of the scrap metal company Alter Trading Co. asked Chinese government officials to consider the long-term implications of upholding the Green Fence standards. Stein warned that continuing to enforce Operation Green Fence would cause Chinese scrap buyers to suffer a competitive disadvantage. He stated, "Importing countries other than China might seem an eminently more attractive option for the reputable exporters with whom, I'm sure, you would prefer to do business" (Taylor 2014). Stein further complained that under Operation Green Fence the compliance costs of supplying scrap to China, from maintaining an AQSIQ license to undergoing inspections by the China Certification and Inspection Group to creating special packaging for recycling bales were "the highest in the entire world" and "inflationary to your [China's] consuming sector" (Taylor 2014). In order to circumvent the strict regulations and costly delays, some companies resorted to attempting to sneak materials into China at night, resulting in government officials

cutting power supplies in some areas to prevent the smuggling activities (Holbrook 2013). Despite the economic implications for China's recyclables sector, the country stood its ground in implementing the Green Fence, acknowledging that in the long run the more stringent regulations would be beneficial to recyclers who "play by the rules." That said, however, since the end of Operation Green Fence in 2013, China has not announced any intention of continuing the strict implementation of its import regulations.

3.3 US E-waste Regulations (Where Are They?)

American recyclers have been permitted to export a large proportion of domestically collected e-waste, rather than manage it internally, because US regulations on the disposal and recycling of electronic materials are minimal and contain significant loopholes. The United States refuses to ratify the Basel Convention (Basel Convention 2011) which would prohibit the continued export of hazardous waste to non-OECD countries such as China and India (the primary destinations for 50 - 80% of the United States' e-waste that is collected for recycling) (Puckett et. al. 2002). Because e-waste is the fastest growing sector of the solid waste stream in the United States, growing by nearly 10% each year (EPA 2011), ratifying the convention would put significant pressure on the domestic recycling industry and, since currently 70% of all e-waste generated in the US is deposited in landfills (EPA 2012), would lead to a major increase in the amount of toxic electronic materials deposited in domestic landfills. The United States' refusal to ratify the convention serves as a strong political message to the rest of

the world: when it comes to the environmental and public health repercussions of passing along its hazardous waste to developing nations, the US does not care.

In contrast to China, the United States has no national-level regulation on e-waste recycling processes. The Resource Conservation and Recovery Act (RCRA) of 1976 is aimed at controlling hazardous materials and is the only federal law that touches upon e-waste, in so far as e-waste falls into the RCRA definition of solid hazardous waste. Particularly problematic is the fact that certain hazardous wastes are exempt from RCRA regulations if they are destined for recycling plants (EPA 2015). This includes materials such as the following, which typically comprise e-waste:

- Processed Scrap Metal – scrap metal that is to be recycled, regardless of trace heavy metals it may contain
- Shredded circuit boards – circuit boards that are being recycled, as long as they are free of mercury switches and relays as well as nickel-cadmium batteris and lithium batteries (equipment containing mercury falls under the RCRA's list of "universal waste," which will be discussed in a moment)
- Closed-loop recycling – secondary materials that are to be reused in their original production process, so long as they are not burned, accumulated for over twelve months, the materials are not used to create fuel, and are not simply repurposed for disposal
- Hazardous secondary materials reclaimed by the generator—hazardous materials that are generated and reclaimed on-site

- Hazardous Secondary Materials Transferred Off-site for Reclamation – Hazardous secondary materials that are sent off-site (including materials exported for reclamation)

In a collaborative report on e-waste prepared by the Basel Action Network and Silicon Valley Toxics Coalition, the authors write of these exemptions: “The concept of pretending a material is not hazardous simply because it is being recycled is an unscientific, dangerous policy and in fact, is a uniquely North American one...this policy was adopted despite the fact that all recycling involves some final residues” (Puckett et. al. 2002).

In addition to these many exemptions, over the year the RCRA has been repeatedly amended to loosen rather than tighten existing controls over toxic electronic wastes. In 2005, the Environmental Protection Agency (EPA) removed mercury-containing equipment from “listed waste” and added it to the list of “universal waste” outlined by the NCRA. “Listed wastes” are wastes that have been determined by the EPA to be hazardous (EPA 2012) while “universal wastes” include many non-hazardous materials (EPA 2012). According to Joy Scrogum (2015) of the Sustainable Electronics Initiative, “handlers of universal wastes are subject to less stringent standards for storing, transporting, and collecting these wastes.” The EPA factsheet on the final rule regarding discarded mercury-containing equipment states that including these toxic materials under the universal waste definition “provides flexibility for its proper management” (EPA 2005). In theory, the rule was aimed at reducing the amount of mercury in landfills by allowing mercury-containing equipment to be reused or recycled

(EPA 2005). In 2006, the EPA passed an amendment that completely excluded Cathode Ray Tubes (CRTs, the glass display component of an electronic device that contains several pounds of lead, varying according to screen size) from the RCRA definition of hazardous solid waste (EPA 2015). Again, the EPA claimed this was done in an attempt to “streamline management requirements for recycling of used CRTs” (EPA 2015).

The lack of regulation surrounding the export of these toxic materials has facilitated the outsourcing of American pollution to countries such as China. Thus far, the only type of e-waste export that has been minimally regulated is CRTs. In 2006 the EPA passed a rule under the RCRA that “exporters shipping broken or unbroken CRTs to another country for recycling must notify the EPA and receive written consent from the receiving country through EPA before shipments can be made” (EPA 2006). In 2014, this rule was revised to more clearly define “CRT exporter” and require additional information from exporters in order to more accurately calculate annual CRT exports (EPA 2014). The RCRA includes a similar rule for the export of hazardous wastes, as described in the *Standards Applicable to Generators of Hazardous Waste* (EPA 2012). However, due to the myriad exemptions mentioned above, almost all e-waste does not qualify as solid hazardous waste under the RCRA, leading to a near complete lack of federal regulation of e-waste exports.

While there are no mandatory federal e-waste recycling directives, the US government has introduced two voluntary e-waste recycler certification programs. The first, the Responsible Recycling Practices R2 Standard was started in 2008 as a way to “identify, aggregate, distribute, and monitor best-practices in electronics repair and

recycling" (SERI 2015). The program is run by the non-profit organization Sustainable Electronics Recycling International (SERI) and is aimed at creating "market incentives for recycling facilities to implement environmental, health, and safety procedures" (SERI 2015). Essentially, e-waste recyclers can use the R2 Standard as a "market differentiator" and "value-add for prospective clients and partners" (SERI 2015). However, as the Electronics TakeBack Coalition points out, R2 standards still allow export of e-waste to developing nations as well as the use of prison labor in domestic recycling operations) (Electronics TakeBack 2011). The second voluntary e-waste recycler certification program is the e-Stewards Standard for Responsible Recycling and Reuse of Electronic Equipment, which was created by the Basel Action Network in collaboration with the EPA (but is now an independently audited certification program) and was first introduced in 2009 (e-Stewards 2015). The e-Steward Standards were written for international use and is "set into the framework of the global environmental management system" (e-Stewards 2015). Unlike the R2 Standard, the e-Steward certification program requires that recyclers operate a management system that is in legal compliance with all international laws, including the Basel Convention (e-Stewards 2015). It also stipulates that e-Steward recyclers be socially responsible by forbidding practices such as the use of sweatshops, child or prison labor (e-Stewards 2015). The e-Steward program is by far the cleanest, most globally responsible standard for e-waste recycling that exists in the United States.

At the state level, twenty-five states have developed their own electronics recycling laws, however none of these state policies cover the full scope of electronic

and electrical equipment or address the issue of e-waste exportation (EPA 2015). California was the first state to institute e-waste recycling laws in 2005 while Vermont and South Carolina are the most recent states to institute e-waste controls, introducing electronic recycling policies in 2011 (Bennett 2015).

Of the states that have introduced e-waste regulation, 23 of the state policies use the Extended Producer Responsibility (EPR) approach to manage e-waste. Essentially, EPR laws are a policy approach that allocates a significant portion of the financial and/or physical responsibility for the treatment or disposal of post-consumer products (OECD 2001). In theory, such laws are meant to create an incentive for the producers to create goods with fewer hazardous materials and making it easier for themselves to recycle. However, the effectiveness of EPR laws are highly dependent on the institution of post-consumer product collection goals and establishment of non-compliance penalties. In the United States, only a few states have instituted e-waste collection goals and as a result the EPR laws have not been very effective in increasing the overall amount of e-waste collected for recycling (Electronics TakeBack 2011). This is because most manufacturers will not take initiative to collect products beyond what is strictly required of them by law. For instance, in 2007 Texas passed an EPR law that requires computer companies to launch takeback programs for their products but does not stipulate specific targets for program performance. In 2010, of the 78 companies selling computers in Texas, 36 of them collected a total of zero pounds of e-waste (Electronics TakeBack 2011). In states where clear minimum collection objectives have been laid out, manufacturers have been found to halt collection once they hit the

minimum collection goal. For instance, in Oregon some manufacturers put a halt to their collection efforts once it became clear that they would exceed that state's annual collection goals. In addition, most EPR laws do not include stipulations on how the e-waste is recycled, leaving this crucial management decision to the producers. As a result, exportation of e-waste has continued even in states with EPR laws.

California and Utah are the two states that have not instituted EPR laws. California has introduced an Advanced Recycling Fee (ARF) law that mandates consumers pay for recycling at the time of purchasing electronics. Utah has a Manufacturer Education directive which requires electronics producers to inform consumers about their recycling programs and to report to the Department of Environmental Quality before putting an electronic out to market. However, as with the EPR laws, this legislature has had minimal success in ensuring that e-waste is collected and processed in an environmentally sound manner.

Chapter 4: Conclusion

The electronics recycling sector in the United States is not the environmentally responsible industry that it purports to be. Conversely, the US electronics recycling industry has been complicit in causing the environmental and public health harm associated with the informal e-waste recycling industry in China. Therefore, while the Chinese government must continue making a concerted effort to enforce the regulations they have put in place if low-income communities in China are to be protected from bearing a disproportionate share of the negative environmental consequences of US citizens' technologically advanced lifestyles. However, this is only half of the solution. The United States must also tighten its own e-waste regulations. Unless stricter e-waste controls are introduced at both the federal and state level, the pattern of e-waste dumping will continue—if not in China (should the Chinese government continue the effort to strictly enforce its e-waste regulations), then in other countries such as Vietnam and Malaysia with similar informal recycling sectors and little environmental policy implementation.

One possible regulatory solution to preventing e-waste dumping would be to create federal e-waste regulations loosely modelled after the 2012 European Union WEEE Directive. The Directive sets minimum targets for e-waste collection (covering the full scope of electronic and electrical products) and uses the Extended Producer Responsibility approach to finance the e-waste recycling operations (European Commission 2015). There should also be a federal ban on the export of hazardous waste, modelled after the 1995 Basel Ban Amendment. At the state level, there should

be legislation requiring a certain number of collection sites for residential areas according to population size and type of residential area (urban or rural) in order to make e-waste collection as convenient as possible. States should also institute e-waste tracking and reporting requirements in order to create more transparency regarding the amount of e-waste being generated and collected, as well as accountability for how it is being recycled.

The United States has been complicit in the causing the environmental and public health harm associated with the informal e-waste recycling industry in China. By continuing to export e-waste collected for recycling, the US is acquitting itself of the environmental repercussions of processing its hazardous waste, all under the guise of an environmentally friendly industry. With the body of research providing evidence that e-waste exported from the United States to China is being dumped in rural e-waste villages, where it is processed with dangerous methods, it is no longer possible for the United States to feign ignorance or innocence. The export of e-waste to China is in direct violation of the principles of environmental justice that the US federal government has embraced, including the specific stipulation that “no group of people should bear a disproportionate share of the negative environmental consequences resulting from industrial, governmental and commercial operations or policies” (EPA 2015). This is not acceptable; our waste and pollution is our responsibility.

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