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E-waste recycling processes in Indonesia, the Philippines, and Vietnam: A case study of cathode ray tube TVs and monitors

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ABSTRACT

The amount of electronic waste (e-waste) is rapidly increasing due to economic growth and the advancement of information technology. End-of-life (EOL) cathode ray tube (CRT) TVs and computer monitors make up the greatest proportion of the total mass of e-waste. Because of international trade in secondhand CRT TVs and monitors and the toxic substances contained in them, the EOL fate of CRTs is an emerging concern in developing countries. In this study, the recycling and treatment techniques of EOL CRT TVs/monitors were investigated in three Southeast Asian countries (Indonesia, the Philippines, and Vietnam). The current recycling methods of CRT TVs/monitors in Japan and China were also reviewed for comparison. The process flows and destinations of materials or parts at both formal and informal recycling sites were compared. Among the three countries, only one formal facility in the Philippines has automated processing equipment for CRTs. CRT glass handled by informal sectors was illegally dumped or disposed of with regular municipal solid waste. Some waste CRT glass was also informally recycled as glass materials or exported to China. A number of recommendations are made to improve recycling conditions at both formal and informal recycling sites.

1. Introduction

The amount of waste electrical and electronic equipment (WEEE), or electronic waste (e-waste), is rapidly increasing due to economic growth in the developing countries and the advancement of information technology. The Solving the E-Waste Problem (StEP) Initiative estimated that the world produced nearly 49 million tons of used electrical and electronic equipment in 2012, and it will be 65.4 million tons by 2017 (UNU, 2013). Because e-waste contains toxic substances such as lead, cadmium, arsenic, and mercury, there are growing concerns that much e-waste will end up in developing countries that lack the necessary infrastructure for proper e-waste management, resulting in adverse economic, social, and environmental impacts (Widmer et al., 2005). Cathode ray tube (CRT) TVs/monitors are items of great concern because they contain hazardous substances and are traded as end-of-life (EOL) products. The peak of CRT waste generation is estimated to occur in 2015–2020 (Gregory et al., 2009).

Solid waste management system usually involves both the formal and informal sectors (Sembiring and Nitivattananon, 2010). In developing countries, the recycling activity is still done in the informal sector, which includes junkshops and private individuals. The informal sector is labor intensive, uses low-level technology, and generally generates low levels of income (Wilson et al., 2006). Those participating in it often do not pay income taxes and generally avoid government regulations.

Despite the gradual development of legal e-waste recycling systems in developing countries, e-waste is still collected and recycled at informal recycling facilities. In fact, in developing countries, most e-waste is currently collected by individual

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collectors and recycled in small-scale facilities or by individuals (Chi et al., 2011).

Many studies have documented the environmental and health impacts of e-waste recycling in developing countries. High-level environmental emissions of heavy metals and persistent organic pollutants have been reported in southern China and India (Sepúlveda et al., 2010). Wire is often open-burned to remove the plastic insulation to recover copper (Gullett et al., 2007). Shredding, grinding, and other size reduction and separation processes generate dust in recycling facilities. The various types of dust may pose not only environmental contamination risk, but also an inhalation and dermal exposure hazard to workers (Tsydenova and Bengtsson, 2011; Takahashi et al., 2011). Approximately 2.7 million tons of plastics containing flame retardants are globally discarded in WEEE annually (Peeters et al., 2014). Polybrominated diphenyl ethers (PBDEs), one of the flame retardants. Major discharge sources of PBDEs are (1) open dumping and stockpiling, (2) crushing/grinding processes, and (3) open burning or uncontrolled thermal processing of printed wiring boards (PWBs) (Kajiwara and Takigami, 2011). Although there is a rich literature about e-waste management practices, disassembly process, processing costs and environmental impacts (Aizawa et al., 2008; Chancerel et al., 2009; Perez-Belis et al., 2013; Ardente et al., 2014), it is still difficult to find a comparison of e-waste recycling process between different developing countries.

Asian countries have started to apply extended producer responsibility principle to e-waste since the late 1990s. China started a WEEE recycling program in January 2011. In India, E-waste (Management and Handling) Rules were placed in force in May 2012. Although the importance of establishing WEEE legislation has been recognized, progress is still relatively slow in Southeast Asian countries (Afroz et al., 2013). Thailand and Malaysia are in the process of finalizing their own e-waste legislation and strategies (Manomaivibool and Vassanadumrongdee, 2012). Indonesia and the Philippines are also in the process of developing e-waste legislation. In Vietnam, Prime Minister Decision No. 50/2013/QD-TTg, which prescribes practices for the retrieval and disposal of discarded products, was placed in force in September 2013. A take-back system and regulation of the proper collection, recovery, processing, and disposal of waste products will begin in 2015 and 2016.

Table 1 shows estimates of the annual amount of e-waste generated in five Southeast Asian countries. E-waste generation in Malaysia and Thailand, which are relatively more economically advanced, was estimated at 6 to 10 kg per capita in 2012. In Indonesia, the Philippines, and Vietnam, three middle-income countries, e-waste generation ranged from 2 to 3 kg per capita. The population of Indonesia, the Philippines, and Vietnam will each be more than 100 million people in 2030. Because of the increasing population, particularly the increasing middle-income population, the market for electronic equipment will continue to expand in these areas. Therefore, consideration of future e-waste generation in these three countries is of growing importance.

In this study, we surveyed current recycling processes and technology in three middle-income Southeast Asian countries: Indonesia, the Philippines, and Vietnam. In this paper, we first review state-of-the-art CRT TV/monitor recycling technology in Section 2 and then describe our survey methods in Section 3. In Section 4, we present our survey results for both the formal and informal recycling sectors. Based on the results of our detailed investigation, we then analyze and discuss current problems and make recommendations for better management options in Section 5 and offer concluding remarks in Section 6.

2. Review of CRT TV/monitor recycling technology

2.1. Toxicity

A CRT is an evacuated glass envelope containing an electron gun and a fluorescent screen, and used in televisions and computer display screens (Herat, 2008). A typical CRT computer color monitor/TV is composed of a plastic casing, a CRT, a deflection yoke, a PWB, connecting wires, and various types of metals.

The CRT contains two types of glass—panel glass and funnel glass. Panel glass is in the front part of the CRT and makes up about two-thirds of its weight. Funnel (cone) glass, which makes up most of the other third, contains about 25% lead (as lead oxide) to shield viewers from the radiation produced by the electron gun (Menad, 1999; Andreola et al., 2005; Nnorom et al., 2011).

Because of the high concentration of lead in CRTs, the environmental impact of discarded CRTs cannot be neglected. The Toxicity Characteristics Leaching Procedure (TCLP) is commonly used to determine the leaching toxicity of wastes. If TCLP analytical results are exceeds the threshold levels, wastes are classified as hazardous and they must be taken to a hazardous waste disposal facility (USEPA, 2015). The neck and funnel glasses of CRTs are classified as hazardous wastes, whereas panel glass has little toxicity (Poon, 2008). Previous studies have examined the leachability of lead from CRTs in landfill sites and attempted to identify its potential risks (Jang and Townsend, 2003; Nnorom et al., 2011).

2.2. State-of-the-art recycling technology of CRT TVs/monitors

Because of its high lead content, CRT glass should not be disposed of in the trash or municipal waste landfill sites without proper treatment.

Fig. 1 shows the recycling process for CRT TVs in Japan (Matsuto et al., 2004; Aizawa et al., 2008). The CRT unit is manually separated from the plastic cabinet, PWB, deflection yokes, power cords, and any other components. After removal of an anti-implosion band, the stripped CRT is vented to remove the vacuum to prevent the risk of implosion. Panel glass is separated from funnel glass by hot-wire cutting or by laser cutting. Phosphor coatings inside the panel glass are removed with a vacuum cleaner. The lead-free glass and the lead-containing glass are crushed and handled separately. After size-reduction (shredding), the crushed glass is processed in dry-scrubbing machines known as “drum shakers” to remove coating materials. A more detailed description of the polished (cleaned) CRT glass recycling process is given in the next section. The fluorescent powders and powdered glass generated from the polishing process are sent to a lead smelter or incinerator for final disposal.

Cabinet plastics are checked by an automatic identification device of plastic types, and bromine containing plastics are separated. The sorted plastics are separately crushed, and then used as material or feedstock for recycling. The PWBs are sold to local smelters for the recovery of copper. The anti-implosion bands and shadow masks are sold to iron and steel plants. The deflection yokes and electron guns are sold to local non-ferrous metal recyclers or iron and steel plants. Power cords and wire harnesses are also sold to local non-ferrous metal recyclers (AEHA, 2010). The cord and wires are crushed into small pieces, and then using vibration and/or water, the fine granules are separated into copper and coating materials in a “nugget” machine. The recycled copper is sold as a resource, and the insulated PVC coatings are incinerated for disposal.

2.3. State-of-the-art recycling technology of CRT glass

In terms of recycling waste CRT glass, there are two types of technologies: glass-to-glass and glass-to-lead recycling. Glass-to-glass