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Review

Emerging issue of e-waste in Pakistan: A review of status, research needs and data gaps

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ABSTRACT

This review article focuses on the current situation of e-waste in Pakistan with the emphasis on defining the major e-waste recycling sites, current and future domestic generation of e-waste, hidden flows or import of e-waste and discusses various challenges for e-waste management. Needed policy interventions and possible measures to be taken at governmental level are discussed to avoid the increasing problem of e-waste in the country. Our findings highlight that there is still a general lack of reliable data, inventories and research studies addressing e-waste related issues in the context of environmental and human health in Pakistan. There is therefore a critical need to improve the current knowledge base, which should build upon the research experience from other countries which have experienced similar situations in the past. Further research into these issues in Pakistan is considered vital to help inform future policies/control strategies as already successfully implemented in other countries.

1. Introduction

Electronic and/or electrical waste (e-waste) is a growing problem all over the world. There is no exact definition of e-waste but according to the Organization for Economic Co-operation and Development (OECD) “any appliance using an electric power supply that has reached its end-of-life” is termed as an e-waste. Another term which is also used along with e-waste is waste electrical and electronic equipment (WEEE) which includes non-electronic items like ovens and refrigerators, but the distinction between both is becoming blurred due to advent of pervasive computing (Directive, 2003). According to the Directive 2002/96/EC of the European Parliament and of the Council (January 2003) on Waste Electrical and Electronic Equipment (WEEE), ten categories of e-waste are defined (Bains et al., 2006). Out of all these ten categories, categories 1–4 contribute with 95% of the amount of e-waste generated worldwide (Table S1). In general, home appliances represent the major fraction of e-waste produced worldwide by weight; it contributes approximately 50% with communication, information equipment with 30% and consumer appliances with 10% (Lundgren, 2012). E-waste is chemically and physically distinct from other types of industrial and municipal waste and includes both valuable metals like copper and gold as well as various hazardous substances (flame retardants, lead, mercury, arsenic, etc.) (Sepúlveda et al., 2010), which requires special handling and recycling techniques to minimize environmental contamination and potential harmful effects on human health. A combination of shorter life span of appliances, increased consumption, low recycling rates, and illegal transboundary transport of e-waste from developed to developing countries (Tong and Wang, 2004) are all driving forces which contribute to elevated exposures to toxic

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substances in some developing regions. High labor costs, strict environmental regulations and lacking facilities for recycling of e-waste make developed and rich countries prone to export some of their e-waste to poor and developing countries. E-waste in poor and developing countries is often treated and recycled at the expense of environment and human health (Wen and Jin, 2010).

United Nations (UN) reported that the world's generation of e-waste in 2006 was 20–50 million tons per year, which accounts for 1–3% of total municipal waste produced worldwide (Schwarzer et al., 2005). A more recent update projected that the global e-waste generation will increase from 48.9 million tons in 2012 up to 65.4 million tons per annum in 2017 (Kandil, 2013). By the year 2030, it is forecasted that developing countries will discard twice as much e-waste as developed countries (Sthiannopkao and Wong, 2013).

Activities related to informal recycling and improper disposal of e-waste can release persistent toxic substances (PTSs) into environment and thus into food webs (Leung et al., 2006). Worldwide attention has been drawn towards the adverse and negative effects of PTSs on the environment including human health. Several PTSs are known to be endocrine disrupters, posing adverse health effects such as reproductive disorders, developmental deformities, and cancer in both humans and wildlife (Leung et al., 2006) (Table S2). Various studies have been carried out on possible negative impacts of e-waste recycling and disposal in developing regions with many discussing the situation in Southeast Asia. Wong et al., (Wong et al., 2007a) carried out a study in Guiyu, China in which the authors determined the levels of flame retardants, polycyclic aromatic hydrocarbon (PAHs), polychlorinated biphenyl's (PCBs) and heavy metals in air, soil and sediment in surroundings of e-waste recycling facilities (Wong et al., 2007a). Similarly, Leung et al., (Leung et al., 2007) Deng et al., (Deng et al., 2007) Bi et al., (Bi et al., 2007) Wang et al., (Wang et al., 2005) have reported high levels of flame retardants, PCBs and Organochlorines (OCs) in Guiyu city, which is considered among the major e-waste recycling site of the world (Li et al., 2008). Fewer studies have been carried out in India addressing the impacts of e-waste recycling on environment (Keller, 2006; Rochat et al., 2007; Brigden et al., 2005). Yet, all these studies have focused on negative impacts of e-waste recycling and imports which have attracted increased attention to the need for improved management strategies in these countries. In contrast, the situation in Pakistan largely remains to be addressed. The unsafe and environmentally damaging practices used for recycling of e-waste represent an increasing challenge for Pakistan with no registered recycling facilities. The issue to this point has received very little attention from governmental and non-governmental organizations in Pakistan. To date no scientific study has been made to assess the impact of e-waste processing to environment of Pakistan. There is no reliable data available on the volume of used electronic components imported and the fraction of it recycled or dumped as solid waste.

The main objective of this study is to review the current situation of e-waste in Pakistan. As Pakistan receives imports of e-waste from abroad, we first briefly discuss the generation and hidden flows of e-waste on a global scale to provide context for this work. This is followed by an analysis of the amounts of e-waste generated and manufactured within Pakistan, including scenarios for the future. We then explore the major flows and destinations of e-waste within Pakistan, followed by a discussion of domestic regulations and regulatory needs to improve the situation in terms of protecting environmental and human health. We close the manuscript by discussing the more critical data gaps and research needs. Our hope is that this study will serve as a baseline study on e-waste in Pakistan which could guide or facilitate more detailed studies in the future and ultimately lead to improve control strategies to better protect environmental and human health.

2. E-waste in a global context

2.1. Global generation and flows of e-waste

There have been several studies estimating the global generation of e-waste. A recent report by UNU (United Nations University) revealed quantities of e-waste generated in 2014, which is 41,800 kt and is forecasted to increase to 50,000 kt in 2018 (Baldé et al., 2015). According to Step, total generation of e-waste worldwide was 48,894 kt (Initiative, U. N. U. S., 2012) in 2012. Robinson et al. (Robinson, 2009) estimated that 20,000–25,000 kt e-waste was generated annually in 2005, while Breivik et al. (Breivik et al., 2014) suggested the annual generation to be ~35,000 kt in the same year, which represents the average of estimates made by Schwarzer et al., (2005). We can assume that the current and future e-waste generation would be at the higher end of historical estimates because of an increase in the global generation of e-waste in time (Breivik et al., 2014; Robinson, 2009).

Despite the existence Basel Convention on the control of transboundary movements of hazardous wastes and their disposal and other conventions, the transfer of e-waste from the United States, Canada, Australia, EU, Japan and Korea to Asian countries such as China, India and Pakistan remains relatively high (Puckett et al., 2002; Terazono et al., 2006; Umwelthilfe, 2007; Cobbing, 2008). Fig. 1 depicts the flow of e-waste entering into major countries in Asia i.e.; China, India and Pakistan. E-waste imported to China is reported to come from US, EU, Japan, South Korea and several other countries of the world (Deng et al., 2006; Puckett et al., 2002), and it has been claimed that 60–75% of e-waste collected in EU is sent to Asian and African countries for recycling or dismantling (Nordbrand, 2009). E-waste in Pakistan is allegedly imported from US, EU, Australia, Saudi Arabia, Kuwait, Singapore and UAE among many other countries (Umwelthilfe, 2007; Li et al., 2013). Dubai in UAE and Singapore supposedly also serves as pre-distribution centers of e-waste coming from EU and US to South Asian countries with India and Pakistan as the major destinations (Cobbing, 2008).

When the e-waste escapes from formal collection and management, it is then handled illegally, referred to as the “Hidden Flow of e-waste” (Puckett et al., 2002). The associated export of e-waste from developed to developing regions has been ongoing for years. Because of the illicit character of such exports, there is still very limited information available on the transboundary movement of e-waste from developed regions and estimates of hidden flows are typically highly variable. This also applies to the European countries, which have very strict rules and regulations. Out of all the e-waste generated in EU, it has been suggested that only 25% of it is collected and treated while 75% is generally the “hidden flow” of EU (Cobbing, 2008). The hidden flow was more recently evaluated by Breivik et al., (Breivik et al., 2014), in which they estimated that 23% (17%–34%) of the total e-waste generated within OECD countries (Organization for Economic Co-operation and Development) was imported to non-OECD countries in 2005 (Breivik et al., 2014). That study also summarized data on the large amounts of e-waste imported to just seven non-OECD countries (China, India and five West African countries). The authors emphasized that there are other non-OECD countries (including Pakistan) implicated as importers, but which remain to be accounted for (Breivik et al., 2014).

Table 1 presents earlier estimates of the global generation of e-waste along with data for major Asian countries. In order to update the estimates to reflect the recent situation, we performed a simple calculation by multiplying the amount of e-waste generated per capita in 2012 with the population of 2014. From Table 1, it can be