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Chapter 1

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Additional information is available at the end of the chapter

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1. E-Waste Management in transition and developing countries

Waste Electrical and Electronic Equipment management (E-waste or WEEE) is a crucial issue in the solid waste management sector with global interconnections between well-developed, transitional and developing countries. Consumption society and addiction to technology dictate the daily life in high and middle-income countries where population consumes large amounts of EEE products (electrical and electronic equipment) which sooner become e-waste. This fraction is a fast-growing waste stream which needs special treatment and management due to the toxic potential of public health and environment. On the other hand, the e-waste contains valuable materials which may be recovered (precious metals, Cu) reused and recycled (metals, plastics) by various industries mitigating the consumption of natural resources.

The new challenge of e-waste management system is to shift the paradigm from a toxic pollution source to a viable resource in the context of sustainable development. Waste hierarchy concept focuses on waste prevention and 3R policy (reduce, reuse, recycle) and give less attention to landfills. The "end of waste" criteria under Waste Framework Directive (Directive 2008/98/EC on waste) specify when certain waste ceases to be a waste and it obtains a status of a product (or a secondary raw material). EU policy promotes the circular economy where wastes are regarded as resources and set up the directions toward a recycling society. E-waste is a special waste stream with proper legislation.

Furthermore, a new WEEE Directive 2012/19/EU became effective on 14 February 2014 due to the importance of this waste flow across the EU. The Member States are required to collect 45 % of the EEE put on the market (in the three preceding years in that Member State) by 2016. This is a more suitable approach considering the flat collection rate for private households until 31 December 2015 (4 $kg.inhab.yr^{-1}$) of the previous Directive which did not take into consideration the socioeconomic disparities across EU-27. In this context, new EU members like Romania cannot yet comply such collection rate despite recent improvements in this sector due to a lower purchasing power and a greater lifespan of EEE products, particularly in rural areas.

Developed countries tend not to recycle e-waste due to the lack of facilities, high labor costs, and tough environmental regulations and this waste stream is disposed in landfills or exported to developing countries [1]. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal prohibits the export of toxic and hazardous waste to poor countries and the national waste regulations of developed countries restrict the landfill of waste in order to promote the recycling and recovery options.

Take-back systems, special collection points for e-waste stream, ad-hoc e-waste collection campaigns, recycling centers, industrial technology may divert the e-waste disposal from landfills in developed and transitional countries and the e-waste collection performed by informal sector in case of developing countries. The EU promotes the Extended producer responsibility (EPR) which moves the responsibility of local authorities to EEE producers and importers regarding e-waste management and the achieving targets on collection,recycling, and recovery. The implementation of this policy has different results across the Europe [2]. However, large quantities of e-waste are legally or illegally exported from high-income countries to emerging economies and low-income countries, creating serious health and environmental threats in the latter case.

National regulations which permit, ban or ignore the electronic and e-waste export/imports practices vary from one country to another, except EU which has a more homogeneous legislation in the field. Several developing countries banned the imports of e-waste (Nigeria, Cambodia, China, Vietnam, Malaysia, Pakistan) others have not ratified this issue (Benin, Cote D'Ivoire, Kenya, Liberia, Senegal, Uganda, South Africa, India) and some of them permitted such imports (Ghana) with special approvals (Thailand, Philipines) according to Jinhui et al. [3]. Transboundary shipment of obsolete EEE and e-waste is a complex issue at regional and global scale and it is difficult to monitor the illegal activities. India, China, Philippines, Hong Kong, Indonesia, Sri Lanka, Pakistan, Bangladesh, Malaysia,Vietnam, and Nigeria are among the favorite destinations for e-waste and significant amounts of e-waste containing hazardous materials can be seen dumped in open lands and waterways [4]. However, e-waste flows have more complicated patterns than the notorious route Global North to Global South where intra-regional trades (e.g. Canada - USA -Mexico, China- Bangladesh) may play a more significant role in present due to the Basel Convention [5]. Secondly, there is no clear distinction between e-waste and second-hand EEE flows in electronic trades between countries.

Major concerns are that many shipments of e-waste are disguised as second hand goods or safe disposal of waste imported in developing countries is either dumped or unsafely recycled in reality [6]. Other key issues are to know the share of e-waste source (domestically vs imported) across formal and informal recycling sites, data about regional and local e-waste collection schemes, the role of the informal sector in this matter.

Dismantling areas of e-waste from Asian or African countries are heavily polluted with persistent organic pollutants (POPs) listed by *Stockholm Convention* such as: polychlorinated dibenzodioxins and furans (PCDD/Fs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) or other toxic substances as follows: polychlorinated and polybrominated dioxins and furans (PXDD/Fs), polycyclic aromatic hydrocarbons (PAHs), heavy metals (cadmium, mercury, lead, chromium). E-wastes contain toxic components such as batteries, brominated flame retardants (BFRs), asbestos waste and components which contain asbestos, and obsolete EEE (e.g. refrigerators) may contain gasses that are ozone depleting such as chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs).

Such toxic components are required to be removed prior to any treatment or disposal under EU Directive. Specific regulations addressed to e-waste management issues must be further developed and enforced by big players of e-waste market such as USA, EU, China, India, Japan,South Korea, Australia. The lack of legislation, the weak administration, corruption, smuggling practices, lack of a formal waste management system, poor living standards expose the developing countries to primitive recycling activities and to e-waste dumping and burning pollution. China is a major e-waste dismantling area with a developed informal sector involved in rudimentary recycling activities such burning, melting and acid bath in order to recover valuable metals and materials for industry and to assure a regular income despite serious health risks. A comprehensive review focusing on heavy metals reveals the scale of this environmental pollution in air, dust, soil, sediments, plants, particularly in the largest e-waste recycling sites such as Taizhou, Guiyu, and Longtang with severe implications on public health [7]. India is facing similar issues due to low-tech of e-waste recycling activities provided by the informal sector [8].

Recycling companies and informal sector exploit the poor labor force in dismantling areas of developing countries which perform their work in poor conditions, manually, frequently without any protection measures. Such activities are also performed by individuals at the household level as the sole income source.

E-waste dump sites are “hot spots” of heavily environmental pollution usually located in the proximity of residential or agricultural lands. Such sites discharge the leachates and toxic liquids into rivers,ponds, groundwater and soil pollution contaminates the crops, livestock and finally its consumers. Open burning sites of e-waste are severely air pollution sources with heavy metals, dioxins, furans, particulate matter, hydrocarbons ashes including PAH's in the surroundings.

Informal sector plays a crucial role in the waste collection and recycling activities across developing countries. The key issue is to improve the dismantling activities in terms of decent safety, health and environmental standards, to develop the formal sector which hires poor population susceptible to such rudimentary practices supported by proper regulations as shown in figure 1. An integrated approach at global scale may consider a combination of best manual pre-processing activities performed at local scale in developing countries with high-tech end-processing activities of developed countries [9]. Separate collection of e-waste must be improved in transition countries where mixed municipal waste (which contain e-waste) are disposed in landfills with significant losses in terms of recovery and recycling and to increase a rigorous control EEEE and waste exports.

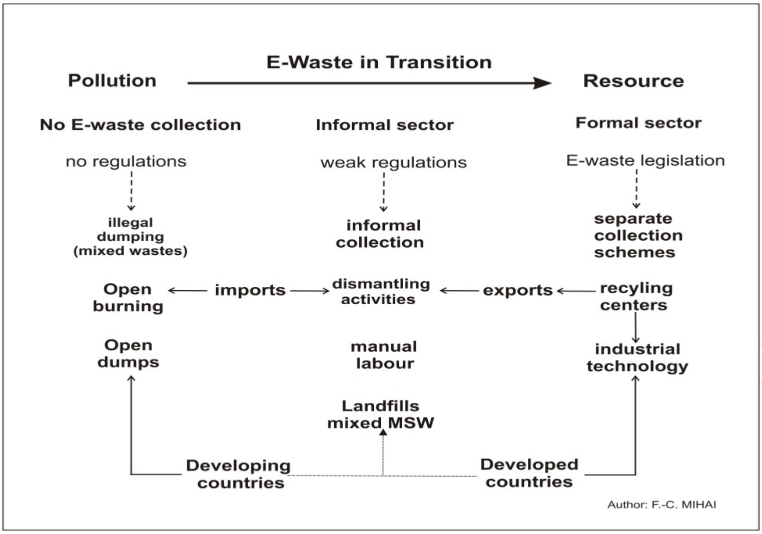

Figure 1. E-waste management interactions in a transitional stage

2. E-waste management in developed countries

WEEE management is carried out worldwide through different approaches. The most holistic national regulation system is the EU directive as it affects the whole life cycle starting from the design phase of an EEE to its end of life management. The recent last update (2012) has posed new targets for recycling as well as for take-back collection schemes: see for example the insertion of "one-to-zero" – distributors have to take back a used product without a purchase of a new one- option for collecting small WEEE. Japan has developed a legislative system similar to the EU [10]; these two systems are quite similar in several common points [11]. A different legislative approach is applied in the US, where there is a lack of a common federal legislation about e-waste management: each state has defined its own system with specific targets and organizations [12-13]. One attempt towards a unified approach has been introduced in 2011 with the so-called 'National Strategy on Electronics Stewardship' [14]: it aims to point out federal actions to improve the design of electronic products and enhance management of used or discarded electronics [15]. Although a common legislative standard could not be outlined worldwide, WEEE management systems applied have common features as well as differences based on the specific legislative approach. One common basic concept is the EPR principle [16]: the EU legislation is heavily based on this approach as collective and individual take back systems shall be applied by producers in managing all phases in the product's life cycle, including also the post-consumer stage [17-19]. The EPR principle is also well established in Japan: manufacturers and importers must organize the take-back system for EEE. Recently, the EPR principle has been also applied in Canada to define new legislation about WEEE [20].

The adoption proposed in the US focuses mainly on the design phase: several incentives and specific programs are developed for supporting manufacturers in designing greener electronic products: the aim is to prevent and reduce these waste flows. Prevention usually represents the most efficient policy to reduce environmental and social impacts arising from wastes: the two options, mostly adopted for WEEE are eco-design strategies and increasing product lifespan [15]. One example belonging to the first category is the Electronic Product Environmental Assessment Tool (EPEAT), defining performance criteria for designing greener electronic products. It is also used as a procurement tool created to help institutional purchasers in the public and private sectors evaluate, compare, and select desktop computers, notebooks, and monitors based on their environmental attributes [21]. The adoption of the EPR principle influences also the cost allocation model for financing the take-back collection system and, also the recycling and disposal processes [22-23]. In Japan, home consumers pay a fee to cover a portion of the recycling and transportation costs; this option could be also applied under the EU directive. By analyzing the second category of intervention – i.e. increasing the life span of an EEE – one possible option is its re-use: positive (mainly due to resource conservation in the production phase) as well as negative (mainly due to increased energy consumption during the use phase) impacts of re-using EEE [24]. The global efficiency of two options – i.e. product re-use versus lease - in Japan was examined by Tasaki et al. [25]. An innovative organizational model for supporting EEE second- hand markets in the U.S was proposed by was proposed by Kahhat et al., [12].

Differences start from the waste flows included in the WEEE legislation: the EU directive is the widest legislation on WEEE as it includes electronic products (e.g. PC, monitors, Tv, etc.), but also household appliances, e.g. brown and white goods. A similar legislative approach has been developed by Japan, which also includes large and small household appliance in its national e-waste legislation. Differently, only electronic products are currently included in e-waste initiatives in the US and in Canada. There is also a restricted use of hazardous substances in EEE products according to Restriction on Hazardous Substances Directive or RoHS recast Directive 2011/65/EU which promotes the alternative environmentally friendly materials in the production and design of EEE products across the EU. Another point of differentiation between national systems is the adoption the Basel Convention (UNEP, 1992) on the control of transboundary movements of hazardous wastes (such as e-waste and used electronics): it affects the interconnections between single national systems to international waste transhipments [26-27]. The adoption of this convention forces stricter rules about international transshipment of these waste flows. National systems where the Basel convention is active are “interconnected” as this convention defines strict rules for international waste transhipments. This topic is a critical issue in WEEE management as it involves environmental, economic but also social impacts.

3. Conclusions

The e-waste management sector is in a full transitional stage at global scale. Despite the major disparities between high-income, transition and developing countries the e-waste management is a global environmental concern. Governments and local authorities across the globe face serious challenges in order to collect, treat, recycle and dispose this fast growing waste stream in a safety manner for the environment and human health. The global interconnections between developed and developing countries, national and regional analyses are further revealed in the book.

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