Formal and Informal E-waste Collection in Mexico City

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Abstract

Cities in emerging countries, which attract the rural population with their higher living standards, cause various problems affecting the environment. One of them is the fast increasing amount of waste electrical and electronic equipment (WEEE), known as "e-waste". One of the main prerequisites for a sustainable e-waste management is the separate collection. This study discusses the collection system of e-waste in Mexico City, both formal and informal. The formal collection includes the separate collection of e-waste according to the new separation system. In addition, the government is running two other initiatives, the Barter Market and Reciclatrón, which represent collection sites for e-waste. However, these efforts are not sufficient, which is why the informal sector plays a significant role in collection, recycling and disposal of e-waste.

1 Introduction

In emerging countries, rapid urbanization as cities attracts the rural population with their higher living standards causes various problems affecting the environment. One of them is the fast increasing amount of waste electrical and electronic equipment (WEEE), known as "e-waste".

Most electronic devices have a useful life pre-established by the producer. After tahe specific time, the equipment should be replaced as defined by the product life cycle. Setting an end to the functional period makes the consumers buy new products. The objective of this practice is to assure a circulation of merchandise, gaining more profits, while the environmental issues are not considered [1]. Therefore, the society in developing economies as well as in industrialised countries accelerates the frequency of replacement of electrical and electronic equipment. Moreover, technological progress also influences the promotion of obsolescence of electronic equipment.

Obsolescence is a concept that considers the influence of marketing and consumption culture to replace one's electronic equipment. It appeals to the desire of customers to have a better lifestyle. This practice is associated with three types of obsolescence promoted by manufacturers: functional obsolescence, when a product substitutes another with a better performance; technical, when a new product substitutes the older version; and style, which occurs when a completely functional electronic device stops being desired because of popular fashion. This pressure on the users directly influences the high generation of e-waste [2].

It is important to highlight that technological obsolescence periods are becoming shorter, and the acquisition costs reflect a downward trend. Technological obsolescence is an incremental phenomenon for our information- and knowledge-based society. The Electrical and Electronic Engineering (EEE) industry is responsible for 10%–20% of the global environmental impact related to the use of non-renewable resources [3]. In 2016, around 44.7 million tons of WEEE were generated worldwide [4]. In response to this challenge, decision-makers worldwide are searching for a sustainable way of handling the e-waste. A recent study describes the solutions to the e-waste problem in Mexico City. The city generates around 12 000 Megagramm (MG, 1 MG corresponds to 1 metric ton) per day, of which 312 MG is represented by e-waste [7].

In this study, the e-waste includes all discarded electrically powered appliances, such as computers, televisions, electronic games, photocopiers, radios, video recorders, DVD players and cell phones, and traditionally non-electronic goods, such as refrigerators, washing machines, dishwashers, and ovens. E-waste includes both 'white' goods (e.g., refrigerators, washing machines, and microwaves) and 'brown' goods (e.g. televisions, radios, and computers) that have reached the end of their life [5]. This corresponds to the WEEE definition of the European Union, which includes household appliances, IT and telecommunications equipment, lighting (except household bulbs), electrical and electronic tools, toys, leisure and sports equipment, medical devices (except implanted and infected products), monitoring and control instruments, automatic dispensers. In general, the WEEE does not include large-scale industrial tools [6].

Latin American countries have adopted the technology of industrialised countries. Latin America generates 9% of the whole WEEE worldwide. Of this, Brazil and Mexico produce the highest amount of WEEE in the region. In 2016, Brazil generated 1534 kg of e-waste and Mexico 998 kg, respectively [4]. Figure 1 gives an overview of the percentage of e-waste in the municipal solid waste (MSW) composition in Latin American countries. Mexico has an elevated level of e-waste generation for the region, as e-waste represents 2.6% of MSW [7].

This huge consumption of electronic devices helps companies to gain more customers in a rapidly evolving market. These consumer trends trigger serious economic, social and environmental problems because of a lack of public policies aimed at sound management of e-waste. When the electronic equipment has completed its life cycle, it becomes e-

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waste, and is in most cases kept opencast without any treatment, even though monitors, keyboards, cable, circuits and drives of computers generate a large volumes of toxic waste. For instance, because of a lack of proper waste management in Mexico e-waste can end up in open dumps, which still exist in the country.

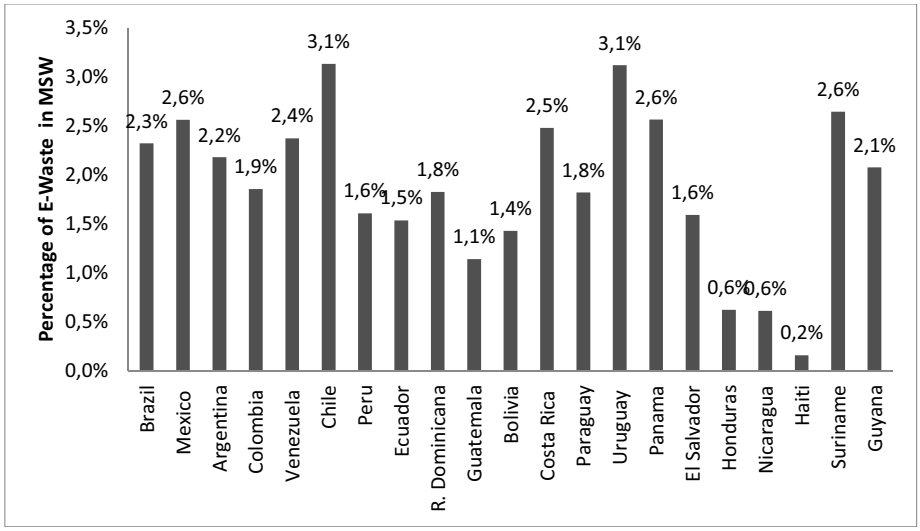

Figure 1. Percentage of e-waste in the MSW composition in Latin America (based on [7] and [8])

It is estimated that 50% of the e-waste weight corresponds to metals. Steel, aluminum, copper and precious metals are the main types. The rest of the materials (plastic and glass) are distributed in similar percentages. Electronic waste also contains high value metals like gold, silver and copper that can be recovered and brought back into the production cycle. In some studies it is mentioned that with appropriate treatment between 70–90 % of e-waste could be recycled or reused [9]. This allows electronic waste to be a source of income, however, in most countries of Latin America, including Mexico, e-waste just occupies space in the landfills instead of being recycled.

The lack of mechanisms for collection and appropriate treatment, and improper handling and management of toxic substances associated with e-waste harm human health and disrupt ecosystems. E-waste can contain lead, mercury and cadmium, all of which are extremely toxic. Up to 6% of the weight of old computer or television monitors may be lead, the main part of which is located in the Cathode Ray Tube [10]. According to Ramírez and Escalera, the main environmental pollutant of all e-waste types are the computer devices (including the batteries and peripheral products) because of their toxic content and their mismanagement, causing damages to the environment [11]. Therefore, it is essential to apply chemical and physical treatments to prevent toxic emissions to the environment. An important prerequisite for the implementation of adequate processing schemes for e-waste is the efficient separation at the source and applicable separate collection. Therefore, it is important to implement separate collection and treatment systems for e-waste. This study gives an overview of collection methods for e-waste applied in Mexico City, both informal and formal. The formal methods include the municipal separate collection of e-waste and collection sites organised by the government. All other activities, which complement the official collection system, are considered informal.

2 State of the Art

Mexico is a diverse country with 125 million residents and abundant natural resources. Mexico is a member of the Organization for Economic Co-operation and Development (OECD) and simultaneously a developing country with a GDP per capita of US $ 8201.3 [12]. This study focuses on Mexico City, the capital and the most populated city. Mexico City is an increasingly globalized and spatially growing city in which waste management is a critical issue in terms of urban and environmental governance.

Aleman [10] sees the main problem associated with e-waste in the absence of a proper regulation of collection and treatment. In Latin America, there are only a few countries that have a defined regulatory framework and can count on formal recycling systems. However, they are often at an initial phase and improvements need to be done in the whole region. As reported by the UN, Mexico collects most of the e-waste in Latin America, approximately 36% of the e-waste generated [4]. However, only 17 % of the produced WEEE is recycled [14].

The legal framework for waste management is based on the Mexican Political Constitution, particularly article 115, which states that municipalities are responsible for providing public cleaning services, as well as being in charge of collecting, transporting, treating, and final disposal of waste. However, only 19 out of 32 states have legislation on waste management. These states are: Aguascalientes, Baja California, Chiapas, Chihuahua, Federal District, Durango,

Guanajuato, Guerrero, Hidalgo, Jalisco, Michoacán, Nuevo León, Puebla, Querétaro, Quintana Roo, Sonora, Tabasco, Tamaulipas and Veracruz [15].

2.1 E-waste in Mexico City

Mexico City, as other cities in the developing world, faces the challenge of having effective strategies of E-waste management. Some of the main problems are the following: lack of infrastructure for pre-process and treatment, absence of facilities and technologies of innovation, lack of investment, high management costs [2].
Several important steps were made in Mexico City in response to this challenge. In 2018, the City Council of Mexico City introduced the cascade use concept (reduce, reuse, recycle) into the general waste law of the city, which was also renamed into the Law of Integrated Waste Management of Mexico-City [16].
According to the new waste law of Mexico City, NADF-024-AMBT 2013, which came into force in 2017, e-waste is considered as a category of special waste, which should be collected separately. Special waste is to be collected on Sundays. However, due to a poor management, e-waste management does not function properly. Because of an absence of waste containers in the city, citizens have to bring their refuse directly to the waste trucks. However, trucks do not follow any schedule, which makes it difficult for the population to follow the regulations. This way, e-waste is delivered to the trucks on other days, consequently it is mixed with other fractions. In addition, household waste may be given to the waste workers who sweep the streets and bring waste to the truck themselves or directly to a transfer station.
Health is one of the problems associated with recovery activities in Mexico. The main reason is that a large share of the recycling activities is performed by the informal sector. Workers involved in the informal sector do not use appropriate equipment and have little or no knowledge about potentially hazardous elements. This lack of knowledge and equipment leads to the exposure to health problems of not only informal WEEE-related workers but also the public [2].
Apart from this, Mexico City has the problem of scarce landfill capacities since the local landfill was closed in 2011. After that, the city has had to send its waste to the nearby disposal areas, which are located in the closest federal states. Consequently, the transportation costs increased significantly. It is assumed that the transportation costs make up the biggest part of waste management costs in Mexico City (16.70 Euros per MG of inorganic waste) (1 € equals 23.97 Mexican pesos as of 18.06.2018) [17]. Due to the poor recovery, the e-waste is sent to the landfills together with unrecyclable litter, which cause an increase of the waste management costs for the city and a shortage in landfill capacity.
In Mexico, full WEEE recycling processes are still not common. Currently, the amount of recovered materials is very small, and the political framework and infrastructure are still limited. Therefore, the existing infrastructure cannot process large amounts of WEEE. Most of the WEEE recycling companies do not offer a full recovery cycle because they focus only on the recovery of valuable components, leaving non-valuable components aside. Those non-valuable components still represent a threat to the environment and public health [2].
The separate collection is important for the solution of the e-waste problem. Today, 50% of generated e-waste ends up in landfills, while 40% remain in the households or warehouses [18]. To change this situation, the city government has started several campaigns ,the results of which are going to be discussed in this study. In order to raise awareness and promote waste separation, the government organizes Barter Markets. At this event the citizens can exchange the separate waste fraction for food products, such as vegetables, dairy products and seeds. Apart from other waste fractions, it is also possible to exchange WEEE for nutrition products. Another campaign, called Reciclatrón, targets e-waste directly. The participants of Reciclatrón have the chance to bring WEEE to the special collection site. As a reward for their environmentally friendly behavior, the participants receive pot plants and a bag of compost that they can utilize for their gardening. The collected waste is sent to the company Cali Resources located in Tijuana, Baja California, for recycling [19].
Apart from recycling, reuse is quite common in Mexico. This activity is much more private than recycling; therefore, people do not depend on the existing infrastructure created by the government. In rural communities, for example, discarded cans, cardboards and glass are often reused in the household. In the city where products are more accessible, this practice is not as popular. Nevertheless, people reuse items in different ways. They use empty bottles as flower pots or storage containers. Reuse of clothes is also broadly accepted. Since the number of family members is high, one piece of clothing can be used by 3-4 children. Other products that are often reused in Mexico are steel components of cars, bicycles and furniture [20]. The study of Corral-Verdugo [20] showed that reuse and recycling are complementary activities in the households. For example, aluminum cans are normally not reused because they are recycled in most of the cases, while plastic bags are never recycled but often reused. However, items such as newspapers and paper are hardly recycled or reused (despite the presence of a paper recycling facility in the region).

3 Case Study Description and Assessment

The waste management system of Mexico City shows different pathways for each waste fraction. This study schematizes the collection of e-waste in Mexico City. The estimation of the rate of collection of e-waste is based on the official data presented by the SEDEMA (environmental authority of Mexico City) and other literature sources.

Separate waste collection represents the prerequisite for reuse, recycling and recovery of raw materials and provides the basis for the use of waste as an economic source. Therefore, the proper separation and collection play an important role in the recycling of e-waste [21]. This section discusses collection practices of Mexico City targeting e-waste.

3.1 Formal Collection

Barter Market

The first official collection program to be discussed is the Barter market (Figures 2 and 3). This initiative started in 2012 based on the environmental protection law of the city. The program takes place every month in one of the sightseeing places of the city. The main purpose of the event is to educate the citizens to separate the waste in their households.

Figure 2 and **Figure 3**. Barter market in May 2017 [22]

In order to participate in the program, the citizens have to bring 1-10 kg of clean separated waste fractions. For the specific waste fractions, the participants get a different amount of points. Table 1 presents the number of points which the participants can earn. The points can be exchanged for food products. The number of points given for e-waste depends on the category: electronics (group A), cables (group B) or mobile devices (group C). However, it should be mentioned that the number of points given for e-waste is significantly lower than for packaging waste, such as Tetra Pak and PET bottles [23]. This focus on PET bottles can be explained by the fact that Mexico has the highest consumption of bottled drinks in the world [24], which leads to a higher generation of wasted PET bottles.

Table 1. Number of points earned for each category [25]

Waste category	Aluminum	Cardboard	Cans and iron	Plastic HDPE	Glass	Paper	Tetra Pak	PET	E-waste		
									A	B	C
Number of points	2					3	8	18	4	2	5

In 2016, 109.68 MG of separated waste fractions were collected in exchange for 47 food products. 24 local producers and 36606 assistants helped with the organization of the event. It should be mentioned that only 7% of the collected recyclables are represented by e-waste, while in 2015 WEEE was the second biggest waste fraction collected. In comparison to 2015, the amount of collected e-waste in 2016 dropped significantly by 16 MG. This fluctuation can be explained by the fact that the generation of e-waste is not as fast as that of other categories, such as the packaging waste. Overall, during all the editions of the Barter market 77.4 MG of e-waste were collected, making up 11% of the collected recyclables since 2012 (Figure 4). The modest results obtained through the Barter market can be explained by the lower exchange rate of e-waste and competing collection programs such as Reciclatrón and informal collection.

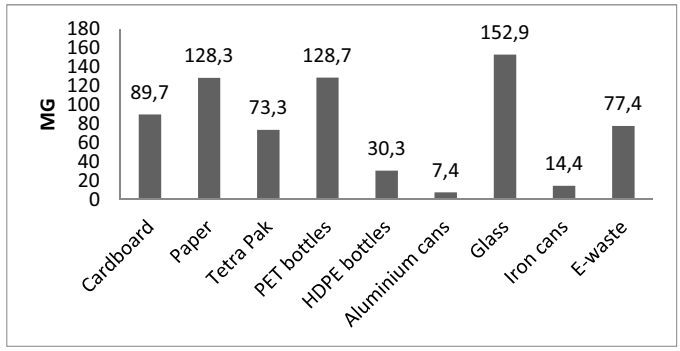

Figure 4. Cumulative quantity of collected waste fractions at the Barter market since 2012 [25]

Reciclatrón

The Reciclatrón (Figures 5 and 6) was organized for the first time in 2013. As the Barter market, Reciclatrón is held each month. It typically takes place in the location of one of the main universities in Mexico City. During Reciclatrón everyone can bring their e-waste in exchange for the compost and pot plants. In 2016, 273.3 MG of WEEE were collected even though the rewards are not particularly attractive, as private gardening is not common in Mexico City.

Figure 5. Reciclatrón at University UAM Azcopotzalco. February 2017

Figure 6. Box for collection of cell phones at Reciclatrón at University UAM Azcopotzalco. February 2017

This program defines five categories of e-waste, while in the Barter market there are only three categories. Table 2 presents the categories of WEEE applied at Reciclatrón. It should be mentioned that the category E that includes monitors, TVs, electrical ballasts, screens, transformators, lamps, heating devices, batteries, toners and refrigerators, was introduced first in 2016. Nevertheless, this category was the largest to be collected and represented 76% of the total sum [25].

Table 2. Categories of e-waste at Reciclatrón [25]

Category	Description
A	Printers, copy machines, keyboards, mice, calculators, cameras, typewriters, faxes, radios, voice recorders, devices of uninterruptible power supply, microwaves, vacuum cleaners, blenders, dishwashers, coffee machines, DVDs, VHS, MP3, video games, amplifier, PDAs, microcomponents, fixed lines, projectors, equalizer, flat irons, speakers, hair dryers.
B	CPUs, laptops, hard disks, cards for computers.
C	Mobile phones.
D	Charger, cables, motors.
E	Electrical ballasts, monitors, alkaline batteries, transformators, lamps, heating devices, betteries, refrigirators, toner cartridges

Reciclatrón showed a rising trend during the last years. The amount of WEEE collected grew by 178.02 MG from the first edition in 2013 (Figure 7) [25].

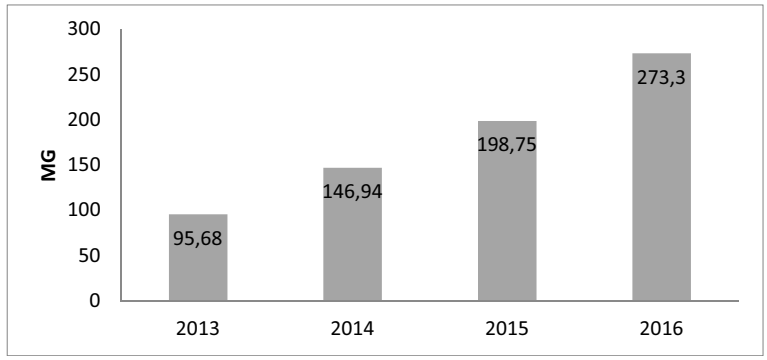

Figure 7. E-waste collected during Reciclatrón 2013-2016 [25]

Municipal Collection of Household Waste

New waste law norm NADF-024-AMBT-2013 was introduced in July 2017. This aims to increase the amount of collected recyclable materials and thereby decrease the quantity of landfilled waste. Since 2011, municipal solid waste in Mexico City has been separated in households into organics and inorganics, while the new law Norma NADF-024-AMBT-2013 mandates the new segregation of residual waste into 4 fractions: organic, recyclables, non-recyclables, hazardous and bulky waste [26]. E-waste is included in the category of hazardous waste and should be collected on Sundays. However, collection of municipal solid waste (MSW) represents one of the biggest challenges in waste management in Mexico City. The staff of a waste truck normally consists of a driver and several volunteers, who help to sort the waste and are part of informal recycling. They normally break the trash bags which the citizens bring to them and sort the content themselves searching for the recyclables that they sell later. This practice of the waste workers does not stimulate the population to perform proper separation. Although the results of the influence of the new law on the efficiency of separate collection are not available so far, it can be assumed that the separation rate is not going to increase. In 2016 the separation was only 34% under the condition of 2-bin-separation [25].

3.2 Informal Collection

Over the past 60 years, Mexican cities have grown rapidly, mostly due to migration from rural areas. Many migrants survive by engaging in informal waste sector activities. The informal sector plays a significant role in the Mexican economy, employing about 20 million people [27]. Urbanization often leads to the creation of new slums. Individuals who live in squatter settlements often do not pay taxes. Municipal solid waste consumes 20–40% of municipal budgets [28]. This low level of taxation translates into a low availability of funds for municipalities. This gap in provision of waste services is normally filled by the informal sector. Mexico City generates over 12,000 MG of MSW a day. For comparison, the whole country of Greece generates 15,054 MG of MSW per day [8]. 67% of MSW from Mexico City are landfilled [25]. A complex informal system has developed around MSW collection, recycling and disposal over the past 60 years. Approximately 20,000 individuals make a living in the informal sector around residues [29]. The informal sector collects around 7% of the e-waste generated in Mexico City [30]. No health and safety standards are followed by the informal sector. Even though the income and living conditions of informal waste workers differ significantly depending on their main activities, the majority of informal waste workers (dump and street waste pickers) constitute the lowest level of society. Working conditions include permanent exposure to dangerous and toxic substances. Waste pickers are subjected to harassment from officials, exploited by traders of recyclables and have no legal protection. They live in humiliating circumstances and generally lack sanitary services, health care and social benefits.

Recoverable e-waste materials are sold according to the value in the local domestic market. Based on the data in Table 3, the greatest economic resources are obtained from motherboards, scrap copper cables [18].

Table 3. Market price of recovered materials [18] (1 € equals 23.97 Mexican pesos. as of 18.06.2018)

Material	Commercial value (€ per kg)
Plastic	0.02
Scrap	0.09
Keyboards	0.04
Cables	1.07
Cooper	3.01
Aluminum	0.8
Motherboard	2.15
Hard Disk	0.21

4 Conclusion

Mexico City is on its way to developing efficient e-waste collection systems. The city is advancing the source separation through the introduction of new legal norms. If the efficiency rate increased, this would contribute a lot to the recovery of bigger numbers of fractions. However, the source separation in Mexico City does not function well and the separation efficiency is very low. For a sustainable e-waste management, it is important that users know how and where to deliver obsolete equipment. For the functioning of the system, it is vital to establish collection sites with basic standards of environmental protection and health and safety [2]. Therefore, the city has developed other initiatives such as the Barter Market and Reciclatrón to promote a better separation and collection of WEEE. Overall, the waste collection campaigns are successful in raising public awareness, but the collection rates for e-waste of both initiatives are low. The Barter Market allows the collection of 0.007% of generated e-waste, while Reciclatrón achieves 0.24%. The food products provided in the case of the Barter Market are more attractive for citizens than the compost and pot plants at the Reciclatrón. Therefore, it is suggested to offer food products as a reward for the environmentally friendly behavior in both campaigns in order to increase the collection rate. In addition, in case of the Barter Market it may make sense to shift the focus from plastic waste to paper since the last fraction is easier to recycle due to its more homogeneous composition. However, there is almost no market for waste paper due to its low price.
Nevertheless, it is expensive to implement such campaigns, as they require high upfront investment. Therefore, the informal sector complements the official programs and participates actively in e-waste management. However, the urgent integration of the informal sector in the formal activities is needed to improve the working conditions and provide legal protection for the workers.
The management of e-waste is a global priority, therefore, Mexico City, as the capital and leader in environmental policy must develop and implement management plans aimed at electronic waste collection, characterization, quantification, recovery and reuse, as well as the commercialization of the components. The linked and coordinated coordination of all levels of government is needed, together with the informal sector to promote a sustainable approach to e-waste management.

5 Zusammenfassung

Großstädte in Entwicklungsländern ziehen aufgrund der besseren Lebensbedingungen die ländliche Bevölkerung an, verursachen jedoch verschiedene Umweltprobleme. Eines davon ist die ständig ansteigende Menge an Elektroschrott (engl. „waste electrical and electronic equipment“ (WEEE)). Als Bedingung für ein nachhaltiges Management des Problems kann die separate Sammlung des Elektroschrotts angesehen werden. Dieser Beitrag diskutiert die formellen und informellen WEEE Sammelsysteme in Mexiko Stadt. Das formelle Sammelsystem beinhaltet hierbei die getrennte Sammlung von Elektroschrott im Rahmen des neuen Mülltrennungssystems. Zusätzlich fungieren zwei weitere staatliche Initiativen, „Barter market“ und „Reciclatrón” als Sammelstätten für Elektroschrott. Da diese Bemühungen bisher nicht ausreichen, spielt der informelle Sektor weiterhin eine bedeutende Rolle bei Sammlung, Recycling und Entsorgung von Elektroschrott.

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