WASTE PICKERS AND E-WASTE: A CASE STUDY IN THE GREATER JOHANNES-BURG AREA

SCHOEMAN DC* AND RAMUTANDA DM**

*Geography, Environmental Management & Energy Studies, University of Johannesburg, Johannesburg, 2000; Tel: (011) 559 3226; E-mail: theas@uj.ac.za

** Geography, Environmental Management & Energy Studies, University of Johannesburg, Johannesburg, 2000; E-mail: 1makhadzi14@gmail.com

ABSTRACT

This study interviewed 229 waste pickers to understand who they are and their operations regarding electrical and electronic equipment (e-waste). Waste pickers that collected e-waste in the greater Johannesburg area were mostly African (87.3%%) men (83.4%) and from South Africa (81.6%). The most collected type of e-waste was cables (45%), followed by screens (39.5%) and 28.2% indicated they collected all types of e-waste. The e-waste they collected is stored at home or in their backyards (46.8%) and a third indicated they store it where they sleep in places such as bushes, under bridges or next to streets. Even though only 3.3% or respondents received training in the dismantling of e-waste, the majority (68.0%) dismantled e-waste to extract mainly metals such as copper, aluminium, steel, lead and tin. A further 60.2% processed e-waste by mostly burning cables to extract copper. Less than half (43.8%) collected e-waste for repair and refurbishment and 75% of respondents indicated they repaired/refurbished the items themselves. The majority (87.4%) of repaired/refurbished goods were sold to generate additional income. The e-waste collected is sold to various buyers such as scrap metal dealers (76.4%), followed by general buy-back centre (49.8%), e-waste buy-back centre (49.3%) and a buyer with a bakkie (49.3%).

KEYWORDS

Waste pickers, e-waste, recycling, processing e-waste, dismantling e-waste, repair of e-waste, Johannesburg.

INTRODUCTION

Waste electrical and electronic equipment (WEEE) or e-waste is considered an emerging environmental problem, due to the amount of e-waste generated and the potentially toxic substances it contains. Not only are the production and consumption of e-waste unsustainable, but the majority of e-waste is not recycled (Forti et al., 2020). E-waste is defined as discarded electrical and electronic devices and includes equipment and devices such as cellphones, televisions, computers, printers, electronic toys, refrigerators and so forth (Bladé et al., 2017; Maes, & Preston-Whyte, 2022). It is society's need to have the newest, fastest and smallest device or equipment that is one of the main reasons for the increase of e-waste generation. Currently the developed countries generate the most e-waste, although contributions from developing countries are increasing (Abalansa et al., 2021). Not only do developing countries generate their own e-waste, but some are also the recipients of e-waste from developed countries – and often from illegal transboundary imports (SBC, 2011) and notably in Ghana and Nigeria (Asante et al., 2019).

In middle- and low-income countries, e-waste is mostly managed by the informal sector as the e-waste management and recycling infrastructure is not fully developed or absent (Forti et al., 2020). In South Africa both the formal and informal sectors are collecting e-waste for recycling. Lydall et al. (2017) states that valuable e-waste is salvaged by the waste pickers on landfill sites. The e-Waste Association of South Africa (eWASA) estimated in 2014 that about 25% of the total volume of e-waste recycled is processed by the informal sector. South Africa does not have reliable information on the dismantling, processing, repair or recycling of e-waste by informal waste pickers. Many studies have focused on the health dangers that waste pickers face with picking waste but very little is known about how they conduct dismantling and processing of e-waste (Orisakwe et al., 2019).

Therefore, this study investigated the operations of waste pickers regarding e-waste in the greater Johannesburg area. To get a better understanding who are these informal workers, profiling was done and an investigation into the dismantling, processing and repair practices of e-waste.

E-WASTE GENERATION AND MANAGEMENT

Global

E-waste is one of the fastest growing and important waste streams with scarce and valuable metals (Borthakur & Govind, 2017; Shaikh et al., 2020; Shittu et al. 2020). The rapid growth in e-waste is due to technological advances and innovations, rapid changes in information and communication technologies (ICT), economic growth, the increasing importance of electrical and electronic equipment (EEE) in our daily lives, the decline in prices and the early obsolescence of many electronic devices (Herat & Agamuthu, 2012; Borthakur & Govind, 2017; Forti et al., 2020).

Forti et al. (2020) in the Global E-waste Monitor 2020 state that in 2019, 53.6 million metric tons (Mt) of e-waste was generated globally – or an average of 7.3 kg per capita. This exceeded the estimated e-waste generation of 52.2 Mt in 2021 (Bladé et al., 2017) by two years and 1.4 Mt. Global e-waste generation is at an alarming rate of almost 2 Mt per year (Forti et al., 2020) or 3.2% per annum (Abdelbasir et al., 2018). Asian countries are the largest producers of EEE and generates the most e-waste (24.9 Mt in 2019), followed by the Americas (13.1 Mt) and Europe (12 Mt) while Africa produced the least with 0.7 Mt (Forti et al., 2020). However, similar to most waste data, conflicting e-waste generation numbers are reported. The Africa Waste Management Outlook (UNEP, 2018) reports that about 2.2 Mt of e-waste was generated in Africa in 2016. The largest generators are Egypt (0.5 Mt), South Africa (0.3 Mt) and Algeria (0.3 Mt) (Bladé et al., 2017).

Forti et al. (2020:15) state "the fate of 82.6% (44.3 Mt) of e-waste generated in 2019 is uncertain" and thus only 17.4% of e-waste generated was formally documented and recycled. A reason for the low collection rate compared to the total amount of e-waste generated is the lack of e-waste statistics. According to Bladé et al. (2017), only 41 countries have official statistics. Europe had the highest collection and recycling rate in 2019 with 42.5%, Asia was second with 11.7%, the Americas and Oceania were at 9.4% and 8.8% respectively, and Africa had the lowest rate of 0.9% (Forti et al., 2020). Furthermore, developing countries often have to manage the additional burden of imported e-waste. E-waste imports to developing countries become a heavy burden as these countries lack technological facilities to deal with e-waste (Acquah et al., 2021). To exacerbate the situation, developing countries themselves are increasingly generating e-waste in large quantities.

There are legislation and guidelines to guide countries in their e-waste practices globally such as the Basel Convention of 1989 and the Paris Agreement of 2015 (Khan, 2016; Ogunseitan, 2013). Atasu & Subramanian (2012) are of the opinion that global regulations attempt to also promote Extended Producer Responsibility (EPR), but that it is often not practiced effectively. However, the e-waste stream is complex and there is lack of general legislation that focuses on e-waste in many countries (Lundgren, 2012). In 2019, less than half of all countries (78 of 193 countries) were covered by a policy, legislation or regulation on e-waste (Forti et al., 2020). Dealing with hazardous e-waste is costly and difficult to treat in an environmentally sound manner. In some developing countries there are lack of waste management infrastructure, as well as legislation (Forti et al. 2018; Ahirwar & Tripathi, 2021). In such countries, e-waste is often treated by the informal sector in illegal and dangerous ways that can contribute to environmental and health issues.

Sub-Saharan Africa

In Sub-Saharan Africa there has been an increase in e-waste generation and the resultant challenge on how to manage e-waste (Asibey et al. 2021). Currently characterised by low waste generation, Sub-Saharan Africa is anticipated to become the dominant waste generator globally including e-waste due to rapid population growth, urbanisation, and increasing middle class, as well as changes in consumption and production patterns (Kaza et al., 2018). As a region that is characterised by developing countries, e-waste is not managed in a safe and sustainable manner. The poor methods of e-waste management are influenced by poor policy interventions and lack of accessible information on how to dispose used and unwanted electronics (Maphosa & Maphosa, 2020). Furthermore, poor e-waste management in Sub-Saharan Africa manifests in the illegal dumping of e-waste or disposal in open dumpsites (Tetteh & Lengel, 2017). Some e-waste components are found in rivers such as in Ghana, Nigeria and South Africa, while some e-waste is disposed in places near residential areas (Lebbie et al., 2021).

As a result of a lack of infrastructure, expertise, and regulations to manage e-waste, in many poor African nations recyclers manage outdated electrical and electronic equipment using primitive techniques such as manual dismantling, open-air burning, and landfilling. Furthermore, e-waste is managed in the informal sector by inexperienced and untrained persons who are unaware of the environmental and health risks associated with their operations (Asante et al., 2019). In Ghana, for example, e-waste is handled informally by children under minimal conditions of health and environmental safety (Tetteh & Lengel, 2017; Grant & Oteng-Ababio, 2021). Legislation for dealing with e-waste in Africa is non-existent or less strict, which promotes illegal dumping. The majority of African countries have legislation governing general waste, the environment, air, water, and health and safety issues, but there are few laws pertaining specifically to e-waste (Tetteh & Lengel, 2017; Grant & Oteng-Ababio, 2021; Lebbie et al., 2021).

The Basel Convention that was adopted in 1989 by 172 countries, the 2003 European Union Waste Electrical and Electronic Equipment (WEEE) Directive that was updated in 2012, and the 1991 Bamako Convention on the Export of Hazardous Waste to Africa that came into force in 1998 and prohibits the import of e-waste into African countries, are examples of international and regional efforts to regulate e-waste (Maphosa & Maphosa, 2020, Twagirayezu et al. 2021).

South Africa

In South Africa, e-waste has emerged as the fastest growing waste stream (DFFE, 2020a). Accurate data on WEEE is largely lacking in South Africa, and if available, conflicting numbers are given. The growth of e-waste is three-times the rate of solid waste and it is estimated that only 11% is recycled annually (Lydall et al. 2017). They further estimated that only 74 923 tonnes of e-waste were produced in South Africa in 2015. In contrast, the Global E-waste Statistics Partnership (2019) state that 416 000 tonnes of e-waste were generated in 2019 in South Africa or 7.1 kg per capita and gives an e-waste collection rate of only 5%. Forti et al. (2020) gives a similar figure with 415 500 tonnes of e-waste generated in South Africa in 2019. The South Africa State of

Waste Report (DEA, 2018) acknowledges the wide range of WEEE generation estimates, but states that based on the opinion of key role players, it is estimated that on average 300 000 tonnes of e-waste is generated annually with a recycling rate of 10%. Maes & Preston-Whyte (2022) gives a similar recycling rate of 9.7% for South Africa.

South Africa is the leading country in Sub-Saharan Africa regarding effective management of e-waste (Tetteh & Lengel, 2017). South African legislation aims at encouraging proper recycling of waste. Furthermore, in South Africa there is the National Environmental Management Act (Act 107 of 1998) and the National Environmental Management: Waste Act (Act 59 of 2008) that encourage waste to be managed properly, commends re-use and refurbishing of e-waste (Perry et al., 2018). The newest legislation is the EPR (Extended Producer Responsibility) scheme for WEEE that has been under discussion by the Government since 2014 (Godfrey & Oelofse, 2017) and the EPR regulations were published on 5 November 2020 (DFFE, 2020b) and amended on 5 May 2021.

E-WASTE – PROBLEM AND OPPORTUNITY

Problem

The literature is becoming more aware of the problems associated with e-waste (Umesi & Onyia, 2008; Herat & Agamuthu, 2012; Acquah et al., 2019; Orisakwe et al., 2019; Maphosa & Maphosa, 2020). WEEE contains a number of different materials, some of which are highly toxic that may cause cancer (Maes & Preston-Whyte, 2022). E-waste ends up in landfills thereby polluting the environment and releasing toxins into the atmosphere and ecosystems (Umesi & Onyia, 2008; Orisakwe et al., 2019). The burning of e-waste discharges hazardous materials that damage the environment (Maphosa & Maphosa, 2020). Harmful materials such as lead, mercury and some inorganic acids are released into the environment due to poor disposal and recycling methods of e-waste (Tetteh & Lengel, 2017). These hazardous materials pollute the soil, water and air which further impacts ecosystems. Thus, unregulated e-waste recycling and processing contribute to environmental degradation and issues like global warming (Lebbie et al., 2021).

It is undeniable that e-waste can have serious impacts on human health as it contains toxic components such as mercury, arsenic, lead and cadmium (Robinson, 2009; Gutberlet & Uddin, 2017). Pollutants released during e-waste processing trigger respiratory infections, eye infections and asthma (Acquah et al., 2019). In studies on waste pickers' health, Asampong et al. (2015) found that waste pickers who dismantle e-waste suffer from acute respiratory infections and chest pains, while Peluola (2016) found that they suffer from skin and eye irritation and persistent coughing. Furthermore, informal waste pickers that rely on stones, hammers, chisels to dismantle e-waste are at risk of musculoskeletal injuries (Maphosa & Maphosa, 2020).

E-waste does not only contain hazardous material, but also valuable material such as gold, silver and copper to name a few. Therefore, if e-waste is managed properly, it can contribute to the circular economy and create sustainable green jobs.

Opportunity

E-waste is a valuable resource for several precious and strategic metals (Herat & Agamuthu, 2012). There is a growing need for the recovery of e-waste resources due to scarcity, restricted global trade and price fluctuations for some of these metals. Noteworthy benefits of harvesting e-waste resources are that substantially less energy is used and less emissions of greenhouse gas compared to mining of these resources (Mudali et al., 2021).

The Mohammadi et al. (2021) study noted that e-waste recycling is contributing to economic growth by creating jobs. In line with this, the unemployed youth and adults in developing countries often work as waste pickers to earn income through waste and e-waste recycling. WEEE recycling has the potential to be an important employer as 25 jobs can be created for every 1 000 tonnes of e-waste managed (Lydall et al., 2017).

In many developing countries, and in South Africa, the informal sector plays a significant role in e-waste recycling. As Maes & Preston-Whyte (2022) state "e-waste has resulted in an informal, yet important industry, with far reaching consequences."

INFORMAL SECTOR IN E-WASTE

In South Africa, the informal e-waste sector consists of collectors and recyclers who are unlicensed and not registered with any official entities (Lundgren, 2012). According to Lydall et al. (2017), these informal waste pickers collect e-waste from landfills, dustbins, shopping malls, industrial malls and suburbs. The informal recycling of e-waste is the livelihood of many poor urban communities. In 2013, the informal sector contributed 25% of the e-waste recycling in South Africa with an estimated 10 000 waste pickers (eWASA, 2013).

Most of the waste pickers practice dismantling and processing of e-waste and sell their materials frequently to local recyclers via exploitative intermediaries (UJ-PEETS, 2020). However, the International Labour Organization (2014) noted that informal waste pickers collect, dismantle and process e-waste due to the lack of formal and public collectors, the high demand for secondary raw materials, and to allow themselves to make a living.

In the City of Johannesburg (CoJ), like most cities in the world, waste pickers are not given the recognition they deserve and authorities do very little to none to enable them to work in a safe manner and to earn more income (Schoeman, 2018). Baker et al. (2016:172) state that "The CoJ recognized the Waste Pickers form [the] integral part of waste minimization". However, Samson (2021) is of the opinion that the CoJ did an about-turn in integrating the informal sectors. The author claims that Pikitup, the waste management service provider in the CoJ, do not incorporate the waste pickers in recycling. She further states that waste pickers are the real recycling experts and Pikitup designs charity-style projects for them and contracted private companies to collect recyclables – which is in direct competition with the waste pickers and threatens their livelihoods. Pillay (2017) has a similar opinion that the CoJ has not made waste pickers part of their waste strategy. She states that the CoJ developed programmes and projects without consulting the waste pickers and the reason given is that they cannot consult waste pickers as they are not organised.

METHODOLOGY AND STUDY AREA

Study area

The City of Johannesburg (CoJ) is located in the smallest province, Gauteng, in South Africa and covers an area of 1 646 km^2. The CoJ population size was estimated to be 5.5 million (Murwirapachena, 2021) making it the most populated city in South Africa. The CoJ is characterised by high buildings, highly industrialised formal businesses, informal businesses and a mixture of cultures from both foreigners and South African citizens. The increasing population has resulted in an increasing waste generation rate within the city.

The research was conducted in the greater Johannesburg area. Although most of the operations of waste pickers occurred in Johannesburg, a few waste pickers interviewed also collected waste in locations in Mogale City and Ekurhuleni municipalities. The CoJ has one official waste management service provider, Pikitup, that is responsible for keeping the city clean. The study of Alao et al. (2021) found that there is no recorded data for the e-waste generated in the CoJ.

Research design, data collection and analyses

The study adopted a mixed method approach and collected both qualitative and quantitative data. The data collection in mixed method approach involves gathering information that is both numeric and textual for the final database to represent both qualitative and quantitative data (Creswell & Creswell, 2017). A mixed method is basically an integration of both qualitative and quantitative information within a single investigation. An interaction between these two methods allows the researcher to have a complete and interactive data collection and analysis (Wisdom & Creswell, 2013).

The setting of the study was the CoJ focusing on informal waste pickers in Johannesburg. The respondents were purposively selected from different areas under the municipality of Johannesburg. Purposive sampling refers to a non-probability sampling technique that identifies and choses participants that have knowledge or experience about the phenomenon of interest by the researcher (Campbell et al. 2020). As this study investigated waste pickers that collect, transport and process e-waste, only waste pickers that work with e-waste were interviewed.

In this research project, interviews were conducted using a questionnaire, allowing for face-to-face interaction with informal waste pickers in the field, as they collected recyclables. A total number of 229 respondents were interviewed at 23 different recycling centers. The different sections of the questionnaire included demographics, operations, dismantling and processing. Both open-ended and closed-ended questions were asked. The researcher and fieldworkers conducted interviews in the field and applied participant observation method for field observation. The observed field work involved processing and dismantling practices.

A problem experienced with data collection occurred when South Africa went into lockdown Levels 3 and 4 during 2021. The fieldworkers were not granted access to the recycling centres and therefore could not conduct interviews. Only when the country moved to adjusted Level 2 in September could the data collection resume. Therefore, not all recycling centres in the CoJ could be included in this study.

Data analyses

Thematic analysis is an identifying, analyzing, organizing, describing and reporting method on themes found within a set of data (Nowell et al., 2017). In line with this, another study by Castleberry & Nolen (2018) defines thematic analysis as a translator for both qualitative and quantitative data allowing researchers to use different methods to communicate. Thematic analysis was applied using a trial version of the Nvivo software to transcribe interview conversations into coded themes.

For quantitative data, descriptive statistical analysis was performed in Excel. Descriptive statistics of demographic variables such as gender, race, education level, etc. were determined. Operational statistics such as type of and place of e-waste collection were also done in the spreadsheet. This method was used because it summarises numerical findings into a representable tables, graphs or charts. According to Carlberg (2014), statistical analysis refers to methods of planning, designing, collecting, analysing and concluding on a meaningful interpretation of research findings. It basically gives meaning to numbers to uncover patterns and trends (Rayat, 2018).

RESULTS AND DISCUSSION

Profile of waste pickers

Waste picking in this study was dominated by men (83.4%) and only 16.6% were women (Table 1). This is in line with the Schoeman (2018) study that found that 80.4% male and 19.6% female waste pickers operated in Johannesburg. Waste picking is a strenuous job and it is expected to be dominated by men as they have greater physical strength than women (DFFE & DST, 2020). The majority of the respondents were Black

(87.3%) followed by Coloureds (11.4%). Only two respondents (0.9%) were White and one respondent (0.4%) identified as Indian/Asian. A total of 81.6% of the respondents were South African followed by 11.4% from Zimbabwe and 3.1% from Malawi. This is in contrast to the Schoeman (2018) study that had 78% foreign nationals and Sentime (2011) that only recorded 56.6% South Africans. The result is more in line with the DEA (2016) report that noted that only 9.3% of waste pickers originated outside South Africa. Possible explanations on the difference in the country of origin with previous studies are the impact of the Covid pandemic that reduced the number of foreign nationals waste picking in Johannesburg, or that undocumented foreign nationals do not participate in surveys as they fear that they would be reported.

Table 1: Socio-demographic characteristics of waste pickers

Characteristic	Class	Frequency	Percentage
Gender	Male	191	83.4
	Female	38	16.6
Race	Black	200	87.3
	Coloured	26	11.4
	White	2	0.9
	Indian/Asian	1	0.4
Country	South Africa	187	81.6
	Zimbabwe	26	11.4
	Lesotho	7	3.1
	Mozambique	6	2.6
	Malawi	2	0.9
	Botswana	1	0.4
Education	Completed some primary school	29	12.9
	Completed primary school	15	6.7
	Completed some high school	146	65.2
	Completed Matric	31	13.8
	Post-matric qualification	3	1.4

The majority of informal waste pickers completed some high school level (65.2%), while 25.9% attended or completed only primary school. The most surprising result was that there are well educated waste pickers, three (1.4%) waste pickers obtained tertiary qualifications, namely a BCom Accounting, a BA Honours Design and Technology and Nursing degree (Table 1). The result is in contrast with the Sentime (2011) study that found that waste pickers in Johannesburg have very limited education. The national study (DEA, 2016) reported that 13.1% waste pickers in Gauteng completed matric, which is similar to the results of this study.

Experience

Almost a quarter of waste pickers (24.0%) had five to six years' experience, while 16.3% had more than ten years' experience (Figure 1). The most experienced waste picker reported 22 years working as a waste collector, while only one (0.4%) was not sure of how many years he worked. There can be several reasons why more almost half (43.0%) of waste pickers in the City of Johannesburg had less than five years' working experience. One reason is that often young people that dropped out from or recently completed school make a living as waste pickers. With very high youth unemployment rates they could not find jobs in the formal sector. For example, in the Alexandra Township, most of the young waste pickers indicated that they are just into waste picking/recycling because they are "*tired of staying at home and doing nothing*". This is in line with the Made et al. (2020) study that found that there is a growing number of 18 years old waste pickers in the CoJ, who just left high school and could not get jobs.

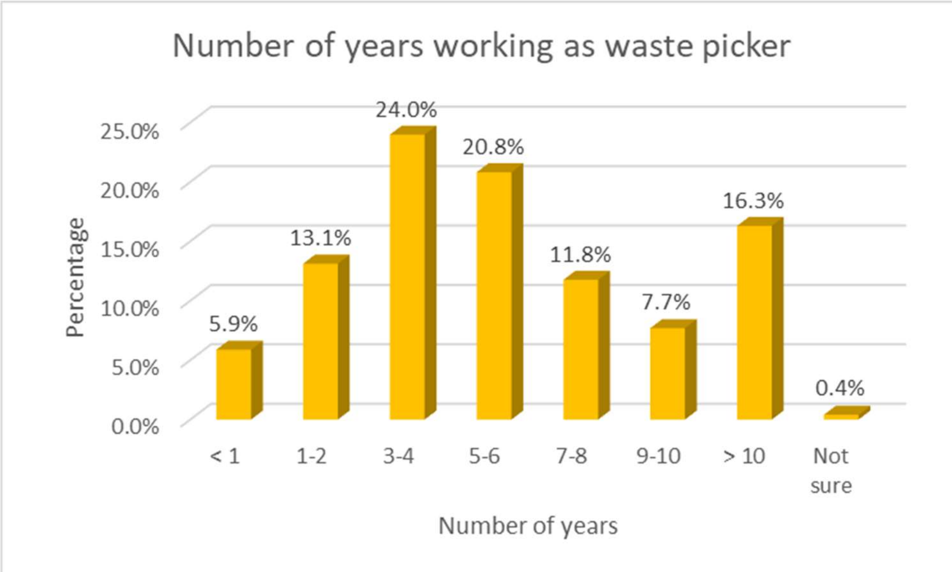

Figure 1: Number of years working as a waste picker

Type of, place of collection and storage of e-waste

Waste pickers collect different types of e-waste and cables (45.0%) were the most collected type of e-waste, followed by screens (39.5%) and radios (19.1%) (Table 2 and Figure 1). The least collected types of e-waste were either bulky and heavy equipment (geyser, washing machine, stove) or those that are perceived to be valuable by their owner (laptop, cellphone) and often stockpiled in homes, businesses, institutions and government departments. A further 28.2% of waste pickers indicated that they collected any e-waste that they can find. However, waste pickers do not only collect e-waste, but all recyclables. Other recyclables collected were metals (79.0% of waste pickers), followed by plastic (77.1%), paper (76.2%), cans (72.0%) and cardboard (71.5%).

Table 2: Types of e-waste collected

Commonly collected waste	Percentage	Commonly collected waste	Percentage
Cables	45.0	Stoves	5.9
Screen	39.5	DVD player	4.1
Radio	19.5	Laptop	4.1
TV	19.1	Cellphone	3.2
Computer/CPU	15.9	Fridge	2.7
Kettles	11.4	Fan	2.3
Machines	10.5	Washing machine	1.4
Microwaves	9.1	Geyser	0.5
Irons	8.2	Air conditioner	0.5
Printers	7.7	Amplifier	0.5
Monitors	5.9	Any thing	28.2

Figure 2: Examples of e-waste collected

Waste pickers in the CoJ collect e-waste from multiple locations (Figure 3). Dustbins outside houses (74.2%) were where the most e-waste was collected, followed by shops/business (60.9%) and 56% was directly collected from residents. A further 7.3% collected e-waste from streets/roads and local illegal dumping areas (other in Figure 3). This is similar to the DFFE & DST (2020) guidelines that described waste pickers as people who collect both re-usable and recyclable material from residential and commercial bins, landfill and open spaces.

Figure 3: Different places where e-waste is collected from

Just more than half (54.9%) of waste pickers store their e-waste. The e-waste they collected is stored at home or in their backyards (46.8%) and a third (33.0%) indicated they store it where they sleep in places such as bushes, under bridges or next to streets. Three (2.8%) of the respondents indicated that they use storage containers at landfill sites and another three paid for storage in a garage.

E-waste buyers

The majority of waste pickers (76.4%) sold the e-waste they collected to scrap metal dealers, while 49.8 % and 49.3% respectively sold it to the general buy-back centre and an e-waste buy-back centre (Table 3). A buyer with a bakkie (49.3%) and an e-waste recycler (45.3%) were the other popular buyers of e-waste collected by waste pickers. Other included factories, other waste pickers and local individuals. The results showed that more than one buyer is used by waste pickers. However, waste pickers indicated that they prefer scrap metal dealers as they are of the opinion that scrap metal dealers pay higher prices than other potential buyers and have less strict requirements.

Table 3: E-waste buyers

Sold to	Frequency	Percentage
Scrap metal dealer	172	76.4
General buy-back centre/depot	112	49.8
E-waste buy-back centre/depot	111	49.3
Buyer with a bakkie	111	49.3
E-waste recycler	102	45.3
I do not know who it is	23	10.2
Other	10	4.1

Willingness of waste pickers to sell to e-waste recyclers

There was a number of waste pickers (45.3%) that indicated that they do sell to e-waste recyclers or buy-back centre (Table 3). For waste pickers that did not sell to e-waste recyclers, a question was administered to find out whether they are willing to sell to e-waste recyclers or not. For those that indicated they would sell to e-waste recyclers, a common theme was depicted from their responses, namely better income. In support, two chosen responses from willing waste pickers were:

"Yes, maybe they will pay better than other dealers."

"Yes, I think they would pay better than scrap yards. I think scrap metals pay less".

In contrast, responses from waste pickers unwilling to sell to e-waste recyclers, three notable themes were identified, namely: location, familiarity, and reduced income. Regarding location, one respondent said:

"*No, I don't know their locations*".

Common problems identified by waste pickers is the fluctuation in prices for recyclables (Kasinja & Tilley, 2018) and not been paid a fair price for recyclables (Schoeman, 2018). Therefore, it is not unexpected that waste pickers will not sell to e-waste recyclers if they get lower prices for goods. This is reflected in the following view of a waste picker:

"*No, they will give me a small amount of money compared to what I get at scrap dealers*".

Been familiar with a buyer and having a good working relationship is also important to waste pickers. This came to the fore in the following reason provided by a respondent:

"*No, I have a good relationship with my current buyers*".

Income

Unfortunately, none of the respondents kept detailed records of their earnings from e-waste. They collect more than one type of recyclable and when paid, the receipts they receive do not show the earnings for different waste types (Figure 4). Therefore, this section reports on total income and not income from e-waste.


CU MIXED
1 @ 85.00 R85.00

TOTAL : R85.00
Cash : R85.00
Change : R0.00
VAT NUMBER : R0.00

Cashier : susan ndlovu
Date : Mon 06 09,2021 16:51
Transaction : 444457022598393
Till : Server

Total Qty : 1

Figure 4: An example of a receipt

Almost three-quarters (72%) of waste pickers earned less than and up to R600 per week for e-waste collected and sold (Figure 5). The lowest figure given for earnings per week was R100 and the highest R7 000. Only 3% earned more than R1 501 per week. The average income calculated was R580 and the median income per week R400. The income earnings for e-waste are very similar to the DEA (2016) report that gave R1 430 as the mean monthly income, which translates to R357 per week.

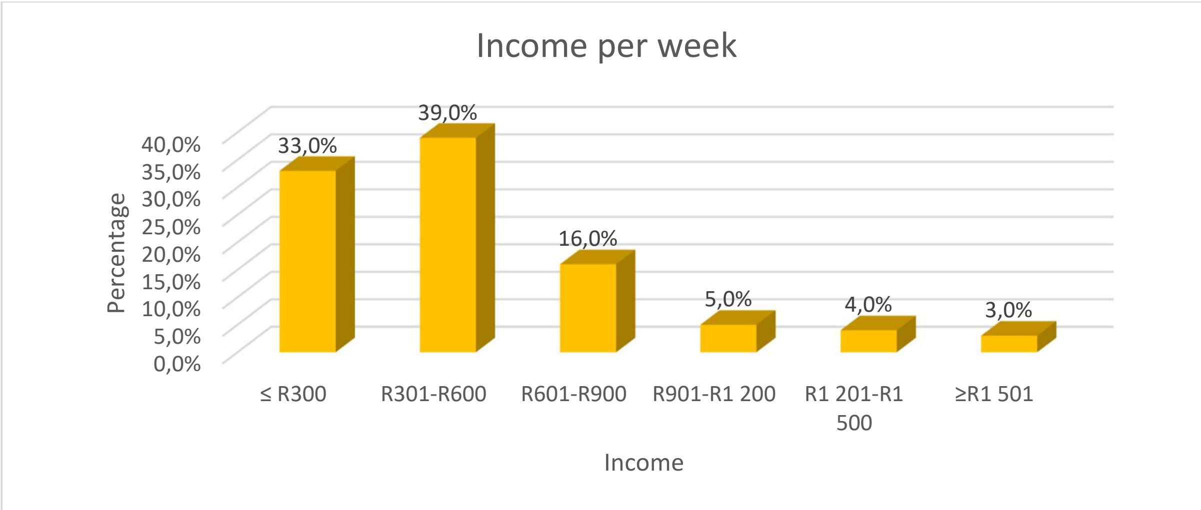

Figure 5: Average income per week

In order to earn higher income for e-waste, often dismantling and processing of e-waste take place. By dismantling e-waste, only the valuable fractions are sold and the rest discarded. Processing involves extracting the valuable components and often includes the burning of cables to extract copper. The next sections briefly explain dismantling and processing of e-waste by respondents.

Dismantling of e-waste

E-waste dismantling involves the breaking down of discarded EEE using tools such as hammers to separate the discarded waste (Heacock et al., 2016). The majority of the respondents (68.0%) dismantled e-waste (Table 4). Out of those that conduct dismantling, only 3.3% received training and a number of them were trained by close relatives and friends and education. To attest to this, some responses:

"*I have learnt by watching other people do it*."

"*From experienced co-workers*."

"*Training from friends*."

"*From my father who was an electrician*."

"*I did an electrical engineering course at Sedibeng College*".

Table 4: Dismantling, training and working together

Response	Dismantle e-waste	Training in dismantling	Work with other waste pickers to dismantle
Yes	68.0%	3.3%	30.4%
No	32.0%	96.7%	69.6%

Field observations confirmed that whether with or without training, waste pickers dismantle goods such as printed circuit boards to extract mostly valuable metals such as copper, lead, aluminum and gold (Figure 6). The majority (69.6%) prefers to do dismantling operations on their own and not with other waste pickers. Those that do work together had different reasons on how they work together. One was 'sharing responsibilities' by dismantling the e-waste by one, while the other waste picker carried the load to the buyer.

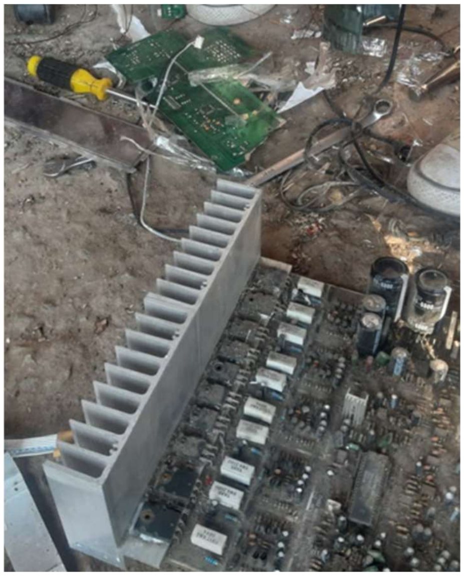

Figure 6: Dismantling of e-waste

Processing of e-waste

Processing e-waste refers to the extraction of valuable metal from discarded cables using chemical and mechanical methods (Masud et al., 2019). More than a half (60.2%) of waste pickers conducted e-waste processing (Table 5). Out of all waste pickers that have done processing, only 1.6% received training. Similar to the findings of the previous section, waste pickers were trained by friends and family and the majority (66.4%) prefer to work alone.

Table 5: Processing, training and work together

Response	Process e-waste	Training in processing	Work with other waste pickers to process
Yes	60.2%	1.6%	33.6%
No	39.8%	98.4%	66.4%

The processing was done by mostly burning cables to extract copper and aluminium. On asking respondents what fraction of the e-waste they consider to be most valuable, 63.7% indicated metals, followed by copper (34.0%), aluminium (28.0%) and cables (11.0%). Field observations (Figure 7) confirmed that waste pickers employ dangerous and harmful practices to process e-waste.

Figure 7: Processing of e-waste

Repair/refurbishment of e-waste

Less than half (43.8%) of respondents collected e-waste for repair and refurbishment. Three-quarters (75.0%) of waste pickers that collected e-waste for repair and refurbishment indicated that they do the repair and/or refurbish themselves. Repaired/refurbished items were sold, but items were also kept for personal use. The majority of waste pickers (87.4%) indicated that they sold repaired/refurbished items to earn additional income and 42.1% indicated that they also kept some of the repaired/refurbished goods for personal use. Items that are kept for personal use included cellphones, kettles, irons, fans, heaters and even large household appliances such as stoves. Only one respondent received training in the repair of e-waste as he was previously employed at a repair centre.

CONCLUSION

It is a given that e-waste generation will continue to increase on a global scale. The growing amount of e-waste is mainly fuelled by an increase in consumerism and shorter life cycles of EEE. E-waste poses both a danger to the environment and human health, but if properly managed, can contribute to the circular economy, job creation, reduction in greenhouse gas emissions, reduction in the use of virgin sources, etc.

The informal sector collects, transports, dismantle, process and repair e-waste – often in an unsafe manner and without proper training and equipment. The rudimentary dismantling and processing of e-waste not only releases toxic pollutants into the environment, but can also lead to several adverse health effects. Waste pickers can be considered a ‘fixed’ feature of waste management in South Africa. E-waste recycling and repairing are an entrepreneurial job opportunity and can lead to a reduction of unemployment and poverty and contribute to economic growth. The question arises if there is political will to integrate the informal sector and/or to assist them with training and equipment to safely recycle and repair e-waste.

ACKNOWLEDGEMENTS

Funding for this project was received from the Department of Science and Innovation through the Waste Research, Development and Innovation Roadmap.
The authors would like to thank and acknowledge the waste pickers that agreed to participate in this study.

REFERENCES

Abalansa, S., El Mahrad, B., Icely, J. & Newton, A. 2021. Electronic waste, an environmental problem exported to developing countries: The GOOD, the BAD and the UGLY. *Sustainability*, 13(9):5302.

Abdelbasir, S.M., Hassan, S.S.M., Kamel, A.H. & El-Nasr, R.S. 2018. Status of electronic waste recycling techniques: A review. *Environmental Science and Pollution Research*, 15:16533-16547.

Acquah, A.A., D'Souza, C., Martin, B., Arko-Mensah, J., Quakyi, I.A., Basu, N., Robins, T.G. & Fobil, J.N. 2021. Work-related exposures and musculoskeletal disorder symptoms among informal e-waste recyclers at Agbogbloshie, Ghana. *Proceedings of the Congress of the International Ergonomics Association*, 222:677-681.

Ahirwar, R. & Tripathi, A.K. 2021. E-waste management: A review of recycling process, environmental and occupational health hazards, and potential solutions. *Environmental Nanotechnology, Monitoring & Management*, 15:100409.

Alao, M.A., Popoola, O.M. & Ayodele, T.R. 2021. Selection of waste-to-energy technology for distributed generation using IDOCRIW-Weighted TOPSIS method: A case study of the City of Johannesburg, South Africa. *Renewable Energy*, 178:162-183.

Asampong, E., Dwuma-Badu, K., Stephens, J., Srigboh, R., Neitzel, R., Basu, N., & Fobil, J. N. 2015. Health seeking behaviours among electronic waste workers in Ghana. *BMC Public Health*, 15(1):1065.

Asante, K.A., Amoyaw-Osei, Y. & Agusa, T. 2019. E-waste recycling in Africa: Risks and opportunities. *Current Opinion in Green and Sustainable Chemistry*, 18:109-117.

Asibey, M.O., King, R.S., Lykke, A.M. & Inkoom, D.K.B. 2021. Urban planning trends on e-waste management in Ghanaian cities. *Cities*, 108:102943.

Atasu, A., & Subramanian, R. 2012. Extended producer responsibility for e-waste: Individual or collective producer responsibility? *Production and Operations Management*, 21(6):1042-1059.

Baldé, C.P., Forti, V., Gray, V., Kuehr, R. & Stegmann, P. 2017. *The global e-waste monitor 2017: Quantities, flows, and resources*. United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna. Available from: https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf.

Baker, M., Memela, S. & Rampete, N. 2016. Empowerment of waste pickers in the City of Johannesburg, creating an enabling environment for the informal waste sector to participate in municipal waste service delivery. *Proceedings of the 23rd WasteCon Conference*. Available from: https://iwmsa.co.za/sites/default/files/downloads/22.%20Baker%2C%20M%20et%20al.pdf.

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D. & Walker, K. 2020. Purposive sampling: Complex or simple? Research case examples. *Journal of Research in Nursing*, *25*(8):652-661.

Carlberg, C. 2014. *Statistical analysis: Microsoft Excel 2013*. New York: Que Publishing.

Castleberry, A. & Nolen, A. 2018. Thematic analysis of qualitative research data: Is it as easy as it sounds? *Currents in Pharmacy Teaching and Learning*, 10(6):807-815.

Creswell, J.W. & Creswell, J.D. 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oakes: SAGE Publications.

DEA (Department of Environmental Affairs). 2016. *Report on the determination of the extern and role of waste picking in South Africa*. DEA: Pretoria.

DEA (Department of Environmental Affairs). 2018. *South Africa State of Waste Report*. Available from: http://sawic.environment.gov.za/documents/11766.pdf.

DFFE (Department of Forestry, Fisheries and the Environment). 2020a. *National Waste Management Strategy 2020*. Republic of South Africa: Department of Environment, Forestry and Fisheries.

DFFE (Department of Forestry, Fisheries and the Environment). 2020b. Extended Producer Responsibility Scheme for the Electrical & Electronic Equipment Sector. *Government Gazette* (Vol. 665, No. 43880).

DFFE (Department of Forestry, Fisheries and the Environment) & DST (Department of Science and Innovation). 2020. *Waste picker integration guideline for South Africa: Building the recycling economy and improving livelihoods through integration of the informal sector*. Available from: https://wasteroadmap.co.za/wp-content/uploads/2021/02/Waste-Picker-Integration-Guidelines.pdf.

eWASA (e-Waste Association of South Africa). 2013. *Business opportunities in South Africa's e-waste sector*. Available from: https://www.ewasa.org/.

Forti, V., Bladé, C.P., Kuehr, R. & Bel, G. 2020. *The global e-waste monitor 2020: Quantities, flows and the circular economy potential*. UNU/UNITAR/ITU/ISWA. Available from: https://globalewaste.org/.

Godfrey, L. & Oelofse, S. 2017. Historical review of waste management and recycling in South Africa. *Resources*, 57(6):1-11.

Grant, R. & Oteng-Ababio, M. 2021. Formalising e-waste in Ghana: An emerging landscape of fragmentation and enduring barriers. *Development Southern Africa*, 38(1):73-86.

Gutberlet, J. & Uddin, S.M.N. 2017. Household waste and health risks affecting waste pickers and the environment in low-and middle-income countries. *International Journal of Occupational and Environmental Health*, 23(4):299-310.

Heacock, M., Kelly, C.B., Asante, K.A., Birnbaum, L.S., Bergman, Å.L., Bruné, M.N., Buka, I., Carpenter, D.O., Chen, A., Huo, X. & Kamel, M. 2016. E-waste and harm to vulnerable populations: A growing global problem. *Environmental Health Perspectives*, 124(5):550-555.

Herat, S. & Agamuthu, P. 2012. E-waste: A problem or an opportunity? Review of issues, challenges and solutions in Asian countries. *Waste Management & Research*, 30(11):1113-1129.

International Labour Organization. 2014. *Tackling informality in e-waste management: The potential of cooperative enterprises*. Geneva: International Labour Organization.

Kasinja, C. & Tilley, E. 2018. Formalization of informal waste pickers' cooperatives in Blantyre, Malawi: A feasibility assessment. *Sustainability*, 10(4):1149.

Kaza, S., Yao, L., Bhada-Tata, P. & Van Woerden, F. 2018. *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank Urban Development Series. Washington, DC: World Bank Group.

Khan, S.A. 2016. E-products, e-waste and the Basel Convention: Regulatory challenges and impossibilities of international environmental law. *Review of European, Comparative and International Environmental Law*, 25(2):248-260.

Lebbie, T.S., Moyebi, O.D., Asante, K.A., Fobil, J., Brune-Drisse, M.N., Suk, W.A., Sly, P.D., Gorman, J. & Carpenter, D.O. 2021. E-waste in Africa: A serious threat to the health of children. *International Journal of Environmental Research and Public Health*, 18(16):8488.

Lundgren, K. 2012. *The global impact of e-waste: Addressing the challenges*. Geneva, Switzerland: International Labour Office.

Lydall, M., Nyanjowa, W. & James, Y. 2017. *Mapping South Africa's waste electrical and electronic equipment WEEE) dismantling, pre-processing and processing technology landscape*. Mintek External Report #74. Pretoria, DST. Policy Report. Available at: https://www.ewasa.org/wp-ontent/uploads/2018/04 /weee_technology_landscape_assessment_report.pdf.

Made, F., Ntlebi, V., Kootbodien, T., Wilson, K., Tlotleng, N., Mathee, A., Ndaba, M., Kgalamono, S. & Naicker, N. 2020. Illness, self-rated health and access to medical care among waste pickers in landfill sites in Johannesburg, South Africa. *International Journal of Environmental Research and Public Health*, 17(7):2252.

Maes, T. & Preston-Whyte, F. 2022. E-waste it wisely: Lessons from Africa. *SN Applied Sciences*, 4(72).

Maphosa, V. & Maphosa, M. 2020. E-waste management in Sub-Saharan Africa: A systematic literature review. *Cogent Business & Management*, *7*(1):1814503.

Masud, M.H., Akram, W., Ahmed, A., Ananno, A.A., Mourshed, M., Hasan, M. & Joardder, M.U.H. 2019. Towards the effective e-waste management in Bangladesh: A review. *Environmental Science and Pollution Research*, 26(2):1250-1276.

Murwirapachena, G. 2021. Understanding household water-use behaviour in the City of Johannesburg, South Africa. *Water Policy*, 23(5):1266-1283.

Nowell, L.S., Norris, J.M., White, D.E. & Moules, N.J. 2017. Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, 16:1-13.

Ogunseitan, O. 2013. The Basel Convention and e-waste: Translation of scientific uncertainty to protective policy. *The Lancet: Global Health*, 1(6):E313-E314.

Orisakwe, O.E., Frazzoli, C., Ilo, C.E. & Oritsemuelebi, B. 2019. Public health burden of e-waste in Africa. *Journal of Health and Pollution*, 9(22):190610.

Peluola, A. 2016. Investigation of the implementation and effectiveness of electronic waste management in Nigeria. *Modeling Earth Systems and Environment*, 2(2):100.

Perry, J., Smit, E., Kuehr, R., Döfnäs, P., Murillo, C., Toorens, B. & Linell, J. 2018. *Developing legislative principles for e-waste policy in developing and emerging countries*. Bonn: United Nations University/Step Initiative 2018.

Pillay, V. 2017. *Amplifying voice, visibility and validity: Waste pickers in Jo'burg city*. Available from: https://www.wiego.org/sites/default/files/publications/files/Villay-SALB-NovDec2017.pdf.

Rayat, C.S. 2018. Applications of Microsoft Excel in Statistical Methods. *Statistical Methods in Medical Research.* Singapore: Springer.

Robinson, B.H. 2009. E-waste: An assessment of global production and environmental impacts. *Science of The Total Environment*, 408(2):183-191.

RSA (Republic of South Africa). 1998. National Environmental Management Act (Act No. 107 of 1998). *Government Gazette*. (Vol. 401, No. 19519).

RSA (Republic of South Africa). 2008. National Environmental Management: Waste Act (Act No. 59 of 2008). *Government Gazette*. (Vol. 525, No. 32000).

Samson, M. 2021. Johannesburg is threatening to sideline informal waste pickers. *The Conversation*. Available from: https://theconversation.com/johannesburg-is-threatening-to-sideline-informal-waste-pickers-why-its-a-bad-idea-159969.

SBC (Secretariat of the Basel Convention). 2011. *Where are WEee in Africa? Findings from the Basel Convention E-waste Africa Programme*. Available from: http://www.basel.int/Portals/4/download .aspx?d=UNEP-CHW-EWASTE-PUB-WeeAfricaReport.English.pdf.

Schoeman, T. 2018. Trolley pushers in the City of Johannesburg. *Proceedings of the Biennial Conference of the Society of South African Geographers*, 360-377. Conducted by the Society of South African Geographers.

Shaikh, S., Thomas, K. & Zuhair, S. 2019. An exploratory study of e-waste creation and disposal: Upstream considerations. *Resources, Conservation and Recycling*, 155:104662.

Tetteh, D. & Lengel, L. 2017. The urgent need for health impact assessment: proposing a transdisciplinary approach to the e-waste crisis in sub-Saharan Africa. *Global Health Promotion*, 24(2):35-42.

Twagirayezu, G., Irumva, O., Uwimana, A., Nizeyimana, J.C. & Nkundabose, J.P. 2021. Current status of e-waste and future perspective in developing countries: Benchmark Rwanda. *Energy and Environmental Engineering*, 8(1):1-12.

UJ PEETS (University of Johannesburg Process Energy and Environmental Technology Station). 2020. Action dialogue report: E-Waste strategy and policy for the Gauteng province. Available from: https://www.uj.ac.za/faculties/febe/peets.

Umesi, N. O., & Onyia, S. 2008. Disposal of e-wastes in Nigeria: An appraisal of regulations and current practices. *International Journal of Sustainable Development and World Ecology*, 15(6):565–573.

UNEP (United Nations Environment Programme). 2018. *Africa Waste Management Outlook*. Nairobi: UNEP.

Wisdom J. & Creswell J. W. 2013. *Mixed methods: Integrating quantitative and qualitative data collection and analysis while studying patient-centered medical home models*. AHRQ Publication No. 13–0028-EF. Agency for Healthcare Research and Quality, Rockville MD.