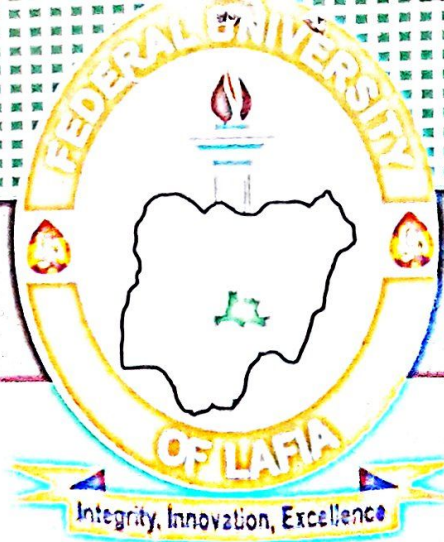




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# Circular Economy and Sustainable Electronic Waste Management: Assessing Public Awareness and Access to Formal Waste Recycling Infrastructure in Ilorin Metropolis, Nigeria

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## Abstract

Nigeria is grappling with the problem of sustainable electronic waste (e-waste) management in all its urban communities. Through policy interventions, the Circular Economy (CE) model was introduced to manage the problem. CE model for e-waste management entails industrial production and post-consumption system that facilitate e-waste management through reduction, recovery, re-using, recycling and, redesigning. CE model also involve collaboration among all the stakeholders in the e-waste value chain, including the consumers of electrical and electronic products during the post-consumption phase. This study investigated public awareness and access to formal e-waste recycling infrastructure in Ilorin metropolis to fill identified gaps in literature. Data collection and analysis entailed both quantitative and qualitative methods. Study participants were selected using a combination of random and convenience sampling. They comprised 477 households that responded to the questionnaire survey, 30 households for in-depth interview and, four artisanal servicemen for key informant interview. Results revealed that approximately 11% of the respondents to the questionnaire survey reported awareness of formal e-waste recycling practices as a sustainable method for the management of e-waste. Furthermore, all the study respondents reported a lack of access to formal e-waste collection centres within the study city, no access to public or private organizations that incentivizes the formal collection of e-waste and, no access to government licensed recyclers. The results of qualitative data analysis also supported these findings. The study recommends public awareness creation and government investment in the necessary infrastructure to promote the CE model for sustainable e-waste management in the study community.

**Keywords:** Circular economy, Extended producer responsibility, Electronic waste, Formal e-waste recycling, Ilorin metropolis, Nigeria

## Introduction

Nigeria is grappling with the problem of sustainable management of electronic waste (e-waste) generated in its urban cities (Woggsborg & Schröder, 2018). E-waste refers to all types of electrical and electronic (EE) devices or equipment, and their components, at their End of Life (EoL), which have been discarded, by the owners (individuals, business entities or formal organizations) as waste, without the plan of reusing (Pandebesie, Indrihastuti, Wilujeng & Warmadewanthi, 2019). E-waste is turning out to be a fast-growing domestic and industrial waste stream in urban Nigeria and its sustainable management demands non-conventional waste disposal methods because of its high content of non-organic materials, compared to common household trash (Bimir, 2020).

Some studies have documented the human and livestock health hazards of the heavy metals and chemical toxicants in e-waste (for example Sonone, Jadhav, Sankhla, & Kumar, 2020); while some other studies have documented the general effects of the hazardous components of e-waste on the eco-system (for example Nithya, Sivasankari & Thirunavukkarasu, 2020). These hazardous environmental effects are universally the same across countries and continents because the toxicants and pollutants in e-waste have the same chemical and metallic properties regardless of the geographical or cultural environment where they are managed non-sustainably (Sonone *et al.*, 2020).

From research findings, e-waste contains several metals and materials which can be recovered, recycled and, reused within industrial production processes, some of them include, mercury, nickel, gold, silver,

zinc, copper and, other chemical solvents which potentially can become new raw materials if recovered (Nithya *et al.*, 2020). In advanced economies (for example European Union and Asian Countries), urban mining is the term employed to describe the process of recovery and recycling of reusable resources from e-waste before the eventual scrapping of non-useful things to which they are attached in products (Arya, Patel & Kumar, 2021).

In many advanced economies, the Circular Economy (CE) model has been mainstreamed into industrial processes and post-consumption cycles to sustainably manage e-waste and facilitate urban mining (Khan, Razzaq, Yu & Miller, 2021; Tsalis, Stefanakis, & Nikolaou, 2022; Cai, Song, Peng, Yuan, Liang & Li, 2020). CE model is a method employed to manage the circularity, efficiency and optimization of industrial raw materials supply system and, the approach promotes the use of e-waste as resources to generate value (Khan *et. al.*, 2021). Furthermore, CE reduces the dependence of industrial manufacturers on virgin mining of natural resources for production processes (Azizuddin, Shamsuzzoha & Piya, 2021).

One of the important components of the CE model is the Expanded Producer Responsibility (EPR). EPR enables industrial manufacturers to extend responsibilities for their EE commodities up to the post-consumption stage of their product's life cycle (Leclerc & Badami, 2020). Important features of CE and EPR, as they relate to e-waste management include, industrial production and post-consumption systems, that facilitate e-waste reduction, recovery, reusing, recycling, redesign, and remanufacturing to achieve economic savings in raw materials sourcing and, reduce non-value-adding activities in

manufacturing processes (Doan, Amer, Lee, Phuc & Dat, 2019). These inter-woven processes are dubbed the 6Rs in contemporary industrial management systems (Azizuddin *et al.*, 2021).

Based on research results, some of the social and environmental benefits of the CE model's adoption and utilization to consumers of EE products and, the physical environment, include monetary gains or income for consumers when disposing of their e-waste (van Yken, Boxall, Cheng, Nikoloski, Moheimani & Kaksonen, 2021) and, opportunities for environmental conservation and protection of natural resources and, the eco-system generally, through reduced virgin mining of solid minerals for industrial raw materials (Kamble & Gunasekaran, 2021; Tansel, 2017). Furthermore, in some of the emerging economies in Asia, both CE and EPR adoption, has been facilitating the generation of new business opportunities and, novel entrepreneurial activities, for individuals seeking avenues for self-employment (Ghisellini, Cialani & Ulgiati, 2016; Kamble & Gunasekaran, 2021; Khan *et al.*, 2021).

Following global trends in CE uptake, EPR was officially launched in Nigeria in 2016 (Woggsborg & Schröder, 2018). Woggsborg and Schröder reported that EPR implementation in Nigeria was envisaged to be a collaborative programme between the national government and a coalition of private sector actors. Based on the accounts of Woggsborg and Schröder, a major goal of the Nigerian EPR initiative, was to seek how to transfer more responsibilities on e-waste reduction and management, onto the few local manufacturers, assemblers, importers and, major distributors of EE products,

whose commodities have the potential to generate e-waste at End-of-Life (EoL).

Little is known about the diffusion and penetration of the CE model and the EPR policy at the community level in Nigeria. Therefore, the general objective of the present study was to investigate the level of public awareness and public access to the formal e-waste recycling infrastructure at the community level in Ilorin, north-central Nigeria. The specific objectives of the study were to (1) assess the level of public knowledge of e-waste as an environmental problem, (2) investigate awareness and patterns of physical access to the formal e-waste recycling infrastructure and platforms for sustainable e-waste management and, (3) examine the popular e-waste management options in the study community.

The remainder of the article is structured into the following sub-sections: sub-section 2 covers the literature review, sub-section 3 handles the research methodology, sub-section 4 reports the empirical results and, sub-section 5 is on discussions of results. The final sub-section of the article carried the conclusion and recommendations based on the findings from the current study.

## Literature review

A review of previous studies revealed that some important works have been undertaken on e-waste in many developing countries. The study by Bimir (2020) examined e-waste trends policies and challenges faced in Nigeria Kenya Ghana South Africa and Egypt. The author Bimir (2020) opined that the increasing e-waste problem in many of these countries was an outcome of compulsive consumption of imported used EE products by the poor in those countries. Bimir noted that the effort

by some of these study Countries to introduce EPR systems for e-waste control has faced structural limitations such as the inability to locate important actors in the local importation of EE commodities corruption in public regulatory departments and bureaucratic laxities lack of funding to provide incentives to local participants willing to participate in formal recycling system and poor manpower capacity on the technical nature of EE products and formal recycling processes.

The study by Ichikowitz and Hattingh (2020) investigated consumers' e-waste recycling behaviour in South Africa 10 years after the launch of the EPR programme in the country. The authors undertook a household consumer survey in the Gauteng region of South Africa. Results from this study revealed that there was a general lack of awareness about formal e-waste recycling and limited formal recycling behaviours among the study population. In the opinion of the authors, these two conditions were both influenced by poor e-waste collection mechanisms and infrastructural deficits. Ichikowitz and Hattingh recommended enhanced opportunities for improved household e-waste recycling through South Africa's collaboration with international e-waste management schemes.

In Nigeria, Miner, Rampedi, Ifegbesan and Machete (2020) studied the level of awareness and willingness to participate in e-waste management among households in Jos Nigeria. The authors found that close to 70% of respondents to their study were aware of e-waste and about the same number reported that they had not received sufficient education on the proper methods of handling and disposing of e-waste. Furthermore, the study by Nduneseokwu, Qu and Appolloni (2017) in Onitsha, Nigeria

investigated the factors that influenced EE consumers' intentions to participate in a formal e-waste collection system in Onitsha, Nigeria. The authors reported that attitude, subjective norm and, environmental awareness, among study participants, had a strong influence on intentions to participate, in formal e-waste collection system. While the study by Nduneseokwu *et al.* (2017) is important, the concepts of attitude, subjective norm and, environmental awareness examined were not explicitly operationalized by the authors. It is against this background that the current study investigated public awareness and access to formal e-waste recycling infrastructure in Ilorin metropolis, Nigeria.

## Methodology

### Study setting

Ilorin is the capital city of Kwara State, Nigeria. The city is located between Latitude 8° 30' and 8° 50' N and, Longitude 4° 20' and 4° 35' E, with a land area of about 100km<sup>2</sup>. The metropolis currently has an estimated population of about three million people. Ilorin city covers part of three Local Government Areas (LGAs), these are Ilorin East LGA, Ilorin West LGA and Ilorin South LGA (National Population Commission, 2021a). The metropolis is home to the various ethnic groups in Nigeria. Foreign nationals are also residents of the city. In the area of modern trade and commerce, both the formal and informal sectors co-exist together and, there are also medium and large-scale industrial organizations in the metropolis (Gemma, 2012).

### Sampling method and sample size

This study utilized a cross-sectional research design and, a mixed-method approach. For

public administrative purposes, Ilorin metropolis is divided into three LGAs. LGAs are the lowest units of Nigeria's federal system of administration. The three LGAs are: Ilorin South LGA, Ilorin West LGA and, Ilorin East LGA. The study employed a multi-stage random sampling system, to randomly select two, out of the three (3) LGAs. Consequently, both Ilorin South (IS) and Ilorin East (IE) LGAs, were randomly selected. The National Population Census' Statistical Areas demarcations of the two randomly selected study LGAs were obtained from the Kwara State office of the National Population Commission (NPC). Based on Enumeration Area (EA) demarcations, Ilorin South LGA is demarcated into 1534 EAs, while Ilorin East LGA is demarcated into 1485 EAs (National Population Commission, 2021b).

The EA maps, of the randomly selected EAs, were procured from the National Population Commission to conduct the second stage of the random sampling for the three independent surveys (one quantitative and two qualitative surveys). Random sampling for the quantitative (questionnaire) survey entailed the use of a Microsoft Excel (MS Excel) function to select a random sample of 30 EAs from each of the two selected LGAs. From the EA maps, a third stage of a random sample of two (2) streets was selected from each EAs and, from each street, five (5) households were selected using convenience sampling. This gave a total sample size of 600 households for the questionnaire survey.

Convenience sampling was used at the last sampling stage because the researcher lacked sampling frame on the number of households per street in the randomly selected EA. Data to build

sampling frame on the number of households per street in each EA could not be procured by the researcher from the Kwara State office of NPC. This is because of the internal administrative policy of the Commission that restricts the kind of data that could be obtained at State level.

Furthermore, the steps outlined above were repeated to select a separate sample for the qualitative survey (in-depth interviews). Consequently, a sample of 15 households was selected from each of the study LGAs. This yielded a total sample size of 30 households. Likewise, four artisanal electronic servicemen were also randomly selected, from the two study LGAs for the key informant interview.

The sample size of 600 study participants for the questionnaire survey was arrived at following Som (2020) sample size determination formula as follows:

$$\text{Sample size} = (Z \text{ score})^2 \times p \times (1-p) / (\text{margin of error})^2$$

Where:

Z score relates to the confidence level (95% confidence level selected)

P is the standard deviation (0.5 to ensure a large sample)

Margin of error relates to the confidence interval ( $\pm 5\%$ )

### Methods of data collection and analysis

Both quantitative and qualitative methods were employed to collect and analyze data for this study. This involved the use of both structured questionnaires, In-depth Interviews (IDIs) and Key Informants Interviews (KIIs). Authors such as Bryman (2016), and Creswell and Plano-Clark (2018) have discussed the usefulness and limitations of these data collection

instruments. For this current study, pre-tested structured questionnaires were administered to 600 randomly selected study households. Pre-tested IDI instrument, was administered on 30 randomly selected study households. Pre-tested KIIs instrument was administered, to the four randomly selected artisanal electronic Servicemen.

Analysis of the quantitative data entailed the use of descriptive statistics. The free online R Statistical software was utilized for the descriptive statistical analysis. The qualitative data (IDIs and KIIs) were collected through audio recording using mobile phones (consent of each Interviewee was obtained before recording of interviews). Transcribed interviews (IDIs and KIIs), were thematically coded and analyzed using content analysis. In the result section of this article, data obtained from the IDIs, supplemented the information obtained from the questionnaire survey.

## **Results**

### **Characteristics of the study respondents**

From the 600 randomly selected households for the questionnaire survey, the response rate was 79.5% (n=477). On the demographic attributes of the respondents, data analysis showed that the mean age of study participants was 38.7 years (Table 1).

Close to 60% of the respondents were males (n=284), while the rest were females. On the marital status of study participants, 62.5% (n=298) were married and, 15.1% (n=72) were singles. Concerning the level of educational attainment among the respondents, individuals with primary school completed (only) were approximately 13% (n=61) and, those who completed secondary and technical school were approximately 18% (n=84). The majority of the respondents (31.9%, n=152) had a First University degree and, equivalent tertiary-level certifications.

On the employment status of the respondents, 73.8% (n=352) reported that they were gainfully employed, while 23.9% (n=114) reported that they were unemployed/not gainfully employed. For those that reported being gainfully employed, the informal sector (comprising largely petty trading, artisanal occupations, daily wage earning and so on) engaged the majority of them (52.4%, n=250), while a sizeable proportion (32.9%, n=157) were also engaged in the formal sector. Fewer respondents (4.4%, n=21) reported that they were engaged in the Charity sector/Religious organizations (mostly religious Clergies like Imams and pastors). On income level, the majority of the respondents (>80%) were in the low and, middle-income categories, and less than 15% were in the high-income category.

**Table 1. Demographic and socioeconomic traits of respondents**

| Characteristics of respondents                                          | Frequency<br>n=477 | of<br>Respondents |
|-------------------------------------------------------------------------|--------------------|-------------------|
| <b>Age (Mean/Years)</b>                                                 | 38.7               |                   |
| <b>Gender</b>                                                           |                    |                   |
| Male                                                                    | 284                | 59.5              |
| Female                                                                  | 193                | 40.5              |
| <b>Highest level of educational attainment</b>                          |                    |                   |
| No formal schooling                                                     | 12                 | 2.5               |
| Arabic school completed                                                 | 69                 | 14.5              |
| Primary school completed                                                | 61                 | 12.8              |
| Secondary/Technical College completed                                   | 84                 | 17.6              |
| National Diploma (and equivalents) completed                            | 30                 | 6.3               |
| Higher Diploma/First university degree/Equivalents completed            | 152                | 31.9              |
| Postgraduate (Master's/ Doctoral degree) completed                      | 37                 | 7.8               |
| Professional Qualifications attained                                    | 27                 | 5.7               |
| Others (specify)                                                        | 5                  | 1.0               |
| <b>Employment status</b>                                                |                    |                   |
| Gainfully employed                                                      | 352                | 73.8              |
| Not gainfully employed/Unemployed/Retired                               | 114                | 23.9              |
| No response                                                             | 11                 | 2.3               |
| <b>Occupational type</b>                                                |                    |                   |
| Self employed                                                           | 271                | 56.8              |
| Paid employment                                                         | 157                | 32.9              |
| No response                                                             | 49                 | 10.3              |
| <b>Sector of employment</b>                                             |                    |                   |
| Informal (e.g. Petty Traders, Artisans, Daily Wage labourers and so on) | 250                | 52.4              |
| Formal (e.g. Public and Private sectors)                                | 157                | 32.9              |
| Religious organizations/Charity                                         | 21                 | 4.4               |
| No response                                                             | 49                 | 10.3              |
| <b>Income categories</b>                                                |                    |                   |
| Low income category                                                     | 232                | 48.7              |
| Middle income category                                                  | 191                | 40.1              |
| High income category                                                    | 54                 | 11.3              |

Source: Survey data analysis, 2022

## **Prevalence of use of EE devices and knowledge of e-waste among respondents**

All the respondents to this study (n=477) reported that they have consistently had access, to EE equipment and devices in the last five years. Data analysis further revealed that respondents' access to EE devices was facilitated by ownership and use of commonplace EE products, at home and for work/business purposes. Data analysis also showed that 68.5% (n=327) of the respondents reported that they were aware of e-waste and that it constitute environmental problems.

### **Public awareness and access to formal e-waste recycling infrastructure among the study respondents**

Questionnaire survey data analysis revealed that approximately 11% (n=51) of the study respondents reported awareness of formal e-waste recycling practices as a sustainable method for the management of e-waste (Table 2). Data analysis further revealed that all the study respondents (100%, n=477) reported a lack of access to formal e-waste collection centres within the study city, no access to public or private organizations that incentivizes the formal collection of e-waste, no access to government licensed recyclers in the city and, no access to prior community-level sensitization on formal e-waste recycling by the CE stakeholders in the e-waste value chain. The CE stakeholders subsumes government agencies, manufacturers of EE commodities or their representatives.

However, approximately 8% of the respondents reported that they had

awareness of the likelihood of financial benefits from participation in formal e-waste recycling programmes and, about 5% of the respondents reported awareness of any private company that carries out products take-back or swapping activities on disused EE devices in the community. Data obtained from the IDIs on awareness and access to e-waste recycling infrastructure at the community level among study respondents (as presented below) lent empirical support to the result obtained from the questionnaire survey.

A female/adult respondent narrated as follows:

I don't know any place where they do formal recycling of disused electronic products in this city.... Some of the electronic devices that I am using for business, especially my Tiger Generator [Gasoline Electricity Generator] and Freezer [Deep Freezer] have been giving me serious problems for several months ...My goods that require refrigeration have been going bad, and I have been recording financial losses. I don't have the cash to replace the two important devices presently ... If there is a place where I could do recycling, it would have been just a case of taking the devices to them, probably adding some cash, dropping the worn-out devices and, pick brand new ones for my comfort...

(IDI/Female/Petty Trade/50 Years/IS LGA/EA 166)

**Table 2. Public awareness and access to e-waste recycling infrastructure at the community level among study respondents**

| Awareness and accessibility criteria                                                                                                           | of Respondents<br>(n=477) |      |
|------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|------|
|                                                                                                                                                | Yes                       | No   |
| Awareness of formal e-waste recycling practices as a method of sustainable management                                                          | 10.7                      | 89.3 |
| Awareness and access to formal e-waste collection centres within the city                                                                      | 0                         | 100  |
| Awareness and access to any public or private organisation that incentivizes formal collection of e-waste                                      | 0                         | 100  |
| Awareness and access to government-licensed recyclers                                                                                          | 0                         | 100  |
| Awareness and access to private companies that carry out product take-back or swapping mandates on disused EE devices                          | 4.6                       | 95.6 |
| Awareness of the likelihood of financial benefits from participation in formal e-waste recycling                                               | 7.8                       | 92.2 |
| Awareness of prior community-level sensitization on e-waste formal recycling initiatives by the government and manufacturers of EE commodities | 0                         | 100  |

Source: Survey Data Analysis, 2022

A male/adult respondent also remarked as follows:

The system of recycling malfunctioning or damaged electronic products or what you have explained as EPR is not common in this environment ...If you buy some brands of electronic products such as Refrigerators or Freezers from reputable Sales outlets they can provide a warranty on the products for a few years.... apart from this, it is only spoilt Automotive batteries that are accepted for informal recycling system through Retailers ... I know about the case of automotive batteries because I own a motor vehicle [Automobile]...

(IDI/Male/Legal practitioner/63 Years/IE LGA/EA 306)

#### **Popular e-waste management practices among the study participants**

The result of data analysis on the popular methods of e-waste disposal accentuates the poor level of access of the study participants to formal e-waste recycling infrastructure in the study community. From the analysis of questionnaire survey data, the most popular e-waste management options, among the respondents, were storage of e-waste at home and within business premises, as well as e-waste dumping and informal recycling

with the artisanal Servicemen at the community level.

All the respondents to the survey questionnaire (n=477) reported that they have used storage as a management option at various times and for diverse categories of e-waste. The respondents estimated that the period of storage of e-waste could range from a few months to several years. Data from IDIs revealed that some of the factors responsible for the storage of e-waste could include the possibility of getting re-usable parts from the damaged device, especially when a replacement for it also becomes faulty, or begins to malfunction. Another important factor was the social prestige that ownership of commonplace property items, such as electronic devices, could accord at the cultural level.

A male/adult respondent in Ilorin South explained as follows:

I am usually not in a hurry to dispose of my damaged electronic devices ... this is because a person may not be able to predict how a replacement would behave .... I try to retain at home the damaged devices for a reasonable period in case the replacement becomes faulty and, there is the need to repair it, it is sometimes possible that the Servicemen can get reusable parts from the damaged device, thereby helping to save money on repairs...

(IDI/Male/Pharmacist/51 Years/ IS LGA/EA 1208)

A female/adult respondent in Ilorin South opined as follows:

In our cultural environment, possession of some commonplace household electronic devices such as

Television sets, Refrigerator, Freezer, Air conditioning units and so on, is an indication, that the head of the household, is leading a responsible life economically and, not a spendthrift ... If any of these devices gets damaged and, the household does not have money, to get a replacement immediately, we try to keep the damaged device in its position for some time ... This is for the sake of social prestige when members of the extended family or friends come visiting ... At least they will be able to see some of the devices around the living room, even if they are non-functioning ...

(IDI/Female/School Principal/56

Years/ IS LGA/ EA 1408)

Questionnaire data analysis also revealed that the second most popular local e-waste disposal option was dumping and informal recycling with artisanal Servicemen in the study community This was reported by approximately 60% (n=283) of the respondents. Data from IDIs revealed that one of the factors responsible for this behaviour was to prevent the clogging of the household's environment or business premises with obsolete or damaged EE devices and equipment.

A male/adult respondent in Ilorin South narrated as follows:

After taking any damaged device to about two Servicemen and, I get about the same result that the damage is irreparable, or maybe the estimated total cost of repairing, is more than half the market price, of a new product, I usually opt for the decision to discard the damaged product and purchase a new one ... In that case, I don't bother to take

home the bad electronic device, I normally leave it with the artisanal servicemen as gift...

(IDI/Male/Self-employed

Businessman/52 Years/IS LGA/EA  
496)

Another interviewee spoke as follows:

Some of us simply dump our irreparable electronic devices with the Servicemen ... It would have been nice if we had access to government-licensed recyclers of disused electronic that could collect them and give us cash [money] .... Frankly speaking, I am not aware of any licensed recyclers, many of us in the community don't even know about people who are collecting spoilt electronics informally too ... Take a visit to the workshops of many of the Servicemen, you will see assortment of spoilt TVs [Television sets], pressing iron, Refrigerators, fans, Air Conditioners, that their customers have dumped with them...

(IDI/Male/Retired Public Servant/67  
Years/IE LGA/EA 127)

#### **Complementary roles of artisanal Servicemen *vis a vis* consumers' e-waste dumping and informal recycling**

Analysis of data obtained from the key informants artisanal servicemen suggested that their workshops served as receiving centres for disused EE devices that consumers were willing to dump/gift out and, possibly recycle informally. The artisanal servicemen, informally collect e-waste from their customers. In the words of a KII respondent in Ilorin East LGA:

We collect disused electronic items from our customers ... as a matter of fact, many clients make our workshops dumping grounds for

electronic items that are no longer useful to them ... But we don't have any access to a formal recycling system in the community either...

(KII/Male/Electronics Serviceman/32  
Years/ IE LGA)

Another key informant in Ilorin East remarked as follows:

On the volition of a few of us engaged in local servicing of electronic products, we try to pay some cash to the customers that turn in their disused electronic devices to us ... it can be described as a form of dumping behaviour on their part ... We give the cash to them from our own purse, because we know we will get some parts to recover and reuse for other future works on repairs ... No foreign or local manufacturer or local distributors gives us any incentives to give cash and collect disused electronic devices from users of electronic products ....

(KII/Male/Electronics Serviceman/54  
Years/ IE LGA)

From the account of the key informants, after the recovery of reusable parts, the end-stage scraps are broken down and, sorted into constituent components (such as steel, plastic, glass/screen, and bronze/brass components). These end-stage scraps are sold to scrap collectors who are in the business of 'Waste-to-Wealth'. A KII respondent in Ilorin South spoke as follows:

After we have completely taken [cannibalized] all reusable materials inside the devices dumped with us and, we have accumulated substantial scraps that are no longer of any use, we break them down into various components and, sort the parts by material types such as

metallic components, plastic components, glass and so on... We sell these scraps to the local scrap collectors ... some of the scrap collectors come to pick metallic materials and some others come to pick plastic materials ...

(KII/Male/Electronics Serviceman/48 Years/ IS LGA)

## Discussion

This study investigated public awareness and access to formal e-waste recycling infrastructure in Ilorin metropolis, Nigeria. Findings on awareness of e-waste and the potential of e-waste production by households revealed that more than half of the study respondents had awareness of what constitutes e-waste and also know that the EE devices and equipment they use at home and for business purposes can produce e-waste their EoL due to irreparable damages and obsolesce. Findings from this current study, on public awareness and access to the CE model and EPR infrastructure/platforms, for e-waste management (at the community-level), revealed a low rate of diffusion, evidenced by the results of data analysis. Approximately, 90% of the respondents reported that they did not have awareness and, have never received any education or sensitization on formal e-waste recycling. Also, findings revealed a complete absence of public access to formal e-waste recycling (EPR) infrastructure/platforms among the study respondents. These findings are consistent with results from previous studies by Uddin, Hoque, Mowla, Uddin and Mamun (2022) and, Ichikowitz and Hattingh (2020). However, the findings are not in agreement, with previous results by Cai *et al.* (2020).

Uddin *et al.* (2022) reported that lack of awareness of the CE model was a major factor constraining the spread and utilization

of the model among industrial manufacturers in Bangladesh. Furthermore, Ichikowitz and Hattingh (2020) investigated consumers' e-waste formal recycling behaviour in the Gauteng Area of South Africa. Their results revealed that there was a general lack of awareness about e-waste formal recycling with resultant low formal recycling behaviours among their study participants. Ichikowitz and Hattingh opined further that these two observed conditions were influenced by inefficient e-waste collection mechanisms and poor access to infrastructural facilities among their study participants. By contrast, however, Cai *et al.* (2020) found that a large percentage of their study participants in Zhuhai City China had sufficient awareness and access to formal e-waste recycling infrastructure which positively influenced the utilization of formal e-waste recycling.

Results on the popular methods of e-waste control from the current study are in agreement with research outcomes from previous studies in developing countries. The findings in this study on home storage of e-waste as a local option for e-waste management are consistent with previous findings by Nuwematsiko, Oporia, Nabirye, Halage,, Musoke and Buregyeya (2021) in their study in Kampala Uganda. The finding from this study on the informal recycling of e-waste through local servicemen which indicates the willingness of some respondents to recycle e-waste even in the absence of formal e-waste recycling infrastructure is supported by research results from previous studies by Hassan and Dhusia (2020) in Delhi India, and Dzah, Agyapong, Apprey, Agbevanu & Kagbetor. (2022) in Ho community in Ghana. These authors reported that informal recycling was the most important alternative in the absence of access to formal e-waste

recycling among their study respondents in Delhi and Ho communities.

## Conclusion and Recommendations

This study investigated public awareness and access to formal e-waste recycling infrastructure in Ilorin metropolis, Nigeria. Results showed a low rate of diffusion and poor access to the formal e-waste recycling infrastructural resources in the study area. Following the results of the current study, this paper argues that very negligible urban mining activities are ongoing in the study community. Furthermore, due to the low urban mining activities there is the likelihood that EE consumers are not deriving financial values from the e-waste they produce periodically. In addition, some of the popular and inefficient e-waste disposal practices especially the storage system portends dangers to the health of members of the society. This paper further argues that failure to stimulate formal e-waste recycling is preventing members of society from harnessing opportunities that come with the novel trend in urban mining.

Findings from this study have implications for two important macro-economic challenges that Nigeria is currently facing which could benefit from the scaling-out and promotion of access to the CE model for e-waste management. Firstly, it is a common awareness that Nigeria is presently facing a fiscal crisis due to the poor global crude oil market. The crisis has propelled a national effort to promote diversification (increased extraction and exportation of non-oil mineral resources) to boost national income earning. Public policy and efforts at diversification of the national economy have targeted virgin mining of solid minerals to enhance national income earning. This paper posits that Nigeria has ample opportunities to augment the volume of solid mineral exports with the materials recovered from

urban mining activities. The paper agrees with the views of Tsalis *et al.* (2022) that efforts at promoting urban mining activities could offer substantial reprieve to virgin mining of natural resources, and equally help to reduce damage to the eco-system.

Secondly, there is a high rate of unemployment (especially among youth) in Nigeria. The promotion of formal e-waste recycling and urban mining activities could provide job opportunities that could help mitigate the problem of youth unemployment. This study agrees with the views expressed by Murthy and Ramakrishna (2022) on the assertion that the e-waste market is increasing rapidly at the global level and there is a need for local entrepreneurs in emerging economies to identify and tap into its diverse employment opportunities by setting up formal e-waste recycling businesses.

Therefore, based on the findings from this study, it is recommended that the government at the Federal and State levels in Nigeria should undertake interventions to stimulate the CE and EPR diffusion to promote formal e-waste recycling in the study community. Some of these interventions include the creation of an enabling environment that would promote private sector-led investment in the e-waste recycling business, the commissioning of licensed recyclers in urban centres, enhancement of public-private partnerships in formal e-waste recycling, and carrying out mass sensitization and awareness creation on the potential benefits of formal e-waste recycling practices to sustainable environmental management.

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