Evaluating the feasibility of effective E Waste management: Case Study

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Abstract
The study investigated the prospects of improving e-waste management system. It was established that the e-waste comprised of personal computers, air conditioners, refrigerators, fluorescent lamps and old telephones handsets. Such discarded equipment was found to contain useful metals such as iron, copper and aluminum as well as ecological contaminants such as lead and mercury. The prevailing practice simply involved storage and transporting to landfill site for disposal without appropriate segregation. The existing legislation framework did not offer satisfactory enforcement effectively appropriate handling of this specific waste. An e-waste handling framework was proposed to enable separation and recovery scheme to get output secondary raw materials containing ferrous metal scrap, non-ferrous scrap, plastics, batteries and glass thereby stimulating for a possible recovery of useful materials and involving local recycling companies who can benefit from these materials.

Keywords
E-waste, energy, efficiency, recycle, environment, management, sustainable

1. Introduction
In recent years, a dramatic increase in the production and consumption of electrical and electronic equipment (EEEs) coupled with a decrease in their lifespan has led to the generation of large quantities of waste. E-waste is the electronic equipment at the end of its useful life period and is of no further use. Waste from electronic equipment is the fastest growing waste stream in the world with a 3-5% increase rate per year compared to generation of municipal wastes (Stenvall, 2013). E-waste contains several substances which are toxic and not biodegradable. The improper disposal practices produce carcinogenic substances which are harmful to the environment and human health. Due to hazardous substances present in e-waste, proper management methods are required. Since e-waste contains appreciable amount of precious metals, it is potentially an important secondary sources of such metals (Yazici et al., 2011).” Nevertheless, effective management of e-waste would require for safe, scientific and environmental sound treatment options that are governed by adequate infrastructure and policies (UNEP, 2017). The policies would aid in creating shared responsibility between affected community of local authorities, industrial consumers of electrical/electronic products and other environmental boards towards an operative collection and treatment of the waste resource. Also integration of treatment options such as the use of the 3Rs (reuse, recycle, recovery) would minimize e-waste. In case of recycling, the yieldable benefits would include recovery of a variety of reusable metals hence reduction in natural resource consumption, reduction in environmental pollution through avoidance of hazardous waste disposal.
2. Background of study
In the country, there is a rising tide of e-waste generated by domestic consumption of electrical and electronic equipment. The rate at which electronic gadgets are flooding the local market is contributing to the increase of e-waste. There is no known environmentally friendly method to dispose e-waste in the country. The current rate of e-waste accumulation is not sustainable as Harare’s limited dumpsites are fast filling up. Thus there was need to investigate the available opportunities for collecting and recycling used electronic equipment to minimise solid e-waste that would go to the landfill with a possibility of recovering any useful materials from this waste, with the aim of coming up with recommended ways of collecting, handling and disposing e-waste as well as evaluating the feasibility of recovering any useful materials from e-waste. In the same vein, economic ways of undertaking this will be interrogated as well as developing sustainably cheap methods to handle e-waste. Recycling of e-waste will have various benefits to the community as well as reducing solid waste to the designated dumpsites. The handling of e-waste will be undertaken sustainably to reduce unnecessary deposition of e-waste on the available landfill site.

The industrial solid waste management framework in the case study area can be improved to accommodate e-waste. The available solid waste management model of “accumulate, collect and dispose” is ineffective and not compatible to e-waste. E-waste is made up of retrievable valuable engineering materials such as metals and non-metals as well as high concentrations of harmful constituents like lead and mercury that contaminate the environment. No accurate information is known about the generation, quantification, characterization and handling of e-waste in the area.” There rises a need to evaluate the present status on e-waste management being done by industries hence amendments are done towards a viable e-waste management framework. The evaluation would give room for rectification of e-waste treatment standards and environmental protection measures in the industrial area. The idea of e-waste treatment would then call for the industries to probably adjust their recycling activities to accommodate the newly emerging waste stream since no sign of e-waste recycling has yet been put in place in the country. Stakeholder awareness can be done to achieve a sustainable e-waste management system. The later would notify stakeholders on the nature of waste they are exposed to actively participate in developing a framework for monitoring and continuously evaluating e-waste flows. Stakeholder involvement would be of essence to acquire a sustainable approach to e-waste management by bringing together industries, non-governmental organizations and government entities together.”

3. E-waste management review
According to (Onianwa, 2016), 41.8 Mt per year of e-waste are produced globally with Africa holding 1.9 Mt of that share. This rapid e-waste production is supported by the continuous improvement on equipment design and utilities hence a shortened life cycle of the equipment as they phase out quickly. Developing regions such as South Africa, Morocco, Brazil and Mexico are recorded as the leading e-waste generators (Premalatha, et al., 2014). In 2015, personal computers, televisions and cell phones contributed 9.8 million tons of e-waste which was a rise from 5.5 million tons in 2010. It was also estimated that by 2021-2025 absolute PCs accumulated in developing regions will be more than those in developed regions. However, technological obsolescence could be considered as the major driver of electrical and electronic equipment disposal as it stimulates the need to replace devices frequently. This behavior directly impacts e-waste generation. The upgrading or consuming of the equipment is related to affordability and availability of the market which are factors to do with the economic state of a region.(Gaidajis, et al., 2010), anticipate that increase in economy growth reflects higher e-waste generation rate due to availability and affordability of commodities within a geographical boundary.

Mostly e-waste consists of plastics, plywood, PWBs, glass, solid, elastic, ferrous and non-ferrous metals, earthenware production and other different substances. As indicated by (Vats & Singh, 2014), e-waste is a blend of significant metals, non-metals and other toxic contaminates. Of the constituents in the waste - iron and steel is about 47.9%, plastics at 21% and non-ferrous metals at 13%. The non-ferrous metals include copper, aluminum and precious metals. According to (EPA, 2011), the proportion of precious metals is estimated as 0.2%, 0.1% and 0.005% for silver, gold and palladium respectively. Compared to the other components which make up electrical gadgets, printed circuit boards contain high amounts of precious metals. Youssef (2012) projects that computers and mobile phones are rich in precious metal content. The values of metal compositions of printed circuit boards from different sources like televisions, personal computers, DVD players, calculators and others were obtained and analyzed to conclude that printed circuit boards from personal computers and mobile phones contain the highest amounts of valuable metals (Youssef 2012) as shown in Table 1.
Table 1. Metal composition in e-waste components (Sims 2012)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Key Boards</th>
<th>Personal Computers</th>
<th>Printed Circuit Boards</th>
<th>Car electronics</th>
<th>Typical Copper ore</th>
<th>Recycling efficient %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag</td>
<td>0.05</td>
<td>0.009</td>
<td>0.3</td>
<td>0.12</td>
<td>0.00034</td>
<td>80</td>
</tr>
<tr>
<td>Au</td>
<td>0.05</td>
<td>0.001</td>
<td>0.008</td>
<td>0.007</td>
<td>0.00001</td>
<td>99</td>
</tr>
<tr>
<td>Cu</td>
<td>13</td>
<td>7</td>
<td>25</td>
<td>20</td>
<td>0.8</td>
<td>90</td>
</tr>
<tr>
<td>Zn</td>
<td>3</td>
<td>1.2</td>
<td>1.5</td>
<td>1</td>
<td>0.12</td>
<td>60</td>
</tr>
<tr>
<td>Pd</td>
<td>0.0002</td>
<td>0.0004</td>
<td>-</td>
<td>-</td>
<td>0.04</td>
<td>60</td>
</tr>
<tr>
<td>Al</td>
<td>18</td>
<td>11</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>80</td>
</tr>
<tr>
<td>Ni</td>
<td>0.16</td>
<td>0.2</td>
<td>0.5</td>
<td>0.3</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Pb</td>
<td>0.3</td>
<td>1.5</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Bi</td>
<td>&lt;0.003</td>
<td>&lt;0.0004</td>
<td>0.17</td>
<td>0.01</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Fe</td>
<td>3</td>
<td>&lt;0.1</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>80</td>
</tr>
<tr>
<td>Sb</td>
<td>0.3</td>
<td>0.5</td>
<td>0.06</td>
<td>0.08</td>
<td>-</td>
<td>70</td>
</tr>
</tbody>
</table>

E-waste hosts hazardous substances embedded in various e-waste components. Lead is commonly used in solders, as an alloy element for machining metals, incandescent light bulbs, cable covering and printed circuit boards. Its oxide is used in the cathode ray tubes leaded glass and batteries. Tin-lead solder is the chief solder type used in most motherboards, 50g/m² lead are expected per typical motherboard (Mmereki, et al., 2016). Cadmium is concentrated in semi-conductor chips and resistors in printed circuit boards, batteries, photocopying machines, printer inks and toners, cathode ray tubes, and infrared detectors. The element is also used in stabilizing PVC. In nickel-cadmium batteries, cadmium forms the negative electrode material. It is conjointly used as associate alloying part in creating low melting brazing or attachment alloys. Cadmium bio accumulates in body parts such as the liver, pancreas, kidney and thyroid thereby posing irreversible effects on the human health. Mercury is found in relay and switches, mobile phones, batteries and relay sensors, gas discharge lamps, pumps, ovens, leveling devices, thermostats and electric ranges. Exposure to mercury causes brain and kidney damage, it affects the cardiovascular system, affects developing fetus, trigger depression and suicide. Furthermore, inorganic mercury mixes with water to form methylated mercury which bio-accumulates in incarnate organisms, mostly fish hence affecting the food chain (Mahajana, , et al., 2015).

Hazardous e-waste affects the environment through soil, air, water and humans in case of inappropriate handling methods. (Gupta, 2012), describes 3 levels of emission of e-waste toxins into the environment as primary emission which involves the release of dangerous constituents in e-waste like mercury and cadmium, secondary emission which implicates subsequent discharge of products of reaction due to improper treatment such as furans or dioxins formed due to burning of plastics containing flame retardants made up of halogens, tertiary emission which involves the release of hazardous substances or reagents used in e-waste treatment such as cyanide or other leaching agents. Therefore, the environmental risk of such hazardous pollutants could be due to nature of the generated waste and how it is being collected, processed, recycled or disposed.

It is in this regard that management of e-waste is not an individual responsibility neither is it a government’s mandate alone but it is rather a collective thing that involves the collective working together of people from various areas of interest in a bid to protect the environment for the present and for the future generation. In order to reduce the extent of e-waste damage to the environment, there is need to come up with strict regulations on the management and disposal of e-waste. Legal framework that governs and regulates e-waste should be in place and should be able to explicitly define e-waste and categorize it. Incentives should be given to those that want to manage and recycle e-waste and those industries that upgrade their plants or facilities towards cleaner production. Since a significant portion of people are not really aware of what e-waste is and what to do with their e-waste, there could be need for training on mitigating dangers of e-waste. Encouraging reuse and investing in recycling could help in alleviating e-waste problems.

4. Methods and materials

A case study design strategy was adopted to carry out an in-depth research towards the development of a viable e-waste management framework in the case study industrial area of Harare. An analysis of current e-waste management situation was undertaken and then a possible e-waste management framework was developed. Waste products and processes are identified for various major industrial players. The analysis towards a suitable e-waste management framework was done by scrutinizing the identified flaws in the existing management scenario. The
Researchers explored on the possible opportunities yield through the rectification of the identified. The industrial area has reduced activity as most of the industrial shells have been abandoned due to closure of companies resulting from the economic hardships being experienced in the country problems. The process covered e-waste treatment scheme establishment based on best collection, recycling technologies and potential opportunities. A computer software simulation was developed as a tool to present a range of different management systems to the stakeholders, especially those to coordinate the framework for e-waste management in the case study industrial area. The computer simulation framework was developed using Visual Basics for Application language in Microsoft Access to generate an interactive user interface.

5. Case study

The case study industrial area based in the Msasa area part of Harare is dominated by manufacturing industries and warehouses. It is located about 10 km from the central business district and has Granite industrial area as its neighboring industrial site. Most of the industries here range from small to medium industries with a few heavy industrial operations. Banks, shops and other commercial services are found in the area. Area is dominated with small scale industries with many of the industries employing less than 100 workers, most of these are into manufacturing with plastic and chemical industries dominating. The industrial area has reduced activity as most of the industrial shells have been abandoned due to closure of companies resulting from the economic hardships being experienced in the country. Most of the companies currently operating are doing so way below capacity.

The majority of industries in the area are mostly involved in the production of food, textile, chemicals, plastic, paper and building material. Among the service industries there are operations which are into transport, banking, retailing/wholesaling, consultancy, funeral, security, motor repairing and construction. Recycling companies are mostly in metal scrap, paper and plastic. The composition of industries is given by Figure 1.

![Industry Composition](image-url)

Figure 1. Industry composition

According to (Gaidajis, et al., 2010; ), the rise in economic growth reflects higher e-waste generation rate since economic growth could imply availability and affordability of commodities within a geographical boundary. This was been proved true for the case study industrial area as was observed that electrical and electronic appliance uptake has been on rise since the dollarization era in 2009. The growth in economy over the past years has given industries better import technologies to replace the older ones hence attaining improved productivity and efficiency.
However, most of the imports are counterfeits of reduced life span and high obsolescence rate from Asian countries. Availability and affordability of the electrical and electronic equipment on the market is pushing these industries not to hesitate to upgrade their equipment to meet the technological advancement. By virtue of the increased variety of these products, the compatibility of equipment components is now infrequent causing some equipment to be irreparable and unusable. For that reason, the industrial community is facing increased e-waste generation due to obsolete electrical/electronic equipment and components. Nevertheless, no determination has been shown towards the quantification and characterization of the e-waste generated by industries in the case study area. The movement of e-waste material in the area is unidentified but only the fact that the e-waste generation sources are the individual industries in the locality.

A large amount of e-waste was generated from service industry entities consisting of administrative, customer service and marketing department. Such e-waste comes from the office and building utilities that include obsolete computers used in data saving, telephones for communication, printing devices, photocopies, lighting equipment, heaters, fans, air conditioners and refrigerators as given in Figure 3.

Also manufacturing and processing industry operations produced waste related to the electrical/ electronic equipment and components used during production, such as inductive devices like motors in drive systems, generators, inductors, capacitors, transducers and sensors in control systems.

Currently e-waste is treated as general municipal solid waste, and no unique consideration is being given to the activities associated to its collection and treatment. Most of the actions related to the e-waste handling are executed by informal players who do not have the practical and infrastructural skills or awareness on the grave consequences of e-waste mishandling on the environment and human health. The characterization, quantification and movement of e-waste is still hazy within this industrial community. Chief stakeholder involved in waste handling in case study
area is the local municipality. It carries out the collection, transportation and disposal of industrial waste but then such traditional methods of waste management cannot be deemed compatible with e-waste requirements. The deficiency of a proper disposal strategy pushes most industries to use the traditional methods of solid waste management which involve dumping of the e-waste scrap with no segregation from regular solid waste.

6. Findings

6.1 E-waste characterization

The characterization of e-waste generated is given by Figure 4. As shown, 30% of companies reported to have discarded fluorescent lights, followed by 25% who discarded computers, 15% for air conditioners, 13% for refrigerators, 9% for photocopiers and printers, 8% for telephones as well as motor and casings, 5% for resistors, 4% for capacitors and 1% reported cases of various discarded items such as batteries and cables.

These findings resonated with those by (Finlay & Liechti, 2008) which indicated that lighting devices comprise the greater share of e-waste material because of their shortened lifespan as compared to other counterparts in the e-waste stream. The dominance of fluorescent lights was observed to be related to the high usage of lighting equipment across industries as recommended by the local factory act in support of enhanced task performance and improved appearance of the working areas. The fluorescent lights comprised of compact and straight lamps are of concern as they contained hazardous amalgams of mercury, neon or metal halides. In standard straight lamp types mercury content can be at most 10mg which is of significance as dosages of mercury can impair human health hence resulting into cases of depression or future heart problems (Ferne & Barker, 2012). On the other hand, the lamps carry valuable engineering material that can retrieved of secondary raw material such as aluminum and copper. Proper handling of such equipment is required to avoid uncontrolled breakages and mercury emissions.

The second highest level of e-waste was personal computers dominated by desktops, telephones, printers and photocopiers which fall under information and technology category. The existence of such equipment in the e-waste stream echoed with findings by (Emmanouila, et al., 2013), that information and technology (ICTs) penetration is increasing with the increase in inbuilt obsolescence in the equipment hence fast replacements. The local survey by (ZimStat, 2014) also confirmed that majority of the electrical and electronic equipment in the country are dominated by information and technology equipment. At industrial level ICTs were observed to find use in various tasks to enhance production. Computers were observed to find use in data capturing and management as well as communication at administration level and automated machinery control. ICTs consisted of various components such as CRTs in computer monitors, printed circuit boards, batteries, connection cables and plastic casings. In these components are hazardous materials such as mercury, lead and cadmium as well as valuable metals like copper, aluminum and iron.

The industrial share of e-waste was found to consist of refrigerators and air conditioners categorized under large appliances, and these were observed to have found use in most food processing and beverage industries. Air conditioners were found across all the industrial buildings as they are used in the process of eliminating heat and
moisture for the improvement of building interiors. These appliances comprised of components such as evaporators, compressors, condensers, fans, screws, motors, cables, metal housing, plastic housing and LCDs.

Lastly there were passive components like resistors, capacitors, induction motor and casings were in the e-waste stream. According to the observation made most drive and power systems in manufacturing and process industries utilizes passive components like capacitors for energy storage and power factor correction. Resistors and inductive devices such as motors easily succumb to wear and tear. However, capacitors contain of leachates such as polychlorinated biphenyls (PCB’s) whilst resistors contain nickel, lead and sulfur hence require proper disposal methods.

6.2 E-waste management in case study industrial area

In the survey done it was shown that only 10% of the respondents had a regular procedure to handle e-waste whilst 90% had none. All respondents confirmed that no formal e-waste collection and treatment is being undertaken in the industrial community. The findings concurred with those by (Feresu, 2010), who found that the Zimbabwean community still lags in e-waste management hence lacks proper treatment facilities to accommodate e-waste since the country is amongst the developing African nations facing insufficient financial upkeep. The handling of e-waste generated was found to be entirely the responsibility of the producers of such waste and majority of the companies highlighted that they are engaging in ways to manage their obsolete equipment.

From Figure 5, 50% of the companies admitted that they store their generated e-waste, 25% of the companies reported to be land filling their e-waste, 19% of the companies indicated that they rely on reuse of their equipment, none was involved in recycling and 6% were reported to be involved in other activities such as auctioning to employees and donations. The findings were hand in hand with those of (Zunguze, 2010) in that, most corporate consumers resort to storage of e-waste.

The storage behavior gave an impression that companies are unaware of proper disposal methods since there was proof on absence of e-waste take back and recycling schemes. Most equipment is being imported hence no original equipment manufacturer(OEM) representatives to engage in take back schemes as seen in developed countries, where take back schemes are exercised to facilitate for effective e-waste collection for recycling. Despite the wide practice of storage as an e-waste handling method, it is not an end-of-life treatment option but rather an intermediary stage within a product lifecycle.

Resorting to land filling which entail throwing of e-waste away with regular solid waste, showed the deficiency of familiarity on the importance of segregation of e-waste equipment from regular garbage. Segregation is vital in handling e-waste as it ensures for the sorting of the waste material of resource value from the waste materials hazardous to the environment. Landfill dumping is the least favored treatment of choice as e-waste contains hazardous leachates that can disturb environment and human health.

On reuse, some refurbishment of equipment at the end of its life was done to extend its useful lifespan. The downside of repetitive reuse of obsolete equipment beyond the useful lifespan compromises on user safety and energy conservation, for instance repeated winding of motors three to four times can result in reduced efficiencies and high energy consumption as well as compromising other circuitry components.
6.3 E-waste legislative framework

The whole spectrum of respondents entirely agreed that, the industries and the country at large have no policies or legislations related to e-waste. Although the Environmental Management Act (20:27) forbids the liberation of harmful materials to the environment it lacks specificity to e-waste. The reason for the above could be that, e-waste is a newly emergent waste type in the country hence no action has been taken since the impact of the waste is unknown yet. Legislative policies would aid in clarifying the roles and responsibilities of affected stakeholders towards a successful management system such as extended producer responsibility. Furthermore, an observation made during the survey was that no policy are known to govern the standard of imported electrical and electronic equipment hence counterfeits and equipment with high use of hazardous elements end up in the industries posing disposal threats. About 95% of companies were found not to be subscribing to ISO14001 whilst only 5% comply with this international standard. The non-conformance by industries to international legislation regarding environmental management was a clear indication of critical challenge regarding e-waste management as most industries might not observe the laid down procedure regarding e-waste handling. However, 100% of the companies hinted on that they look forward to introduce e-waste management policies at individual level.

6.4 Impacts of e-waste

Storage was done without proper segregation of the waste types and these sites are mainly open back yards or warehouses. As a result the environmental risk lies in that, fragile fluorescent tubes can be found on the same site as heavy motor casing in industrial warehouses hence increasing chances of breakages of the light tubes that can possible leak off mercury pollutants. Varying weather conditions affect the openly stored equipment at backyards such that fragile material such as glass give in due to cyclic stresses related to temperature changes induced by alternating cold and sunny weathers. The resulting leachates can possibly be washed by rain into storm water drains hence contaminating water sources. The present e-waste management approach in the industrial community could be deemed a threat to sustainability of the environment as it holds higher risks to the communities around the industrial area.

As the majority of companies resort to storage of e-waste, the increasing storage can be viewed as loss of potential revenue for local investors. Most companies storing e-waste were observed to be doing it chaotically within premises hence potential health and safety risk to workers due to injuries by sharp objects. Landfill disposal is being exercised without proper segregation hence the resource value of waste is failing to be discovered. The informal sector players involved in recycling are generating income from the auctioned products from various companies.

6.5 E-waste based software

The study came up with an ideal e-waste management proposal to reduce the loopholes in the processes of collection, treatment and monitoring of e-waste material flows in the case study industrial area. The ideal situation is supposed to be informed by gathered information and findings in this study.

![Proposed e-waste management flow diagram](attachment://image.jpg)
A software based version of e-waste management would serve as tool for policy makers and e-waste management coordinators in the industrial area. Figure 7 below shows a sample of the software prototype which was formulated to assist the gathering of information required in the e-waste management.

Figure 7.Main Menu of proposed prototype software

7. Recommendations

It was observed that there is need to upgrade recycling skills and technologies incorporate processes that accommodate glass from fluorescent lamps and cathode ray tubes in personal computer monitors as well as thermoset plastics material from e-waste casings. There would be need for importers to bring in products with less impact to the environment which can be easily recycled. Guidelines need to be developed to control the quality and standards of imported equipment with attached financial and regulatory incentives to promote practices of importing green recyclable equipment. This could be implemented through levying higher taxes on substandard products and engaging certified distributors of original equipment manufacturers. There is need to undertake e-waste awareness campaigns at industrial, municipal and local leadership level. The improved awareness would ensure that an increased number of participants in the e-waste management scheme hence a well as an operative collection and handling system of the targeted waste.

The study highlighted gaps in the current legal and institutional framework such as the insufficiency in addressing the uniqueness of e-waste as well as absence of clarity on crucial stakeholders’ roles in e-waste supervision. Therefore, specific legislation on e-waste needs to be put in place to aid in achieving maximum control of the e-waste resource at the same time creating a shared responsibility amongst affected stakeholders of the importance of extended producer responsibility (EPR) schemes in the area. Environmental management board could register and issue licenses to local recyclers to initiate development of formal e-waste collection and recovery facilities. The city council could also formulate bye-laws to manage e-waste at industrial levels such that the uniqueness of the waste is observed towards proper segregation prior to disposal. An environmental board would need to develop an e-waste management steering community to regularly monitor and control e-waste management activities across industries. Considering the fact that no resources have been known to be allocated for e-waste management, the industrial community therefore require an e-waste fund establishment to ensure sustainable financing of e-waste management activities. Such funding would enable the recyclers to have the potential to modify their systems to effectively handle e-waste. The same fund would enable training in technical maintenance, dismantling and segregation techniques for e-waste to avoid health and environmental risks.

8. Conclusion

The study evaluated the existing e-waste management in the case study industrial area. It was established that no formal e-waste collection and treatment was practiced. The responsibility of managing such waste lied with the producers of such waste but nevertheless almost 90% of the industries were lacking regular e-waste handling procedures. Storage and landfill disposal of the generated e-waste without proper segregation was prevalent due to lack of e-waste related policies to regulate e-waste flow across the industries. Lack of e-waste awareness contributed to poor stakeholder coordination towards combating the e-waste menace. The e-waste was found to contain high proportion of lighting equipment such compact and straight tube fluorescent lamps followed by ICT equipment.
was observed that the larger the share of any appliance in the e-waste the shorter the lifespan and the higher the usage demand in the industries. Computer based software was developed as a prototype to demonstrate the necessity of such an application as a tool for the e-waste management stakeholders to improve the know-how in quantification, characterization and management of e-waste across the industrial area. Further study research could be done to develop a compact design of e-waste recycling facilities to effectively treat e-waste materials generated across industries and the country at large.

References


Biography

**Ignatio Madanhire** is a Senior Research Associate at the University of Johannesburg (SA) in the Department of Quality and Operations Management. He is a PhD holder in Engineering Management. He is also a Senior Lecturer with the Department of Mechanical Engineering at the University of Zimbabwe. He has research interests in engineering management and has published works on cleaner production in renowned journals.

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