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Development of an Integrated Sustainable Electronic Waste Management System for Higher Institutions in Rivers State

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ABSTRACT

High obsolescence rate and end-of-life of electronic equipment resulting in high generation of electronic waste remains the biggest challenge with use of ICT in higher institutions. This study evaluated and developed an environmentally sound E-waste management system for higher institutions in Rivers State. The study employed research surveys in data acquisition through questionnaires, interviews and observation. Hypotheses were postulated to test areas of interest. Study indicated that institutions generate a reasonably amount of electronic/ICT wastes that are poorly managed. Desktop computers, printers, laptops, UPSs, old CRT monitors, and printer cartridges are the majority generated and available E-waste in storage in these institutions. Results revealed that the level of awareness on hazardous nature of E-waste among the sampled population was significant. The level awareness on E-waste recycling among sampled population was also significant. There are no accurate records or inventory of ICT equipment procurement and E-waste generation and disposal in the institutions. Policies and programs on source reduction E-waste segregation and handling, facilities for E-waste recovery, recycling and reuse are practically not available in the institutions. The study concluded that there is no proper management and disposal of electronic/ICT waste in higher institutions in Rivers State. Significant numbers of respondents expressed the need for the institutions to establish an integrated electronic/ICT waste recycling center. An Integrated E-waste management system that will not only address the current poor E-waste management practices in the institutions but also achieve environmentally sound management of E-wastes in the institutions has been developed in the study.

KEYWORDS: Electronic Waste Management, Waste management Systems, ICT waste, ICT waste in higher Institutions, Integrated electronic waste management system, E-waste remanufacturing unit, Electronics recycling center.

I. INTRODUCTION

The use of information communication and technologies (ICT) in higher institutions in Nigeria has greatly evolved over the years. ICT has to a large extent enhanced teaching methods and information access and exchange, learning processes, scientific research, and working conditions in higher institutions in Nigeria. Notwithstanding the numerous benefits of ICT to the development of educational system or sector in Nigeria, the biggest challenge posed is high obsolescence rate as well as end-of-life of electronic/ICT equipment that have resulted in high generation of electronic/ICT waste in institution of higher learning in Nigeria. This study comparatively assessed and evaluated electronic/ICT waste (E-waste) management in three higher institutions in Rivers State, Nigeria and developed an integrated E-waste management system for environmentally sound management of E-waste in the institutions. The study employed research surveys in data gathering and acquisition through the use of questionnaires, interviews and observation. The research design and methodology include sampling procedure, sampling type, sampling technique and data analysis. Several hypotheses were postulated to test the different area of interest considered in the study. Study indicated that the institutions generate a reasonably amount of electronic/ICT wastes that are poorly managed ($t = 0.00026$, $t_{0.95} = 1.833113$ and $p = 0.499899$ for UNIPORT; $t = 0.00041$, $t_{0.95} = 1.859548$ and $p = 0.499617$ for RSUST; and $t = 0.00038$, $t_{0.95} = 1.859548$ and $p = 0.499855$ for KENPOLY) Desktop computers, printers, laptops, UPSs, old CRT monitors, and printer cartridges are the majority generated and available E-waste in the storage in the institutions. Results revealed that the level of awareness on hazardous nature of E-waste among the sampled population was significant at 95% confidence levels ($t > t_{0.95}$ and $p < 0.05$). The level awareness on E-waste recycling among sampled population was also significant at 95% confidence level ($t > t0.95$ and $p < 0.05$). There are no accurate records or inventory of ICT equipment procurement and E-waste generation and disposal in the institutions ($t < t0.95$ and $p > 0.05$). Policies and programs on source reduction E-waste segregation and handling, facilities for E-waste recovery, recycling and reuse are practically not available in the institutions ($t < t0.95$ and $p > 0.05$). The study concluded that there is no proper management and disposal of electronic/ICT waste in higher institutions in Rivers State. Significant numbers of respondents ($t < t0.95$ and $p > 0.05$) expressed the need for the institutions to establish an integrated electronic/ICT waste recycling centre. An Integrated E-waste management system that will not only address the current poor E-waste management practices in the institutions but also achieve environmentally sound management of E-wastes in the institutions has been developed in this study. This multi-objective planning system is based on the goal and concept of remanufacturing for reuse and E-waste processing for material recovery and recycling. By employing this integrated approach, the institutions can set a standard for sound environmental performance and achieve green electronic/ICT utilization in Nigeria higher institutions.

Statement of the Problem

Educational institutions which are our centres of research and development have not done very well in terms of managing their electronic waste. It is evidently clear that higher institutions have substantially high amount of computer and computer related equipment necessary to satisfy and accomplish some of their educational demands or needs and most of them have no plan on how to manage their electronic waste meanwhile they should be the pace setters which the general public will learn from. Due to the fast growing space of ICT, the majorities of ICT equipment have become obsolete or outdated and are no longer required for intended academic purposes. In the society where there is poor maintenance culture, this equipment is not repaired or refurbished for reuse and recycling activities are totally absent; older, broken and unserviceable ICT or computer waste are thus generated causing increase in the generation and accumulation of computer waste in school campuses. This obsolete ICT equipment are discarded and disposed of among municipal solid waste where some toxic constituents such as mercury, cadmium, lead, chromium etc. leached into the environment over time resulting in soil contamination and water pollution. The accumulation of these toxic substances in surface also affects aquatic lives.

Aim and Objectives of the study

The aim of this study is to examine and evaluate computer waste management system in three educational institutions in Rivers State namely; University of Port Harcourt (UNIPORT), Kenule Beeson Saro-Wiwa Polytechnic (KENPOLY) Bori, and the Rivers State University of Science and Technology (RSUST). The study also aims to quantify computer waste generated by the institutions, identify methods presently employed in the management and disposal of computer waste by the institutions, to evaluate current computer waste management strategies and policies applied and recommend management techniques or technologies that may be employed to achieve sustainable electronic/ICT (E-waste) waste in the institutions.

The objectives of this study are to:

i. Characterize and quantify computer waste streams in three selected institutions in Rivers State,
ii. Identify and evaluate current computer waste management practices in these institutions,
iii. Identify levels of staff and student's awareness and participation in computer waste management,
iv. Identify challenges to effective computer waste management in the institutions,
v. Recommend best practice strategies for resource recovery and safe disposal of computer waste, and
vi. Develop an integrated computer waste management system based on material recovery for effective computer waste management in the institutions.

Significance of the Study

Inappropriate management and disposals of computer waste not only results in significant environmental problems but also loss of valuable secondary materials (John et al., 2012). It is necessary to address current practices in the disposal of unwanted ICT equipment or computer waste in higher institutions in order to proffer best integrated approach to sustainable computer waste management that is environmentally sound and acceptable. It is believed that this study will open a new research area into integrated management of electronic/ICT waste in our higher institutions for material recovery and protection of the environment and human health. The result of this study will also assist management of higher institutions establish research centre for proper treatment of computer waste to recovery valuables/sellable materials and reduce toxicity before final disposal.

Scope of the Study

This is a comparative study of the three institutions and will employ a research survey in data gathering and acquisition. The main data acquisition tools will be questionnaires, observation, interviews, and documents reviews. The designed sampling technique will be targeted at heads of property management, director of works, procurement departments and storekeepers as sample respondents. This study is limited to a comparative assessment and evaluation of computer waste management in the University of Port Harcourt and Kenule Beeson Saro-Wiwa Polytechnic Bori, Rivers State. The following approach shall be employed in this study:

i. Questionnaires, observation and interviews will be used to gather primary data, while documents reviews will provide secondary data,

ii. Analysis of collected data will be carried out,
iii. An integrated computer waste management system will be developed for effective computer waste management in the institutions and beyond.

II. LITERATURE REVIEW

Definitions and Classification of E-Waste

Generally, Electronic waste or E-waste refers to Computers and related accessories, Televisions, Stereos, Video recorders, Fax Machines, Copiers, communication devices and other Electronic appurtenances, which have become obsolete or ceased to function or are no longer wanted and therefore have been discarded. E-waste can also be described as end-of-life electronic equipment which have been discarded or disposed by their original users, whether they are reusable, repairable, and recyclable or destined for disposal (Harold, 2013; Ernest, 2015).

E-waste can be grouped into three categories (Ernest, 2015) as following:

i. Large household equipment and appliances: this group includes refrigerator and washing machine;
ii. Information communication technologies (ICT): this group includes personal computers, computer monitors, laptops and telecommunication devices and gadgets, and
iii. Consumer equipment: this includes television sets.

Each of these categories of E-waste equipment has been further classified as hazardous and non-hazardous depending on their compositions.

Components of E-waste that contains toxic elements or compound such as mercury, lead, cadmium, lead, arsenic, asbestos, flame retardants and polychlorinated biphenyls (PCBs) are classified as hazardous waste or special waste. Some examples of hazardous components of E-waste are compressors, transformers, plastics, fluorescent lamp, printed circuit boards, metals casing, wiring, brominated flamed retardant (BFR), older computer monitors, televisions, cathode ray tubes (CRTs) etc. Others that contain no toxic elements or compound are classified as non-hazardous. E-waste such as computers equipment contains over 1000 different materials and substances (MoEF, 2008; Sunil, 2009; Ernest, 2015), which are either hazardous or non-hazardous in nature. Due to the high toxicity nature of some constituents of E-waste, the Basel Convention has classified it as hazardous waste, and has developed a framework on the controls of its trans-boundary movement. The general classification of E-waste is presented in Balde et al., (2015). CRT glass (Figure 2.1) contains lead oxide and is classified as a hazardous waste under the International Basel Convention (UNEP, 2007; Balde et al., 2015; Ernest, 2015). Also the Government of the United Kingdom has classified Cathode ray tube (CRT), flat screen (plasma or LCD) computers, printers, computer towers and projectors as hazardous (GOV.UK, 2016).

Characteristics and Hazardous Nature of E-Waste

The production of electrical and electronics equipment involves the use of heavy metals and certain chemicals that are not easily degradable or break down. Waste electronic equipment contains many hazardous metallic contaminants such as cadmium, lead, beryllium and brominated flame-retardants (Monika and Jugal, 2010). Studied indicated that iron, aluminium, copper, gold, and other metals form over 60% fraction of E-waste, about 30% are plastics while hazardous pollutants constitute only about 2.70% (Widmer et al,; Monika and Jugal, 2010). Thus, E-waste is a composite mixture of hazardous and non-hazardous waste, which comprises of materials and elements with economic values. Study has shown that cathode ray tubes (CRTs) from televisions and old computer monitors (Figure 2.1) are highly hazardous because they contain a radioactive substance called Zirconium, Zr, (Bhuvanesh et al., 2015). Study has also revealed that one old computer color monitor contains an average of 1.8 to 3.6 kg of lead (Keirsten and Michael, 1999; Lynne and Stephan, 2004) which can migrate into the environment when the monitor is disposed of in dumpsites. It has been shown that the average computer alone contains 500 to 1000 components or materials (UNEP, 2007; MoEF, 2008; Sunil, 2009; Earth Day, 2011). A typical personal computer is said to be made up of 23% Plastic, 14% Aluminum, 6% Lead, 25% Silica, 25% Iron, 7% Copper, 2% Zinc, 1% Nickel and 1% Tin; while, Chromium, Cadmium, Arsenic, Mercury, Gold, Titanium, Silver, Manganese, Antimony, and Platinum constitute less than 1% (Lynne and Stephan, 2004).

Below are some chemicals elements of most significant concern found in E-waste:

1. Lead

This element is found in glass panels in computer monitors (cathode ray tubes) in older computer monitors; it is also used for soldering of printed circuit boards and to make electrical connections on printed wire boards. Lead content of computer may represent as much as 80% of toxic metals in discarded electronics (Lynne and Stephan, 2004). According to Sunil (2009) over 40% of Lead found in landfills in the United States comes from E-waste

2. Mercury

This is found in flat screen displays, circuit boards, laptop computers and discharge lamps. About 22% of yearly world consumption of mercury is used in electronics manufacture (Sunil, 2009).

3. Cadmium

This heavy metal is found in computers, old CRTs, chip resistors, infrared detectors, semi-conductors, & batteries. It is also used as plastic stabilizer Lynne and Stephan, 2004).

4. Chromium

This metal is found in computer metal housing or casing (used as hardener in metal and plastics casing)

5. Brominated flame retardants (BFR)

This material is found in plastic casings, printed circuit boards (Figure 2.2), connectors, plastic covers, and cables plastic covers of television sets (Lynne and Stephan, 2004; Sunil, 2009). Computer casing or housing contains 59% of BFR, Printed Wire Boards contain 30%, connectors and relays contain 9%, while, wire and cabling contain 2% (Lynne and Stephan, 2004).

6. Polyvinyl Chloride (PVC)

PVC is used for cables and wiring cover because of its fire retardant properties (Lynne and Stephan, 2004). Older computer housings as well as newer computers are made with PVC plastic, while electronics manufacturing uses about 26% of plastics (Lynne and Stephan, 2004).

Environmental and Health Impacts of E-Waste

Electronic equipment consists of a complex mixture of several tiny components, many of which contain toxic chemicals and other hazardous materials. A review of literature shows that an estimated 500 million of computers produced worldwide contained 2.87 billion kilograms of plastics, 716.7 million kilograms of lead, and 286,700 kilograms of mercury (Keirsten and Michael, 1999). These hazardous chemicals and substances are capable of impacting negatively on human health and the environment. Regrettably, when toxic materials (lead, cadmium, mercury, etc.) are disposed in unsecured dumpsites they leached into the environment after a period of time where they eventually pollute surface and ground water, harm aquatic lives, and contaminate soil and wildlife (Keirsten and Michael, 1999). They can persist or remain in both the environment and human bodies for a long time. Environmental Defence, a non-profit advocacy group, has conducted tests which revealed that Canadians have chemicals like lead, flame retardants, pesticides and stain repellents in their bodies in levels that are not healthy (Earth Day, 2011). Keirsten and Michael (1999) stated the impacts on human health to include high rates of birth defects, miscarriages, and cancer. In fact, lead and mercury are known to be highly neurotoxins, especially among children, and can cause significant reduction in intelligence quotient (IQ) and developmental abnormalities even at very low levels of exposure (BAN/SVTC, 2002). Several studies have reported the elevated levels of toxic heavy metals and organic contaminants in samples of air particulates, soil, surface water, river sediment, and groundwater of Guiyu in China (Qiu et al., 2004; Huo et al., 2007; Monika and Jugal, 2010). High incidence of headaches, vertigo, skin damage, nausea, gastric and duodenal ulcers and chronic gastritis, were found among residents in some areas (Qiu et al., 2004). Table 2.1: Constituents of E-waste and their associated health effects are shown in Table 2.1. While the permissible limits of some hazardous constituents are shown in Table 2.2.

Table 2.1: Constituents of E-waste and associated health effects

Material	Source	Health Effect
Brominated Flame Retardants (BFR)	Found in plastics PCBs to prevent fires	Can disrupt human hormones. Increases cancer risk to digestive system. May cause thyroid and neurobehavioral diseases in children (Adediran and Abdulkarim, 2011; Lynne and Stephan, 2004).
Cadmium	Found in computer switches, CPU and monitors, also found in NiCd batteries used in computer motherboards	Cadmium is carcinogenic. It can cause damage to the lung and even death when inhaled. Inhaling high levels of cadmium cam cause high blood pressure, and damage kidney (Adediran and Abdulkarim, 2011; Lynne and Stephan, 2004)
Cadmium Chromium	Used as hardener in metal and plastics casing as well as other metal parts	Chromium has a variety of effects depending how it enters the body. Chromium is also a carcinogen and if inhaled may cause damage to DNA (Adediran and Abdulkarim, 2011; Lynne and Stephan, 2004).
Lead	Used as solders in PCBs and also found in Cathode-ray tubes (CRTs)	When inhaled, Causes anorexia, headache pains, malaise. Lead poisoning may affect nervous systems and retarded growth in children (Bathurst et al., 1992; Lynne and Stephan, 2004; Sunil, 2009. Long-term exposure to elevated level of lead may cause brain

		damage and even death.
Mercury	Contained in Flat screen and LCD monitors, as well as switches	Exposure to mercury may cause lung damage, vomiting, high blood pressure skin diseases and eye irritation and increase in heartbeat; damage to the kidneys, brain, and developing fetus may also occur due to long term exposure.
Polyvinyl chloride (PVC)	PVC plastic is used in the insulation of some cables used in ICT equipment.	It produces highly toxic furan and dioxins when incinerated or burnt in open dump; can disrupt human hormones (Lynne and Stephan, 2004)

Table 2.2: Permissible Limits of some metals in E-waste

S N	*METAL*	*SOIL*		*WATER*		
		FM Env (mg/ kg)	*WHO (mg/ kg)*	*FME nv (µg/l)*	*WH O (µg /l)*	*USEP A (µg/l)*
1	*Cadmium*	0.8	2	0.4	3	5
2	*Chromium*	100	100	1	50	100
3	*Lead*	85	75	15	10	15
4	*Mercury*	3	0.5	0.05	1	2

Method for E-Waste Inventory and Determination of E-Waste Generation

E-waste inventory assessment and determination of E-waste generation is very important for planning and implementation of proper E-waste management system. E-waste inventory gives baseline data that can be used to predict E-waste to be collected, segregated, transported, and treated and final disposal Thus, the quantification or inventory of E-waste forms the basis for an integrated E-waste management (UNEP, 2007). Total or complete inventory of E-waste helps to determine the economies of scale for institutional operations with respect to disposal cost.

(a) The Carnegie Mellon Method (CMM)

In this method, the calculation of E-waste is done using sales data, storage, assumed lifespan and recycling. This model takes consumer's behaviour when disposing of end-of-life electronic equipment into consideration. The method defines and follows the flow and movement of electronic equipment from purchase to end-of-life.

The possessor of electronic equipment has four options to decide on when the equipment becomes obsolete. The owner may decide on any of the options described below.

i. Reuse: the possessor may possibly donate the used equipment as gift to another user without any major modification.
ii. Storage: the owner may decide to not use the equipment but keep to store for a period of time.
iii. Recycled: possessor of used electronic equipment may also decide to recycle it and parts sold as scrap.
iv. Finally, the owner may decide to dispose of it in dumpsite or landfilled.

This method is adopted in this study for mass flow and life cycle analysis of E-waste.

Regulations for E-Waste in Nigeria

E-waste is regulated In Nigeria by National Environmental Standards and Regulations Enforcement Agency (NESREA). NESREA defines E-waste as any Waste Electrical Electronic Equipment (WEE) that is old, end of life or discarded electrical/electronic appliances using electricity (Abdussalam, 2014).

The National Environmental Electrical Electronic Sector Regulations S.I No 23 of 2011) under the EE Sector Regulations defines hazardous Waste as any (solid, liquid or sludge) which even in low concentration is injurious/harmful/dangerous to animals, plants, human health and the environment (Abdussalam, 2014).

All non-functional Electrical Electronic Equipment (EEE) are covered in the Electrical Electronics (EE) Sector Regulations and are regulated as hazardous waste in Nigeria. The covered EEE are the ten categories as also classified in EU WEEE Directive.

Federal Ministry of Environment and NESREA are in charge of E-waste management in Nigeria. The Ministry is responsible for policies while NESREA is responsible for enforcement.

National Laws and Regulations Relating to E-Waste Control

There are four major regulatory instruments for e-waste control in Nigeria they are:

i. The Environmental Impact Assessment Act Cap E12 LFN 2004
ii. Harmful Waste (Special Criminal Provisions) Act Cap HI, 1988 and updated in 2004;
iii. Guide for Importers of Used Electrical Electronics and Equipment (UEEE) into Nigeria; and
iv. The National Environmental (Electrical/Electronic Sector) Regulations S.I No 23 of 2011.

The objective of the above Laws and Regulations is to ensure that hazardous substances are not dumped in the country and also environmental factors are considered in the decision making process (Abdussalam, 2014). In January 2013, the Agency intercepted a Ship loaded with two containers of E-waste; the shippers were apprehended and made to pay a bail bond before the E-waste was repatriated back to the country of origin (Abdussalam, 2014).

The Agency required certified importers of used electrical and electronic equipment (UEEE) to provide records on quantities of imports as a prerequisite for the renewal of their certificates. The Agency then used this information to build data bank on UEEE imported into the country. Recently, the National Assembly recognized the importance attached to the issues on waste control including e-waste and has held stakeholders meeting with those in the industries and businesses on compliance with the requirements of the Regulations on Extended Producer Responsibility, EPR, (Abdussalam, 2014).

Economic Viability and Environmental Benefits

About 60 different substances including precious valuable elements are contained in electronic equipment (Namias, 2013). A printed circuit board alone is said to contain 18% of Copper, 5% of Silver, 61% of Gold and 15% of Palladium (Namias, 2013). A personal Computer contains 20% of copper (by weight) 1000ppm of Silver, 250ppm of Gold and 110ppm of Palladium (Chatterjee and Kumar, 2009. Chatterjee and Kumar (2009) estimated sellable metals in E-waste as 330,000,000kg, metals in PCBs is estimated as 16,500,000kg and precious valuables metals in a PCB as 272, 250kg. These elements (lead, gold, silver etc.) have a high economic value in the market. Recovered substances and materials (Lead, gold, silver, copper, palladium plastics etc.) can be sole to manufacturer of products such as boxes, toys and shoe soles (Chatterjee and Kumar, 2009).

It has been estimated that E-waste contains between 0.2% and 14% of printed circuit boards (WRAP, 2014). Percentage composition of precious metals in a typical printed circuit boards by Yanhong et al. (2008) and contained in WRAP (2014) is shown in Table 2.3.

Component	Percentage (by weight)
Non-metallic e.g. glass-reinforced polymer	70%
Copper	16%
Solder (containing tin)	4%
Iron, ferrite (from transformer cores)	3%
Nickel	2%
Silver	0.05%
Gold	0.03%
Palladium	0.01%
Other (bismuth, antimony, tantalum etc.)	<0.01%

Recovering and recycling of precious metals from discarded electronics will reduce the environmental impacts associated improper disposal of E-waste (Namias, 2013). It will prevent the leachate of hazardous elements such as lead and mercury into the environment. It will also significantly reduce risks to public health.

III. METHODOLOGY

The following general approach was used in data gathering.

I. Literatures on the E-waste generation and management were reviewed.

II. Data on ICT procurements for the past 10 years were obtained from the institutions

III. Data on E-waste generated by the institutions for the past 10 years were collected

IV. Questionnaire instrument was used as the research survey for data acquisition

V. Collected field data were analyzed using appropriate statistical tools.

VI. Integrated E-waste management system for a sustainable management of E-waste in higher institutions was developed.

The research design and methodology include sampling procedure, sampling type, sampling technique and data analysis. Relevant literatures were extensively searched, administering of questionnaire, interview and personal observation were employed. Administered questionnaires covered major areas of interest. The E-waste assessment was carried out in accordance with the E-waste assessment methodology developed by EMPA (Schluep et al., 2012). This methodology involved primarily data acquisition and analysis of the E-waste through literature review, consultations with stakeholders, interviews, field study questionnaires and observations.

Study Area

The three institutions selected for this study are located in Rivers State in Niger Delta, South-South Region of Nigeria. Map of Nigeria showing Rivers State is presented in Figure 3.1.

The University of Port Harcourt (UNIPORT) is located in Choba town in Ikwere Local Government Area (Figure 3.2) of Rivers State, Nigerian. It was founded in 1975 as a University College, and was later accorded a university status in 1977. The university currently has 12 faculties and a school of graduate studies and 76 departments. In addition to these, there are about 28 centres, institutes and units (such as centre for information and communication engineering, centre for gender and conflict studies, Centre for Disaster Risk Management and Development Studies, basic studies unit, etc.).

Rivers State University of Science and Technology (RSUST) is a university located in located at Nkpolu-Oroworukwo area of Obio/Akpor Local Government Area

Rivers State, Nigeria as shown in Figure 3.2. It was founded in 1972 as College of Science and Technology and later assumed a University status in 1980 as the first university to be situated within the Niger Delta region. The university presently has about 27 departments.

Kenule Beeson Saro-Wiwa Polytechnic (KENPOLY) was formerly called Rivers State Polytechnic Bori. It is a state-owned higher institution located in Bori in Khana Local Government Area of Rivers State, Nigeria as shown in Figure 3.2. The polytechnic was founded in 1988 by the Rivers State Government and was renamed Kenule Beeson Saro-Wiwa Polytechnic by the Rivers State Government in 2015. The polytechnic offered courses that lead to award of Ordinary National Diploma (OND) and Higher National Diploma (HND) certificates. Presently it has about 16 accredited departments.

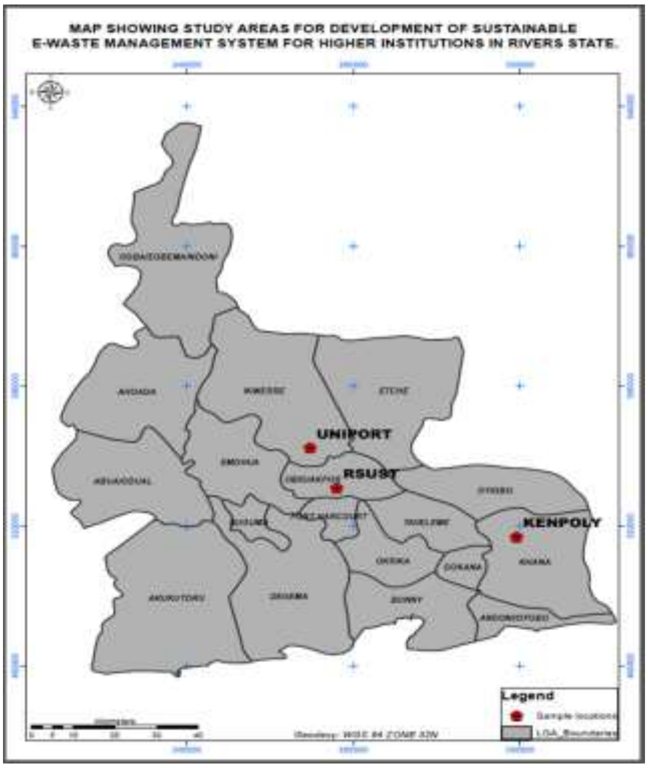

Figure 3.1: Map of Rivers State showing study areas

Data Acquisition

The main data gathering tools were questionnaires, interviews, observation and review of documents. Through goal-directed sampling technique, heads of departments/units/centres or management heads, directors, purchasers and storekeepers were selected as sample respondents.

Questionnaires collected primary data on:

i. General/background information about respondents,
ii. Information on purchase and stock,
iii. Information on E-waste generation,
iv. Information on ICT waste management including disposal,
v. General information on the existing policies with regard to E-waste management, and
vi. General awareness level on E-waste issues in the institution.

Data Gathering Challenges/ Limitations

- Collecting reliable data from key stakeholders
- Obtaining a reasonable sample size from the various respondents and stakeholders was also a big challenge as most of them lack or do not have easily accessible information on E-waste generation and storage. As a result, some of them provided only estimated quantities for their stocks, purchases or E-waste generation. However, the study showed the general magnitude of ICT or E-waste generation in the institutions.

Data Analysis and Presentation

Data was analysed using statistical tools in Microsoft Excel and Prison software. This study utilized descriptive statistics such as correlations, frequencies and percentages to analyze collected data and the results are presented in tables, figures, graphs and percentages.

Determination of sample size

The sample size was determined using the formula contained in Arsham (1996).

$$n = \frac{\left[t^2 Np(1-p)\right]}{\left[t^2 p(1-p) + \alpha \ (N-1)\right]}$$

where n is the required sample size
N is the total number of population,
α is the expected error or degree of freedom expressed as a proportion,
t2 is the desired confidence interval, a value taken from Chi-square representing 1 degree of freedom, and
p is the population proportion assumed to be 0.5.

The sample size is determined based on the number of departments, centres and units in each institution.

The University of Port Harcourt has 76 departments and 28 centres/institutes/unit. RSUST has about 26 departments, while Kenule Beeson Saro-Wiwa Polytechnic has about 16 departments. These give a total sample population of 146.

t2 taken from Chi-square table = 3.841

The degree of freedom expressed as a proportion, α is taken as 0.01

To obtain maximum sample size, the population proportion, p is assumed to be 0.5.

Considering that:
N = 104 for University of Port Harcourt,
N = 26 for RSUST, and
N = 16 for Kenule Beeson Saro-Wiwa Polytechnic

Using Equation (3.1) and a confidence levels as 95%; the sample size for each institution is computed as 50 for the University of Port Harcourt, 20 for RSUST and 15 for Kenule Beeson Saro-Wiwa Polytechnic. These give a total sample size of 85.

Administration of Questioners

Questionnaires were administered to staff of the institutions; whose day-to-day duties and business are such that they handle ICT related issues in their respective institutions. A total of thirty-four (34) questions (grouped from A to F) were established and tailored towards major areas of interest as follows:

i. Identification of job as it relates to ICT issues
ii. Purchase of Electronic/ICT Equipment
iii. E-waste management policy
iv. Disposal of Electronic/ICT Equipment Waste
v. Staff awareness on E-waste conditions
vi. Awareness and Behavior on hazardous nature of E-waste
vii. Staff opinion on the establishment of electronic/ICT waste recycling centre in their institution

A total of eighty-five (85) questionnaires were served to staff of the following departments in each of the institutions. Out of which eighty (80) questionnaires were completed and returned, which formed the basis of the questionnaire response analysis presented in chapter 4.

i. Department of Electrical/electronic engineering
ii. Department of computer engineering,
iii. Department of computer science,
iv. Information and communication centre,
v. Procurement centre,
vi. Works department, and
vii. Any other department responsible for handling of E-waste.

IV: RESULTS AND DISSCUSSION

Questionnaires response analysis was performed using the completed and returned questionnaires on E-waste management in the institution to fulfil the major areas of interest identified in the methodology. All respondents considered in this study have served in their respective position for at least two years either as head of departments, centres, unit or as system analysts in charge of ICT related issues.

Questioner Response Analysis

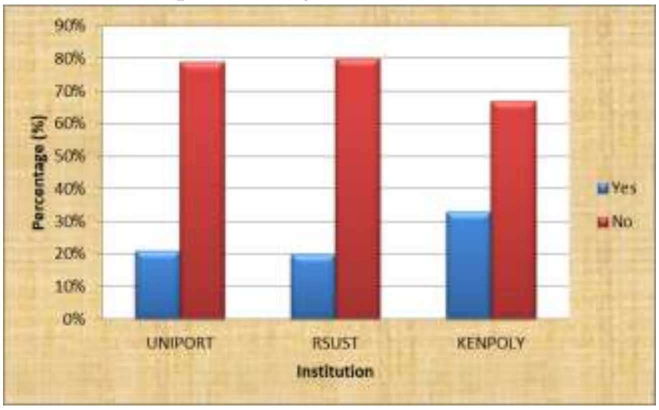

Figure 4.1: Percentage response on availability of a procurement centre for ICT equipment in the institutions.

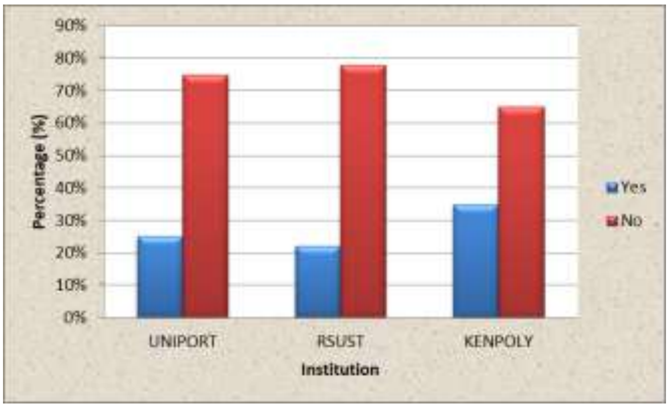

Figure 4.1: Percentage response on Records of ICT equipment in the institutions

Results showed that 21% of respondents in both UNIPORT indicated that there is a central procurement centre for ICT equipment in their institutions, while 79% indicated the absence of such a centre; in RSUST, 20% says there is a central procurement centre, while 80% says there is none; and in KENPOLY, 33% of respondents indicated that the institution has a centre for procurement of ICT equipment, while 67% says no, there is no centre for ICT equipment procurement. However, interviews with some heads of departments and faculty officers in all three institutions indicated that ICT equipment are procured or purchased by each faculty, department or centre/unit. On the issue of records of ICT equipment procured, 25%, 22% and 35% of respondents in UNIPORT, RSUST and KENPOLY respectively say there are records of procured ICT equipment in their faculty, department or centre/unit; while 75%, 78% and 65% in UNIPORT, RSUST and KENPOLY respectively say there are no records of new ICT equipment procured. However, findings indicated that scanty records exist in some departments and centres. These scanty records are not organized and are therefore not reliable or credible. Respondents in all three institutions (100%) indicated that new ICT equipment are procured through suppliers and in some cases the equipment purchased directly in the market by the faculty, department or centre/unit. The numbers of functioning ICT equipment sampled in some Departments/Centres/Unit in the institutions as given by respondents are shown in Figure 4.3. In UNIPORT, data on the number of functioning ICT equipment and E-waste in store were obtained from respondents in Information Communication and Technology Centre (ICTC), Centre for Information Communication and Technology Engineering (CICTE), Basic Studies Unit and Works Department. In RSUST, these data were obtained from respondents in Information Communication and Technology Centre, Estate and Works department, and computer science department. While in KENPOLY, the data were obtained from respondents in Information Communication and Technology Centre, Services and Works department and Computer Science Department.

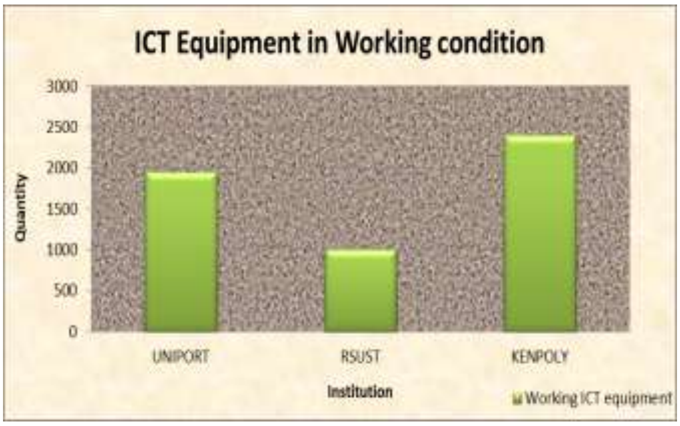

Figure 4.3: Functioning ICT equipment sampled in some Departments/Centres/Unit in the institutions

Results from respondents in all three institutions studied indicated that used ICT equipment (including used printer cartridges) are kept in store for between 2 to 4 years before disposal. Some waste or used ICT equipment kept in store in the institutions are shown in Figures 4.17 to 4.19. The total numbers of ICT-waste in store obtained from sampled departments/centres/units UNIPORT, RSUST and KENPOLY are 299, 110 and 156 respectively (Figure 4.4 and Table 4.1). Scaling down to all other departments/centres/units and offices, it is seen that the institutions generate significant amount of ICT waste.

Figure 4.4: Stored ICT waste sampled in some Departments/Centres/Unit in the institutions.

Table 4.1: Working Conditions of ICT equipment sampled in the institutions

S/No.	Item	UNIPORT Working	UNIPORT Stored	RSUST Stored	RSUST Working	KENPOLY Working	KENPOLY Stored
1	Personal Computer	507	124	250	24	837	60
2	CRTs/Monitors	503	119	250	56	832	23
3	Laptops	510	3	392	11	147	24
4	Printers	16	11	27	8	34	10
5	Routers	3	2	5	-	8	2
6	Scanners	5	-	11	3	22	4
7	Switches	8	3	10	2	21	3
8	Modems	4	1	2	-	21	5
9	UPS	397	36	45	6	480	25
	Total	1953	299	1007	110	2402	156

On the issue of existence of a central E-waste disposal department or centre or unit in the institution, 20% of respondents says "Yes" such a centre exists, 70% says "No", while 10% was not sure of the existence of such a centre in UNIPORT; in RSUST, 30% says "Yes", while 60% says "No" and 10% was not sure; also, in KENPOLY, 25% says "Yes", 65% says "No", while 10% was not sure (Figure 4.5). However, interview with one of the heads of a unit who answered "Yes" indicated that in UNIPORT electronic/ICT waste are collected together with other campus waste by a unit called Campus Environmental Beautification and sanitation Unit (CEBAS). This unit is responsible for the collection of all wastes (including electronic/ICT waste and other scrap materials) on UNIPORT campus. Used or discarded computer systems, printers, scanners, UPS and other similar devices that are still intact are later sent to another unit called Physical Development Administration (PDA) (which is under the control of a board called Board of Surveys). PDA then sells these items or auctions to staff and other interested persons as unserviceable items (Figure 4.6). The others that are badly damaged or burnt are disposed of together with campus wastes by CEBAS. The practice in RSUST and KENPOLY is similar to that of UNIPORT. Discarded ICT equipment are collected from different departments and offices and sent to Estate and Works department for RSUST or Service and Works department for KENPOLY. Works department either sell the items to staff or sell to dealers on scrap materials.

The issue of separation or segregation of E-waste was raised in the questionnaire, 80% of respondent in UNIPORT says E-waste separation is not practiced in the institution, while 20% says they separate their ICT waste (Figure 4.7). It was observed that in some departments staff mixed their E-waste with other office waste in a common waste bin. On the issue of waste separation in RSUST, 30% says E-waste is separated from other waste, while 70% says otherwise. In KENPOLY, 28% says E-waste separation is being practiced, while 72% says separation of E-waste from other waste is not practiced (Figure 4.7). Overall result indicates that source separation of E-waste is not practiced in the institutions. However, partial separation of E-waste was observed in information communication and technology centres (ICTC) in the institutions. Separation of E-waste at source of generation can help in the quantification of E-waste generated in each department, centre or unit.

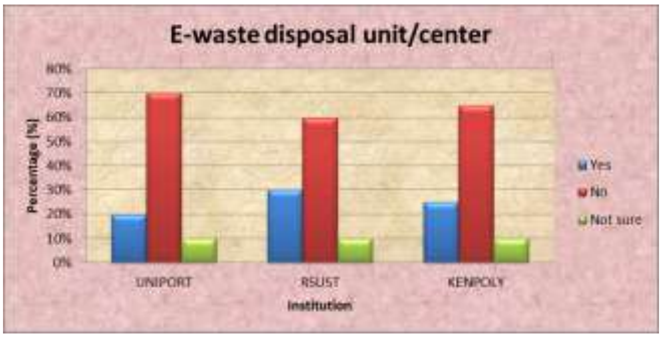

Figure 4.5: Percentage respondents on availability of central E-waste disposal centre

Figure 4.6: Methods of E-waste management in the institutions

Figure 4.7: Percentage respondents on E-waste separation

Figure 4.8: Percentage of respondents on Records of collected E-waste

The study also examined the issue of records of E-waste generated in the respective institutions. In UNIPORT, 20% of respondents says there are records of E-waste collected and 80% says there are no records; in RSUST, 30% says there are records and 70% says there are no records; while in KENPOLY, 35% says there are records and 65% says there are no records. These results are shown in Figure 4.8. Keeping records of E-waste generated and collected can help in proper planning of management strategies.

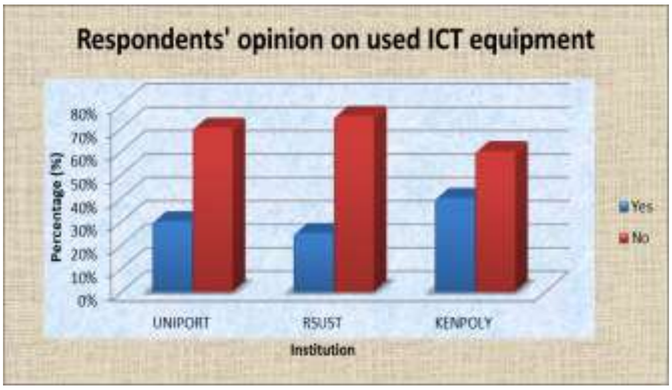

Figure 4.9: Respondents opinion on used ICT equipment

Respondents' opinion on used ICT equipment was also examined as a way of finding out their views about what they consider as waste ICT equipment. In UNIPORT, 30% of respondents consider used ICT equipment as waste, while 70% says used ICT equipment can be repaired and reused (Figure 4.9); in RSUST, 25% viewed used ICT as waste, while 75% says they can be repaired; and in KENPOLY, 40% regarded them as waste, while 60% says used ICT equipment can be repaired and reused (Figure 4.9).

Figure 4.10: Percentage of respondents on E-waste repair centre

The establishment of an electronic/ICT repair centre or unit in the institutions (for repair, refurbish and upgrade of ICT equipment) can help minimizing the amount of used ICT equipment that becomes waste. That is, it will minimize the generation of E-waste in the institutions as repaired equipment will be returned back to the system for reuse.

In UNIPORT, 15% of respondents say there is a repair centre in the institution, while 85% says there is none; in RSUST, 30% says there is a repair centre, while 70% says there is none; while in KENPOLY, 35% says there is a repair centre in their institution, while 65% says there is none. These results are shown in Figure 4.10. However, interviews and observations indicated that the information communication and technology centres of the three institutions have small repair unit that take care of damage ICT equipment within the centres. This accounts for the number of respondents that say a repair centre exist in their institutions.

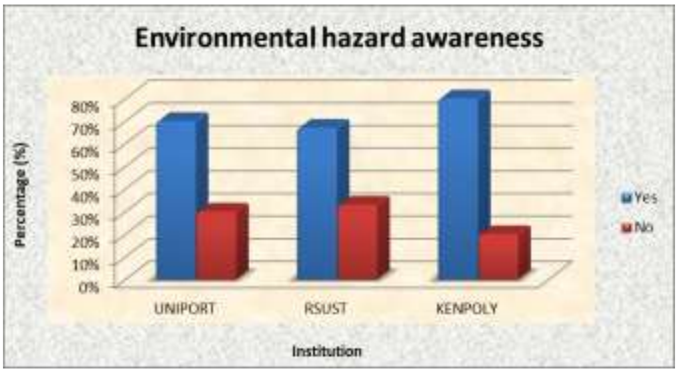

Figure 4.11: Respondents awareness on environmental hazard of E-waste

The study also examined respondents' awareness levels on the hazardous nature of E-waste. Awareness of the hazardous nature of E-waste will help to determine its handling, treatment and disposal methods. The results of respondents' awareness levels are shown in Figure 4.11. In UNIPORT, 70% says they are aware that some fractions of E-waste are hazardous, while 30% are not aware; in RSUST, 67% are aware of the hazardous nature of some components of E-waste, while 33% are not aware; while in KENPOLY, 80% are aware that E-waste has some hazardous components, while 20% are not aware (Figure 4.11).

Figure 4.12: Respondents awareness on E-waste recycling

E-waste recycling will help reduce toxic substances in E-waste and safeguard human health and the environment. On the issue of E-waste awareness, 78% of respondents in UNIPORT say they are aware that some E-waste components can be recycled, while 22% says they are not aware; In RSUST, 75% says they are aware that E-waste can be recycled, while 25% says they are not aware; also in KENPOLY, 80% of respondents say they area ware that E-waste can be successfully recycled, while 20% say they are not aware (Figure 4.12).

Figure 4.13: Respondents awareness on E-waste policy in their institutions.

The issue of E-waste policy in the institutions was also examined. E-waste policy will govern and define generation, handling, treatment and disposal of E-waste in the institutions. In UNIPORT, 10% of respondent sampled say there is a policy on E-waste, while 90% says there is no policy on E-waste handling and management in the institution; in RSUST, 35% of respondents says there is a policy on E-waste in their institutions, while 65% say there is none; and in KENPOLY 30% says that the institution has a policy on E-waste, while 70% says otherwise (Figure 4.13). Generally, there is no clearly defined E-waste policy in all three institutions studied. What transpires in UNIPORT is that each department or centre or unit stores the E-waste they generate and periodically sent them to PDA for sale or auction. The same thing is what transpires in RSUST and KENPOLY.

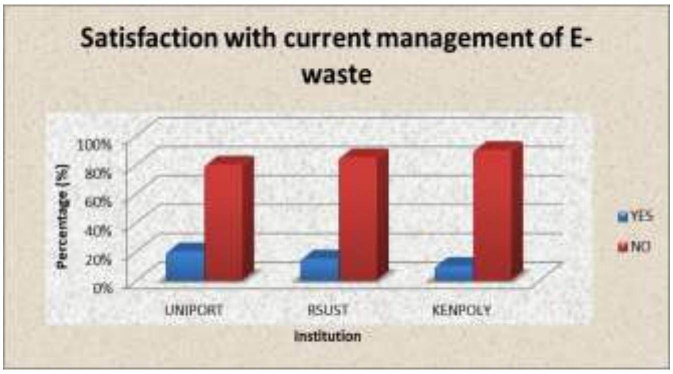

Figure 4.14: Respondents level of satisfaction on current on E-waste management

The study also examined respondents' levels of satisfaction on the current methods of E-waste management in their institutions. Respondents were allowed to freely express their level of satisfaction with the current E-waste management practices in their respective institutions. In UNIPORT, 20% of respondents say they are satisfied, while 80% says they are not satisfied; in RSUST, 15% says they are satisfied with present E-waste management, while 85% says they are not; and in KENPOLY, 10% of respondents say they are satisfied, while 90% say they are not satisfied (4.14). All those who expressed dissatisfaction with current level of E-waste management in their respective institutions say the present management methods are not environmentally sound.

Figure 4.15: Respondents opinion on the need for an E-waste Recycling Facility

Finally, the study sampled respondents' opinion on the need for an E-waste recycling facility in their institutions. In UNIPORT, 88% says there is need for an E-waste recycling facility in the institution, while 12% says there is no need; In RSUST, 85% of respondents say there is need for such a facility, while 15% says there is no need. In KENPOLY, 90% of respondents say there is need for a recycling facility, while 10% says there no need for it (Figure 4.15).

Those (respondents) who said there is need for an E-waste recycling facility in their institutions gave reasons that it will create jobs, generate income/revenue for the institutions and bring about proper or sound E-waste management in the institutions. While who said there no need for E-waste recycling facility considered the cost of establishing such a facility in the present unpleasant economic recession in the country.

DISCUSSION

Description of Current E-Waste Management in the Institutions

Assessment of current practices was carried out to determine the methods of E-waste management by the institutions. Field observation and questionnaires responses as well as personal interviews revealed that there is no system in place for proper management of electronic/ICT wastes generated in the institutions. In this study, a t-test approach was employed as the statistical tool to analyze the collected data. The results of statistical data analysis are presented in tables 4.2 and 4.3.

Present E-waste management methods and practices by the institutions in study are discussed as follows:

Statistical results of analysis carried out on generation and storage of ICT waste showed t = 0.00026, t0.95 = 1.833113 and p = 0.499899 for UNIPORT; t = 0.00041, t0.95 = 1.859548 and p = 0.499617 for RSUST; and t = 0.00038, t0.95 = 1.859548 and p = 0.499855 for KENPOLY as shown in Table 4.2. These results indicated that the institutions generate and store reasonable amount of electronic/ICT waste that requires proper management before disposal. Some used ICT equipment such as computer systems, printers, scanners, UPSs that are complete are kept in store for a long period of time before sending them to a unit that auction them to staff or sell to interested buyers (scrap dealers) as unserviceable items.

Result of hypotheses showed that E-waste separation is not clearly practiced by the institutions and is statistically significant at 95% confidence level (t < t0.95 and p > 0.05) as shown in Table 4.3. Electronic/ICT wastes such as printer cartridges, UPS batteries, and switches generated in each department/centre or units are mixed with other office wastes in common waste bins and later taken to common waste dumping points within the institutions. The mixed wastes are later evacuated by approved general waste collectors and taken to public waste dump sites. E-waste separation or segregation at source of generation is not also practiced by the institutions. Electronic wastes are not segregated or separated at source; rather they are disposed of together with other office wastes and scraped materials. E-waste minimization and reduction strategy is absent in all three institutions sampled in this study. In work department of the University of Port Harcourt, computer wastes (printers, UPSs) were seen stored in a common place with other scrap materials such as submergible pumps, metal pipes, and plastics.

Table 4.2: Test of the Significant of the amount of ICT waste generated and store in the Institutions

	t	$t_{0.95}$	p-value	df
UNIPORT	-0.00026	1.833113	0.499899	8
RSUST	0.00041	1.859548	0.499861	8
KENPOLY	-0.00038	1.859548	0.499855	8

Table 4.3: Results of Statistical Analysis

		t	$t_{0.95}$	p-value	df	H_o $(t<t_{0.95})$	$H_a(t>t_{0.95})$
1	E-waste separation	-1.87383	2.919986	0.100906	2	Accepted	Rejected
2	E-waste policy	-1.6565	2.919986	0.119732	2	Accepted	Rejected
3	Records of E-waste	-1.30614	2.919986	0.16076	2	Accepted	Rejected
4	E-waste repair centre	-1.75740	2.919986	0.110464	2	Accepted	Rejected
5	E-waste disposal centre	0.365826	2.353363	0.369384	2	Accepted	Rejected

6	E-waste hazard awareness	-6.71951	2.919986	0.010719	2	Rejected	Accepted
7	E-waste recycling awareness	-5.60567	2.919986	0.01519	2	Rejected	Accepted
8	Satisfaction with current management of E-waste	-2.71703	3.182446	0.072731	2	Accepted	Rejected
9	need for E-waste Recycling Facility	2.687936	2.919986	0.057508	2	Accepted	Rejected

There is no policy or legislation on E-waste management in the institutions. This fact was confirmed by majority of respondents who attested to the absence of E-waste policy in their respective institutions (t < t0.95 and p > 0.05) as shown in Table 4.3.

Results of statistical analysis (t < t0.95 and p > 0.05) as shown in Table 4.3 revealed that the institutions have no central unit or centre where used electronic equipment from different departments, centres or units can be refurbished and repaired for reused and extend their end-of-life. However, Information Communication and Technology centres (ICTCs) of the three institutions sampled have computer repair units that take care of only the centres' electronic/ICT equipment. In these cases, minor repairs are carried out on some ICT equipment for reuse. The conceptual flow or life cycle of Electronic/E-waste equipment in the institutions can be described as shown in Figure 4.15.

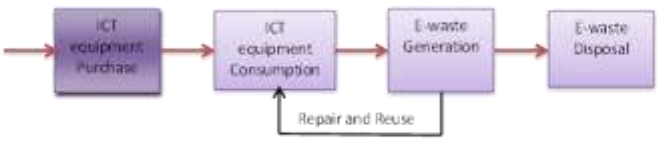

Figure 4.16: Conceptual Life Cycle of ICT Equipment in institutions

Data analysis results (t < t0.95 and p > 0.05) shown in Table 4.3 showed that the institutions do not keep accurate records on E-waste generated and collected for disposal; this may be due to the poor E-waste management methods practiced by the institutions as stated above. Data on quantities of waste in store was collected from few departments and centres/units (Table 4.1). Lack of proper documentation of E-waste generation and disposal in the institutions makes it impossible to accurately collect data on such waste.

Figure 4.17: Stored E-waste in ICTC, UNIPORT

Figure 4.18: Stored E-waste in Basic Studies Unit, UNIPORT

Figure 4.19: Stored E-waste in ICTC, RSUST

Figure 4.20: Stored E-waste in ICTC, KENPOLY

Results of data analysis shown in Table 4.3 ($t < t0.95$ and $p > 0.05$) further indicated that there are no E-waste disposal centres in the institutions. In UNIPORT, E-waste are collected along with other municipal wastes by a general waste collector (CEBAS) while, in RSUST and KENPOLY, E-waste are collected with other municipal wastes and send to works departments in their institutions for disposal.
Results revealed that the level of awareness on hazardous nature of E-waste among the sampled population was significant at 95% confidence levels ($t > t0.95$ and $p < 0.05$). The level awareness on E-waste recycling among sampled population was also significant at 95% confidence level ($t > t0.95$ and $p < 0.05$) as shown in Table 4.3. This may be because majority of the sampled populations are ICT professionals whose routine duties and business are such that they handle ICT related issues in their respective institutions.

Results of data analysis ($t < t0.95$ and $p > 0.05$) shown in Table 4.3 further indicated that significant numbers of respondents are not satisfied with current management of E-waste in the institutions.
Finally, significant numbers of respondents ($t < t0.95$ and $p > 0.05$) shown in Table 4.3 expressed the need for the institutions to establish an integrated electronic/ICT waste recycling centre.
Results of the sub hypothesis showed that there is poor management of E-waste in the higher institutions. Also, the sub hypotheses were combined and together and tested for the general hypothesis 1, statistical result showed $t = -1.310639547$, $t0.95 = 1.717144374$ and $p = 0.101748838$. This result is not significant at 95% confidence level thus Ho is accepted. Hence, it can be concluded that there is no proper management and disposal of electronic/ICT waste in higher institutions in Rivers State.

Potential Risk Associated with Poor Management of Electronic waste

The current E-waste management practiced by the institutions poses serious danger to the environment and public health due to toxic elements contained in some components of E-waste. Humans, plants, animals and the entire environment can be exposed to toxic constituents of improper disposed E-waste. Human exposure may be through inhalation, ingestion or dermal exposure, while soil, surface and groundwater contamination may be through leachate migration and percolation.
Element such as mercury and lead can bio accumulate and exist in both the environment and human bodies for a long time. People may eat fish, fruits or vegetables, or meat that has been contaminated through exposure to toxic constituent of E- waste. Drinking contaminated water is probably the most common exposure. Detailed impacts on human health are discussed in the literature review which include headaches, vertigo, skin damage, nausea, gastric and duodenal ulcers and chronic gastritis, cancer, etc.

INTEGRATED ELECTRONIC - WASTE MANAGEMENT SYSTEM (IEWMS)

Effective management of E-waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life. A number of processes are involved in effective management of these E-wastes. These include generation, collection, transport, processing, recycling and disposal. Responsible E-waste management may be accomplished through hierarchical application of the practices of remanufacturing for reuse, recycling, recovery, treatment and responsible disposal. The aim of this study is to develop an integrated E-waste management facility for proper management of E-waste in higher institutions. It is therefore a multi-objective planning system based on the goal of reuse and material recovery as shown in Figures 4.22 and 4.23. E-wastes are discarded electronic equipment generated from a combination of activities that have the characteristics of toxicity, reactivity, flammability, ignitability, infectious etc.). To achieve environmentally sustainable management of E-waste in the higher institutions an overall integrated management approach becomes imperative.

Objective of IEWMS

The objective of the proposed integrated E-waste management system is:
To manage E-waste in an environmentally sustainable manner in line with national and international standards in order to prevent harm to human health and the environment.

Description of the IEWMS

The integrated E-waste management system is to function or operate in two phases as shown in Figure 4.22 and 4.23. The first phase is the remanufacture (refurbish, repairs and upgrade) of waste electronic and ICT equipment for re-use. The second phase involves the processing for recycling of end-of-life waste electronic for recovering of valuable substances such as lead, gold, silver etc.
The key concepts in IEWMS are:

i. Remanufacture (Refurbishment, Repairs and Upgrade),
ii. Recycle, and
iii. Disposal (Residues)

To achieve the above objective, the IEWMS shall employ the following management strategies

i. To ensure sustainable collection of E-waste
ii. To ensure safe transfer of E-waste to the facility
iii. To ensure safe handling of E-waste (pre-processing, disassembling)
iv. To ensure responsible treatment of E-waste
v. To ensure responsible disposal of E-waste.

The proposed integrated approach should be evaluated against the following factors

i. Technical Feasibility
ii. Economic Feasibility
iii. Quality of recovered secondary materials
iv. Employee/Personnel Health and Safety factors
v. State and Federal Compliance
vi. Research and development needs

Dimensions of IEWMS

The IEWMS shall cover the following dimensions

i. Stakeholders,
ii. Aspects
iii. System elements,

Stakeholders: these include management and staff involved in E-waste generation and management in higher institutions.

Aspects: for effective operation and sustainability of the integrated E-waste management scheme, the formulation of objectives and policies are necessary. The use of policies and practical action will not only address the identified problems of poor E-waste management but also meet the needs and expectation of all stakeholders including the public.

Functional elements of IEWMS: The following functional elements shall interplay in the implementation of the IEWMS.

i. Generation of E-waste
ii. Storage of E-waste
iii. Collection of E-waste
iv. Processing of E-waste
v. Transfer of E-waste
vi. Disposal of E-waste

DEVELOPMENT AND IMPLEMENTATION OF THE INTEGRATED E-WASTE MANAGEMENT SYSTEM

E-waste Collection Scheme

Establish appropriate collection system and strategies to ensure that high volumes of E-waste are collected and sent to the IEWMS facility for remanufacturing and recycling. E-wastes are to be collected from various departments, centres and units, within the institution and the general public. The general public should be included for the purpose of collecting large amount of E-waste and to make the waste management facility a profitable business. Services of informal collectors can be engaged in the collection system. The informal sector such as local people involved in the E-waste collection scheme should be motivated with some incentives as wages for E-waste brought to the facility. The E-waste recycling or treatment centre can also take advantage of the abundant labor force in the State. Involving the informal sector in the system will help create employment and build capacity through appropriate training.

Drop-off and Buy-back Centres

Large amount of E-waste can be collected for the centre by creating drop-off and buy-back centres in major cities in the Niger Delta or South-South zone. Drop-off centres can be located in small scale business areas while buy-back centres are to be located in large industrial and commercial areas. Stipend payment (or other remuneration) should be given to those who brought their E-waste to the buy-back centres as a means of increasing output. Extending the services of the centre beyond the boundary of higher institution will ensure availability of E-waste materials and hence increase the viability of the E-waste management facility.

Management can ensure that E-waste collectors are registered; monitoring and reporting system are in place. Collection system may consist of the following main channels such as those that collect from municipal waste dump sites, those that collect from private organizations, those that collect from government offices as well as institutions in the region under cover.

Separation of collected E-waste

The quantity of electronic waste collected and brought to the facility are to be kept in the storage area within the facility. They are then manually separated into different categories by informal or local workers. After separation, items for repairs, refurbish and upgrade are remove and sent to Remanufacturing unit (ERU) of the facility, while items such as plastics, metal fittings, glass, printed circuit boards, batteries, cables, screws, connectors and casings are removed and sent to material recycling/recovery facility (MRF).

FIRST PHASE TREATMENT OF E-WASTE

E-Waste Remanufacturing Unit (ERU)

In the proposed IEWMS remanufacturing is considered the first phase treatment for collected E-waste and this can be done in E-waste Remanufacturing Unit (ERU). E-waste are collected from different faculties, departments, centre or units and the public and taken to a consolidation area within the IEWMS facility for storage where the waste are accumulated and integrated into large volumes of waste. While in the storage area, the waste ICT equipment are segregated, evaluated, tested and some are refurbished, repaired or upgraded for reuse.

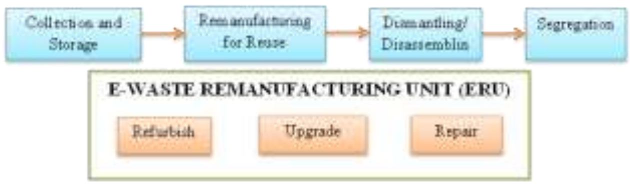

Figure 4.21: IEWMS First Phase Unit Operation

Activities in this phase include collection and storage, Remanufacturing, dismantling, and segregation.

Remanufacture for Reuse

In E-waste management, direct reuse of electronic equipment is deemed as the best management approach (CIWMB, 2004). The discarded electronic equipment can be directly used by someone else without change or with minor change. A very good percentage of ICT waste in higher institutions in Nigeria is likely fall into this category as the institutions store old electronic equipment for a couple of years before disposal (Ideho, 2012; Ogungbuyi et al, 2012). Tested and/or upgraded reusable ICT waste equipment can be donated to junior schools (primary and secondary schools) for direct reuse. Before such donation the equipment should be tested to ensure they will be usable to the recipient.

Refurbish for Reuse

Much of the electronic equipment can be upgraded or refurbished by making minor repairs. The E-waste remanufacture unit as part of the IEWMS in the institutions can have training programs for repairing and upgrading computers for resale. The modular nature of some ICT equipment such as the personal computers makes it possible for some parts to be replaced with the similar parts or with equivalent parts (CIWMB, 2004). This can extend the useful life of a personal computer and such refurbished computer can be sole to staff or donate to NGOs or secondary schools.

Disassembling and dismantling

When remanufacturing of electronic waste equipment is not economically feasible, some valuable components can be removed for reused (CIWMB, 2004). The electronic waste is dismantled and parts such as memory chips, hard disk drives, printed circuit boards, microprocessor chips and microprocessor cooling fan are removed to repair other equipment. Old cathode ray tubes computer monitors in working conditions can be sold and converted into televisions. Components such as plastics, metal parts, cables containing copper and aluminum housings should be separated and sent to E-waste processing unit for material recovery. The ERU can recover more valuable materials from end-of-life electronic equipment through disassembling, which requires de-soldering and/or use of simple hand tools. This is a conventional method or process that involves a high degree of manual labor and is being used in India (Chatterjee and Kumar, 2009; RESEARCH UNIT, 2011) for dismantling of computers. Outputs of the first phase treatment of E-waste include:

i. Second hand computer equipment for reuse or sale
ii. Segregated hazardous and non- hazardous materials such as Plastics, Metals, Cables & Wires, Glass, PCBs, switches, CRTs, batteries and capacitors

SECOND PHASE TREATMENT OF E-WASTE

Some material outputs of first phase treatment will serve as input to second phase treatment. The second phase treatment is carried out in the E-waste processing and recycling section of the IEWMS to recover constituent substances in E-waste. Activities in this phase of the E-waste treatment include shredding, sorting grinding, comminution and final separation.

Raw Material Recovery through Recycling

After remanufacturing and removing of reusable parts from E-waste in the ERU, a large mixture of metals, plastics, glass, etc. still remain. To recover remaining valuable materials, the waste electronic equipment is segregated into different material types. Hazardous components such as batteries or mercury-containing part are to be removed and sent to material recovery facility (MRF) in the E-waste Processing and Recycling Unit for second phase treatment. Mercury, batteries, leaded glass and other hazardous materials are sorted out and prepared for recycling before final disposal of residues.

The remaining materials are shredded, segregated and sorted using techniques such as eddy currents, magnets, and wind winnowing to extract metals (CIWMB, 2004). This second phase of treatment is presented in Figure 4.21. This produces new type of materials such as aluminum, iron, plastics, copper, ceramics, composite metal granulates, and glass. These recovered high-quality metals or materials can be used as raw materials to manufacture new products (CIWMB, 2004).

E-WASTE MANAGEMENT TECHNOLOGIES

Disassembling and Sorting

At the ERU, the E-waste are disassembled, sorted and segregated to separate constituents or components. Parts such as printed circuit boards (PCBs), batteries, plastics, containing hazardous substances, are removed and sent to recycling plant. PCBs are said to be the most valuable parts of electronic waste as they contain precious metals such as gold, silver, copper, palladium and so on (Handout 10, 2012; Namias, 2013).

Shredding and comminution/Pulverization

After sorting, the bulk E-waste materials are then shredded into smaller sizes of homogeneous materials. Shredding reduces the size of the materials to enable the separation of ferrous materials from the non-ferrous and plastic fractions. Vibratory conveyor or screen is used to further separate the shredded materials. The separated materials are ground or pulverized through a comminution or dry grinding process into very fine materials and then made to pass through an electromagnetic system for the removal of ferrous metals which are used as secondary raw materials. Eddy current separation system is used to remove non-ferrous metal which are mainly aluminum and copper; while plastic components are removed through density separation system (Empig and Tobias, no date; Chatterjee and Kumar, 2009; Namias, 2013). Finally, the recovered materials are subject to essay or assay content test for content valuation. This process will assess the content of different metal (ferrous and non-ferrous) in the recovered materials. The process is shown in Figure 4.22.

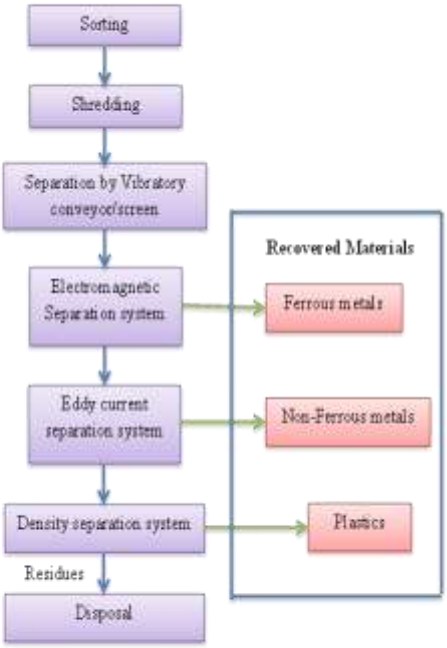

Figure 4.22: Second phase E-waste Treatment; modified from Kang and Schoenung (2005)

Engineering Considerations

The E-waste recovery facility or centre is to function or operate in two phases. The first phase is to remanufacture (refurbish, repairs and upgrade) of waste electronic and ICT equipment for re-use. The second phase involves the processing for recycling of end-of-life waste electronic and ICT equipment to recover valuable substances such as lead, gold, silver etc. Therefore engineering design must consider the technological as well as technical viabilities of the proposed E-waste recovery centre.

Engineering considerations will thus include the following factors:

i. E-waste entering into the centre including rates of material delivery,
ii. Materials storage and Equipment loading rates,
iii. Material flow and handling patterns,
iv. Equipment selection,
v. Equipment usage,
vi. Environmental controls and
vii. Aesthetics aspect

Planning and Design Process for the Integrated E-waste management system

In planning and designing the E-waste management system, the following activities and details need to be carried out.

i. A comprehensive feasibility study needs to be conducted to determine the technical and economic viability of the E-waste recovery facility. Economics, finance/capital and operating costs should be considered. A sensitivity analysis of the effects of the prices of recovered secondary materials is particularly important
ii. The E-waste recovery facility is to be coordinated into an overall integrated E-waste management plan.
iii. Type of ownership and operation should be determined from onset. The facility could be solely owned by the institution or joint ownership with interested private organization
iv. Services of qualified and competent engineers should be engaged for preliminary design and final design of the facility.

Technical viability

E-waste collection will be carried out using collection agents. Segregation and Disassembling/dismantling would be done manually. Manual segregation and dismantling of E-waste streams will save cost. Sorting should be done manually to remove specific components such as PCBs and microprocessor chips for reuse. Semi-automated method with local shredding techniques can be employed. Mechanical shredding of E-waste to reduce size and the separation of saleable ferrous and non-ferrous metals can be done with manual removal or picking of components such as PCBs. Semi-automated crushing with local grinding techniques can be used at this stage of the treatment. Further grinding of the remaining materials into smaller size can be done using locally fabricated hammer mills and grinding machines. Density separation can be achieved by means of air blowing using air compressors or any other similar devices. The recycling centre can evolve and adopt local technologies, locally fabricated shredding, sorting and grinding machines can be employed instead of using expensive imported machines.

Economic and Market viabilities

The economic viability of an integrated E-waste management has been discussed in Chapter 2. Remanufactured computer systems can be sole as second hand equipment to staff or other interested buyers for reuse. The market share for used electronic equipment such as computer is very high in the country especially in this period of recess economy that the price of new electronic equipment is on the increase. Recovered substances and materials (Lead, gold, silver, copper, palladium plastics etc.) can be sole to manufacturer of products such as boxes, toys and shoe soles (Chatterjee and Kumar, 2009). Waste brokers or agents can buy and sell an entire set or some components before E-waste enters the recycling process. This may offer economies of scale to reduce transportation, recycling and disposal costs (CIWMB, 2004). To further ensure availability of market for valuable recycled materials, the centre should synergize and interconnect with international recycling organizations and network with them to create market outlets for recovered materials. This will help maximize return on recovered valuable secondary raw materials.

Cost consideration

For a sustainable business operation of the integrated E-waste management system, the revenue from reused, recovered and recycled waste electronic equipment resale must exceed the costs of collection, transportation, storage, testing, refurbishment and recycling.

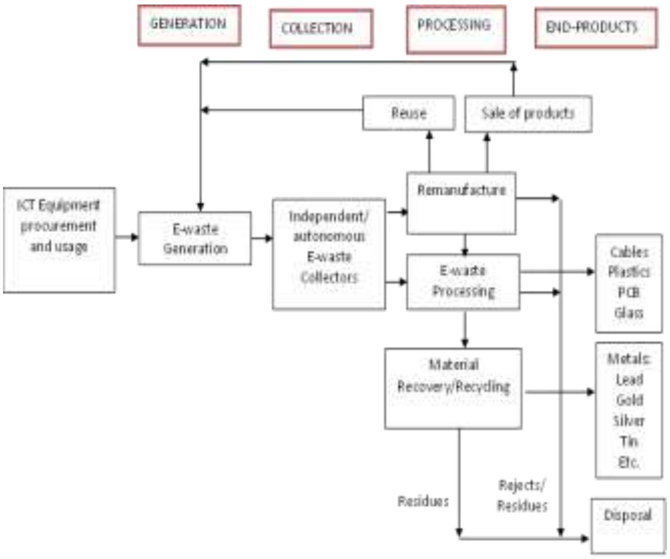

Figure 4.23: An Integrated E-waste Management System (IEWMS)

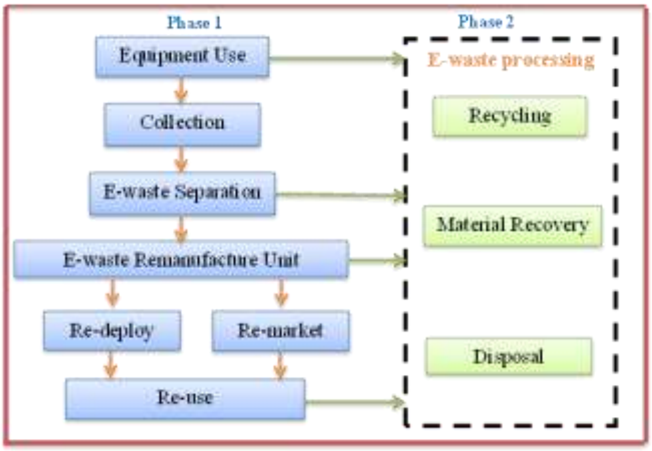

Figure 4.24: E-waste treatment process in the IEWMS

Management Roles in Achieving the Goal of IEWMS

The IEWM system needs integration between management and various key players for good E-waste management practices. Management decisions can help to promote the adoption of remanufacturing and recycling approach. These decisions may include developing an E-waste management policy within the institution; perform an assessment of E-waste generation, establish an E-waste collection scheme and set up employee training and incentive programs on E-waste management.

The various aspects of management roles, participation and commitment to implement measures for sustainable IEWMS are discussed as follows. Based on the principles of IEWMS, several defined measures should be taken to make the E-waste management system more sustainable. These measures include:

I. Establishment of a Centre for Electronic Waste Management (CEWAMA)

Higher institutions such as the University of Port Harcourt, being an entrepreneurial university, should conduct a feasibility study on the establishment of electronic waste management centre to manage E-waste generated in the institution. To make the centre more viable services can be extended to the entire Niger Delta region and beyond. With this in place, E-waste generated would be locally recycled within the geo-political zone and thus reduce the cost of transporting them to Lagos for recycling as is being presently practiced (Manhart et al, 2011; Ideho, 2012). An integrated E-waste management system suitable for environmental sound management of E-waste is presented in Figure 4.22. The system is designed to encompass a comprehensive flow of E-waste from generation through collection and processing, to final recovery of valuable end-products. Generally, the designed material recycling/recovery facility system shows that E-waste generated is collected and is either repaired and upgraded for reuse and sales or send to E-waste processing centre for recycling and recovery of valuable materials such as lead, gold, silver, etc.

II. Technical and Operational measures

i. E-waste collection and handling

The institution should gather data regarding E-waste streams and sources of E-waste and disseminate technical guidelines for E-waste collection process. This can be done on faculty or departmental basis, institutes, centres and units should also be included in the scheme.

Gather data on E-waste sources and quantities disseminate technical guidelines for sound E-waste handling and identify possibilities for E-waste separation at source. Integrate storage, collection and transportation systems and adapt collection frequency to E-waste generation. Establish a record-keeping and monitoring system to support continuous improvement of the system. Resource recovery

Management should encourage separation of E-waste at source through education and economic incentives; Gather data on types and quantities of recyclables generated, collected and recycled. Also, encourage resource recovery through establishment of remanufacturing unit and material recovery facilities (MRF). Set up a training program for participating personnel.

ii. Disposal of Residues

Residues from the recovery and recycling processes should pass through toxicity and leachate test before final disposal. Disposal of E-waste residues after treatment and recycling in the facility should consider thermal destruction (incineration), landfill, burial etc.

III. Environmental measures

To achieve environmentally sound practices in the implementation of IEWMS management should monitor flow of E-waste into the facility from all collection points or centres. Monitoring should cover E-waste collection services and their frequencies. Monitor environmental effects of the remanufacturing and recycling facilities on employee’s and public health. This should include control of leachate, gaseous emissions and effluent discharge.

IV. Financial measures

a. Budgeting and cost accounting:

The integrated E-waste management system will need adequate financing scheme; management commitment is therefore necessary in this respect. Management should transparently assess the real costs of establishing and operating the E-waste management facilities and make financial commitment for its implementation.

b. Revenue generation

Management can sell some of the refurbished computer systems as second hand to prospective buyers. The institutions can also generate revenue from sales of valuable secondary materials such as lead, gold, plastics, silver etc.

c. Cost reduction and control:

Management should encourage informal sector participation in E-waste collection and dismantling or disassembling, expectedly this will result in efficiency gains and cost savings. Cost can also be saved on use of indigenous or local technologies especially in sorting and grinding.

V. Socio-economic measures

a) Monitoring of staff and public health during facility operation. Monitor waste-related diseases (such as morbidity and mortality) in adjacent communities.

b) Systems Design

System design involves identification of all stakeholders and their interests in E-waste management (stakeholder analysis). The roles of Research and Development department are very crucial in the design and implementation of the IEWMS.

c) User participation

Involvement of all users in the implementation and operation of the IEWMS is very important. There should be awareness and collective participation of all stakeholders (including end users). This can be done through effective communication and development of linkages and trust between different groups of actors involved in E-waste generation and management in the institution. Capacity building among groups of stakeholder is needed to enable them to participate through training of leaders, involving them in committees (including involving them as enumerators in social surveys). Prepare a social profile of areas to be served on all stakeholders through social surveys, focus group discussions, interviews, and other techniques. Also assess demands and needs of users (phase and quality of services) through meetings, social surveys and other social research methodologies.

d) Social conditions of workers:

Social status of workers (E-waste collectors) can be improved by providing them with uniforms, ID cards and the required training. Improve working conditions of E-waste collectors by providing loading trucks, and better working tools. Introduce measures to improve their working conditions and raise their awareness on health and hygiene conditions (including introduce special collection in areas such as dump site), provide them with protective wears (gloves, boots), water and sanitary facilities.

VI. Institutional and administrative measures

Institution building

Management should establish a centre to be called and known as Centre for Electronic Waste Management (CEWAMA) with the sole responsibility of designing, implementing and overseeing the operation of the IEWMS. CEWAMA should be autonomous and function under a jurisdiction with clear cut roles and responsibilities in E-waste management in the institution. The centre should establish a transparent procedure for competitive bidding and contracting out of E-waste management services. Improve organization of the informal sector and increase their integration into the formal E-waste management system by recognizing them, allowing them to participate in tenders and contracting.

Education, Training and Awareness-raising

Initiate awareness-raising programs about E-waste reduction and prevention, resource recovery and E-waste handling. Prepare guidelines for environmentally sound E-waste collection, treatment and disposal systems. Training of facility operators, remanufacturing engineers and technicians, and E-waste contractors is important for effective operation of the IEWMS. This will keep employees current on E-waste regulations and policies. The training program should also emphasize the benefits of good housekeeping and reduction in the amount of liquid and gaseous effluents.

VII. Policy and legal measures

Planning and policy

Planning and policy should emphasize on the segregation of E-waste at source in each faculty, departmental, institute/centre or unit. Develop an E-waste management strategic plan for each process generating E-waste. As part of the strategic plan, each faculty, departmental, institute centre or unit should have an officer responsible for E-waste gathering and collection in their respective domain.

Regulatory framework

Establish unequivocal effective bye laws and ordinances for E-waste generation, storage, collection, handling and management in the institution. Establish unambiguous and effective regulations and procedures for stakeholders' participation.

Rules and regulations

Develop and enforce environmental legislation governing collection, disposal, and treatment of all E-waste types. Make an EIA obligatory before site selection and implementation of the E-waste management facility

E-waste Management Cost Allocation

E-waste management costs should be allocated or apportioned to cover all phases involve in the implementation and operation of the IEWMS facility. Cost should cover the following areas:

a) Preliminary assessment (feasibility study and analysis) phase,
b) Preliminary design phase,
c) Main design phase,
d) Implementation and construction phase, and
e) Operation phase.

Challenge or Obstacles to the proposed system:

a) Requires initial fund for implementation
b) May needs collaboration with the private sector
c) May needs collaboration with Federal regulatory agencies

Expected Achievements of proposed system

The IEWMS is expected to achieve the following:

a) Cost recovery (selling of refurbish equipment, and recyclables)
b) Produce new innovations in E-waste management in the institution
c) Create staff awareness and participation (source separation)
d) Environmentally sound practices with modern technology
e) Safeguard staff and public health
f) Job creation for local people

Benefits of IEWMS

The benefits of the integrated E-waste management system are both environmental and economical, as it brings about reduction in environmental pollution as well as revenue generation.

The specific benefits that can be derived from the implementation of the IEWMS are:

a. Reduction in the amount of E-waste to be managed
b. Reduction in the amount of E-waste to be disposed
c. Reduction in E-waste disposal cost
d. Generate income through sales of refurbish equipment and recyclables
e. Reduction in the release of pollutants into the environment
f. Employment generation
g. Minimize or eliminated environmental hazards.
h. Conservation of resources through direct reuse of recovered materials.
i. Cleaner and safer environment
j. Efficient use production materials
k. Better business opportunities and economic growth for the institutions.

Management Commitment

The implantation of the IEWMS requires total management participation and commitment. These may include the establishment of clear set of goals, funding and other administrative strategies. The institutions may decide to begin with the establishment of a small scale pilot project.

V. CONCLUSION AND RECOMMENDATIONS

SUMMARY

This study was carried out to comparatively assess and evaluate electronic/ICT waste (E-waste) management in three higher institutions in Rivers State, Nigeria and to develop an integrated E-waste management system for environmentally sound management of E-waste. The study employed research surveys in data gathering and acquisition through the use of questionnaires, interviews and observation. The research design and methodology include sampling procedure, sampling type, sampling technique and data analysis. Relevant literatures were extensively searched and reviewed as part of the data gathering processes. A total of eighty-five (85) questionnaires were served to staff of the following departments in each of the institutions. Out of which eighty (82) questionnaires were completed and returned, which formed the basis of the questionnaire response analysis presented in the study.

Field interviews, observations and questionnaires responses revealed that there is no proper management of electronic/ICT wastes generated in the institutions. Electronic/ICT wastes generated in the institutions are mixed with other office waste in common waste bins and later taken to common waste dumping points within the institutions. A common practice observed among the institutions is the storage of E-waste for a period of time before disposal or auctioning them to staff and interested buyers.

An integrated E-waste management system based on the concept of remanufacturing and material recovery/recycling approach was proposed and developed in the study. It is believed that this integrated approach will ensure environmentally sound management of E-waste for the protection of human health and the environment.

CONCLUSION

A comparative study of electronic/ICT waste (E-waste) management in a three higher institutions in Rivers State, Nigeria has been carried out. Based on survey results and findings of this study, the following conclusions can be drawn:

(a) Study survey indicated that the institutions generate a reasonably amount of electronic/ICT waste that requires proper management before disposal.

(b) Survey findings further showed that desktop computers, laptops, UPSs, old CRT monitors, and printer cartridges are the majority generated and available E-waste in the storage in the institutions.

(c) Survey results showed that the institutions have no legislation or policy that deals with E-waste management,

(d) Findings also revealed that there are no accurate records (inventory) of ICT equipment procurement and E-waste generation and disposal in the institutions.

(e) Findings indicate that E-waste separation or segregation at source of generation is not also practiced by the institutions. Rather E-waste is disposed of together with other office wastes and scraped materials.

(f) The study showed that the institutions have no central unit or centre where used electronic equipment are refurbished and repaired for reused.

(g) The institutions have units that collect used electronic/ICT equipment from various departments/centres or units and auction or sell to staff and other interested buyers.

(h) The institutions stored their E-waste for between 2 to 4 years before disposal.

(i) The current E-waste management practiced by the institutions poses serious danger to the environment and public health. Humans, plants, animals can be exposed to toxic constituents of improper disposed E-waste through inhalation, ingestion or dermal exposure.

(j) There is high level of dissatisfaction among staff with current methods of E-waste management in their respective institutions. Majority of respondents expressed the need for a holistic approach to environmentally sound management of Electronic/E-waste.

(k) Taking all together, it can be concluded that there is no proper management and disposal of electronic/ ICT waste in higher institutions in Rivers State.

(l) An Integrated E-waste management system that will not only address the current poor E-waste management practices in the institutions but also achieve environmentally sound management of E-wastes in the institutions has been developed in this study. This multi-objective planning system is based on the goal and concept of remanufacturing for reuse and E-waste processing for material recovery and recycling.

The overall aim of the integrated approach developed is to improve the environmental performance of the higher institutions in Nigeria through sustainable E- waste management.

By employing this integrated approach, the institutions can set a standard for sound environmental performance and achieve green electronic/ICT utilization in Nigeria higher institutions.

RECOMMENDATIONS

(a) The institutions should develop and enforce environmental legislation governing collection, disposal, and treatment of all E-waste types.

(b) Management should encourage separation of E-waste at source through education and awareness.

(c) Develop an E-waste management strategic plan for each process generating E-waste.

(d) As part of the strategic plan, each faculty, departmental, institute centre or unit should have an officer responsible for E-waste gathering and collection in their respective domain.

(e) Management of institutions should adopt and incorporated the proposed integrated E-waste management system as part of the overall E-waste management plan.

(f) The institution should establish a centre to be called and known as Centre for Electronic Waste Management (CEWAMA) with the sole responsibility of designing, implementing and overseeing the operation of the IEWMS. CEWAMA should be autonomous and function under a jurisdiction with clear cut roles and responsibilities for E-waste management.

(g) The institutions may decide to begin with the establishment of a small scale pilot project.

(h) The proposed Integrated E-waste System is limited to management of ICT waste in selected higher institutions in Rivers State. A comprehensive research study should be conducted to cover all Electrical Electronic Equipment (EEE) waste management in higher institutions in Nigeria.

CONTRIBUTION TO KNOWLEDGE

The following are the contributions of this study to knowledge:

(a) The study provides background information on management of electronic/ICT waste (E-waste) in higher institutions in Nigeria.

(b) It provides effective integrated techniques for management of electronic/ICT waste based on the concept of remanufacturing and recycling.

(c) The study opens a new research area into integrated management of electronic/ICT waste in our higher institutions for material recovery and protection of the environment and human health.

(d) The result of this study will also assist management of higher institutions establish research centre for proper treatment of electronic/ICT waste to recovery valuables/sellable materials and reduce toxicity before final disposal.

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