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Awareness Concerning Electronic Waste Management and Disposal: Prototype for an e-Waste-Free Nation

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ABSTRACT

The study seeks to identify the knowledge and barriers related to the disposal of e-waste, as well as the employees' perspectives on e-waste management. The current study provides information about employee e-waste usage, awareness, disposal intent, and e-waste management practices at the regeneration centre. This paper recognizes the issue and suggests turning e-waste materials into valuable products. The study was conducted in the Coimbatore district among selected software employees using a convenient and purposive sampling method. A structured questionnaire with a Likert scale was used to collect primary data using appropriate statistical analysis. SketchUp was used to achieve a more realistic visual effect for the prototype floor broom and flower pot. The study's findings demonstrate the use of technological products, the motivation behind buying new gadgets, and the understanding of e-waste disposal techniques. In addition to discussing the prototype flower pot and floor broom designed using e-waste, the study also addressed how recycling and reusing electronic waste into functional or decorative products can decrease the amount of e-waste in the dump yard, which subsequently reduces the negative health impacts triggered by improper disposal methods. Even though research has been conducted among employees on different facets of e-waste, more research is still required to produce products employing materials from e-waste. Due to time constraints, the products were designed but not developed, and only a few recycling centres were available in the selected area.

Keywords: E-Waste, Disposal intention, Barriers, Prototype

INTRODUCTION

The modern-day devil is and always will be electronic garbage. Using numerous gadgets has been the vogue of the day, and no one is concerned about those gadgets in the future (Nautiyal and Agarwal, 2020). According to Sahu and Agrawal (2008), the rapid development of information and telecommunications technology has impacted nearly every aspect of contemporary life, even in the most rural regions of developing countries. As a result of this rapid technological advancement, manufacturers produce more new products, which has increased the amount of used electronics destined for recycling or landfills. Due to its extensive use in our daily lives, the electronics industry has been at the forefront of a revolution for several years. These electronic products are discarded or reused and are currently considered electronic garbage (Patel, 2021). In this sense, "waste" denotes a product that has outlived its usefulness. It is the term used to describe something no longer in use, including tiny and large items like computers and circuitry wires (Chatterjee, 2011).

A developing nation, India has one of the most rapidly expanding economies worldwide. Electronic items' use has increased due to the expansion of the Indian IT industries—additionally, the life cycle of many gadgets has been shortened by technical improvements. As a result, an argument can be made that India is the "Third largest

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electronic waste generator in the world" and that its electronic waste stream is one of the waste streams that is increasing the quickest in India. About 2 million tonnes of e-waste are produced yearly, while an unspecified amount of e-waste is imported from other nations (Gupta, 2012).E-waste generation has increased by 20–21% globally during the last five years, according to Verrendra (2021), and is projected to quadruple by 2030. According to Patel (2021), by 2030, the total is predicted to reach 74.7 million metric tonnes, nearly doubling the annual production of new e-waste in just 16 years. It makes the fastest-growing home waste stream in the world, primarily due to increased purchases of electronic items, which have shorter life spans and fewer repair alternatives.

E-waste recycled using crude techniques could be harmful. Several materials found in electronic waste, including heavy metals, glass, plastics, and other materials, are poisonous and dangerous to human health and the environment if not disposed of in an environmentally responsible way. Using rudimentary techniques to recycle electronic debris in the informal sector can harm the environment (Chatterjee, 2011). Approximately twenty-one products are registered in the e-waste category, according to the e-waste management standards (Condemi and Schettini, 2019). According to Tyagi (2022), our nation must establish decisive plans to put used e-waste into practice at specialised facilities while focusing on environmental contamination and health dangers.

E-waste is a significant problem that impacts both people and the environment, and its disposal is risky for wealthy and developing nations. The toxic chemicals in e-waste pose severe dangers to human health, negatively impacting the environment, and contain certain hazardous chemical elements. E-waste management has fantastic business potential. The study intends to comprehend the employees' perspective on e-waste management; it proposes to understand the knowledge of e-waste management among staff members, its disposal intention and barriers to e-waste disposal and to design a product to decrease the e-waste by developing a new product. Improper handling of e-waste can lead to health and environmental challenges.

Objectives:

The study has been undertaken with the objectives to:

- Find out the usage of technological products among employees
- Assess the extent of awareness among employees on the e-waste challenge.
- Examine the employees' intentions and obstacles regarding the disposal of e-waste.
- An in-depth study of e-waste management among software companies and regeneration centres.
- Designing prototypes for utility purposes using E-waste, specifically a Floor broom and flower pot.

METHODOLOGY

The "Awareness Concerning Electronic Waste Management And Disposal: Prototype For An E-Waste-Free Nation" had three phases and technological gadgets were considered "e-waste." Phase I involved polling employees about e-waste management and disposal. Phase II consisted of a case study focusing on e-waste recycling facilities and software companies, and Phase III involved creating a prototype utilising e-waste. A Phase I survey was conducted among software employees to collect information, and the city of Coimbatore was chosen for the study with a representative group of 100 software company employees. The method used for this study was convenience sampling, in which the interviewer determined the schedule for the interview and employed a scale to gauge awareness of the problem caused by e-waste, consisting of 23 statements from 2 dimensions. The scale used to measure consumer intentions for e-waste disposal was adapted from Anusree (2021), and 40 statements from eleven dimensions were used. For this study, the data were gathered, coded, and analysed using tables and graphs, pie charts, and other visual aids to explain the findings. Percentage analysis and ANOVA were utilised in this study.

Phase II involved conducting a case study on an e-waste regenerating centre and software company. Coimbatore was chosen as the study location, and five companies and three regenerating centre units were selected for the in-depth investigation. Information was gathered from software businesses and regeneration centres using convenience and purposive sampling methods. In the present research, questionnaires were designed to collect data from the chosen organisations, while both observation and interview methods were chosen to acquire information from the regeneration centre. In Phase III, a prototype that combined a floor

broom and a flower pot was created utilising e-waste. Five samples of a single product were measured to develop the prototype, and a standard measurement was computed. The product was designed using the software Sketchup to achieve a more realistic impression.

RESULTS AND DISCUSSION

The results and discussion of the study *"Awareness concerning electronic waste management and disposal: Prototype for an e-waste-free nation"* were discussed and interpreted under the following topics:

PHASE I: Conduct of Survey on E-waste management and disposal:

Information on this topic is discussed under the headings given below:

Usage of technological products among employees:

Background information:

According to the information on the respondents' characteristics that was gathered, eighty-five per cent of the respondents were between the ages of 20 and 30. Further details included that 58 per cent of respondents were men, 65 per cent were single, and 71 per cent came from nuclear families, with 55 per cent residing in urban areas. Regarding educational background, the data revealed that 60 per cent of respondents worked as system engineers, 25 per cent held program manager positions, and 45 per cent of respondents had completed their undergraduate degrees, while 28 per cent had professional degrees. Information on work experience revealed that 60 per cent of the respondents had 1-3 years of experience, while 30 per cent had 4-6 years.

Details on Technological Product:

The frequency of technical product utilisation, its present use, and the items no longer in use were stated in this section; the data also encompassed storage duration, the justification for not utilising technological products, and the appliances acquired in the previous ten years.

According to the current technical items, more than 90 per cent of respondents used one to three smartphones, PCs, or laptops. In comparison, 61 per cent and 80 per cent used one to three iPads and computer peripherals, respectively. The information collected shows that 46 per cent of respondents frequently kept these products in their homes, 24 per cent occasionally donated their no longer utilized items to known people who required them, and 27 per cent sometimes preferred to put the technological merchandise in debris. The products that were no longer in use were evaluated using seven attributes. Additionally, the research revealed that 25 per cent of respondents always claimed to exchange products that were no longer in use. According to the study by Olmez *et al.* (2022), a large portion of participants either sold the device as a used item, kept it at home or kept it as a spare item, while a smaller number used the device waste as household waste and threw it away, gave or donated the item to a friend, or took their used device to a recycling facility.

The information was also gathered to determine how long technological products were stored when not in use, and it revealed that 25 per cent and 42 per cent of respondents held their unused smartphones for more than six months and 1-3 years, respectively. The study also revealed that 16 per cent, 9 per cent, and 28 per cent of respondents kept their laptops, iPads, and computer peripherals for one to three years, while 11 per cent retained their computers for five years or more.

The information regarding the barriers to technology adoption was rated on a five-point scale. The results showed that 34 per cent of those who participated strongly agreed that they do not use technical products because they are broken, 30 per cent of respondents and 28 per cent of respondents strongly agreed about not using technological products because they were not operating normally, and 33 per cent of respondents and 34 per cent of respondents agreed and strongly agreed on not using technological developments because they were functional but slow. Today's technology was developing, and many respondents used particular technical products as they opted for more advanced technological products. Additionally, 25 per cent of those who responded strongly agreed that they were not using the product because of the development of new technology. Due to their longer battery lives, 42 per cent of respondents and 32 per cent of respondents brought new smartphones and laptops.

In comparison, 31 per cent, 29 per cent, and 12 per cent of respondents brought new computer accessories, smartphones, laptops and computers during promotional sales. The respondents also purchased new technology to elevate their social standing. The data revealed that 48 per cent, 23 per cent, and 13 per cent of respondents specifically mentioned buying a new smartphone, iPad,

or laptop to elevate their status. According to Almulhim (2022), among the many different kinds of electronic gadgets used in homes, mobile/cell phones (which account for 96% of all electronic devices in Dammam households in Saudi Arabia), TVs (79%), and laptops (71%), were the most common.

Extent of awareness among employees on the e-waste challenge:

Workers' knowledge of the issues or challenges brought on by e-waste was evaluated. The statements were divided into two categories, the first of which included ten statements relating to the health risks of e-waste and the second of which had 13 views relating to the environmental dangers of e-waste. According to the evaluation of respondents' degrees of awareness using a five-point Likert scale, 67 per cent of respondents had a medium grasp of the problems produced by e-waste. Comparatively, 16 per cent showed a high level of awareness, while 17 per cent had a low level. According to an investigation conducted in 2017 by Ohajinwa *et al.,* the level of awareness regarding health risks among e-waste workers was much lower than that of their peers in the same informal sector, and there was a positive association between the workers' knowledge and their attitude and behaviour. The study suggested that enhancing worker education could reduce dangerous practices.

According to the specifics of the awareness dimension about the health risks associated with e-waste, 48 per cent of respondents strongly agreed that they were aware of the risks associated with e-waste, whereas 11 per cent strongly disagreed. The study also revealed that 48 per cent of respondents strongly concurred that landfills and the harmful elements found in e-waste were the cause. Children's health was also negatively impacted by e-waste, as evidenced by the fact that 54 per cent of respondents strongly agreed with this statement, and 51 per cent were aware that e-waste seriously influenced children's respiratory systems. The survey also revealed that 44 per cent of respondents knew that hazardous compounds in e-waste can harm the skeletal system (Fig. 1).

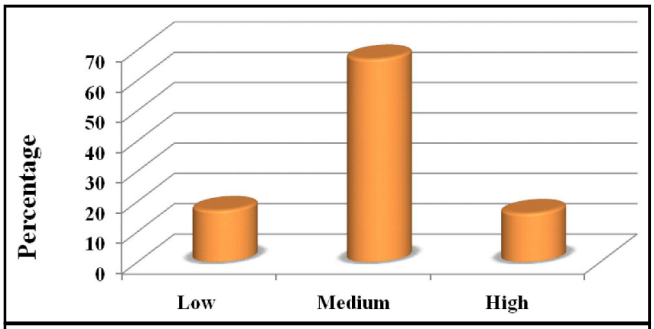

Fig. 1 : Awareness on e-waste challenge among Employees

The data comparing respondents' knowledge of health risks based on educational attainment revealed a significant difference, with the ability being highest among those with professional degrees (Mean=43.036) and lowest among those with undergraduate degrees (Mean=35.844). The study revealed that the F value (F= 7.956) was significant (p = 0.00) at the 1% level. Information on how environmental danger awareness varied by educational level was assessed, and it showed that there was a significant difference in educational attainment and that understanding was high among respondents with diplomas (Mean=55.000) and low among respondents with undergraduate degrees (Mean=46.244). The research revealed that the F value (F= 7.610) was significant (p-value 0.00) at the 1% level (Table 1).

The information comparing levels of knowledge of the e-waste problem according to educational background was evaluated. The data revealed a substantial range of educational experiences. The knowledge level was high among respondents with professional degrees (Mean = 98.036) and low among respondents with undergraduate degrees (Mean=82.089). According to the research, the F value (F= 8.167) was significant (p = 0.00) at the 1% level. The present study supported the study by Sivathanu (2016), which showed that there was a significant

Table 1 : Comparison of Awareness on Health Hazard and Educational Qualification

Educational qualification	N	Mean	Std. deviation	f	Sig
Under graduate	45	35.844	7.2141		
Professional degree	28	43.036	6.7081		
Post graduate	13	37.692	7.9623	7.956	.000
Diploma	14	42.857	4.7694		
Total	100	39.857	7.5848		

Table 2 : Comparison of awareness on problem created by e-waste and educational qualification

Educational qualification	N	Mean	Std. deviation	f	Sig
Under graduate	45	82.089	9.8907		
Professional degree	28	98.036	8.1967		
Post graduate	13	84.308	10.5399	8.167	.000
Diploma	14	97.929	4.8113		
Total	100	89.060	9.8452		

relationship between the education of consumers and their awareness of e-waste. It clearly showed that the current study's findings aligned and confirmed with the previous studies (Table 2).

According to Miner *et al.* (2020), most people disposed of their electronic waste and regular household trash together since they were uninformed of the adverse effects of doing so. To ensure safe e-waste removal and treatment, the government and other stakeholders needed to launch public awareness programmes.

Employees' intentions and obstacles regarding the disposal of e-waste:

A Likert scale with 11 characteristics were used to compare consumer intentions for disposing of e-waste among respondents based on educational background. The data showed a significant variation in educational qualification, and it was discovered that consumer intention on e-waste disposal was high among respondents with postgraduate degrees (Mean=18.8503) and low among respondents who completed diplomas. According to the analysis, the F value (F=.923) was not deemed to be significant, as the p-value was found to be (.433).Based on their educational levels, respondents' hurdles to getting rid of their electronic waste were compared based on the data. The data demonstrated a significant difference in respondents' educational backgrounds and revealed that respondents with undergraduate degrees had a high awareness level (Mean=6.3172). In contrast, respondents with professional degrees had a low awareness level (Mean=4.0229). According to the analysis, the F value (F=2.757) was significant (p =.047) at the 5% level.

As per the data on e-waste disposal methods, 48 per cent of respondents occasionally kept e-waste in a store without using it, 31 per cent of respondents sometimes gave e-waste to friends, 26 per cent of respondents sometimes sold e-waste to spare parts dealers, and 44 per cent of respondents permanently dismantled the scrap material from electronic debris. Regarding the garbage disposal rationale, the data revealed that 30 per cent of respondents rarely disposed of non-functional devices. The data also showed that respondents discarded these things aside as they purchased a new device while the repairs were so expensive (Fig. 2).

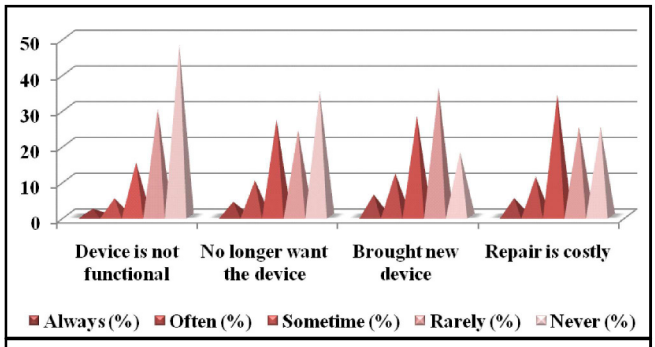

Fig. 2 : Frequency of Disposing Electronic Waste

The data revealed that 24 per cent of respondents had access to e-waste drop-off points, 37 per cent specified that they did not have e-waste drop-off points, and 39 per cent of respondents needed clarification about their access to e-waste drop-off points. The data also revealed that 15 per cent of respondents did not understand proper e-waste recycling and that 54 per cent did not have many drop-off containers for e-waste nearby. Three per cent of respondents indicated they do not have the vehicle facilities to carry e-waste to the collecting site, 17 per cent did not have the time, and 11 per cent revealed they did not even care about delivering e-waste to the gathering point. The respondents also stated that 35 per cent of the respondents did not have recycling centres in their communities, 37 per cent were unsure, and 28 per cent did not know whether they had recycling centres in their communities. Almulhim (2022) stated that the proportion of people aware of the current e-waste management technique was limited, suggesting that nearly no one knew how to use this approach. A flawed mechanism for collecting it, an absence of information systems, and customer ignorance were the root causes

of ineffective e-waste management. One of the problems with e-waste management was that the public needed to understand the problem; as a result, if the government wanted to see a change in e-waste management, it should have implemented an awareness-raising programme that would have served as the cornerstone of all initiatives.

PHASE II: Case study on E-waste Management in Software Companies and Regeneration Centre:

Software Company:

Techmithra, Techgenzi, CADD Centre, Image Creative Education, and Dharamalingam Associates were chosen for this case study. The majority of the businesses were founded before 2005. The organization was mostly headquartered in the heart of Coimbatore. The study revealed that most companies selected had between 0 and 25 laptops. They had between 26 and 50 computers, and the data indicated that it would take all companies over five years to replace a computer.

Additionally, it was stated that all businesses bought their computers from brand showrooms or dealers and sold their used equipment to recycling organizations. The data also demonstrated that the garbage collection method was a municipal or government system. It further indicated that most waste collectors only came to pick up paper or plastic waste; they did not collect electronic waste. These companies purchased used computers from brands like HP and DELL and assembled computer brands; however, these manufacturers did not allow their products to be taken away for recycling.

Regeneration centre:

The facility for gathering electronic waste was called Tharani. The waste regeneration unit in Rathinapuri, next to Gandhipuram in Coimbatore, was established in 1999. Although it was not authorized when it began, the Tamil Nadu Pollution Control Board issued a certificate. The electronic garbage generated daily was roughly 740 kilogrammes, with a monthly volume of 22 tonnes. Items were gathered, transported, and securely delivered to 57 recycling units. Not all electronic gadgets are recycled; instead, they are disassembled, the batteries and cartridges were recycled, the remaining parts were shredded, the recycled materials were separated, then delivered to the client, and recycled materials were sold.

Another organization that treated electronic waste was Green India Recyclers, founded in 2016 and situated in the Coimbatore village of Sulakkal. This recycling centre's monthly revenue was between 20 and 25 lakhs. Here, e-waste was gathered from all over India, and Pan India was the term used to describe the nationwide collection of e-waste in India. The Green India recyclers were dismantlers; they did not recycle materials or produce new goods from e-waste. Later, they collaborated with the Tamil Nadu Pollution Control Board on a programme to raise awareness, and their long-term goal were to shift people's present preferences from recyclers to dismantlers.

Green Era Recyclers was another business that recycled electrical and electronic trash. It was established in 2017 and was situated in Coimbatore's Edayarpalayam. The Tamil Nadu Pollution Control Board granted them permission for five years. Since 150 tonnes of electronic garbage were generated a year, a product was developed to collect it. It is a unique container for homeowners with four compartments for organizing bulbs, wiring, printers, toners, and other random stuff. They spent 15 lakhs to create the special bucket for household e-waste collection. They collect e-waste from homes in one or two wards in collaboration with the Tamil Nadu Pollution Control Board.

PHASE III: Designing prototypes for utility purposes using e-waste Floor Broom and Flower Pot:

The prototype is only one example of the creative ways that inventors can reuse the increasing amounts of dangerous electronic garbage (e-waste). It provides the means for breathing clean air or cessation of emissions. The long-term objective is to encourage a recycling environment that is safer and greener. Different prototypes of floor brooms and flower pots are shown below.

Floor broom:

Some dimensions for existing brooms made by the suppliers- Mitsico, Trady, and Morebuy were collected to create a floor broom. The prototypes were designed using a motherboard and resin and measured according to standards. Brooms are used for demanding duties like sweeping dirt off concrete floors or sidewalks or even smoothing and texturizing wet concrete. Therefore, it was decided to design a floor broom out of e-waste using a motherboard, a wood handle, bristles, and resin. The floor broom was created using the sketch-up program, and the motherboard was chosen as the material for the

prototype.

The floor broom was measured at 88 cm in length, 65 cm in handle length, 2 cm in handle thickness, 9.5 cm in bristle length, 25 cm in bristle breadth, and 4 cm in bristle side width. The floor broom handle was designed using wood because stainless steel could quickly break when repeatedly submerged in water. Because of this, the handle was designed of high-quality timber. The floor broom's body was also made from an e-waste motherboard. It was planned to split the motherboard into two pieces for the sides and remove two centimetres from the top. We could link the two components and the top sections by welding. Welding was used to link the two components and the top sections. An aperture was provided on the bristles for better flexibility and movement, enabling them to pick up dust and debris from various surfaces effectively; it also contributed to the broom's performance and usability (Fig. 3).

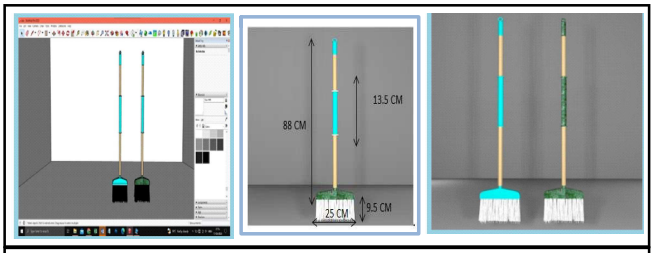

Fig. 3 : Prototype of Floor Broom from E-Waste and resin using Sketch up

Flower Pot:

A standard measurement was determined when designing the flower pot by taking a few measures from several brand flower pots (Vinshra, Inkulture and Exclusive Lane.) on the market. Motherboards, as well as resin, comprise the materials utilised to design the prototype. Flowerpots could be used for various purposes, including moving plants to new locations, growing plants on patios and indoors, and cultivating delicate plants indoors in colder climates. The flower pots were built using motherboards, and SketchUp software was used to complete the design. The flower pot has the measurements of a 12 cm base, a 17 cm side/depth, a 20 cm top length, and a volume of 3-litre capacity. The motherboard was marked with the measurement and was cut into five parts. It was designed to provide a small hole in the bottom of the pot after welding the five pieces together to form the correct shape. After finishing, the resin could be applied to the product.

Fig. 4 : Prototype of Flower Pot from E-Waste and resin using Sketch up

Conclusion:

E-waste is often the trash of technologically related products, which consists of unwanted, broken, and useless devices that are disposed of. Every year, enormous volumes of e-waste are produced and dumped in open areas, endangering the health of e-waste collectors and the neighbourhood. It can have harmful compounds when left out in the open, and these pollutants can affect the ecosystem and soil, impacting the survival of people and animals. These are known to have detrimental effects on the human nervous and reproductive systems and can damage the kidneys, liver, heart, skin, and bones. Burning electronic components such as circuit boards and cells can produce hazardous chemicals that may potentially cause cancer.

The study's findings reveal a significant correlation between educational attainment and awareness of the issues brought on by e-waste. Investigations were also conducted into the usage patterns of technical products, the justifications for purchasing new technology, and knowledge of e-waste and disposal methods. In comparison to respondents with higher education levels, it is stated that respondents holding degrees needed to be made aware of health risks. We must be mindful of both the beneficial uses of e-waste and the negative consequences of careless disposal. The study also discussed a prototype of an e-waste-made flower pot and floor boom that would inspire others to reuse and recycle e-waste into functional or decorative products to reduce the amount of e-waste in landfills, which would reduce the health effects associated with disposal methods.

Future Scope:

Compare e-waste management strategies and practices in different countries, identifying best practices that could be implemented locally.

Move beyond conceptual design by developing and

testing functional prototypes made from e-waste, analyzing their feasibility, durability, and market potential.

Develop and evaluate targeted awareness campaigns aimed at changing consumer behaviour regarding e-waste disposal.

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