Macro Perspective: E-Waste Environmental Impacts

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Abstract
The industrial revolution followed by the advances in information technology during the last century has radically changed people's lifestyle. The increasing economic development has introduced another aspect of pollution in the environment and that is “E-waste”. Electronic waste, abbreviated as e-waste, consists of discarded old computers, TVs, refrigerators, radios—basically any electrical or electronic appliance that has reached its end-of-life (EoL). The high tech boom has brought with it a new type of waste—electronic waste or E-waste, a category that barely existed 20 years ago. Now E-waste represents the biggest and fastest growing manufacturing waste.

E-waste contains materials that are both valuable and toxic. E-waste contains a host of toxins such as lead, mercury, cadmium and brominated flame retardants as well as aluminum, iron, gold, silver, copper and rare earth metals. Disposal of e-waste is a particular problem faced in many regions across the globe. Computer wastes that are landfillcd produces contaminated leachates which eventually pollute the groundwater. Acids and sludge obtained from melting computer chips, if disposed on the ground causes acidification of soil. Now water is being transported from faraway towns to cater to the demands of the population. Incineration of e-wastes can emit toxic fumes and gases, thereby polluting the surrounding air. Improperly monitored landfills can cause environmental hazards. Mercury will leach when certain electronic devices, such as circuit breakers are destroyed. The same is true for polychlorinated biphenyls (PCBs) from condensers. The most dangerous form of environmental pollution is by burning e-waste is the open-air burning of plastics in order to recover copper and other metals. The toxic fall-out from open air burning affects the local environment and broader global air currents, depositing highly toxic bi-products in many places throughout the world.

In this paper, the author discusses the environmental impact of E-waste. Also this study attempts to understand the consumers’ awareness and their viewpoints towards environmental pollution caused by the E-waste. This research conveys the significance of the contribution of all the stakeholders regarding the E-waste management. This paper suggests the various pathways to create awareness so that the environmental concerns of E-waste and its management can be properly tackled.

Keywords: Awareness, environmental pollution, impact, E-waste management.

Introduction
Information and communication technology has revolutionized our economies, industries and our lives. These improvements have led to generation of E-waste and other wastes from electric and electronic products. This E-waste consists of valuable and hazardous substances. E-waste contains valuable materials like gold, copper, iron, and aluminum. This toxic e-waste poses a great threat to the human and animal health along with environment. Therefore E-wastes management is crucial for health and environment protection.

Environmental scientists found that soils in the e-waste areas are often contaminated by heavy metals and organic compounds (Zhang et al., 2012). These non-biodegradable pollutants contaminate agricultural soils and water thereby gets included in the food chain through the crops. Burning of e-waste causes air pollution posing severe health problems to living beings in the near vicinity of the incineration site. E-waste is most of the times dumped in the landfill which contaminates ground water table due to the leaching of toxic substances such as arsenic, chromium and lead present in it. E-waste discharge in water causes harm to aquatic life, plants, animals and micro organism. Toxic substances in e-waste are the reason for severe physiological or neurological defects, infertility, breathing disorders, skin problems and cancer among e-waste processing workers. Thus there is an alarming need to illustrate health hazards and environment pollution due to e-wastes and focus on the techniques and strategies to wards E-Waste Management.

In this paper, the author delineates the environmental impact of e-waste. The paper is organized as follows: in section 1 author discusses the e-waste generation in Pune city; section 2 enumerates the contaminants associated with e-waste and how soil, air water, and human are contaminated by e-waste; in section 3 the researcher attempts to understand how the awareness level of individual consumers, E-waste processing workers, NGO initiatives and Government policies have impact on the health and environmental pollution caused by the e-waste; section 4 conveys the significance of the contribution of all the stakeholders regarding the e-waste management; in section 5 researcher concludes by suggesting the various pathways to create awareness among all the stakeholders so that the environmental concerns of e-waste and its management can be properly tackled.

Review of Literature
(Jain, 2008) in his research highlights that the complex composition of e-waste can be categorized as ‘hazardous’ and
'non-hazardous’. E-waste consists of ferrous metals like iron and steel in major, non-ferrous metals like aluminum, copper, silver and gold, plywood, plastics, glass, printed circuit boards, ceramics and rubber. The Basel Action Network (BAN) and Silicon Valley Toxics Coalition (SVTC, 2002) in their report mention about the presence of elements like arsenic, cadmium, lead, hexavalent chromium, mercury, selenium, and flame retardants beyond safe levels which makes e-waste especially computers the major pollutants of the health and environment. (Jadhav, 2012) in his article referred to the MPCB report which mentioned that Maharashtra state produces largest amounts e-waste in India. As per The Central Pollution Control Board, Pune is one among the top 10 cities producing e-waste. The MPCB report mentioned that the obsolescence rate of Electronic consumer goods is high in Pune. Hence Consumer’s awareness towards health and environmental pollution due to e-waste can contribute towards proper e-waste management. Electronics producers will be more responsible to manufacture less toxic products and be ready for material recycling. Government policy decisions would be implemented correctly. Huang et. al., (2006) in his research reported that environmental protection depends primarily on government and individual and then by the producers. Respondents were dissatisfied with their local environment highlighting that e-waste was the most serious environmental problem. (Afroz et al., 2013) conducted public awareness study in Kuala Lumpur. The ill effects of e-waste on health and environment were known to 59% public, and that environmental factors when purchasing electronics for household use were significant to 65% public respondents. (Shah, 2014) emphasized to change public behavior, people must be sensitized that unused electronic products are e-waste, should be oriented to deal with e-waste, and made aware about e-waste management. Author pointed that people in India are not even sensitized.

Operational Definition
E-waste comprises a whole range of electrical and electronic items such as refrigerators, washing machines, computers and printers, televisions, mobiles, I-pods etc. containing 1000 different substances many of which are toxic materials. Under The Hazardous Waste (Management and Handling) Rules-2003 Waste Electrical and Electronic Equipment (WEEE), all sub components and assemblies except batteries were defined as e-waste. (Sinha-Khetriwal, 2002) defined any electrical product which has reached end of life stage is e-waste.

Conceptual Model

Research Objectives
1. To study the environmental impact of E-waste.
2. To understand how the awareness level of consumers, E-waste processing workers, NGOs and Government policies have impact on the health and Environmental pollution caused by the E-waste.
3. To explore the significance of the contribution of all the stakeholders regarding the E-waste management.

E-Waste Production in Pune
Large electronics industries belt has developed in Pune due to the availability of engineering skills, access to skilled labour and raw materials, low manufacturing costs, and heavy demands. Pune has culture of consumerism due to large and growing middle class people. The e-governance and e-commerce initiatives adopted by the municipalities, governments and enterprise organization lead to the increased consumption in the electronics market. Individual household consumers, public and private (industrial) sectors, manufacturers and the government are the sources of e-waste in India (Borthakur and Sinha, 2013). In Pune city the e-waste collection, recycling process and management is not properly regulated and the recycling is majorly done by informal sectors.

Potential Environmental Contaminants Associated With E-Waste
Methods to treat e-waste:
1. Storing e-wastes in landfills.
2. To incinerate or burn the goods concerned.
3. Reusing.

Environment and Health Pollutants in E-Waste
Pollutants in e-waste are typically concentrated in Monitors, LCDs, batteries, circuit boards and plastics. In Pune recycling of e-waste is done by dissolution in strong acids and burning. Such recycling results high air and soil pollution and later on these pollutants are received by the water bodies and get included in food chain. (Johri, 2008), (SVTC, 2002)

<table>
<thead>
<tr>
<th>Electronic / Electrical component</th>
<th>Pollutant Element</th>
<th>Hazardous Impact on Health</th>
<th>Hazardous Impact Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor Glass crushed in landfills, PVC, rechargeable batteries, lithium batteries, solar, transistors</td>
<td>Lead</td>
<td>Effects plants, animals and microorganisms, inhibits the functioning of particular enzymes in human body causing severe physiological or neurological effects, damage to the nervous system, kidney, reproductive system in human, blood system and the development of brain in kids.</td>
<td>Leaching into ground water and causes soil acidification.</td>
</tr>
</tbody>
</table>

4867
Sulphuric acids are used from circuit boards hydrochloric acid is flows into water bodies and affects the human food chain through aquatic. Mercury is used in mother’s milk, Affects the central nervous system, kidneys and immune system. Mercury in water bodies can enter the human food chain through aquatic.

Circuit boards contain heavy metals such as Cadmium, which causes cancer, softens bones, severe pain in the spine and joints and affects the kidneys. Mercury is used as a flame retardant in plastic, which is toxic to the skin and eyes. Lead, used in circuit boards, is a heavy metal that is toxic to the brain.

Printers and toner contain trace elements such as Lithium, which affects the kidneys. Sunlight can break down PVC to form dioxins in the soil.

Mobile telephones, photographic equipment, batteries, mother boards and printed circuit boards, finger clips switch boards and printed circuit boards, and plastic used in circuit boards contain heavy metals such as Beryllium, which causes lung cancer.

Environmental awareness towards Health and Environmental Pollution Due to E-Waste

Author attempt to understand how the awareness level of consumers, E-waste processing workers, NGO initiatives and Government policies have impact on the health and environmental pollution caused by e-waste. Increasing the level of awareness is vital for effective e-waste management. Therefore this research is significant to understand how health and environmental pollution due to e-waste could be managed.

Hypothesis of the study:
H1: There is a significant impact of the awareness level of consumers on the health and Environmental pollution caused by E-waste.
H2: There is a significant impact of awareness level E-waste processing workers on the health and Environmental pollution caused by E-waste.
H3: There is a significant impact of NGO initiatives on the health and Environmental pollution caused by E-waste.
H4: There is a significant impact of Government policies on the health and Environmental pollution caused by E-waste.

Research Methodology:
Respondents i.e. individual consumers, E-waste processing workers, NGO representatives and Government officials living in different areas of Pune city were contacted. Convenience sampling technique was used to select respondents.

Research Design:
In this study exploratory research design has been followed to find the impacts of level of Awareness of various stakeholders towards health and environmental pollution caused due to E-waste. According to Environment Protection Agency report on India, Pune is among top 10 cities generating e-waste, hence chosen as the study area.

Data Collection:
In the present research both primary and secondary data has been used. Primary data is collected through Survey method. The instrument used for the present study was a structured questionnaire. 3 questionnaires were designed to measure awareness levels of individual consumers, E-waste processing workers, NGO initiatives and Government officials. The secondary data like E-waste in India has been used to find out how E-waste is a major source of environment and public health hazard. The secondary data had also been used to find various E-waste management initiatives and their benefits.

Research Instrument:
A. Questionnaire for Individual consumer awareness level were taken to determine their consumption habits of household electronics, awareness regarding the presence of hazardous materials in electronics; awareness...
regarding government regulation of e-waste; and Perception on E-waste disposal like separate waste, spend high on products that are environmentally more sustainable. Response was taken to understand the structure of e-waste management systems, with support from government organizations and NGO in Pune city.

b. Questionnaire response from recyclers, dismantlers and formal and informal collectors were conducted as well. Response to determine the awareness towards occupational hazards, their perspectives on household waste disposal practices, their opinion about which stakeholders should be primarily responsible for E-waste management and the significance of the role of our Government.

c. Responses from NGOs were taken to understand whether E-waste Management is a priority at individual level or Government level, Significance of the contribution of unorganized sector in E-waste management, Mass awareness of the policies and regulations and compliance of companies and individual with policies and regulations.

d. Responses from Government official were taken to get insights about the policies and regulations in force with additional points similar to NGO questionnaire.

All these variables are measured using Interval scale i.e. 5 point likert scale.

Sample Size:
A sample of 300 individual consumer respondents, 46 E-waste processors, 5 NGOs and 30 Government officials from different localities of Pune city were selected on the basis of non-probabilistic convenience sampling.

Data Analysis and Results:
We have used K-S test, Cronbach alpha test and Regression Analysis Technique to analyze the primary data collected.

1. K-S test to check the Normal distribution of measured variables

<table>
<thead>
<tr>
<th>Table1: K-S test for Normality</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-S test for Normality</td>
</tr>
<tr>
<td>Consumers Awareness about E-waste mean</td>
</tr>
<tr>
<td>E-waste Processing workers Awareness about E-waste mean</td>
</tr>
<tr>
<td>NGO initiatives mean</td>
</tr>
<tr>
<td>Government Policies mean</td>
</tr>
</tbody>
</table>

a. The Significance value for Consumers Awareness about E-waste, E-waste Processing workers Awareness about E-waste, NGO initiatives and Government Policies is > 0.05 thus all the values are normally distributed.

2. Cronbach Alpha reliability measure:
The reliability test was conducted on the questionnaire designed to elucidate good reliable responses from the respondents.

<table>
<thead>
<tr>
<th>Table 2: Cronbach Alpha test for reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
</tr>
<tr>
<td>Consumers Awareness about E-waste</td>
</tr>
<tr>
<td>E-waste Processing workers Awareness about E-waste</td>
</tr>
<tr>
<td>NGO initiatives</td>
</tr>
<tr>
<td>Government Policies</td>
</tr>
</tbody>
</table>

a. Cronbach’s Alpha for reliability of measuring Consumers Awareness about E-waste, E-waste Processing workers Awareness about E-waste, NGO initiatives and Government Policies greater than 0.6 is established.

The results propose that the questionnaire is a suitable tool for understanding the impact of E-waste on environment pollution.

3. Multiple Regression Analysis
Multiple Linear Regression technique was used for the analysis of the primary data collected as shown below:

<table>
<thead>
<tr>
<th>Table 3: Model Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

This table provides the R, R², adjusted R², and the standard error of the estimate, which can be used to determine how well a regression model fits the data.

The "R" multiple correlation coefficient is measure of the quality of the prediction of the dependent variable; in this case, environmental pollution due to e-waste. A value of 0.795, in this example, indicates a good level of prediction.

The "R Square" called the coefficient of determination, which is the proportion of variance in the dependent variable that can be explained by the independent variables. The value of 0.632 that our independent variables explain 63.2% of the variability of the dependent variable i.e. Environmental pollution due to awareness level consumers, e-waste processors, NGOs and Government officials.
a. Statistical significance

The $F$-ratio in the ANOVA table

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>$F$</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>2.558</td>
<td>3.853</td>
<td>3.464</td>
<td>0.028</td>
</tr>
<tr>
<td>Residual</td>
<td>4.431</td>
<td>18.246</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6.989</td>
<td>21.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table shows that the regression i.e. the predictability of this model is 0.853 while the residual i.e. the error is 0.246. The $F$ value is significant at 0.028 i.e., $p < 0.05$ (i.e., the regression model proposed by the researcher is a good).

b. Estimated model coefficients

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>2.470 (926)</td>
<td>2.669 (0.016)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumers Awareness about E-waste</td>
<td>0.679 (427)</td>
<td>0.770 (5.89)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-waste Processing workers awareness about E-waste</td>
<td>0.312 (548)</td>
<td>0.270 (2.569)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NGO initiatives</td>
<td>0.287 (162)</td>
<td>0.125 (1.873)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government Policies</td>
<td>0.129 (142)</td>
<td>0.107 (1.364)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

i. The $t$ value for consumer awareness about e-waste is significant at 5% hence we reject the null hypothesis that there is no significant impact of consumer awareness about e-waste on environmental pollution due to e-waste. We accept the alternate hypothesis there is a significant impact of consumer awareness about e-waste on environmental pollution due to e-waste.

ii. The $t$ value of e-waste processing workers awareness is significant at 5% hence we reject the null hypothesis that there is no significant impact of e-waste processing workers awareness on environmental pollution due to e-waste.

iii. The $t$ value of NGO initiatives is significant at 5% hence we reject the null hypothesis that there is no significant impact of NGO initiatives on environmental pollution due to e-waste.

iv. The $t$ value of Government policies is significant at 5% hence we reject the null hypothesis that there is no significant impact of Government policies on environmental pollution due to e-waste.

a. Durbin Watson test

<table>
<thead>
<tr>
<th>Model</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.795</td>
<td>.632</td>
<td>.496</td>
<td>2.224</td>
</tr>
</tbody>
</table>

Table 6: Model Summary

The independence of observations i.e. independence of residuals is established by Durbin Watson statistics which is 2.224.

Findings and Discussion

1. As per the table 3, the $R$ Square” the coefficient of determination, this is the proportion of variance in the dependent variable that can be explained by the independent variables. In this study independent variables explains 63.2% of the variability of our dependent variable, Environmental pollution due to E-waste.

2. The $F$ value in the table 4 is significant at 0.028 the regression model proposed by the researcher is a good fit of the data.

3. Consumers Awareness about E-waste, E-waste Processing workers Awareness about E-waste, NGO initiatives and Government Policies were found to be positively impacting the environmental pollution due to E-waste.

4. Table 5 shows Coefficient values with the information on each independent or the predictor variable. The coefficient for Consumers Awareness about E-waste, E-waste Processing workers Awareness about E-waste, NGO initiatives and Government Policies is significant at 0.05; hence we reject the null hypothesis and accept the alternate hypothesis.

5. The results arrived at by the researcher can also be attributed to the small sample size. Also the response given by the respondents were not given accurately and spontaneously.

6. 100% of respondents mentioned that they used computers or laptops and mobile phones, while 92% indicated that they used computers/ laptops and mobile. Consumers in Pune purchased a computer every 3.2 years and new mobile phone approximately every 1.9 years.

7. Up gradation to the latest technology is the motive for 81% consumers to purchase latest electronic items. 26% favored to keep unused electronics at their home whereas 69% respondents sold or gave their goods to known person in need. 61% consumers planned to reuse / repair / upgrade unused electronic goods, some respondents kept unused electronics to be a source of spare parts. 27% of consumers knew of formal collection services such as SIMS Recycling Solutions and Hi-Tech Recycling India (P) Ltd while 73% of
consumers were not aware of electronics collection service in Pune city and had knowledge about the informal services. 65% of respondents did not perceive any health or environmental hazards to e-waste. 89% of consumers were not knowing about any organizations in place to handle e-waste or government policies.

8. 95% consumers mentioned to get good money in exchange of their electronic goods. 89% consumer felt insecure about the data present on their unused electronics which prevented them from disposing it.

9. E-waste processing workers reported that very small amount of dismantling activity occurred in Pune. The entire amount of e-waste from Pune is transported to Mumbai Municipal Region (MMR) for dismantling and further supply to Delhi market.

10. Most respondents from NGO, government bodies, and the formal e-waste processing sector reported about low public awareness of health and environmental pollution due to e-waste. Lack of public awareness regarding the hazards of e-waste was the major obstacle for the proper e-waste management. Also some respondents reported about the lack of proper collection and monitoring system for improper disposal of e-waste.


11. 89% of respondents reported that E-Waste Rules of 2011 did not penalize illegitimate e-waste processing. 90% respondents felt that producers should take the responsibility of their goods to be recycled. There is massive mismatch in the amount of e-waste to be collected and disposed and authorized recyclers required. There are very few collection points and within Pune. Consumers are not encouraged to hand over e-waste to the formal sectors by giving them some monetary benefits.

E-Waste Management by Various Stake-Holders

United Nations 2014 report, reported that 1.7 million tones of e-waste is generated in India. Central Pollution Control Board (CPCB) should coordinate with State Pollution Control Boards for collection and compilation of data regarding numbers of producers, collection centers, dismantlers and recyclers authorized in each state as per the CAG report (2015). Formal recyclers are approved and registered by the state board.

E-waste Rules, 2011 had the Extended Producer Responsibility (EPR) to be implemented. Under EPR, producers of electronic goods are mandated to manage the ‘end of life’ of goods. Thus, even after consumers discard the electronic goods, the producers are responsible to collaborate with the government to collect e-waste and organize systems to process it scientifically. The CAG report though has noted that CPCB set up a committee to formulate EPR mechanisms only in May 2015, a good three years after E-waste Rules, 2011, came into effect.

Disposal and Recycling of E-waste and associated environmental contamination

Recycling a product from landfill results in the preservation of valuable resources such as gold and silver, landfill reduction also toxic chemicals in municipal waste will reduce (American Chemical Society, 2007). The cost of extracting the valuable materials in e-waste would be more than the value of the material extracted. (Mining Innovation, 2002).

Formal E-Waste Management

Ministry of Environment and Forests (MoEF) through the State Pollution Control Board (SPCB) registers and licenses formal e-waste recycling facility operating in India. The formal set-up consists of electrical and electronic equipment manufacturers, logistics companies, and recyclers.

Informal e-waste management services

The informal sector is well established in India and comprises scrap dealers, wholesale dealers, and recyclers. Consumers sell old, unwanted electrical and electronic equipment to a small scrap dealer in their area for a nominal price. The small dealer either sells it directly to a recycler or to a wholesale scrap dealer. The wholesale dealer dismantles and segregates the e-waste and sells it to informal recyclers.

Conclusions

1. Pune industrial belt is one of the electronic items manufacturing hubs of India. The main e-waste operations undertaken in Pune were collection and transportation of e-waste to Mumbai and physical extraction of copper wire from cables. Dismantling activities reported were limited. E-Waste collection, transportation, track inventory and disposal did not have any formal mechanism in Pune.

2. E-waste recycling methods were threat to not only the environment but also human and animal health. The formal and informal sector should be integrated to develop an environment-friendly infrastructure for e-waste recycling. Contribution of informal sector in e-waste recycling should be recognized.

3. E-waste management could become effective by promoting EPR, recycling e-waste, creating awareness about safe disposal of e-waste, developing the infrastructure for safe e-waste recycling, regulating imports of e-waste and implement strict Government regulations and Policies. Government should set up regulatory agencies in each district for the coordination with various government authorities regarding e-waste.
4. Electrical and electronic equipment manufacturers should take responsibility of educating consumers regarding the threats of e-waste. Producers should ensure the safe disposal of the equipments produced by them. Materials used in manufacturing should be easy to re-use and recycle and, most importantly, should contain zero to very minimal hazardous components also should label products mentioning the material used.

5. The e-waste management market is very under penetrated and offers immense potential for recyclers. Various business opportunities exist for new and existing companies across the value chain-from collection to segregation, to dismantling to recycling.

6. EPR implementation should mandate the domestic producers and importers to finance the e-waste collection and treatment systems. Producers/importers of e-waste should become members of a take-back company and have to pay a fee for their membership to the take-back companies. This is how it could provide the funding for collection and treatment of the waste. Producers should safer technologies for producing electronic items devoid of toxic metal oxides.

7. Consumers should choose to upgrade their devices rather than purchasing new devices. The task to create awareness should be taken up by agencies like Municipal Bodies/State Pollution Control Boards/ Central Pollution Control Board. Financial assistances is offered by MoEF for conducting trainings, workshops, conferences on issues related to e-waste management through industrial associations, CPCB, SPCBs and reputed institutions.

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Website:


4872
Articles:


