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Electronic Products and E-Waste Management –an approach to minimize & Regulate e-Waste in country, India.

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Big industries approach towards producing a newer product each time dismissing the earlier product as discarded is basically a wrong concept. Instead, they should ensure utility of earlier products with minor modifications to keep the earlier products viable; thus avoiding the e-waste generation.

To be more explicit today in market all older Personal Computers are treated as waste. Perhaps R&D could have created some solutions to make them compatible with recent models with minor modifications, alteration, or through modular approach. Humankind has to learn that reusability is an essential part of living.

Approach of western world to use and throw has been in conflict with the same that has resulted into mountains of wastes everywhere, particularly in third world countries.

Reutilization of electronic products should be encouraged, which had been practiced earlier by elders. The industries generating these products must look the product life cycle starting from its creation till its disposal. The calculation of products cost should be done with a view of products life cycle. Reutilization is very vital concept and need to be implemented in electronic waste specially to reduce load of this type of garbage on earth.

Electronic waste management has become a gigantic task. The problem needs to be addressed critically. Author feels that use and throw approach has been the main reason behind this problem and suggests reutilization/useful modifications of existing system. Author has deliberated upon areas relating to automotive power management, data processing heavy machinery to illustrate utility of principles.

Authorities responsible for environment and environmentalists have already taken up the issue regionally, and have formed guidelines or are in the process to do so, for the disposal of e-waste in conjunction with electronic industry. Key problems of implementation of such guidelines and its financial implications have been deliberated upon in the paper.

Keywords: e-Waste, electronic waste, CPCB: Central Pollution Control Board.

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1.0 OBJECTIVE

Objective of this paper is to place the state of e-waste management as on date in the country like India, where regulations have been framed for disposal of e-waste, health effects of e-waste are informed, requirement of developing formal e-waste recycling facilities stressed and management techniques exploring regulation of such problems are being proposed.

2.0 INTRODUCTION

E-waste, e-scrap or waste electrical and electronic equipments are phenomena's of today's world, which have touched upon the internal chord of environmentalists and in general mass. The term e-waste generally describes both electronic and electrical wastes. That means, any item which is based on an electric current or an electromagnetic field to operate it and contains a hard-drive or magnetic drive and other electronic components like printed circuit board (PCBs) etc. electronic switches fall in this category.

Rapid technological changes, changes in media types (electronic tape medias, software, MP4), rapidly declining prices, and planned obsolescence have resulted in a fast-growing surplus of electronic waste all around the globe. The most expensive TV, phones, Computer CRT, Cellphones, electronic games become old and useless due to rapid change in technology, lack of maintenance support, high maintenance costs. At the same time changes in media and falling prices converts electronic gadgets to garbage and called e-waste. Increasingly, smaller and cheaper electronic items are being easily disposed off in municipal waste. According to UNEP, waste from electronic and electrical equipment (WEEE) is becoming a significant component of the waste stream, increasing at a rate of 3–5% per annum, outstripping the general growth rate of the municipal waste. This means that electronic and electrical wastes are being significant in ratio to deal with by Local Government's waste management. It is the fastest growing component of municipal waste and is a challenge to authorities to dispose it off in the Environmentally sound manner. Hence it can be concluded that increase in both hardware and software consumption & their obsolescence have lead us to such stage.

A survey of local Councils within Queensland (Davis et.al 2008) was undertaken in order to determine the current level of understanding and action on e-waste, and to solicit key responses regarding the identification of areas where improvements could be made. Survey results identified key barriers experienced by Councils regarding the collection and treatment of e-wastes as being cost and geographical distances between source of generation (households) and the limited number of specialist reprocessors.

E-waste is the fastest growing waste worldwide. In a latest estimation, nearly 130 thousand computers and hundreds of thousands of cell phones per day are being thrown as waste in US alone and allowed to be exported to other countries with the policy adopted by newer generation "Newer is better and Older is out" the latest trends of the developing/ developed countries. Even the developing countries like India are not lagging behind in generating e-waste. According to a latest estimate the Mumbai city alone the estimated e-waste per annum is about 12000 tons annually followed by Delhi ~9000 tonnes followed by Bangalore ~4500 tonnes. Short products life span (less than two years) for many gadgets at an average 15% per year is going to double this hazard to become double over next five to six years. But even this figure must have been surpassed due to rapid and more and more effective gadgets introduction in the common man's life. Toxic substances used in these commodities get accumulated at one place(at recyclers place or at certain areas) and converts into hazardous substances above the allowed threshold limit at a location and contributes to degradation of environment in terms of air, water and soil pollution. The substances present in such quantities are lead, cadmium, chromium, mercury, poly vinyl chloride.

E-waste was considered to be a minor component at one point of time, which has become a serious health hazard as on date, having the most critical elements like lead, cadmium, beryllium, mercury, chlorinated and brominated poly vinyl chloride & flame retardants.

No processing/ dumping or and Informal processing of electronic waste in countries like India, China, Cuba is polluting our environment and causing serious health problems to workers and communities which is indirectly due to practices adopted by the developed countries like US, UK, Canada, Germany. E-wastes indirectly contribute to ambient air, water and soil pollution. Figures 1 & 2 are depicted here to show how e-waste is being handled in even some of waste handling facilities.

Figure1: Plastic removed from e-waste handling facility

Figure2: Recent Photo of e-waste

The voluminous amounts have been transported from developed countries like US, EU to under-developed or developing countries. This is because of big difference in e-waste processing cost between developed and developing countries. According to an estimate the single computer e-waste processing cost in US is approx. 30 US$, in Brisbane is approximately AU$8 for a CPU; AU$15 a monitor; AU$7–18 for a printer and AU$30 for a television (Davis et.al 2008) as estimated in year 2007 while it is just $2 in China or India. This cost difference attracts the transportation of e-waste to other countries for the revenue saving.

As per declaration in developing countries, it is said to be disposed in environmentally sound manner but, instead of that e-waste is being burnt in the open air, where all plastics gets burnt and materials are being removed physically by human beings and remaining waste/ashes are being disposed into water bodies. The rivers turn into ASH RIVERS. Figures 3, 4 & 5 show the same.

Figure3,4: Open Burnings of e-waste

Figure5: Burnt E-waste disposal in river

Figure 6: Crude process of Lead removal from e-waste.

The removal of components and metals from the e-waste is being done in crude way, as can be seen in Figure 6, where lead is being removed by heating, leading to very dangerous exposure of human being to carcinogenic lead. Similarly, instead of retrieving the carbon and other precious materials from picture tubes the carbon ash is being thrown into the river directly, which leads to pollute the entire water body having toxic elements. Once the trace elements gets into the water cycle, these enter into the human body and cause various cancerous and kidney diseases. Hence, proper processing and disposal of e-wastes has become the necessity of the hour especially in the countries like India.

Number of firms involved in the e-waste disposal, have grown in the world, but number is quite high in developing countries like India, China because of huge margins available in the business if disposal can be

done the way it has been mentioned above. But this margin is narrow, if e-waste disposal is done in environmentally sound manner. Special growth of such firms has been observed in the countries, where law is not properly defined for this new concept. Here, the processing cost is low, laws are yet to be framed, if already framed yet to be implemented or if laws are there, there are ways to flout these laws. In India, the direct import of e-waste is prohibited and similarly it will be in other developing countries also. But e-waste is being exported from the developed world as reusable second hand electronic gadgets.

E-waste is dangerous if dumped in dumpsites. As per one of the estimates in US on 9% of e-waste is being reused or recycled. The Australian Government's Productivity Commission Report on Waste Management (Commonwealth of Australia, 2006) highlighted the potential environmental impacts of batteries, phones and computers in landfill as "sources of heavy metals and other toxic compounds that can be mobilised in leachate"(Commonwealth of Australia, 2006). This will lead to soil & ground water contamination. In one of the recent studies it was found that plant uptake of weathered PBDEs (polybrominated diphenyl ethers (used as flame retardents)) in the soils of e-waste recycling sites and planting contributes to the removal of PBDEs in e-waste contaminated soils(Huang et. Al. 2011). PBDE may cause liver cancer and are dangerous for human health. So there may be ways to remediate contaminated sites but it is preferred not to contaminate soil itself.

3.0 EFFORTS MADE BY INDIA IN DEALING E-WASTES

3.a.National Policy and e-Waste Handling Rules in India

India has a National Environment Policy which is available at Ministry of Environment and Forests (MoEF), Government of India website http://envfor.nic.in/nep/nep2006e.pdf. Accordingly law is in place to ensure sustainable development process and at the same time it is facilitated through the guiding plans to recover and/or reuse the useful materials from waste generated from a process or/and from the use of any material (p-38 of NEP 2006). These guidelines are available at website of Central Pollution Control Board, Delhi www.cpcb.nic.in an autonomous body under Ministry of Environment and Forests and at the website of MoEF http://moef.nic.in/downloads/public-information/Draft%20E-waste-Rules%2030.3.10.pdf. Guidelines are framed for the disposal of e-waste in environmentally sound manner. Specific methods of treatment and disposal for specific wastes has been worked out according to hazard/risk potential of the wastes. At the same time law makers have made rules called e-waste (Management and Handling) Rules 2010 which are basically governed through "The Hazardous Wastes (Management and Handling) Rules, 2003", which defines, wastes as 'Hazardous' and 'Non-hazardous'.

These rules have been again modified in December 2010 with emphasis on individual's responsibilities and available at Ministry's website addressed at http://moef.nic.in/downloads/public-information/Modified%20Draft%20E-waste.pdf. Modifications are the part of evolutionary process to arrive at an applicable and sustainable system. These rules shall come in force from 01.01.2012 after the due legal process of the constitution of India.

These rules provide direction in this regard to all stake holders like e-waste generators, collectors, transporters, dismantlers, recyclers, consumers and bulk consumers, distributors, refurbishers.

4.0 ISSUES IN ENFORCEMENT OF RULES IN INDIA

Main issues in the enforcement of these rules are:

4.1 Collection of e-waste from society or from dustbins of Municipal Authorities

Collection of e-waste and its proper segregation is a challenging task. People sale these electronic gadgets to Waste collecting vendors popularly known as Kabari Wala in India. These people segregate the valued waste material from their know-how, based on the requirements of waste collectors purchasing waste from them. In the process the major reusable e-waste gets separated but it is done non systematically. Kabari Walas try to recover the waste in a crude manner by breaking

components openly, burning plastic waste directly during wee hours to collect the metal parts melted without caring air pollution, throwing waste chemicals directly into the river/pond water. Getting exposed directly to hazardous material, without knowing the implications. Such was the example when radio active material was found at certain location and played with the lives of people.

Another issue is mixing of e-waste in municipal waste, which is thrown in the Municipal dustbins. These dustbins are emptied in dhalaos (Place designated for waste collection in the urban areas) from where it is transported through trucks to waste disposal sites. Here, rag pickers (Persons collecting useful material and reselling to Kabari Walas) pick up the material, which can have some resale value and get themselves exposed to such a horrible smelling waste having garbage, and the area waste of every kind.

4.2 Management of identity of each electronic gadget

As per the developing countries culture, the machine having any possibility of repair will be repaired till its maintenance cost becomes higher than the 50% of the cost of same or better device in the market at any given point of time. Which means, all of its components gets opened several times and marking over them gets destroyed. Hence, the identification of electronic gadgets after the life cycle of the product becomes big problem. Some time it is observed that products become orphan, where manufacturers can not be identified, or has ceased trading completely or withdrawn from the market. Also the responsibility may not be accurately assigned due to differenced between existing market share and previous market share; additionally overseas importers do not wish to cco-operate.

4.3 Enforcement of extended producer responsibility

The actual manufacturer also does not like to bear with the responsibility of destruction of e-waste produced by them in environmentally sound manner, as the machine gets repaired several times and several components inside of it get changed. For example, the copper motor windings, sometimes being changed with aluminium, some of the critical components of automotive or electrical equipments are replaced by the components of other manufacturers by refurbishers & so on. In such case, the responsibility sharing becomes tough.

4.4 Enforcement of distributors & refurbishers responsibility

Considering the economic concerns, refurbishers are using one manufacturer's old instruments and utilizing as per their requirements and to make a different product as demanded by the market. And earlier they were not sharing any responsibility of proper disposal.

4.5 Enforcement of ensuring the return of gadgets to the manufacturers

The manufacturers are not accountable for collecting the products manufactured by them after product life cycle. The considerations for the same are to be done by the manufacturers as per their long term policy planning for the safe and sound e-waste disposal.

4.6 Creating awareness in mass

4.7 Safe transportation of e-waste

Transporters have to be made responsible for the fallout of e-waste during transportation. Unsafe transportation may cause dangerous health effects.

4.8 Handling of toxic components

The toxic components used in specific components and their actual quantity used is directly known to the manufacturers especially the trace quantity of hazardous metals. If it gets mixed with the complete waste then it will be a herculean task to recover these hazardous substances from the waste.

4.9 Scarcity of infrastructure

A number of firms mushrooming in the country for processing electronic wastes because of economic concerns. These firms are involved in the process of physical segregation, dismantling, size reduction. None of these firms has an integrated facility of completely recovering the useful material out of e-wastes. Hence, finally processed e-waste is being exported to the countries having such facilities. There are very few such integrated units in the world like one in GERMANY, CANADA, BELGIUM, etc. which means, the metal which could have been recovered and reused has been exported to other countries and is a serious concern. But such a system requires huge infrastructure for recovery. The margins in running such integrated plant are low in comparison to e-wastes' other processing systems.

In developing countries economic concerns are having the highest priority which plays significant role in case of e-waste also. Mostly e-waste is channelized through Kabari Walas, because profit margin out of waste is high to the individual selling the e-waste to a Kabari Wala in comparison to a recycler/dismantler. At the same time, the reusable components are sold in the grey market and provide good returns, which makes the business lucrative.

These dismantlers/ recyclers have huge profit margin in performing segregation and size reduction processes hence, purchasing e-waste from Kabari Walas through informal channel (Since, from formal channel profit margins are low) makes it a profitable business. Hence, one side these recyclers and dismantlers are not getting the material for processing formally and on other side through informal channel they have more profit. Hence, the business is on in the informal sector.

The rules framed for e-waste also cover the issue of municipal solid waste management through "The Municipal Solid Wastes (Management and Handling) Rules, 2000 and touches upon the Basel Convention which is the root of the such governing rules in place for the e-waste management in the world. There is a category wise distribution to identify electronic waste components.

The modifications in these rules have definitely covered the entire chain responsible for the safe disposal of electronic waste. Besides the product developers, transporters, dismantlers and recyclers other chain members, have been considered as important stake holders and mainly playing a big role in the market of developing countries like India where economics plays the crucial role.

5.0 HAZARDOUS MATERIALS IN E-WASTE & THEIR EFFECTS

According to an estimate (Watson et. al. 2010) only 10% of annually produced e-waste is recycled globally in recycling plants appropriately designed with eco-friendly approach. E-waste contains several toxic and allergenic metals as well as other toxic and harmfull chemicals. Such as Brominated flame retardents (BFR) and polychlorinated biphenyls . the hazardous components in e-waste include Cathode ray tube, Liquid crystal display (LCD) & Light emitting Diodes (LED), batteries, circuit boards, mercury containing equipments, plastics with BFRs. Some of the toxic metal used in the electronics are antimony, arsenic, beryllium, lead, mercury, nickel, thallium, cadmium, cobalt and indium. Several rare elements are also used (Frazzoli et al 2010). The depiction of possible attack points in the human body of some of the predominant hazardous components are shown in figures 7-10.

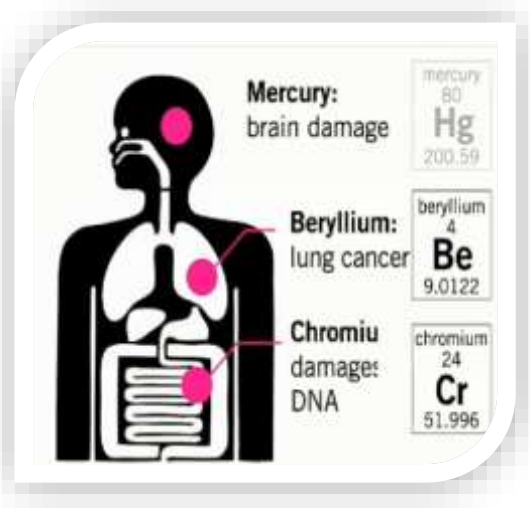

Figure 7: Hazardous substances Hg, Be & Cr effects on human being

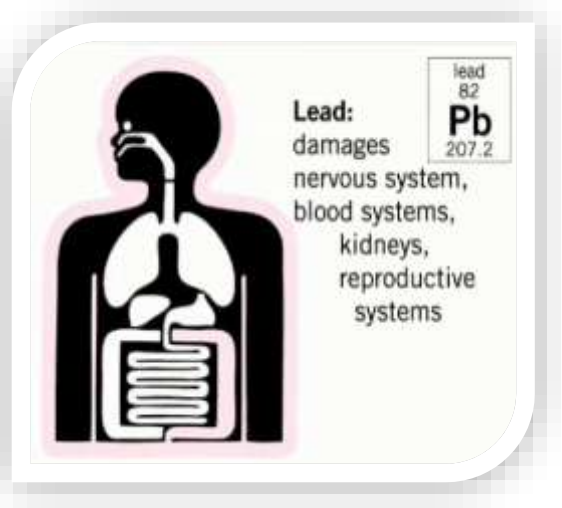

Figure 8: Hazardous substance Pb effects on human being

Figure 9: Hazardous substances Co & Ba effects on human being

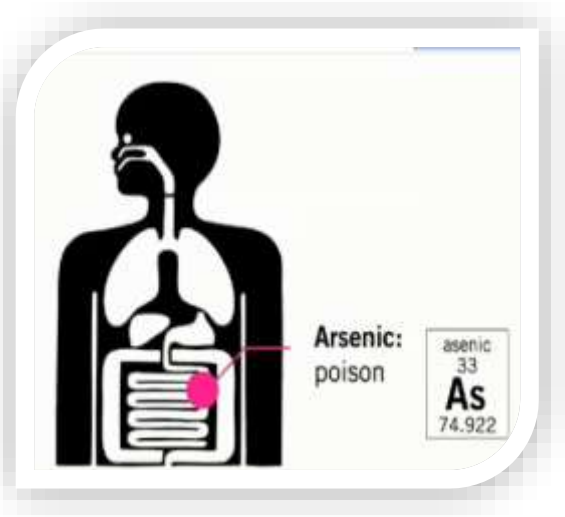

Figure 10: Hazardous substances As effects on human being

E-waste consists of carcinogenic substances, which effect human health and severely damages brain, lung, DNA, nervous system, blood system, kidney & reproductive systems. Predominant effects by various substances in human being are listed as below:

a. Mercury is responsible for Brain Damage
b. Beryllium causes lung cancer
c. Chromium damages DNA
d. Lead damages nervous system, blood systems, kidneys & reproductive systems
e. Cancer causing dioxins: Poly chlorinated and poly brominated dioxins.

While other substances like *Cobalt is radioactive*, *Barium is toxic* and *Arsenic is poisonous*. Even these substances in trace amounts may cause severe problems to human beings.

Most of these compounds are released during recycling. The workers are generally exposed through three different routes: inhalation, skin contact or ingestion(Grant et al 2013). The impacts of metals in surface matrices from formal and informal electronic waste recycling around Metro Manila, the Philippines, and intra-Asian comparison was studied (Fujimori et al 2012) by authors in 2012. The, exposure to heavy metals may directly influence the health of e-waste workers at the original site rather than the surrounding habitat and environmental media was studied by authors (Fujimori et al 2014). Contamination by trace elements at e-waste recycling sites in Bangalore & Chennai, India has been studied (Nguyen et al 2009). The contamination status was measured for trace elements in soil, air, dust, and human hair for trace elements like Cu, Zn, Ag, Cd, In, Sn, Sb, Hg, and Pb. The study concluded that male worker's hair were contaminated by trace elements and these workers are at high risk.

6.0 METHODOLOGY

In view of the seriousness of the problem efforts have been made by the authorities to develop guideline and rules in countries like India and these rules are called these e-waste management rules. The target is to develop mechanized treatment facilities, where e-waste is disposed in environmentally sound manner and material from e-waste be recovered optimally.

With the developing newer Cradle to Cradle concept (creation to disposal and again creation of product), problem of e-waste has been addressed from the root. Major players in the field have now understood the problem and have taken care through new concept. Major players are defining the cost of product considering cradle to cradle concept. Definitely the manufacturer is the one who knows what material is important and real revenue for him and at the same time he knows that what material is harmful in their product and needs outmost care while handling.

In nutshell, major players are now taking responsibility from end to end solution for the entire life cycle of the products. This will make the manufacturers responsible to the society and will make the best use out of waste material.

6.1 Responsible approach of manufacturers of Electrical and Electronics Industry: The manufacturers should bear responsibility in different means.

6.1.1 Technology based :

Humankind has to learn that reusability is an essential part of living. Author feels that there is a need of paradigm shift in the approach. Manufacturers should over rule the approach of declaring system old and having no use. Manufacturers should come up with a plan of maintaining the older systems and a possibility of technological improvement in the older systems at a lower cost than new system. Manufacture should take the responsibility of maintaining the systems and updating systems with the new technologies for nearly 5-7 years. This way developing or starting a relationship would mean development of a long term relationship rather than short term relationship (manufacture and forget) approach.

6.1.2 Parallel Computing for Speed enhancement in Personal Computers or peripherals

The systems developed today should be developed with an approach of parallel computing systems, where speed is updatable through the application of parallel systems for which technologically arrangements may be made in advance.

For example: if the computers today are having P-V systems then there should be a possibility of attaching a second CPU in the system so that further developing technological speed could be matched by little modifications in the existing systems. As being done in case of Servers where mother board is capable of having more number of CPUs on board and hence, speed of the system can be improved later by the introduction of another CPU on motherboard. This has to be ensured by the firm that the production of compatible CPUs continues for not less than 5-7 years from its date of sale.

6.1.3 Adding another module for capacity Enhancement in Uninterrupted Power Supply (UPS) Systems

Whenever required the capacity of system should be expandable. Example of such system could be like updating a UPS system having 1 or 2 or 5 KVA capacity today to 2 or 4 or 7.5 KVA capacities tomorrow by having the possibility of connecting a parallel system on its PCB for which necessary arrangements may be done today.

6.1.4 Speed enhancement of Gadgets

The provisioning in the system may be made such that the speed could be enhanced through adding more processors. For example, Computers becoming outdated should have arrangements or attachments possible to enhance its capacity to higher speed as and when customer desires to do so in its following five years. This will develop confidence in the system and sense of responsibility in the manufacturer and manufacturer than has to ensure that products of it's company do not go out dated in less than 5-7 years of time.

6.1.5 Use of best available technology (BAT) from environment point of view

Before selecting any item in its product a manufacturer should definitely see that at the end of life, how the material can be re-used or how better its reuse it. Some authors studied end of life of Cathode Ray Tube and TFTs (Rocchetti et al 2014) and related the burden on environment and possible energy recovery from CRT in terms of Kg of CO_2 saved for recovery of panel and funnel glass for the manufacturing of new CRT screens. They also studied recovery from TFT of, glass cullet and lead, for other applications. Recovery was converted in terms of Kg of CO_2 and it was estimated that recovery of secondary raw materials from CRT was 1Kg of CO_2 per CRT and 0.9Kg of CO_2 per TFT. Authors also addressed the recycling of yttrium from the fluorescent powders (Rocchetti et al 2013) as compared with the disposal of the powders in a landfill site for hazardous materials. The study concluded that recovery is environment friendly and economics confirms that TFT are the best available technologies in terms of

use and end of use as disposal. The benefits derived from the secondary raw material production are from the avoidance of primary raw material production (Noon et al 2011),(Koltun et al 2010), (Andreola et al 2007a,2007b,2008,2009,2010).

6.2 Responsible approach of manufacturers of Electrical and Electronics Industry: The manufacturers should bear responsibility in different means.

Similar approach is desired in the automobile and industrial sectors also. As the new vehicle is introduced parts of old vehicles become unavailable and hence old vehicle has to be abandoned due to lack of availability of spares especially, electronics hardware of which technology is not disclosed or not fully understood by other manufacturers. The main problem lies with the automotive power sectors.

Similar problems have been faced in the industrial sector, the manufacturers whose products fail in the market, have no obligation of maintaining the supplied systems for next 5-7 years with technological improvements.

7.0 SOLUTION

There are various ways and means to bring the hazardous compounds in the category, where disposal is subjected to be governed by law. These laws are having provisions to declare the material hazardous in terms of its being part of a defined hazardous process or having concentration or quantity, which may harm the health of human being normally. Besides these, separate provision can be made to deal with the import and export of such materials. Issues raised have been dealt carefully and solution proposed through rules are as under:

7.a Collection of e-waste from society or from dustbins of Municipal Authorities

Considering the Kabari Walas as stake holders in the process, registration and accountability of their work has been considered in the rules. After the implementation of rules, it will be mandatory for these Kabari Walas to register with the Authorities. Specific training may be imparted to them for e-waste disposal mechanism. At the same time, separate e-waste collection dustbins are being placed at various locations, specifically in the premise of offices/firms to keep it segregated at source itself. Once, this waste is definitely segregated, the interest of rag pickers will reduce and menace may be stopped.

7.b Management of identity of each electronic gadget

Refurbishers have been brought in the ambit of e-waste management. This will help in shouldering the responsibility of e-waste management.

7.c Enforcement of extended producer responsibility

Cradle to cradle approach is likely to resolve the issue.

7.d Enforcement of distributors & refurbishers responsibility

Distributors have been brought into the system and will have to be responsible for collection and safe disposal of e-waste. This will plug the gaps of the system.

7.e Enforcement of ensuring the return of gadgets to the manufacturers

The manufacturers have taken a keen interest in shouldering this responsibility as it is good for them and probably their expenses will overall reduce on the products in the long term.

7.f Handling of toxic components

The source of pollution can be tapped, if manufacturers take up this responsibility. Recovery of toxic components can be done in the range of 95-100% ensuring spreading of toxic components in the ambient. This will certainly help directly to the people involved in the e-waste recovery & in turn health impact can be improved.

7.g Scarcity of infrastructure

Integrated e-waste recovery facilities need to be developed in the country. This may change today's scenario. Due to lack of infrastructure, some recyclers are segregating the valuable metal bound lumps and sending these lumps to other countries for metal segregation. But it is done only when recyclers get its value otherwise the contaminated metal in the form of mixed lump is thrown into the river or in the open ground.

8.0 CONCLUSION

Presently, due to economic factors, recyclers or dismantlers are involved in single step processing, or involved in resale of parts in open market, where they get good returns. However, reuse is good thing, but non-systematic processing is leading to severe health impacts. The enforcement of the rules will develop a system having shared responsibilities of the society and e-waste management in environmentally sound manner. The system will evolve dynamic, seller of e-waste may be benefitted as manufacturers can also list down the components reusable from their various products and indirectly benefit of cost margins may be transferred to the seller instead of to middleman. At the same time the better utilization of reusable materials can be managed. The Kabari Walas shall become the distributors of the manufacturers for e-waste management and the system may be regularized. To manage entire e-waste actions could be initiated at four levels:

Level 1: Actions initiated at manufacturing stage focused on reducing the environmental footprint of production of the equipment and products developed with capacity enhancement.
Level 2: At the end of product life, involving extending product life and recovery of material resources by making producer responsible and
Level 3: Educating users to avoid purchasing short life items and encourage correct disposal.
Level 4: To create and implement rules in such a way that users are benefitted in financial terms which encourages the user to save the environment.

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