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E-Waste

Pravin Pathak
K. K. Wagh Polytechnic, Nashik, Maharashtra, India
pravin.pathak77@gmail.com

Abstract: *Growth in the IT and communication sectors has enhanced the usage of the electronic equipment exponentially. Faster upgradation of electronic product is forcing consumers to discard old electronic products very quickly, which, in turn, adds to e-waste to the solid waste stream. The growing problem of e-waste calls for greater emphasis on recycling e-waste and better e-waste management.*

Keywords: E-Waste, India, Recycling

I. Introduction to E-Waste

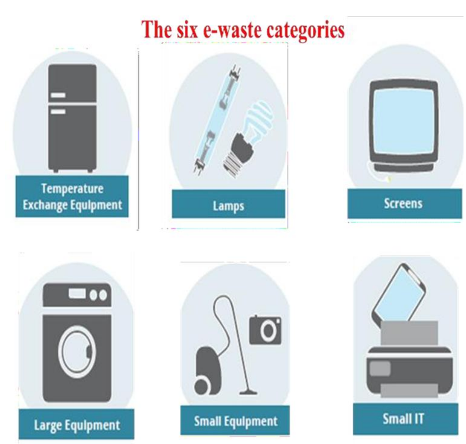
Electronic waste, or e-waste, refers to all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of re-use or have crossed the expiry date. Computers, servers, mainframes, monitors, compact discs (CDs), printers, scanners, copiers, calculators, fax machines, battery cells, cellular phones, transceivers, TVs, iPods, medical apparatus, washing machines, refrigerators, and air conditioners are examples of e-waste (when unfit for use). These electronic equipment get fast replaced with newer models due to the rapid technology advancements and production of newer electronic equipment. This has led to an exponential increase in e-waste generation. People tend to switch over to the newer models and the life of products has also decreased.

E-waste typically consists of metals, plastics, cathode ray tubes (CRTs), printed circuit boards, cables, and so on. Valuable metals such as copper, silver, gold, and platinum could be recovered from e-wastes, if they are scientifically processed. The presence of toxic substances such as liquid crystal, lithium, mercury, nickel, polychlorinated biphenyls (PCBs), selenium, arsenic, barium, brominated flame retardants, cadmium, chrome, cobalt, copper, and lead, makes it very hazardous, if e-waste is dismantled and processed in a crude manner with rudimentary techniques. E-waste poses a huge risk to humans, animals, and the environment.

Hazardous materials generally found in electronics waste are Arsenic, Beryllium, Cadmium, Nickel, Zinc, Antimony, Lead, Chromium, Etc. which Can cause damage to brain, lungs, and other organs. Lead especially toxic to developing children [Jackson]

Other Hazardous Materials may be Toxins found in the plastics, Brominated flame-retardants (BFR) added to plastics to reduce chance of fire, which may damage to sexual development and growth attributed to some BFRs [Jackson]

Equipment Category	% Composition (by weight)
Computer equipment	75
Telecommunication equipment	13
Entertainment equipment	3
Electrical equipment	4
Medical equipment	4
Other equipment includes household E-waste	1



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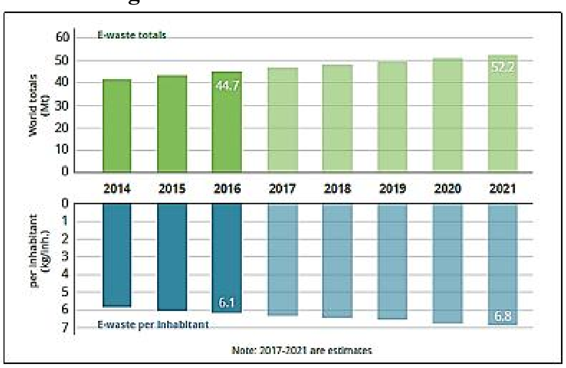
II. Global E-Waste Problem

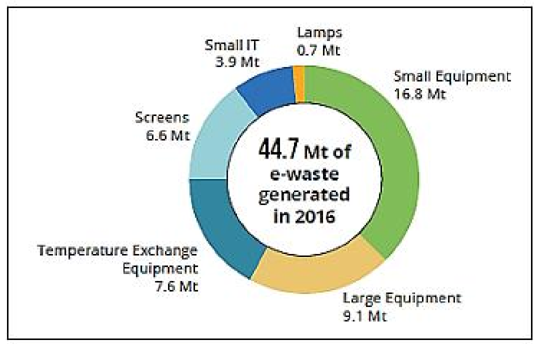
It is estimated that 50 million tonnes of e-waste was generated globally in 2018. The rate at which the e-waste volume is increasing globally is 5 per cent to 10 per cent yearly. In India, the volume of e-waste generated was 146,000 tonnes per year (Borthakur and Sinha, 2013). However, these data only include e-waste generated nationally and do not include waste imports (both legal and illegal) which are substantial in emerging economies such as India and China. The reason is that large amount of waste electrical and electronic equipment (WEEE) enters India from foreign countries. Switzerland is the first country in the world to have established and implemented a formal e-waste management system that has recycled 11 kg/capita of e-waste against the target of 4 kg/capita set by the European Union (EU).

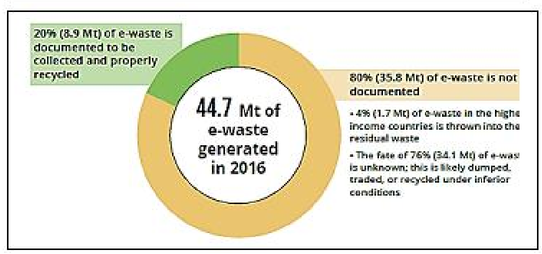
China, Peru, Ghana, Nigeria, India, and Pakistan are the biggest recipients of e-waste from industrialized countries (Mmereki, et al., 2016). The Basel Action Network (BAN) aims to ensure that e-waste is dealt with in an environment-friendly manner. It safeguards the planet from toxic waste trade. The BAN, Silicon Valley Toxic Coalition (SVTC), and Electronics Take-Back Coalition (ETBC) constitute an associated network of environmental advocacy NGOs in the US. The three organizations' common objective is to promote national- level solutions for hazardous waste management. A recent initiative has been e-Stewards, a system for auditing and certifying recyclers and takeback programmes so that conscientious consumers know which ones meet high standards.

In 2016, **44.7 million metric tonnes** of e-waste were generated. This is an equivalent of almost 4,500 Eiffel towers. Estimates of e-waste totals per category in 2016

Global e-waste generated



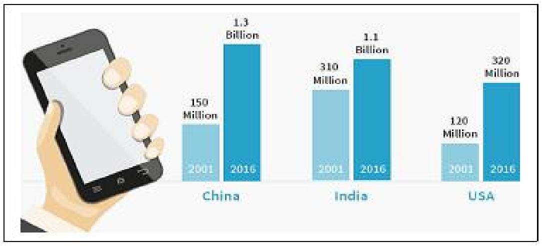


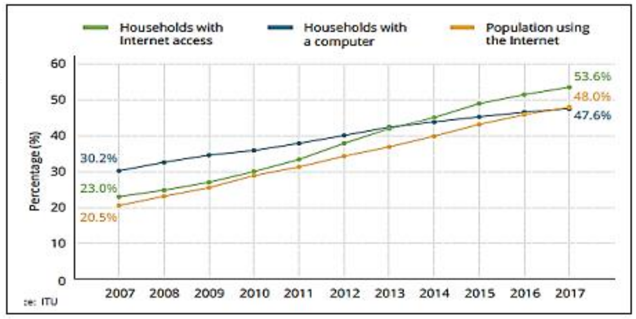


Globally, only 8.9 Mt of e-waste are documented to be collected and recycled, which corresponds to 20% of all the e-waste generated.

Of those 44.7 Mt, approximately 1.7 Mt (4%) are thrown into the residual waste in higher-income countries, and are likely to be incinerated or land-filled.

Countries with the highest mobile users.





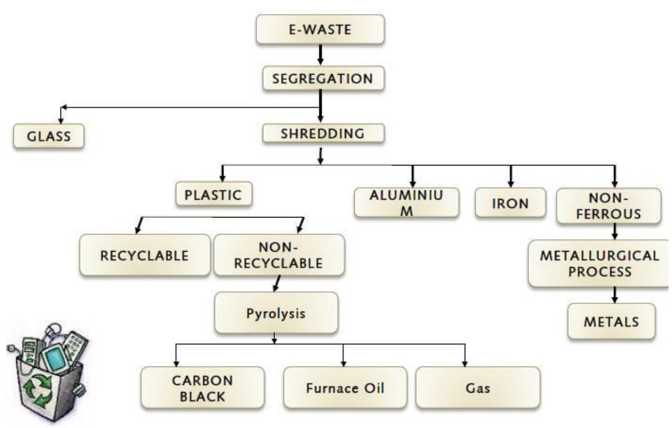
Percentage of households with Internet access and a computer, and percentage of the population using the Internet, 2007-2017

III. E-Waste Problem in India

India ranks 177 amongst 180 countries and is amongst the bottom five countries on the Environmental Performance Index 2018, as per a report released at the World Economic Forum 2018. This was linked to poor performance in the environment health policy and deaths due to air pollution categories. Also, India is ranked fifth in the world amongst top e-waste producing countries after the USA, China, Japan, and Germany and recycles less than 2 per cent of the total e-waste it produces annually formally. Since 2018, India generates more than two million tonnes of e-waste annually, and also imports huge amounts of e-waste from other countries around the world. Dumping in open dumpsites is a common sight which gives rise to issues such as groundwater contamination, poor health, and more. The Associated Chambers of Commerce and Industry of India (ASSOCHAM) and KPMG study, Electronic Waste Management in India identified that computer equipment account for almost 70 per cent of e-waste, followed by telecommunication equipment phones (12 per cent), electrical equipment (8 per cent), and medical equipment (7 per cent) with remaining from household e-waste.

E-waste collection, transportation, processing, and recycling is dominated by the informal sector. The sector is well networked and unregulated. Often, all the materials and value that could be potentially recovered is not recovered. In addition, there are serious issues regarding leakages of toxins into the environment and workers' safety and health.

General E-Waste Recycling Process



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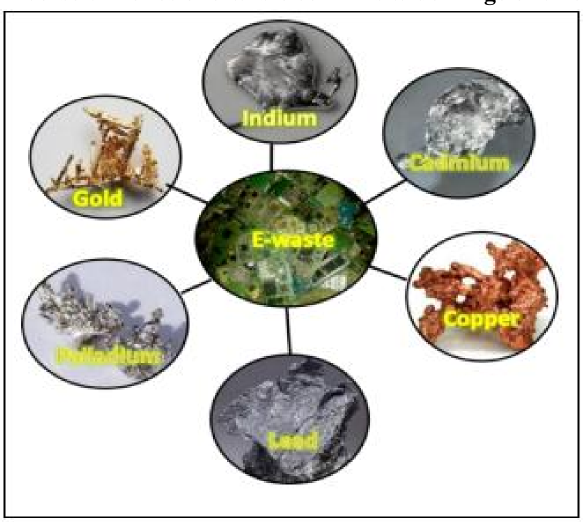
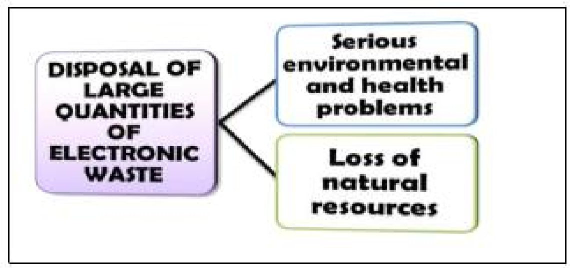
Current E-Waste handling techniques

Current wrong practices in the Informal sector

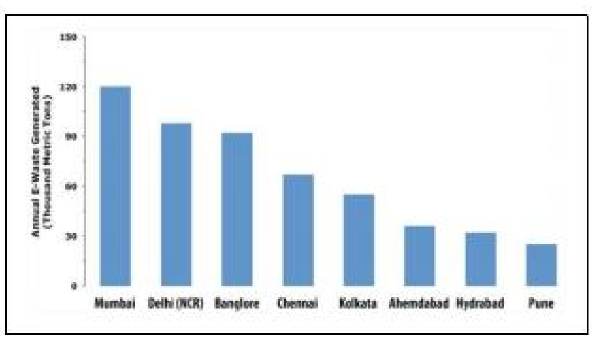
Diverse varieties of e-waste contains wide range of valuable & toxic substances





Seelampur in Delhi is the largest e-waste dismantling centre of India. Adults as well as children spend 8–10 hours daily extracting reusable components and precious metals like copper, gold and various functional parts from the devices. E-waste recyclers use processes such as open incineration and acid-leeching. This situation could be improved by creating awareness and improving the infrastructure of recycling units along with the prevalent policies. The majority of the e-waste collected in India is managed by an unorganized sector.

Also, informal channels of recycling/reuse of electronics such as repair shops, used product dealers, e-commerce portal vendors collect a significant proportion of the discarded electronics for reuse and cannibalization of parts and components.



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IV. Impact of Recycling E-Waste in Developing World

Almost all e-wastes contain some form of recyclable material, including plastic, glass, and metals; however, due to improper disposal methods and techniques these materials cannot be retrieved for other purposes. If e-waste is dismantled and processed in a crude manner, its toxic constituents can wreak havoc on the human body. Processes such as dismantling components, wet chemical processing, and incineration are used to dispose the waste and result in direct exposure and inhalation of harmful chemicals. Safety equipment such as gloves and face masks are not widely used, and workers often lack the knowledge and experience required to carry out their jobs properly. In addition to this, manual extraction of toxic metals leads to entering of dangerous material in the bloodstream of the individual doing so. The health hazards range from kidney and liver damage to neurological disorders. Recycling of e-waste scrap is polluting the water, soil, and the air. Burning to retrieve metal from wires and cables has led to the emission of brominated and chlorinated dioxins as well as carcinogens which pollute the air and, thereby, cause cancer in humans and animals. Toxic chemicals that have no economic value are simply dumped during the recycling process. These toxic chemicals leach into underground aquifer thereby degrading the local groundwater quality and rendering the water unfit for human consumption as well as agricultural purposes. When e-waste is dumped in landfills, the lead, mercury, cadmium, arsenic, and PCBs make the soil toxic and unfit for agricultural purposes. Very recent studies on recycling of e-waste has pointed towards increasing concentrations of PCBs, dioxins and furans, plasticizers, bisphenol-A (BPA), polycyclic aromatic hydrocarbons (PAH), and heavy metals in the surface soil of the four metro cities of India, that is, New Delhi, Kolkata, Mumbai, and Chennai where e-waste is being processed by the informal sectors (Chakraborty et al., 2018 and 2019). In those studies, it has been observed that the sites engaged in metal recovery processes are the prime sites for such persistent toxic substances. Studies from the same group also reported that the persistent organic pollutants produced or released during the recycling process are escaping in the ambient air due to their semi-volatile nature.

V. Regulations in India

Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008

Electronic Industry is part of Schedule I

The hazardous constituents of the e-waste are covered under Schedule II

Waste EEAs comprising of hazardous constituents are regulated for import purpose in Schedule III A

Waste EEAs without hazardous constituents and EEAs for direct reuse are regulated for import purpose in Schedule III B

Waste EEAs comprising of hazardous constituents are regulated for import purpose in Schedule III A

E-Waste Management and Handling Rules, 2011

Come in to force from 1st May 2012

The objective is to ensure environmentally sound management of E-waste generated from the end of life electrical and electronic equipments.

Applicable to the e-waste generated from IT and telecommunication equipment and Consumer electrical and electronic equipments as specified in Schedule-I

E-Waste Management and Handling Rules, 2016

The objective is to ensure environmentally sound management of E-waste generated from the end of life electrical and electronic equipment.

Applicable to the e-waste generated from IT and telecommunication equipment and Consumer electrical and electronic equipments as specified in Schedule-I

Recycling and responsibility of manufacturers extended

Stakeholders in E-Waste Rules

Producer

Consumer or bulk consumer Collection centre Dismantler

Recycler MoEF/CPCB/SPCB

E-Waste Management Scenario

Generation more than 800000 MTA

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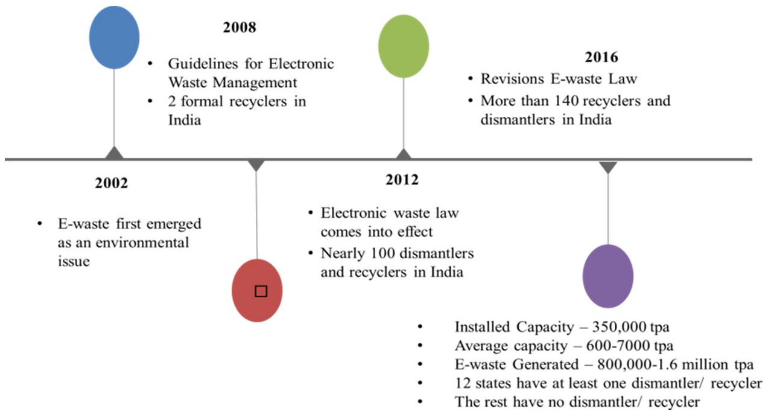
Authorized Producer - 35
Authorized Collection Centres - 76
Dismantler/Recycler - 98
Dismantling/recycling capacity - 293748 MTA

Evolution of E-waste management in India



Take Back Policy In India

Apple, Microsoft, Panasonic, Philips, Sharp, Sony, Sony Ericsson and Toshiba observes take back option at their production plant. (Not available in India)

Samsung claims to have a take back service but only one collection point for the whole of India, Other nine branded companies do not have take back service.

Two brands stand out as having the best take back practice in India, HCL and WIPRO Other brands that do relatively well are Nokia, Acer, Motorola and LGE.

The details of availability of take back service, service on ground reality and accessibility of information on take- back service in India is as follows.

Take Back Service on Ground in India		
Properly working	Partially Working	Not Working At All
Acer , HCL, WIPRO	LG Electronics Motorola and Nokia	Dell, Hewlett-Packard (HP), Lenovo and Zenith
Accessibility of Information on Take-Back Service in India		
Easily Accessible	Partially Accessible	Not Accessible
HCL and WIPRO	Acer, Lenovo, Motorola, Nokia	Dell , LG Electronics and Zenith

Source: An Assessment of E-waste Take back in India- , www.designouttoxics.org

Composition and Characteristics of E-Waste

The various parts/materials/ composition of e-waste may be divided broadly into six categories such as
Iron and steel, used for casings and frames
Non-ferrous metals, especially copper used in cables, and aluminum Glass used for screens, windows
plastic used as casing, in cables and for circuit boards Electronic components
0thers (rubber, wood, ceramic etc.).

VI. Opportunities of E-Waste Management in India

The Ministry of Environment, Forest and Climate Change rolled out the E-Waste (Management) Rules in 2016 to reduce e-waste production and increase recycling. Under these rules, the government introduced EPR which makes producers liable to collect 30 per cent to 70 per cent (over seven years) of the e-waste they produce, said the study.

The integration of the informal sector into a transparent recycling system is crucial for a better control on environmental and human health impacts. There have been some attempts towards integrating the existing informal

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sector in the emerging scenario. Organizations such as GIZ have developed alternative business models in guiding the informal sector association towards authorization. These business models promote a city-wide collection system feeding the manual dismantling facility and a strategy towards best available technology facilities to yield higher revenue from printed circuit boards. By replacing the traditional wet chemical leaching process for the recovery of gold with the export to integrated smelters and refineries, safer practices and a higher revenue per unit of e-waste collected are generated.

E-waste is a rich source of metals such as gold, silver, and copper, which can be recovered and brought back into the production cycle. There is significant economic potential in the efficient recovery of valuable materials in e- waste and can provide income-generating opportunities for both individuals and enterprises. The E-Waste Management Rules, 2016 were amended by the government in March 2018 to facilitate and effectively implement the environmentally sound management of e-waste in India. The amended Rules revise the collection targets under the provision of EPR with effect from October 1, 2017. By way of revised targets and monitoring under the Central Pollution Control Board (CPCB), effective and improved management of e-waste would be ensured

Suggested Good practices for Recycling Use of Occupational Health & Safety equipment's segregation and storage

protective glass, mask and gloves

fire extinguisher and first aid kit

storage of received material

storage boxes for large size segregated material

service room

computer testing

dismantling of non-functional appliances

dismantling of CRT tubes

segregation of CPU components

tools used for dismantling and segregation

hood

CRT dismantling area

cyclone and dust collector

6 m high chimney

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Functional Testing Dismantling Scrap Recovery Pollution control equipment's Storage of hazardous waste

Modern Recycling Plant

Formal Recycling should be as follows:-

Collection of e-waste Segregation/separation of components Physical beneficiation

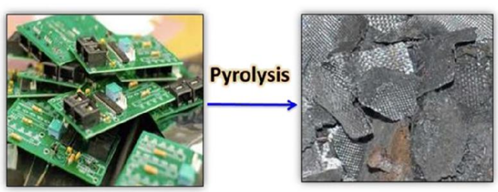
Recovery of valuables following

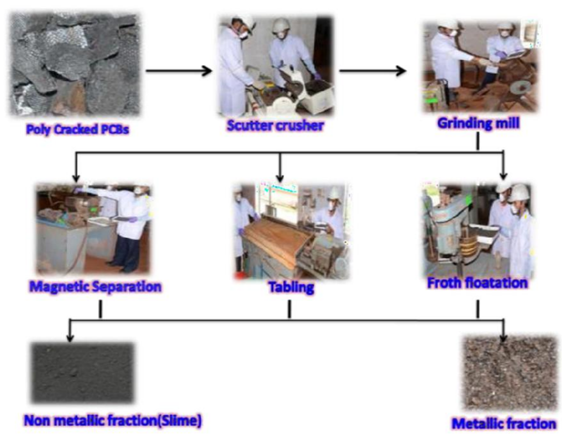
Pyro / hydrometallurgical techniques

Poly cracked ash of PCBs

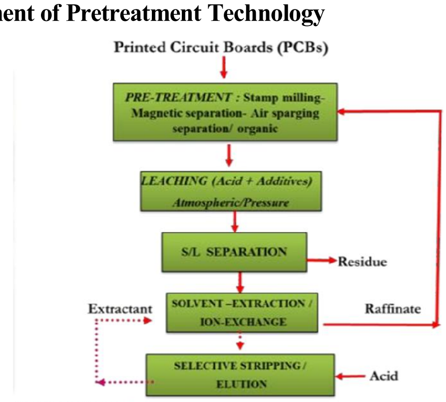
Poly cracker ash is generated during poly cracking practices of depopulated PCBs and plastic components.

General process flow-sheet for the recycling of metals from waste PCBs





Development of Pretreatment Technology



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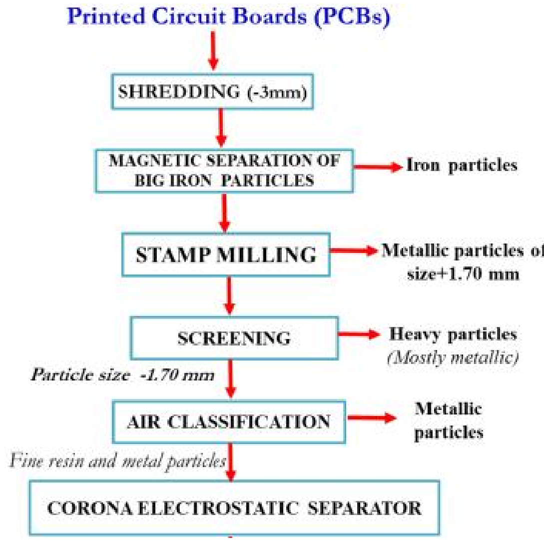
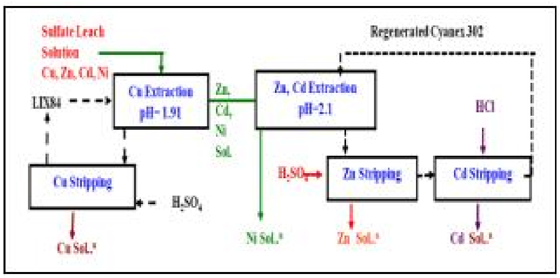
Flow sheet for the Pre-treatment of PCBs for the beneficiation



Liberation of resin=70% only



1. Process for the removal of hazardous metal elements from leach liquor of electronic scraps following solvent extraction and recovery of valuables.

2. Recovery of Pb and Sn from the liberated resin of PCBs swelled by organic

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Treatment of Effluents

Acidic fumes generated during metal dissolution can be absorbed in scrubbing solution

The effluent left after process can be detoxified by electrolytic as well as chemical oxidation. Precautions

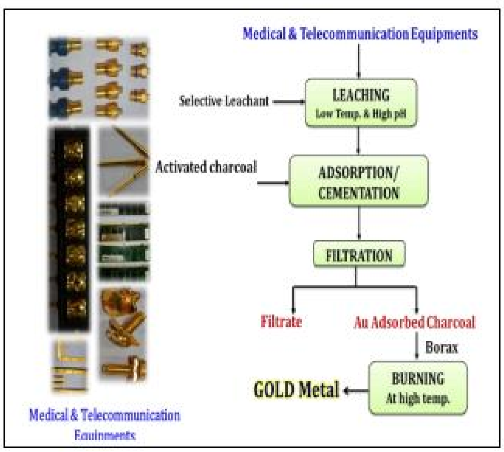
A gas mask should be worn to prevent the any inhalation Fume hood chamber is used for experimental work.

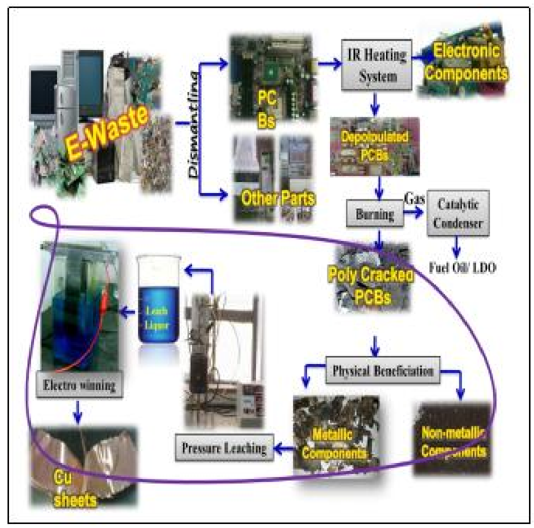
Good ventilation is strongly recommended. Recovery of Copper from Poly-cracked PCBs

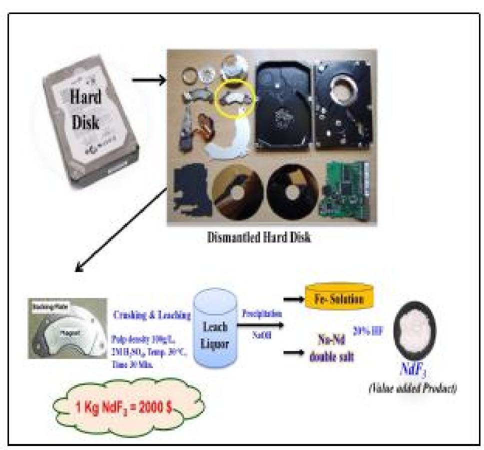
Recovery of gold from the scrap of telecommunication and medical devices

Recovery of Copper from Poly-cracked PCBs

Recovery of gold from the scrap of telecommunication and medical devices







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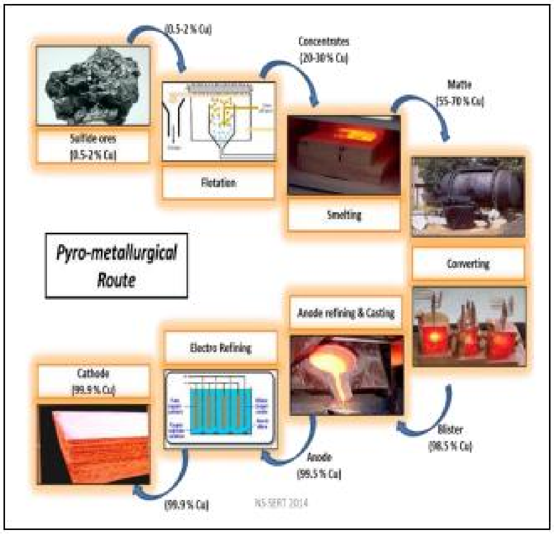

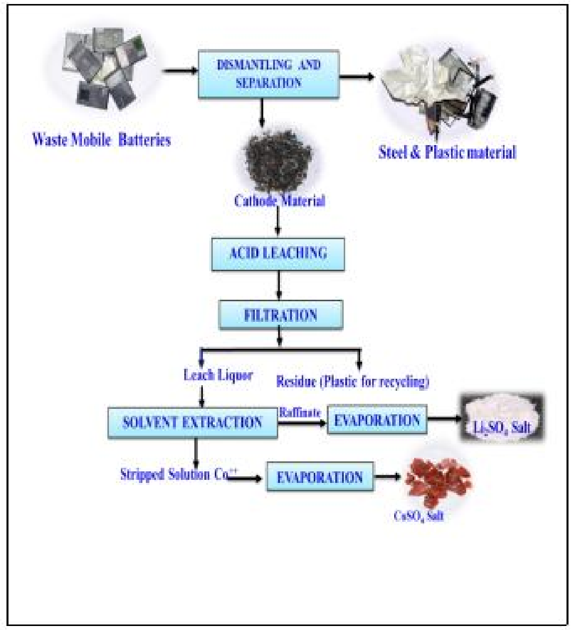

Process for the recovery of Co and Li from waste mobile batteries Copper Extraction
Column flotation technology
Recent success story and research directions
150 tpd flotation column of NML for sillimanite beneficiation at OSCOM
Automated columns up to 150 tpd
Columns field tested for sulphide ores, beach sands, bauxite, limestone, iron ore etc
Commercial technology – operational in various Indian plants (e.g. GMDC, HZL, HCL, KIOCL and IRE Ltd.)
Research Directions
> 2.5 m dia columns Spargers for large columns New applications/ reagents
About Birla Copper
Cu-1 Unit: Outokumpu Flash Smelter - PS Converter
Cu-2 Unit: Ausmelt (On hold)
Cu-3 unit: Mitsubishi Continuous process

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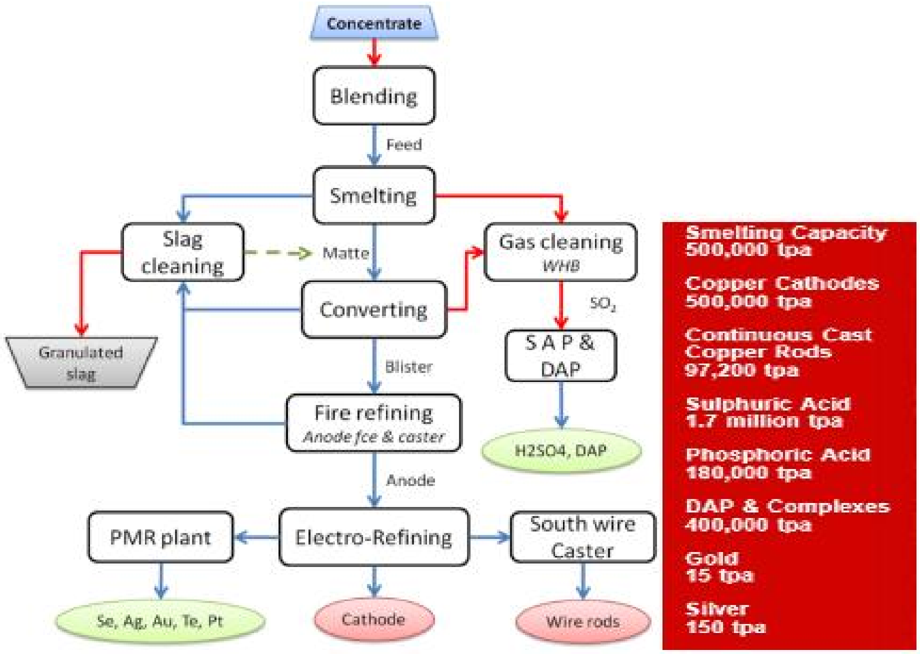
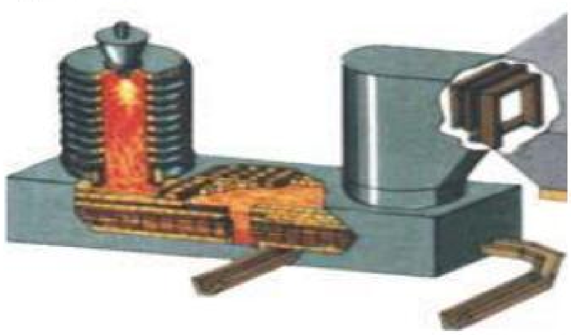
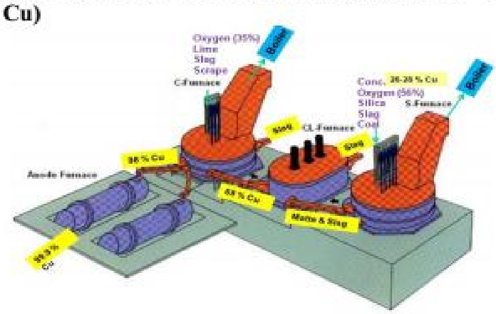


High dust rate
Low operating cost
Widely employed technology
High oxygen utilization
Outokumpu Flash Smelting
RS Height: 6 m (IH)
RS Diameter : 3.6 m (ID)
Settler Height : 1.9 m (IH)
Settler Length : 17.7 m (IL)
Settler Width : 5.4 m
Uptake ID : 2.7 m

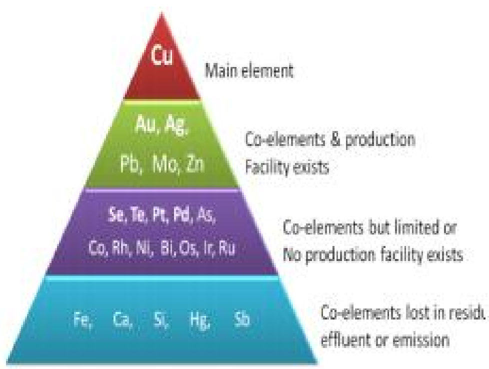


Mitsubishi Process
Commissioned in March, 2005 with the capacity 250000 TPA
High speed reactions in the furnaces ensure high recovery ratios of Cu
Distribution of lances ensures proper distribution of feed through out the furnace
Versatile process - can handle raw materials having Cu concentrate within 25-40%
Low copper content in discard slag (0.6 to 0.8 % Cu)

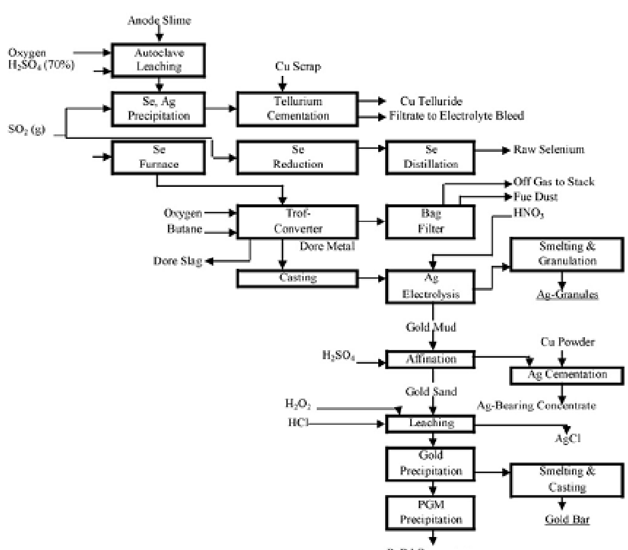


Ausmelt / Isa-smelt Smelters
Low capital & operating cost
Highly automated control
High productivity
Submerged lance process
Copper Smelting : By-products
More valuable but market price more volatile
Types :
Sulphuric acid
Metals
Gold, Silver, Cobalt, Molybdenum
(worth >10% of overall revenue)
Selenium, Tellurium, Platinum group,
Nickel, Zinc, Rhenium, Bismuth
Challenges in by-product recovery:
Not present in ore/concentrate
Main processing techniques prohibit extraction
Outside core business
Technology not available
Extraction not economic

ICSG: Study of Risk Factors in Developing Mineral and Metal Projects , Peter Willis, Senior Economist Oakdene Hollins, Oct 2013



By-product recovery process



Recycling by Indian copper smelters
Infrastructure & expertise already available for extraction of Copper, Gold, Silver, Selenium, Tellurium
Copper scrap
Electrical scrap, Mattes, Anodes, Cathodes No E-scrape recycling
Global Scenario : E-scrape processors Copper Smelters
Boledin, Sweden Umicore, Belgium Aurubis, Germany Xstrata, Canada Dowa, Japan
Biggest "competitors" Exports to China and Africa
Waste deposal instead of recycling
Noranda Copper Smelter, Canada
The smelter recycles about 100,000 tonnes of used electronics per year, representing 14% of total throughput
J. Cui, L. Zhang / Journal of Hazardous Materials 158 (2008) 228–256

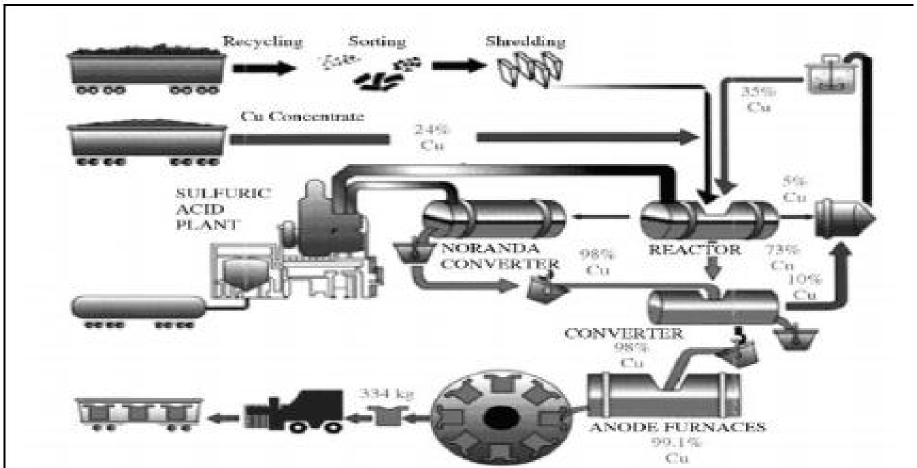


Fig. 1. Schematic diagram for the Noranda Smelting Processing [32].

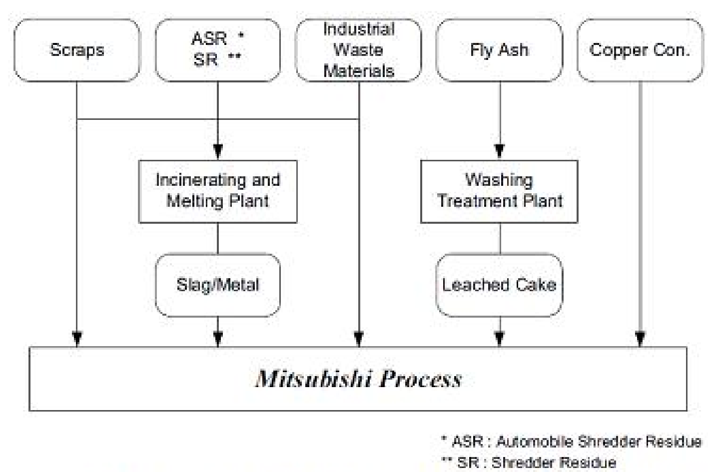


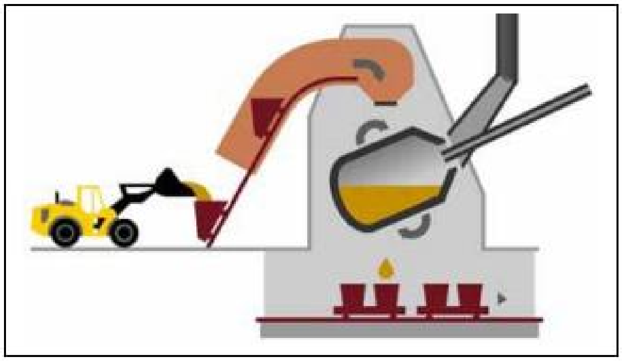
Figure3. Schematic flow sheet of recyclable material treatment at the Mitsubishi Process

NS-SERT 2014

Major concerns discussed:

Attack on refractories by new slag components – Al_2O_3, Cr_2O_3

Attack on boiler & gas handling system - Cl_2, Br_2



Mitsubishi Smelter, Japan The Kaldo plant

In operation since 1976 Smelting e-scrap since 1980

Alternate smelting of e-scrap & lead conc Capacity – 45,000 tonnes per year

New plant investment

E-scrap recycling capacity from 45,000 to 120,000 TPA Investment of approx. SEK 1.3 billion

Start up 2011 -12 Increases metal production

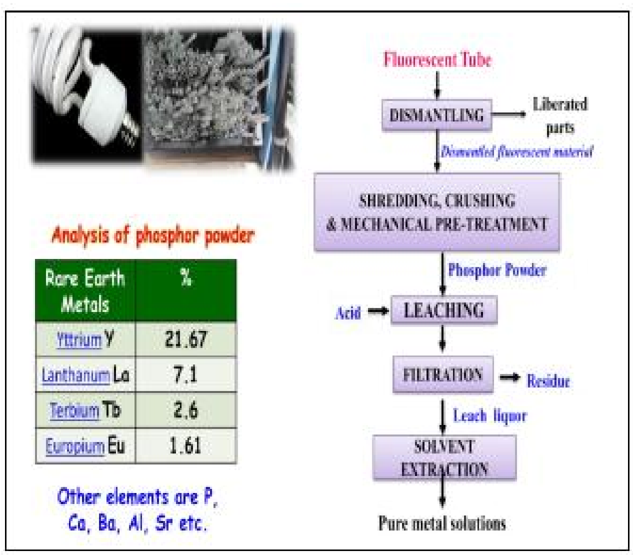
–Gold +2 tonnes

–Silver +32 tonnes

–Copper +14,500 tonnes Synergies with existing production

–Pay back less than 4 years

Process for the recovery of REM's from discarded Fluorescent tube



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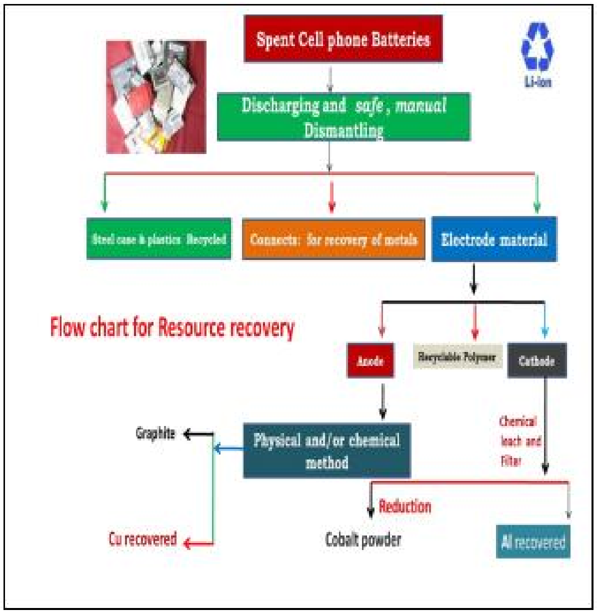

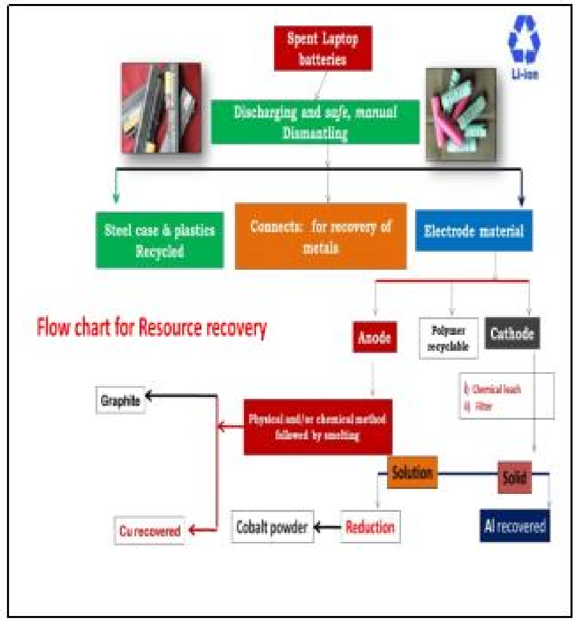

Implementation Challenges for Better e-Waste Management in India

- Due to diversion of large chunk of e-wastes from retail consumers to informal recyclers and demand- supply mismatch organised e-recyclers are not getting adequate e-wastes to recycle.
- Collection centres are currently present only in a few cities in India and the collection process for these facilities are restricted due to logistical and geographical problems.
- Lack of motivation for the top management of producers is one of the major concerns and is unable to drive the e-Waste management initiative. 90% of Indian electronic producing companies and IT companies are not in favour of the EPR concept.

- Donation of obsolete equipments by companies to schools without any monitoring as to what happens to the donated material when it reaches its end of life. Hence the loop of reverse supply chain is unable to function in an organized manner.
- There is no recycler for materials of lamps (CFL bulb, tube light etc.) in India because of cheaper sources in China. Hence lamp recycling is a great challenge in India.
- There is no recycler for Ni-Cd batteries, Alkaline batteries and Dry cell batteries within the country. Such materials are either dumped in landfills resulting in loss of resources or exported to authorized recyclers in foreign countries resulting in logistic costs.
- There is a lack of authorized recyclers for Ni-MH batteries and Li-ion batteries in the country. There are some back-yard recyclers for Ni-MH and Li-ion batteries but are unregistered with the MoEF. Therefore formal intermediate recyclers (like E-Parisaraa) are unable to dispatch them.
- Issues –
    - Poor Infrastructure for E-Waste recycling
    - Lack of awareness and financial incentives
    - Less information on E-waste generation rates
    - Mismanagement in market for the end-of-life products
    - Environementally unsustainable informal sector practices
    - Inadequate regulatory design and enforcement

How Can Governments, City Administration, and Citizens Help?

The ASSOCHAM report (2017) suggests that the government may look at collaborating with the industry to draw out formal/standard operating procedures and a phased approach towards the agenda of reducing e-wastes to the lowest. Alternatively, the government may also refer methods adopted by other countries for efficient collection and recycling of e-wastes. For example, South Korea, one of the largest producers of electronics managed to recycle 21 per cent of the total 0.8 million tonnes of e-waste that it produced in 2015, said the study.

Considering the adverse impacts caused by untreated e-waste on land, water, and air; the government should encourage the new entrepreneurs by providing the necessary financial support and technological guidance. Establishment of start-ups connected with e-waste recycling and disposal should be encouraged by giving special concessions. The unorganized sector has a well-established collection network. But it is capital-intensive in case of organized sector. Therefore, if both the sectors coordinate and work in a harmonious manner, the materials collected by the unorganized sector may be handed over to the organized sector to be processed in an environment- friendly way. In this kind of scenario, the government can play a crucial role between the two sectors for successful processing of the e-waste. It is high time that the government takes a proactive initiative to recycle and dispose of e-waste safely to protect the environment and ensure the well-being of the general public and other living organisms.

The principle of EPR is increasingly being applied for management of e-waste across many countries, and its relative effectiveness and success has been demonstrated in EU countries. Instruments for implementation of EPR can be a mix of economic, regulatory, and voluntary/informational. While producers are responsible for e-waste management (EPR), consumers, retailers, state governments, municipalities, NGOs, CSOs, Self-Help Groups (SHGs), local collection agencies such as extracarbon.com and others should play an appropriate role in collection, facilitation, and creation of infrastructure to make e-waste management a success.

At present, Design for Environment (DfE) is attracting much attention in the world as a new method to solve environmental pollution. DfE principle in the product design is a process to significantly reduce the environmental impact of products being put into the market. It is often seen that the robust rules in India are ineffective due to slack implementation.

The citizens have a very important role to play in e-waste management. We casually throw many small gadgets along with dumped waste and many people openly burn those accumulated waste. A number of hazardous substances such as dioxins and furans are released in the process which we breathe. This is a very unhealthy practice, which we should immediately stop. Some of the very progressive Resident Welfare Associations (RWAs) have separate bins clearly marked for collecting e-wastes. All the other residential societies should follow this practice. Students and Women SHGs can be mobilized for this activity in their respective RWAs.

VII. Improvement of E-waste Management in India

There are various ways of improving e-waste management in India. However, there are five key components that can be linked together for improving e-waste management in India in a summarised way. It is discussed as below: Providing Market Information about E-waste Prices

It is a well-established market for e-waste within and between informal and formal sector operators. However, the prices for e-waste & its components are not widely known or publicized among urban consumers. A consolidated price list must be updated on a weekly basis as it would be a powerful market signal for customers who sell the e-waste to local vendors.

The price list has to cover all components of e-waste, starting from bulk e-waste to various glass, metals, plastic, ceramics, and batteries. The information must be presented on dedicated websites by urban municipalities and local newspapers similar to commodity price listings or foreign exchange rates. The price list must reflect the prevailing market demand for e-waste components and enable informal sector collectors to buy and sell e-waste at the fair market prices to private processors or government-approved recycling and dismantling centers.

7.1 Incentivizing Formal E-waste Recycling

The Indian Government has introduced a point-based reward system of E-waste Recycling Credits (ERCs) for formal organizations to incentivize them to channel their e-waste through government-approved recycling centers. The E-Waste Rules already classify and code e-waste like laptops, computers, and mobile phones. These categories have to be correlated at different ERC reward levels. Depending on the type of e-waste supplied, organizations must earn the requisite ERCs that can be used to offset energy utility bills. Such an initiative will also provide a strong incentive for informal sector e-waste businesses to formalize the operations and establish supply chain links with approved recycling centers.

The ERCs can be piloted over a 3 to 5 years period to assess the efficacy and to fine-tune for further implementation. The government and industrial sectors in metropolitan cities generate more than 70 % of e-waste. The ERCs can be trialed with a few large industries and government organizations in Mumbai, Delhi, or Bangalore.

The Indian government can also expand formal e-waste recycling capacity by co-funding infrastructure upgrades and processing systems at existing government-approved recycling centers. It can provide co-funding incentives to governments for setting up new recycling units through public-private partnerships with large e-waste companies. State governments could also develop grant schemes for incentivizing small-scale, informal e-waste recycling centers to upgrade the facilities so that they comply with them both environmental and occupational health and safety regulations. States can apply for national urban development funding schemes, which can be used to link the well-established informal sector network of decentralized collection and small recycling units with large-scale industrial recycling centers.

7.2 Training and Upskilling Informal Sector Players

The majority of an informal e-waste recycling workforce needs upskilling, particularly for handling and dismantling hazardous materials. It must ensure the work's environmental and occupational health and safety and link supply to formal sector processors. It is pursued by the Indian government's National Skill Development Mission. Innovative short courses and training programs can be specially designed for e-waste collectors, handlers, and dismantlers by the Electronics Sector Skill Council's combined expertise, the Green Jobs Sector Skill Council, and regulatory agencies like the Central and State Pollution Control Boards.

Training and A concerted, nationwide campaign should accompany up skilling of informal sector workers campaign by central and state governments to increase public awareness about the hazards associated with e- waste. The importance of an informal sector in e-waste collection, e-waste dumping, and the locations of formal e-waste collection depots as approved by the government.

7.3 Deploying Readily Available and Mature Recycling Technologies

There is an urgent need for deploying mature recycling technologies alongside existing manual techniques to improve the recycling efficiency of the large volumes of e-waste management in India. India has a very large and mature plastics processing sector which can recycle plastic material from e-waste.

The Indian government must promote joint ventures between international and domestic companies for setting up large industrial e-waste recovery plants. These ventures can be funded by a combination of private and public investment.

Developing Innovative Methods & Technologies for Processing New Forms of E-waste

The composition of e-waste is changing rapidly due to the new electronic devices to enter the market. It requires significant investment in research & development for innovative recycling methods and technologies for future- proofing India's e-waste policies and management. For example, smartphones usage has expanded dramatically in India over the past five years, but any e-waste recycling rules do not yet cover the lithium-ion batteries that power the devices.

Various new battery and materials technologies are being developed for manufacturing the next generation of electronic devices. Thus, the Indian government must promote and fund research that develops innovative, future- oriented technologies for recycling and transforming new e-waste streams into high-value products.

7.4 How we can Create Robust E-waste Management in India?

We are constantly evaluating the effectiveness of e-waste regulation and bringing in necessary changes. The government plays an important role in bringing together various stakeholders in a system. We have a few measures that can be considered to move forward.

A. Strengthen the Informal Sector

The first step can be to more explicitly recognize the informal sector as the stakeholder in any future e-waste regime. Addressing the problem of informal sector e-waste practices requires a greater understanding of the sector itself in terms of its incentives and challenges. Engagement with informal sector workers and the groups, in a manner that recognizes the right of their livelihoods, builds trust, and develops an understanding of the problems along with potential solutions, can be an initial step. The government must institute a platform that facilitates consultations among various stakeholders like informal sector workers, NGOs working with the informal sector, third parties, private entities, and registered recyclers, and manufacturers. The forums can be constituted under the Ministry of Environment, Forest and Climate Change at a certain level under the State Department.

B. Policy Instruments under EPR

The government needs to rethink the policy instruments under the EPR approach. In a presence of the informal sector, it requires strengths in collection logistics. A mandatory take back with collection targets cannot be the ideal instrument. Producer responsibility comes in many varieties other than mandatory take-back.

The economic instruments like advanced recycling fee or advanced disposal fee on every unit of the product sold in the market will relieve the producers of the physical responsibility of collection, and the revenues generated can be used to develop markets for the end-of-the-life or useless products. The revenues that go into a separate fund can be used in several ways.

Some examples are (a) Subsidize consumers to deposit their e-waste at designated centers, (b) Directly fund recyclers (c) Assist informal sector workers in training or skill development or provide a greater social security net to the workers. These decisions can be made within the consultative forum recommended in an informal sector. The problem with economic instruments will be to determine the right fee. Principles of economics will suggest a fee equivalent to the marginal external cost of the end-of-life equipment. While the external costs assessment is difficult in practice, the fee must be high enough to fund the environmentally safe e-waste processing and disposal. The sufficient fee can also provide incentives for a design for environmental changes in product design that has been one of the main goals of the EPR approach globally. In a long run, to further incentivize changes, the fee can be based on such factors as the ease of recyclability, dismantling, and environmental impact of materials used in a piece of equipment. The policy framework must also focus on the development of indigenous technologies and/or technology transfer to encourage the widespread application of environment-friendly e-waste recycling technologies.

C. Regulatory Enforcement

Shifting to the economic instruments such as an ADF can also relieve the regulatory burden since the producers need not be regulated anymore. The long experience with tax collection must make it easy to divert the ADF on electronic products to a separate fund.

The State and Central Pollution Control Board will still be required to monitor and enforce compliance with the standards specified for collection centers, dismantlers, recyclers, and PROs. The MoEFCC must make regulatory actions related to e-waste transparent. Regulatory actions like authorizations and their conditions, data on inspections of registered facilities, and inspected facilities' compliance status should all be made publicly available for scrutiny.

A few SPCBs already publicly provide some of these documents on their websites, but these practices should be institutionalized as part of the country's regulations. Developing the regularly updated and publicly available inventory of district-wise generation of e-waste quantities by e-waste type (e.g., mobiles, computers, and appliances), waste composition, and flows will also play an important role in enforcement.

D. E-waste Imports

Under the existing regulations, e-wastes are not allowed to be imported for final disposal but can be imported for reuse and recycling. In an absence of adequate infrastructure in the country for recycling, we must seriously consider banning all kinds of imports. To develop accurate estimates of e-waste, data on imports must be integrated with an e-waste inventory.

E. Public Awareness for E-waste Management

The current e-waste regulations require the producers to provide, on the websites, information on the impacts of e-waste, appropriate disposal practices, and other issues. There is also a requirement for an awareness campaigns at regular intervals. Many producers have already provided information on the websites, but evidence shows that the overall awareness levels remain low among bulk consumers. Stricter guidelines/regulations to the producers on these awareness campaigns' frequency and mode might improve the situation.

Alternatively, the producers must be mandated to run these campaigns through grassroots-level organizations working in the area of e-waste. On its part, the government must consider integrating e-waste awareness campaigns with other waste streams such as batteries and municipal solid waste.

Research on the effective messaging techniques and evaluation of information campaigns could also form a part of the role of the government. These awareness efforts must be geared towards achieving safe handling of e-waste and reducing consumption of electronic products in the long run. Overall, public awareness generation initiatives should be based on partnerships and collaboration among various stakeholders.

F. Your Role in E-waste Management System

Increasing information campaigns, capacity building, and awareness are critical to promoting environment- friendly e-waste management programs. Increasing efforts are urgently required on the improvement of the current practices like collection schemes and management practices to reduce any illegal trade of e-waste. Reducing the number of hazardous substances in e-products will also positively affect the specific e-waste streams since it will support the prevention process.

Most of the e-waste is recycled in India in unorganized units, which engage a significant number of manpower. Recovery of metals from PCBs by primitive means is the most hazardous act. Proper education, awareness, and, most importantly, alternative cost-effective technology need to be provided to provide better means to those who earn the livelihood from this.

A holistic approach is needed to address the challenges faced by India in e-waste management. The suitable mechanism needs to be evolved to include small units in the unorganized sector and large units in the organized sector into a single value chain. Our approach can be for units in the unorganized sector to concentrate on collecting, dismantling, and segregation, whereas the organized sector could do metal extraction, recycling, and disposal.

Top E-Waste Management Companies In India

1. Attero, Noida, Uttar Pradesh

Attero is an E-waste management company. They spin around the unwanted electronics into sustainable resources. End of life electronics are recycled at their recycling units using disruptive technology. Attero recovers nearly 98% of high-quality minerals through its cutting edge technology. And they are India's largest producers of Tin. Their services are data security, take back action, recycling, upcycling, reverse logistics, and extended producer responsibility compliance. Some of their clients are LG, Acer, Whirlpool, OPPO, Nexcharge, etc.

2. Namo eWaste Management Ltd., Faridabad, Haryana

Namo eWaste Management Ltd. is on a mission to make e-waste disposal sustainable and clean across the country. They provide door-to-door services to collect and transport the e-waste to their recycling facility.

3. Eco Credible Enviro Solutions Pvt. Ltd., Pune, Maharashtra

Eco Credible Enviro Solutions Pvt. Ltd. specialises in e-waste recycling. It also offers solid waste management and wastewater treatment. It is a Maharashtra Pollution Control Board Certified recycler company.

IX. Conclusion

E-waste management is a great challenge for governments of many developing countries such as India. This is becoming a huge public health issue and is exponentially increasing by the day. In order to separately collect, effectively treat, and dispose of e-waste, as well as divert it from conventional landfills and open burning, it is essential to integrate the informal sector with the formal sector. The competent authorities in developing and transition countries need to establish mechanisms for handling and treatment of e-waste in a safe and sustainable manner.

Increasing information campaigns, capacity building, and awareness is critical to promote environment friendly e-waste management programmes. Increasing efforts are urgently required on improvement of the current practices such as collection schemes and management practices to reduce the illegal trade of e-waste. Reducing the amount of hazardous substances in e-products will also have a positive effect in dealing with the specific e- waste streams since it will support the prevention process. Mobile phone manufacturer Nokia is one of the very few companies that seem to have made serious effort in this direction since 2008. The companies were made responsible for creating channels for proper collection and disposal of e-waste in accordance with a Central Pollution Control Board (CPCB) approved EPR Authorization plan in India. Recently, the import license of some of the big companies were suspended for violation of E-waste rules. Such measures have a great impact on effective implementation of e-waste management in India. Any task undertaken must have its share of incentives which attract stakeholders. In the field of e-waste management, the government must announce incentives, which could be in the form of tax concessions or rebates, to ensure compliance across the electronics industry. Additionally, the e-waste collection targets need to be regularly reviewed and renewed to ensure compliance across India on collect.