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REGULATING E-WASTE IN INDIA: A LEGAL AND ENVIRONMENTAL PERSPECTIVE

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Abstract
The electronic waste and its management is a global problem and the concern towards the proper management in view of environmental protection is to be given top priority. In 21st century, the information and communication revolution brought enormous changes in lives, economies, industries and institutions.

In the knowledge-driven economy, electrical and electronic gadgets play a significant role in all walks of life. Electrical gadgets are very necessary in the present world to make work easier in all fields like offices, educational institutions, hospitals, supermarkets, malls, etc., and even changed the lifestyles. Hence, the increased use of electrical and electronic equipment is causing a great threat to the environment. This electrical and electronic equipment consists of both valuable and toxic materials and if disposed without proper care, drastically affects the health of humans and the quality of the environment.

The management of e-waste in developing and transition countries has become very difficult due to the recycling of e-waste in the informal sector, the lack of technology to extract the materials from e-waste to the fullest, lack of technically skilled persons.
The study highlights the sources of e-waste, current disposal practices and reveals gaps in awareness, infrastructure, and regulatory compliance. It suggests measures such as implementing awareness programs, establishing e-waste collection centres, adopting green procurement policies, and fostering collaborations with government-authorized recyclers. By adopting these strategies, the government can play a pivotal role in promoting environmental sustainability and setting an example for responsible e-waste management practices. This article serves as a call to action for policymakers, educational administrators, and stakeholders to work collaboratively towards a cleaner, greener future.

Key words: e-waste, recycling, e-waste management, formal and informal sector, proper disposal

1. Introduction

In the last ten to fifteen years, e-waste has become a global issue. India also generates a large quantity of e-waste. People are not much aware of e-waste and how to dispose of e-waste as the media does not cover this issue. The Information Technology industry is the backbone for the economic development of any country.[1] With the fast development of technology, producers are producing a variety of electrical and electronic gadgets each year. New models with increased features are being manufactured and people are discarding their old gadgets and going for new models. This is increasing the e-waste year by year. This e-waste has the worst impact on the environment and human beings if it is not properly stored, collected, transported, treated and disposed off. The generation, treatment and disposal of e-waste pose a great challenge to waste management professionals and governments in developing and transition countries. The management of e-waste in developing and transition countries has become very difficult due

[1] Daniel Mmereki, Baizhan Li, Andrew Baldwin and Liu Hong, 'The Generation, Composition, Collection, Treatment and Disposal system and impact of E-waste', E-waste in Transition-From pollution to Resource, June 29th, 2016, ISBN-978-953-51-2500-6 https://www.intechopen.com/chapters/49247

to the recycling of e-waste in the informal sector, the lack of technology to extract the materials from e-waste to the fullest, lack of technically skilled persons.

According to the European Union WEEE Directive (EU, 2002a)[2], "e-waste means any electrical or electronic equipment which is waste including all components, sub-assemblies and consumables, which are part of the product at the time of discarding.

Categories of electrical and electronic equipment according to Directive 2002/96/EC of The European Parliament and of The Council of 27 January 2003 on WEEE[3] are large household appliances, small household appliances, IT and telecommunications equipment, consumer equipment, lighting equipment, electrical and electronic tools (with the exception of large-scale stationary industrial tools), toys, leisure, and sports equipment, medical devices (with the exception of all implanted and infected products), monitoring and control instruments and automatic dispensers.

"E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos and consumer electronics to computers, which have been discarded by their users", according to Basel Action Network (Puckett and Smith, 2002)."

Under section 3(l) of The E-waste (Management) Rules, 2022 of India, which came into effect from 1st April 2023, "e-waste means electrical and electronic equipment, including solar photo-voltaic modules or panels or cells, whole or in part discarded as waste, as well as rejects from manufacturing, refurbishment and repair processes."

As technology continues to advance at a rapid pace and consumerism surges, the generation of e-waste has reached alarming levels, and the management of electronic waste has become a pressing global concern, and India is no exception.

2. Management of E-waste

As per E-Waste (Management) Rules, 2022, of India Rule 3(i), "environmentally sound management of e-waste' means taking all steps required to ensure that e-waste is managed in a manner which shall protect health and the environment against any adverse effects, which may result from such e-waste."

The management of e-waste includes taking proper care in the process of collection, recycling, treatment, transportation and disposal of e-waste to protect the human health and environment against the adverse effects that will result from such wastes. The management of electronic waste has become a pressing global concern and India is no exception. As technology continues to advance at a rapid pace and consumerism surges, the generation of e-waste has reached alarming levels.

In India, the management of e-waste is governed by the E-Waste (Management) Rules, 2022 which came into force on 1st April 2023, which replaced the earlier E-Waste (Management) Rules enacted in 2016 and the main objectives of these rules are to strengthen the Extended Producer Responsibility rules, environmental compensation and also promote resource recovery. These rules are also applicable to solar photo- voltaic modules and panels or cells.

[2]https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0096.
[3] https://eur-lex.europa.eu/resource.html?uri=cellar:ac89e64f-a4a5-4c13-8d96-1fd1d6bcaa49.0004.02/DOC_1&format=PDF

The survey done by Central Pollution Control Board in the year 2005 reveals that nearly 1.347 lakh MT of e-waste was generated in India in the year 2005, and it is going to increase to 8.0 lakh MT by 2012. In 2007, Manufacturer's Association of Information Technology (MAIT), India and GETZ Bros & Co.Inc (GTZ, India) had carried out an inventory on e-waste. The report is called as 'E-waste inventorisation in India', MAIT-GTZ Study, 2007. Table-1 clearly shows that more e-waste is generated from domestic goods.

Table 1: E-waste inventorisation in India, MAIT-GTZ Study, 2007

S.No	Items	Weight (MT)
1	E-waste domestic generation through-Computers, Mobile Phones, Televisions	332979
2	Imports	50000
3	Total	382979
4	WEEE available for recycling	144143
5	WEEE actual recycled	19000
6	Domestic generation of WEEE quantity by 2011	467098

Source: MAIT, GTZ, 2007,https://www.meity.gov.in/writereaddata/files/E-waste_Sep11_892011.pdf

According to the Rajya Sabha Report titled 'E-waste in India' published in 2011, more than 50MT of e-waste is generated globally every year. The report says that major reason for e-waste is high rate of obsolescence in the electronics market. According to the report, 10 states contribute to 70% of total e-waste generated in the country, while 65 cities generate more than 60% of the total e-waste in India. Among the 10 largest e-waste generating states, Maharashtra ranks first followed by Tamilnadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Among the top ten cities generating e-waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat and Nagpur.

According to the Global E-Waste Report 2020, India generated 3.2 million tonnes of e-waste and rank third among e-waste producing countries after the China, United States.

Table 2: Year Wise E-waste Generation in India 2015-2019

Year	E-waste generation (Million metric tonnes)
2015	1.97
2016	2.22
2017	2.53
2018	2.86
2019	3.23

Source: CSE, 2020 compiled from The Global E-waste Statistics Partnership

Ashwini Kumar Choubey, Union Minister of State for Environment, Forest and Climate Change have given the status of 'e-waste generation in India' in the Rajya Sabha on July 20th 2023.[4]

[4]E-Waste Management, Ministry of Environment, Forest and Climate Change Posted On: 20 July 2023 by PIB Delhi, https://pib.gov.in/PressReleasePage.aspx?PRID=1941054.

Table 3: Year Wise E-waste Generation in India 2019-2022

S.No	Financial Year	Quantity of e-waste generated in tonnes
1	2019-2020	10,14,961
2	2020-2021	13,46,496.31
3	2021-2022	16,01,155.36

The analysis of tables 2 and 3 clearly shows that from year to year e-waste generation is increasing in India.

Ashwini Kumar Choubey, Union Minister of State for Environment, Forest and Climate Change told in the Rajya Sabha on February 8th 2024 that e-waste recycling has increased from 2016-2022 in India from 21 types of EEE notified under E-waste (Management) Rules 2016.[5] Table 4 shows that e-waste recycling through registered recyclers has increased from 2016 to 2022.

Table 4: Year Wise E-waste recycling in India 2016-2022

S.No	Financial Year	Quantity of e-waste processed in tonnes
1	2016-2017	23330.3
2	2017-2018	69,413.69
3	2018-2019	1,64,663.0
4	2019-2020	2,24,041.0
5	2020-2021	3,54,540.70
6	2021-2022	527,131.57

The analysis shows that in the year 2021-2022 e-waste generation is 16, 01,155.36 tonnes. However, the e-waste recycling through registered recyclers is 5, 27, 131.57 tonnes. From the year 2016 to 2022, the e-waste recycling through registered recyclers has increased, but the total e-waste that is generated is not being recycled through the formal sector. The analysis of the data shows that 10, 74, 023.79 tonnes (16, 01,155.36- 5, 27, 131.57) of e-waste is either being recycled by the informal sector or going to the landfills along with household waste.

The CPCB have framed an action plan for the enforcement of e-waste rules in the country. Table 5 shows the action plan for the enforcement of e-waste rules. The CPCB, SPCBs, PCCs, Customs Department and District Administration are responsible for the implementation of the action plan. The cooperation of Ministry of Commerce and Ministry of Electronics and Information Technology is also necessary for proper implementation of the action plan. CPCB, Customs Department, Ministry of Commerce and Ministry of Electronics and Information Technology has to identify the producers who have not obtained EPR Authorization. CPCB, SPCBs and PCCs should verify the quantity of e-waste collected, process of collection and channelization of e-waste by producers. They should verify the facilities of dismantlers and recyclers and monitor whether they are maintaining proper infrastructure and records. SPCBs and PCCs should carry on the inventorization of e-waste generation in their respective states. SPCBs and PCCs in coordination with District Administration should check the informal trading, dismantling and recycling of e-waste in their respective states. SPCBs, PCCs, District Administration and CPCB should facilitate collection and disposal of e-waste, monitor compliance, capacity building for management of e-waste, frame Information, Education and Communication Plan for e-waste management and strengthen the system of enforcement.

[5]Recycling of e-waste, Ministry of Environment, Forest and Climate Change Posted On: 08 FEB 2024 4:18PM by PIB Delhi, https://pib.gov.in/PressReleasePage.aspx?PRID=2004015

Table 5: The action plan framed by CPCB for enforcement of e-waste rules

S.No.	Challenges/Activities	Stakeholder responsible for implementation	Action
1	Inventorization of e-waste generation	SPCBs/PCCs	SPCBs/PCCs to complete this activity within one year.
2	Identification of Producers who have not obtained EPR Authorization	CPCB, Custom department, Ministry of Commerce and Ministry of electronics & telecommunication	This is a continuous activity for which support of SPCBs/PCCs/Custom department/ Ministry of Commerce and Ministry of electronics & telecommunication is required.
3	Verification of quantity of e-waste collected by producers	CPCB/SPCBs/PCCs	This is a continuous activity. All the EPR Authorized producers will be verified per year.
4	Verification of systems provided by producers for collection and channelization of e-waste	CPCB/SPCBs/PCCs	This is a continuous activity. All the EPR Authorized producers will be verified per year.
5	Verification of facilities of dismantlers and recyclers for their infrastructure and records	CPCB/SPCBs/PCCs	This is a continuous activity. All the dismantlers/recyclers will be verified per year.
6	Checking of informal trading, dismantling and recycling of e-waste	SPCBs/PCCs/District Administration	SPCBs/PCCs in coordination with District Administration has to carry out quarterly drive for checking of this activity.
7	Facilitate collection and disposal of e-waste	SPCBs/PCCs/District Administration/CPCB	State Government to formulate mechanism for collection and for incentivizing setting up of recycling facilities.
8	Governance frame work for monitoring compliance	SPCBs/PCCs/District Administration/CPCB	Monitoring to be ensured at city/district and state levels for which nodal officers (state environmental secretary, district collector, CMD/ Commissioners) to be designated.
9	Capacity building at district/State/CPCB level	SPCBs/PCCs/District Administration/CPCB	Special workshops to educate functionaries in government/NGOs be run over one year.
10	Information Education & Communication (IEC)	SPCBs/PCCs/District Administration/CPCB	State Government to firm up IEC plan for educating public at large about the system of collection, incentive structure and facilities for recycling. Time frame- three months.

	plan be firmed up and executed		The IEC plan to be executed over one year.
11	Strengthen system of enforcement	SPCBs/PCCs/District Administration/CPCB	Quarterly review of violations and enforcement actions at city/district/state level and quarterly reports to be filed with CPCB.

Source: Central Pollution Control Board Consolidated Status Report dated 3-11-2022 submissions of the CPCB to NGT in Original Application No.08 of 2022 in Shri Varun Sheokand v. CPCB & others.

Table-6 indicates the operational and compliance status of e-waste dismantlers/recyclers in 35 States /UT in India submitted by SPCBs/PCCs. In India, there are 530 authorized dismantlers/recyclers units. Out of those 375 are complying and 29 are non-complying units. The SPCBs/PCCs did not provide the status of 126 units. Regarding the status of operation - 437 units are operating, 32 are non-operating, 47 are closed and 14 units status is not provided by SPCBs/PCCs. Highest number of authorized dismantlers/recyclers units are in Uttar Pradesh -124, followed by Maharashtra-114, Karnataka-70, Haryana-48, Tamilnadu-40, Rajasthan-34, Gujarat-28, Telangana-19, Uttarakhand-9, Punjab-8, Odisha-8, Andhra Pradesh-8, West Bengal-5, Delhi-3, Himachal Pradesh-3, Jharkhand-3, Chhattisgarh-2, Madhya Pradesh-2, Assam-1, Jammu & Kashmir-1. Out of 35 States/UT, 15 States/UT-Arunachal Pradesh, Andaman & Nicobar Islands, Bihar, Chandigarh, Dadra & Nagar Haveli & Daman & Diu, Goa, Kerala, Lakshadweep, Manipur, Meghalaya, Mizoram, Nagaland, Puducherry, Sikkim and Tripura do not have any authorized e-waste dismantling/recycling units. The study of the report indicates that the SPCB/PCCs are not taking any action against the non-complying units and even a few SPCB/PCCs are not even providing the status of the units, whether they are complying or non-complying.

Table 6: Operational & Compliance status of e-waste dismantlers/recyclers as per the reports of SPCBs/PCCs

S. No	State	Total number of Authorized dismantlers/ recyclers	Status of Compliance			Status of operation				Remarks
			Complying (C)	Non-complying (NC)	Status not provided (SNP)	Operational (OP)	Non-operational (NOP)	Closed	Status not provided (SNP)	
1	Andhra Pradesh	8	5	-	3	5	-	-	3	Status provided w.r.t 5 units only
2	Arunachal Pradesh	0	-	-	-	-	-	-	-	No authorized units reported in the State
3	Assam	1	1	-	-	1	-	-	-	-
4	A&N Islands	0	-	-	-	-	-	-	-	No authorized units reported in the State
5	Bihar	0	-	-	-	-	-	-	-	No authorized units reported in the State

6	Chandigarh	0	-	-	-	-	-	-	-	No authorized units reported in the State
7	Chhattisgarh	2	2	-	-	2	-	-	-	-
8	DD&DNH	0	-	-	-	-	-	-	-	No authorized units reported in the State
9	Delhi	3	-	-	3	-	-	-	3	-
10	Goa	0	-	-	0	-	-	-	0	-
11	Gujarat	28	25	-	3	22	5	1	-	-
12	Haryana	48	47	-	1	47	-	1	-	-
13	Himachal Pradesh	3	3	-	-	-	3	-	-	-
14	Jammu & Kashmir	1	1	-	-	-	1	-	-	-
15	Jharkhand	3	1	2	-	1	2	-	-	-
16	Karnataka	70	-	-	70	59	-	11	-	Status report has not provided the status of compliance in these 70 units
17	Kerala	0	-	-	0	-	-	-	-	-
18	Lakshadweep	0	-	-	-	-	-	-	-	No authorized units reported in the UT
19	Madhya Pradesh	2	2	-	-	2	-	-	-	-
20	Maharashtra	114	104	3	7	105	-	9	-	-
21	Manipur	0	-	-	-	-	-	-	-	No authorized units reported in the State
22	Meghalaya	0	-	-	-	-	-	-	-	No authorized units reported in the State
23	Mizoram	0	-	-	-	-	-	-	-	No authorized units reported in the State
24	Nagaland	0	-	-	-	-	-	-	-	No authorized units reported in the State

25	Odisha	8	-	-	8	-	-	-	8	Odisha has no recycling units but has 8 dismantling units
26	Puducherry	0	-	-	-	-	-	-	-	No authorized units reported in the UT
27	Punjab	8	7	-	1	7	-	1	-	-
28	Rajasthan	34	18	5	11	24	1	9	-	-
29	Sikkim	0	-	-	-	-	-	-	-	No authorized units reported in the State
30	Tamil Nadu	40	27	-	13	27	1	12	-	-
31	Telangana	19	17	-	2	17	2	-	-	-
32	Tripura	0	-	-	-	-	-	-	-	No authorized units reported in the State
33	Uttarakhand	9	6	3	-	9	-	-	-	-
34	Uttar Pradesh	124	105	16	3	105	17	2	-	2 units are self-closed and 1 unit CTE has been issued
35	West Bengal	5	4	-	1	4	-	1	-	-
	Total	**530**	**375**	**29**	**126**	**437**	**32**	**47**	**14**	

Source: Central Pollution Control Board Consolidated Status Report dated 3-11-2022 submissions of the CPCB to NGT in Original Application No.08 of 2022 in Shri Varun Sheokand v. CPCB & others.

Table 7 indicates the status of informal activities in States/UT as provided by the SPCBs/PCCs. Out of 35 SPCBs/PCCs, 8 SPCBs/PCCs did not provide any information regarding informal activities. They are Andhra Pradesh, Bihar, Chandigarh, Goa, Karnataka, Odisha, Tripura and Uttarakhand SPCBs/PCCs. 14 SPCBs/PCCs did not carry any drive for checking the informal activities. They are Arunachal Pradesh, Andaman & Nicobar Islands, Chhattisgarh, Dadra & Nagar Haveli & Daman & Diu, Jharkhand, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Nagaland, Sikkim, Tamailnadu and Uttar Pradesh SPCBs/PCCs. According to the Rajya Sabha Report[6] the 10 largest e-waste generating states are Maharashtra ranks first followed by Tamilnadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. But according to the reports of SPCBs/PCCs the states having highest e-waste generation i.e., Maharashtra, Tamilnadu, Uttar Pradesh are not conducting the check drives for identifying the informal activities which may lead to informal recycling.

Thirteen SPCBs/PCCs have conducted check drives. They are Assam, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Kerala, Meghalaya, Puducherry, Punjab, Rajasthan, Telangana and West Bengal SPCBs/PCCs.

[6] 'E-waste in India' published in 2011. This is the only report on e-waste released from Rajya Sabha before The E-Waste (Management & Handling) Rules, 2011 have come in to force. Then after, it did not release any report on e-waste.

In these drives, the SPCBs/PCCs of Delhi identified 205 informal units, West Bengal 4 informal units, Himachal Pradesh 2 informal units, Meghalaya 1 informal unit, Puducherry 1 informal unit and Haryana 1 informal unit. All these SPCBs/PCC have closed these units and have taken action against them. Kerala SPCB have identified some informal units. To reduce informal recycling, it has taken steps to formalize informal units. It motivated M/s Eco Solutions Pvt Ltd, which is an authorized collection center to collect the e-waste from the informal sector and give some initiative to them. Thus, during October 2021 to March 2022, they collected 437.418 tonnes of e-waste, out of which 90% is collected from the informal sector. The other SPCBs/PCCs of Assam, Gujarat, Punjab, Rajasthan and Telangana did not identify any informal activities in their respective states. Haryana and Punjab SPCBs have received complaints regarding informal activities of e-waste. The complaint filed in Haryana SPCB has been decided by the NGT.[7] The facts of the case are many industrial units in the Sarupur industrial area are burning e-waste. Daily they are burning nearly 50 tons of e-waste which is damaging the environment and health of human beings and animals. The toxic residue evolved after burning the e-waste is left on the land which is causing groundwater pollution. The SPCB of Haryana has inspected this industrial area. It closed and stopped supply of electricity to nearly 68 non-compliant units. The NGT Delhi has opined that the Haryana SPCB has taken the proper action by closing and stopping the supply of electricity. The NGT, to overcome this problem, ordered regular police patrolling to prevent the burning of e-waste and dumping ash in open lands. It also ordered CPCB to monitor compliance at least twice a year by holding virtual conferences with the Member Secretaries of all Pollution Control Boards and Pollution Control Committees. However, the complaint received by Punjab SPCB was found to be fake.

According to Rule 17 of E-waste (Management) Rules, 2016, the SPCBs/PCCs have to conduct random inspection of dismantlers, recyclers or refurbishers. If these are not complying with the rules the SPCBs/PCCs should take action against them. However, the report indicates that nearly 22 SPCBs/PCCs had not provided any information regarding the informal activities or did not carry any drive for checking the informal activities. This shows that SPCBs/PCCs are not performing their duty properly. According to Article 48A of the Constitution of India, the State has the duty to protect and improve the environment. However, the SPCBs/PCCs are violating Article 48A by not performing their duty. The analysis of the report shows that only two complaints regarding informal activities are received by the SPCBs/PCCs. According to Article 51A (g) of the Constitution of India, the citizens have a duty to protect the environment and have compassion for living creatures. Article 51A (g) gives a right to the citizens to move to the court on any issue relating to environmental pollution. The complaints received in SPCBs/PCCs shows that the citizens are violating Article 51A (g).

Table 7: Status of Informal Activities in States/UTs as per reports received from SPCBs/PCCs

S.No	SPCBs/PCCs	Status of Informal Activities	
		Complaints received	Drive for checking Informal activities
1	Andhra Pradesh State Pollution Control Board	Information not provided	Information not provided
2	Arunachal Pradesh State Pollution Control Board	NIL	No drive carried out for checking informal activities
3	Assam State Pollution Control Board	NIL	Yes, but not identified any informal activity so far
4	Andaman & Nicobar Islands P.C.C	NIL	No drive carried out for checking informal activities

[7]Original Application No.08 of 2022 in Shri Varun Sheokand v. CPCB & others.

5	Bihar State Pollution Control Board	Information not provided	Information not provided
6	Chandigarh Pollution Control Committee	Information not provided	Information not provided
7	Chhattisgarh Environment Conservation Board	NIL	No drive carried out for checking informal activities
8	Pollution Control Committee, DD&DNH	NIL	No drive carried out for checking informal activities
9	Delhi Pollution Control Committee	NIL	In joint drives, during the last three years, DPCC has carried out drives against 348 informal handlers of e-wastes in Delhi and 205 such units have been closed
10	Gujarat Pollution Control Board	NIL	Yes, but not identified any informal activity so far
11	Goa State Pollution Control Board	Information not provided	Information not provided
12	Haryana State Pollution Control Board	Yes the present matter OA 08/2022	Yes, carried out
13	Himachal Pradesh Pollution Control Board	NIL	Yes, the State has reported two incidents of informal trading and has taken necessary action against such informal units
14	Jammu & Kashmir State Pollution Control Board	NIL	Carrying out regular drives for checking informal activities. Board has taken action against some informal kabadiwala identified during the drive
15	Jharkhand Pollution Control Board	NIL	No drive carried out for checking informal activities
16	Karnataka State Pollution Control Board	Information not provided	Information not provided
17	Kerala State Pollution Control Board	NIL	Board is carrying out various drives for checking informal activities of e-waste in the State. Steps have been taken for formalizing informal traders/refurbishers etc. The report mentions that a collection agency, M/s Eco Solutions Pvt Ltd collected 437.418 tonnes of e-waste from October 2021 to march 2022, out of which 90% is from the informal sector, especially from scrap feeders and scrap pickers.

18	Lakshadweep Pollution Control Committee	NIL	No drive carried out for checking informal activities
19	Madhya Pradesh Pollution Control Board	NIL	No drive carried out for checking informal activities
20	Maharashtra Pollution Control Board	NIL	No drive carried out for checking informal activities
21	ManipurPollution Control Board	NIL	No drive carried out for checking informal activities
22	Meghalaya Pollution Control Board	NIL	Yes, one incident of informal activity has been reported and Board has taken necessary action on the same.
23	Mizoram Pollution Control Board	NIL	No drive carried out for checking informal activities
24	NagalandPollution Control Board	NIL	No drive carried out for checking informal activities
25	Odisha Pollution Control Board	Information not provided	Information not provided
26	Puducherry Pollution Control Committee	NIL	Yes, PPCC has carried out around 7 drives for checking informal trading and dismantling/recycling of e-waste. During such drives one informal unit has identified which was sealed and necessary action has been taken against it.
27	Punjab Pollution Control Board	Reported one complaint, however, as per the Board the content of the complaint was fake	Yes but not identified any informal activity so far
28	Rajasthan Pollution Control Board	NIL	Yes, 7 drives but not identified any informal activity so far
29	Sikkim Pollution Control Board	NIL	No drive carried out for checking informal activities
30	Tamil Nadu Pollution Control Board	NIL	No drive carried out for checking informal activities
31	Telangana Pollution Control Board	NIL	Board has carried out around 125 check drives during last two years, however, no informal unit has been identified so far.
32	Tripura Pollution Control Board	Information not provided	Information not provided
33	Uttar Pradesh Pollution Control Board	NIL	No drive carried out for checking informal activities
34	Uttarakhand Pollution Control Board	Information not provided	Information not provided

35	West Bengal Pollution Control Board	NIL	Yes, 4 informal units were identified during the check drive on March 2021 and the Board has issued directions to these units for necessary compliance.

Source: Central Pollution Control Board Consolidated Status Report dated 3-11-2022 submissions of the CPCB to NGT in Original Application No.08 of 2022 in Shri Varun Sheokand v. CPCB & others.

Key stakeholders involved in e-waste management in India include manufacturers, producers, collection centers, bulk consumers, dismantlers, recyclers, and authorized refurbishers. Each stakeholder has specific roles, responsibilities and liabilities to ensure the effective management of e-waste and mitigate its adverse effects on the environment and human health. Authorized collection centers are designated facilities where individuals and businesses can deposit their e-waste for proper disposal and recycling[8]. These centers are established by government agencies, recyclers, or authorized third-party entities. They play a vital role in facilitating the organized collection of e-waste from consumers. Drop-off points are convenient locations, such as retail stores, electronic product outlets and community centers, where individuals can deposit their small e-waste items for collection. These points encourage responsible disposal and make it easier for people to contribute to proper e-waste management.

2.1. Modes of Collection and Segregation of E-waste

Effective collection and segregation of e-waste are crucial for its proper management and recycling. Segregation plays an important role in the reduction of waste. Through proper segregation, the metal value in the sludge can be recovered fully[9] and this reduces raw material extraction. According to Global E-waste Monitor 2020, "*E-waste is an 'urban mine' as it contains several precious, critical and other non-critical metals that, if recycled can be used as secondary materials. The value of raw materials in the global e-waste generated in 2019 is equal to approximately $57 billion USD."* As per the Global E-waste Monitor 2024, "the economic value of the metals contained in the e-waste generated globally in 2022 is estimated at USD 91 billion". Currently, e-waste management generates USD 28 billion worth of secondary raw materials out of the maximum of USD 91 billion. Most losses occur due to incineration, landfilling, or substandard treatment. The current secondary raw material production avoids the extraction of 900 Mt of ore[10]. This section examines the different modes of e-waste collection and segregation that help streamline the recycling process.

2.1.1 Segregation and Categorization

a. Identification and Sorting: Once collected, e-waste undergoes segregation and categorization based on different types of electronic devices, components and materials[11]. This step involves identifying and separating reusable, recyclable and hazardous components for further processing.

[8]Rule 3(e) of E-Waste Management Rules, 2016. Retrieved from http://www.moef.gov.in/sites/default/files/E-waste%20Management%20Rules.pdf.

[9] Ramachandra T.V, Saira Varghese.K, '*Environmentally Sound options for e-waste Management'*, E-Waste Management, https://www.researchgate.net/publication/257137715_ENVIRONMENT_ALLY_SOUND_OPTIONS_FOR_E-WASTES_MANAGEMENT

[10]The Global E-waste Monitor 2024,https://ewastemonitor.info/wp-content/uploads/2024/03/GEM_2024_18-03_web_page_per_page_web.pdf.

[11]Van Schaik, A., et al. (2019). E-Waste Recycling: Where Does It Go from Here? Science, 365(6454), 20-22. doi: 10.1126/science. aax3909

b. Material Recovery: Segregation allows for the efficient recovery of valuable materials, such as metals, plastics, and rare earth elements, present in e-waste[12]. These materials can be extracted through various recycling techniques and utilized in the production of new electronic devices.

Effective collection and segregation of e-waste are essential for ensuring its safe handling, proper recycling and resource recovery. Collaboration among stakeholders, including government authorities, manufacturers, recyclers and the informal sector, is crucial for establishing robust collection and segregation mechanisms.

2.1.2 Formal sector and Informal sector

Formal sectors are licensed operators to manage the waste. The International Labour Organization (ILO) defines informal sector waste workers as individuals or small and micro-enterprises that intervene in waste management without being registered and without being formally charged with providing waste management services. During 1980's in metropolitan cities, the scrap dealers identified e-waste and came to know how to make monetary benefit from this e-waste. Therefore, they particularly concentrated in the collection, processing and recycling of e-waste. They made huge profits and thus this informal sector for recycling of e-waste grew from 1980's. The informal sector makes money through collection of recyclable material, manual dismantling and metal recovery. The Informal sector has a well-planned collection network that collects e-waste from each household and also from bulk consumers.

In developed countries, e-waste is recycled by formal sector as they have very well, established recycling system, advanced equipment and abundant financial resources to manage e-waste recycling. However, these facilities are not available in developing countries. Therefore, e-waste recycling is done by informal sector in developing countries. The present challenge before the developing countries is scientific and environmentally friendly recycling and to protect the livelihood of urban poor in the informal recycling sector. Back in 2007, GETZ Bros & Co.Inc - Manufacturer's Association of Information Technology (GTZ-MAIT) survey estimated that the informal sector recycles, 95 percent of the e-waste generated in the country. According to Mahajan Niyati, "*the main reason for informal sector active role in recycling of e-waste is they have small-scale units which are labor intensive, largely unregulated and unregistered*". As India is a thickly populated country where most of the people are unemployed, the informal sector has grown to its fullest. The informal sector recycles much of the e-waste; it gives employment to many people and reduces the burden of formal management agency like the municipalities. The informal sector consists of waste collectors, intermediaries, scrap dealers and recyclers. The waste collectors play an important role in collection of e-waste and also other wastes from houses, roads, offices and companies. They segregate and sell it to the middle men. From middle men it goes to scrap dealers and recyclers. The informal sector has much labor but it lacks the technological knowledge in handling the e-waste. Due to this, it does not recycle the e-waste in a scientific manner and degrades the human health and environment a lot.

According to authors[13], "environmental concerns regarding the operations in the informal sector due to illegal extraction of precious metals is causing highly dangerous and toxic emissions such as dioxins, heavy metals, lead, cadmium, mercury etc. Additionally, the discharges and the smudges from e-waste processing leads to contamination of water bodies and soil due to residues e.g. acids, spent fluids/chemicals, traces of polychlorinated biphenyl (PCB), brominated flame retardants (BFRs), etc. This leads to considerable occupational health and safety concerns and environmental hazards. The contact with the chemicals used during the operations, improper ventilation and working

[12]Zhou, C., et al. (2018). Recycling of WEEE: Characterization of Spent Printed Circuit Boards and Potential for Resource Recovery. Waste Management, 72, 357-368. doi: 10.1016/j.wasman.2017.11.017.

[13] Lakshmi Raghupathy, Christine Kruger, '*E-waste recycling in India-Bridging the gap between the informal and formal sector*', Environmental Science, 2010.

without use of personal protection equipment's lead to direct exposure to hazardous chemicals. Apart from this, workers are also exposed to other hazards leading to physical injuries and chronic ailments such as asthma, malnutrition, skin diseases, eye irritations etc. and in some cases even to long term and incurable diseases. However, in the formal sector the e-waste is recycled in an environmentally sound manner by using Best Available Technologies (BAT) leading to better environment management and enhanced resource recovery".

The recycling of e-waste to extract valuable metals in developing countries is more unorganized. Mostly, the workers in the informal sectors, who are illiterate and do not have the knowledge of health effects of unscientific disposal of e-waste, dismantle the e-waste for copper, steel, plastics, aluminum, printer toners and printed circuit boards. This manual dismantling affects not only the human health but also the environment and ecosystems. The workers involved in this recycling process are severely affected, as they do not use any personal protective equipment. Moreover, these workers dismantle the e-waste with bare hands without using any gloves, without masks, in improper lighting and ventilation facilities. Due to this, they are prone to many health hazards like respiratory problems, skin and eye rashness and irritation, nausea and headaches.

The informal sector is very strong because many people depend on trading, repairing and regaining metals from the e-waste. They earn their livelihood through this means, but they are unaware of the risks posed by this e-waste on health and environment. They also do not know any other best practices as to how to extract the valuable materials from the e-waste. Even if they know about the best practices, they cannot afford the finance for it because of their economic conditions.

In case of the developing countries, the local municipal authorities are not well-trained to handle the e-waste. To great surprise, they do not know about the dangerous effects of e-waste on human health and the environment. Only through NGO's activities, the media started to bring awareness to people about e-waste in developing countries and how e-waste is affecting the health of the people and degrading the environment. In the informal sector, mostly the workers are women and children. They work without any protective measures for a long time and thus are exposed to many toxic gases and suffer from many diseases related to lungs, liver, respiratory system, skin etc.

If there is cooperation between informal sector and formal sector in recycling of e-waste, it is very easy to achieve a great success in sound recycling and conservation of metals to large extent. According to authors,[14] *"if there is cooperation between two sectors it enhances social welfare, reduces pollution, better resource management and creation of green jobs in the recycling sector"*. Collection, segregation and primary dismantling of non-hazardous fractions of e-waste should be focused in the informal sector while the other higher order recycling processes may be concentrated in the formal sector. However, integrating the informal and formal sectors is a big and challenging task. If achieved, it works well for the developing economies and success in e-waste management. The e-waste can be managed very scientifically if both the formal and informal sectors cooperate. The formal sector has abundant technological equipment and if it combines with the cheap labor-intensive operations of the informal sector, the e-waste can be managed in a sound manner without affecting human health or damaging the environment. Integrating informal sector workers into the formal e-waste management system, providing them with proper training and ensuring their adherence to environmental and safety standards can enhance the overall collection and segregation process

[14] Ibid.

2.1.2.1 Formal Sector Collection Centers

Formal sector collection centers play a vital role in the organized and regulated collection of e-waste. This section focuses on formal sector collection centers and their significance in the proper management of e-waste. Formal sector collection centers are established by government agencies, recyclers, or authorized third-party entities. They are equipped with the necessary infrastructure, trained staff and permits to collect and handle e-waste in compliance with environmental regulations. Formal sector collection centers adhere to specific regulatory standards and guidelines for the collection, storage, and transportation of e-waste. They ensure that e-waste is managed in an environmentally sound and safe manner.

Ashwini Kumar Choubey, Union Minister of State for Environment, Forest and Climate Change told in the Rajya Sabha on July 20th 2023 that e-waste recycling through registered recyclers has increased in India from 21 types of EEE notified under E-waste (Management) Rules 2016. Table 8 depicts the details of state-wise e-waste collected and processed during the financial year 2021-2022. According to the Rajya Sabha report on e-waste, Maharashtra is highest in the generation of e-waste followed by Tamilnadu, Andra Pradesh, Uttar Pradesh, Delhi, etc. However, regarding e-waste collection and recycling by formal sector Maharashtra is in ninth place and Delhi is in eleventh place. Uttarakhand is collecting and recycling more e-waste, Tamilnadu and Telangana are also better in e-waste management. The analysis shows that informal recycling is more in Maharashtra and Delhi. The SPCBs of Maharashtra and Delhi where e-waste generation is more should implement the e-waste rules effectively and increase the collection and recycling of e-waste through formal sector.

Table 8: States/UT wise details of e-waste collected and processed during FY 2021-2022

S.No	State/UT	E-waste collected and processed in Tonnes
1	Andhra Pradesh	2021.19
2	Assam	67.0
3	A&N Islands	0.78
4	Bihar	41.07
5	Chandigarh	67.92
6	Chhattisgarh	4167.90
7	DD&DNH	12.34
8	Delhi	2130.79
9	Gujarat	30569.32
10	Haryana	245015.82
11	Himachal Pradesh	373.20
12	Jammu & Kashmir	561.61
13	Jharkhand	366.71
14	Karnataka	39150.63
15	Kerala	1249.61
16	Madhya Pradesh	553.59
17	Maharashtra	18559.30
18	Mizoram	14.85
19	Odisha	477.54
20	Puducherry	31.77
21	Punjab	28375.27

22	Rajasthan	27998.77
23	Sikkim	8.47
24	Tamil Nadu	31143.21
25	Telangana	42297.68
26	Tripura	13.67
27	Uttarakhand	515841.12
28	West Bengal	320.44
	Total	**5,27,131.57**

Source: e-waste management posted on 20th July, 2023 by PIB, Delhi, https://pib.gov.in/PressReleasePage.aspx?PRID=1941054.

A. Role of Formal Sector Collection Centres:

a. Controlled Collection: Formal sector collection centers provide a controlled environment for the collection of e-waste. They receive and document the e-waste received, ensuring proper record-keeping and traceability.

b. Segregation and Categorization: These centers facilitate the segregation and categorization of e-waste into different categories, such as computers, mobile phones, televisions and other electronic devices. This categorization enables efficient recycling and resource recovery processes.

c. Safe Handling and Storage: Formal sector collection centers prioritize the safe handling and storage of e-waste. They implement measures to prevent environmental contamination and reduce occupational health risks for workers involved in the collection and handling processes.

d. Collaboration and Reporting: These centers collaborate with various stakeholders, including government agencies, manufacturers, recyclers and consumers, to ensure effective e-waste management. They maintain records of the collected e-waste and provide reports to relevant SPCB authorities on the quantities and types of e-waste received.

B. Awareness and Education:

a. Public Outreach: Formal sector collection centers actively engage in public outreach initiatives to raise awareness about e-waste management. They organize awareness campaigns, training program, and workshops to educate the public about the importance of proper disposal and the availability of collection centers.

b. Consumer Convenience: By establishing formal sector collection centers in easily accessible locations, such as recycling centers, municipal waste management centers and designated collection points, convenience is provided to consumers which encourages them to utilize these centers for the responsible disposal of their e-waste[15].

Formal sector collection centers ensure the proper collection, segregation and recycling of e-waste within a regulated framework. Their compliance with environmental regulations, safe handling practices and collaboration with stakeholders contribute to the overall effectiveness of e-waste management.

[15]Rani, S., et al. (2018). *Factors Influencing Consumer Behavior towards E-Waste Handling and Disposal - A Review.* Journal of Cleaner Production, 205, 483-497. doi: 10.1016/j.jclepro.2018.09.127.

2.1.2.2. Informal Sector Collection Centers

Informal sector collection centers refer to small-scale operations or individuals engaged in the collection of e-waste without formal authorization or regulatory oversight[16]. These centers often operate in informal settings such as scrap yards, open markets, or small-scale workshops. Informal sector collection centers are part of informal networks involving waste pickers, scavengers and small-scale recyclers. These networks are typically driven by economic motivations, with individuals collecting e-waste to extract valuable materials for resale[17].

Ashwini Kumar Choubey, Union Minister of State for Environment, Forest and Climate Change have given the status of 'e-waste generation in India' in the Rajya Sabha on July 20th 2023.[18] In the year 2021-2022, e-waste generation is 16, 01,155.36 tonnes. However, the e-waste recycling through registered recyclers is 5, 27, 131.57 tonnes. From the year 2016 to 2022, e-waste recycling through registered recyclers has increased, but the total e-waste that is generated is not being recycled through the formal sector. The analysis of the data shows that 10, 74, 023.79 tonnes (16, 01,155.36- 5, 27, 131.57) of e-waste is either being recycled by the informal sector or going to the landfills along with household waste.

The informal sector is well organized in the collection and not in other aspects of management of e-waste and they go door to door and collect the e-waste. The informal sector, consisting of waste pickers and small-scale recyclers, plays a significant role in e-waste collection and segregation[19]. In the informal sector, there are many stakeholders' like-government offices, IT industries, public and private establishments, educational institutions, companies, rag pickers, scrap dealers, wholesalers, recyclers and dismantlers. This section explores the characteristics and implications of informal sector collection centers.

A. Role and Challenges:

a. Collection from Informal Sources: Informal sector collection centers primarily collect e-waste from informal sources, including households, businesses and informal waste collectors. They play a vital role in diverting e-waste to inappropriate disposal methods such as open burning or landfilling.

b. Lack of Regulation: Informal sector collection centers often operate outside the formal regulatory framework, resulting in challenges related to environmental and occupational health concerns. The absence of proper handling, storage and disposal practices can lead to pollution and health hazards.

c. Limited Infrastructure and Expertise: Informal sector collection centers may lack the necessary infrastructure, equipment and expertise for safe and efficient e-waste management. This can result in improper dismantling, crude recycling methods and potential exposure to hazardous substances.

[16]ILO & UNITAR. (2018). *E-waste and the Informal Sector: A Global Outlook*. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_643331.pdf.
[17]Schluep, M., et al. (2013). *Recycling - From E-Waste to Resources*. United Nations Environment Programme (UNEP). Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/30888/EWaste_Report_2013.pdf.
[18]E-Waste Management, Ministry of Environment, Forest and Climate Change Posted On: 20 July 2023 by PIB Delhi, https://pib.gov.in/PressReleasePage.aspx?PRID=1941054.

[19]Baldé, C. P., et al. (2017). The Global E-Waste Monitor 2017: Quantities, Flows, and Resources. United Nations University (UNU), International Telecommunication Union (ITU), and International Solid Waste Association (ISWA). Retrieved from https://collections.unu.edu/eserv/UNU:6349/Global-E-waste_Monitor_2017__20Nov17.pdf.

d. Informal Recycling Practices: Informal sector often engage in rudimentary recycling processes to recover valuable materials, such as metals and components, from e-waste. However, these practices may not adhere to environmentally sound methods, leading to environmental degradation and health risks[20].

The informal sector recycling process includes dumping in open spaces, dismantling, or shredding, which adversely affects the environment. After shredding, they burn and leave the residue and this residue leaches in to the soil or nearby water bodies. The by-products, which are released due to unscientific recycling, are leachates, coarse particles, fine particles, fly ashes, bottom ashes, fumes, effluents, wastewater and solid materials. Leachates, coarse particles and bottom ashes are polluting human beings, soil and groundwater. Effluents are polluting the surface water and fly ashes; fine particles and fumes are polluting the air.

B. Integration and Regulation:

a. Formalization and Integration: Recognizing the significant role played by the informal sector, efforts are being made to integrate informal sector collection centers into formal e-waste management systems. This involves providing training, access to proper infrastructure and establishing partnerships with formal recyclers.

b. Informal Sector Empowerment: Empowering the informal sector through capacity building and training programs can enhance their ability to handle e-waste in a safer and more environmentally friendly manner. This includes educating informal workers about the potential risks associated with e-waste and promoting sustainable practices.

C. Regulation and Enforcement:

a. Monitoring and Enforcement: Regulatory bodies need to strengthen monitoring and enforcement measures to ensure that informal sector collection centers comply with environmental and occupational health regulations. This can help mitigate the negative environmental and social impacts associated with informal e-waste management.

b. Incentives for Formalization: Providing incentives, such as financial support, tax benefits, or access to technology, can encourage informal sector collection centers to transition towards formalization and adhere to responsible e-waste management practices.

Efforts should be made to engage with the informal sector, improve their practices and integrate them into formal e-waste management systems. This can lead to a more comprehensive and sustainable approach to e-waste collection and management.

2.1.3 Recycling and Reuse of E-waste

Even in developed countries where they are having a good e-waste management system, the collection and recycling of e-waste is low because of exporting the e-waste in name of donations and charity. Monitoring of how much e-waste is generated and is recycled, is very necessary for the sustainable societies and circular economy. Only if the countries maintain their e-waste data, they can make laws for stopping more e-waste generation and also can establish good recycling equipment for scientific disposal of e-waste. According to John Babington Chibunna, "*technology is one of*

[20]Robinson, B. H. (2009). *E-waste: An Assessment of Global Production and Environmental Impacts*. Science of the Total Environment, 408(2), 183-191. doi: 10.1016/j.scitotenv.2009.09.044.

the components for successful recycling of e-waste, the other components are involvement of people and maintenance of environmentally responsible behavior".[21]

Steps to minimize the generation of e-waste from the get-go would greatly reduce the strain on the disposal and recycling sector. The 3R principle establishes a hierarchy for effective management of waste; the 3Rs stand for "reduce, reuse, recycle".[22] The policy's objective is in fact to primarily avoid the generation of waste and not, ensuring compliance with regulation or elevate the management of waste.[23] It also calls for treating waste as a "resource waiting to be recovered and used" wherein the generation of waste is inevitable.[24] A worthwhile application of this hierarchy to e-waste would effectuate the intended goal of the framework i.e. minimizing generation. Recycling and reuse are essential processes in the management of e-waste. This section explores the significance of recycling and reuse in diverting e-waste from improper disposal and reducing its environmental impact.

2.1.3.1. Recycling of E-waste:

a. Resource Recovery: Recycling of e-waste allows for the recovery of valuable resources such as metals (e.g., gold, silver, copper), plastics and rare earth elements. These materials can be extracted, processed and reused in the manufacturing of new electronic products or other industries[25].

b. Reduction of Environmental Impact: Proper recycling of e-waste helps minimize the environmental impact associated with raw material extraction. It reduces the need for new resource extraction, conserves energy and mitigates pollution from mining activities[26].

c. Recycling Technologies: Various technologies are employed in e-waste recycling, including mechanical shredding, separation processes (such as magnetic separation and eddy current separation), hydrometallurgical methods and pyrometallurgical processes. These technologies enable the recovery of different components and materials from e-waste[27].

d. Responsible Disposal of Hazardous Materials: E-waste often contains hazardous substances such as lead, mercury, cadmium and flame retardants. Recycling ensures the proper treatment and disposal of these hazardous materials, preventing their release into the environment[28].

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[21] John Babington Chibunna, Chamhuri Siwar, Rawshan Ara Begum & Ahmad Fariz Mohamed, "*The Challenges of e-waste management among institutions: a case study of UKM*", 2011, Elsevier-UKM Teaching & Learning Congress.

[22]United Nations Environment Programme and United Nations Institute for Training and Research. (2013), *Guidelines for National Waste Management Strategies: Moving from Challenges to Opportunities*, UNEP, https://wedocs.unep.org/xmlui/handle/20.500.11822/8669.

[23]*Ibid*.

[24]*Ibid*.

[25]World Health Organization (WHO). (2012). *E-Waste and Children*. Retrieved from https://www.who.int/ceh/publications/electronic_waste_children/en/.

[26]Li, J., et al. (2015). *E-Waste Recycling in China: A Health Disaster in the Making*. Environmental Health Perspectives, 123(5), 7-9. doi: 10.1289/ehp.1509930

[27]Su, F., et al. (2018). *A Review on End-of-Life Printed Circuit Board Recycling Technologies*. Journal of Hazardous Materials, 344, 646-666. doi: 10.1016/j.jhazmat.2017.10.055.

[28]Schluep, M., et al. (2013). *Recycling - From E-Waste to Resources.* United Nations Environment Programme (UNEP). Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/30888/EWaste_Report_2013.pdf.

2.1.3.2. Reuse of E-waste:

a. Extended Product Life Cycle: Reuse involves refurbishing and extending the life cycle of electronic devices by repairing, upgrading, or repurposing them for secondary use. It helps to reduce the demand for new products, conserves resources and reduces the overall e-waste generation[29].

b. Donations and Resale: Reusable electronic devices, such as laptops, smartphones, and tablets, can be donated to charitable organizations, educational institutions, or resold in the second-hand goods market. This allows others to benefit from functional devices and reduces the need for new purchases[30].

c. E-waste Exchange Programs: E-waste exchange programs facilitate the exchange or trade-in of old electronic devices for new ones. These programs encourage consumers to responsibly dispose of their e-waste by providing incentives or discounts for returning their old devices[31].

d. Repair and Refurbishment: Reuse initiatives often involve repair and refurbishment services to restore the functionality and performance of electronic devices. This extends their lifespan and promotes sustainable consumption and production practices[32].

Recycling and reuse are integral components of sustainable e-waste management. They enable the recovery of valuable resources, reduce environmental impacts and contribute to a circular economy approach for electronic products.

2.1.4 Safe Disposal of E-waste

Safe disposal of e-waste is a major problem faced by many countries around the world. E-waste recycling is comparatively an unknown concept in the developing countries. Because of this, the electronic waste is dumped in water bodies or dump yards without proper recycling.[33]If the e-waste is thrown along with the household waste and landfilled, it releases contaminated leachates and pollutes the soil and ground water. Due to this, it becomes very difficult to grow crops in that soil and there will be shortage of clean water and finally results in food and water crisis. Even if the e-waste is incinerated, it releases toxic gases and pollutes the air. In worst cases, uncontrolled fires may arise at landfills and due to these metals and chemicals like extremely toxic dioxins and furans -tetrachloro-dibenzo-dioxin, polychlorinated dibenzo-dioxins, polybrominated dibenzo-dioxin and poly-chlorinated dibenzo furans from halogenated flame-retardant products and PCB containing condensers can be emitted[34].

[29]Reike, D., et al. (2018). *A Systematic Review of Drivers and Barriers for the Recycling of Waste Electrical and Electronic Waste.* Journal of Cleaner Production, 197(Pt 1), 1270-1284. doi: 10.1016/j.jclepro.2018.06.055

[30]He, W., & Li, X. (2019). *Understanding the Intentions behind E-Waste Recycling Behaviors: An Empirical Study in China.* Resources, Conservation and Recycling, 144, 126-133. doi: 10.1016/j.resconrec.2019.01.022

[31]Isenstadt, J., & Gillingham, K. (2017). *Energy Efficiency Rebound and Jevons' Paradox: A Review of the Literature.* Energy Policy, 107, 585-597. doi: 10.1016/j.enpol.2017.05.015.

[32]Geissdoerfer, M., et al. (2017). *The Circular Economy - A New Sustainability Paradigm?* Journal of Cleaner Production, 143, 757-768. doi: 10.1016/j.jclepro.2016.12.048.

[33] Neha Garg, Deepak Kumar adhana, '*E-waste Management in India: A Study of Current Scenario'*, International Journal of Management, Technology and Engineering, Vol.IX, Iss.I, January 2019.

[34] Ramachandra T.V, Saira Varghese.K, '*Environmentally Sound options for e-waste Management'*, E-Waste Management.

Considering the lack of precious metals in the earth, if proper recycling methods are developed they would contribute to the optimization of the product life cycle and ensures the long-term supply of precious metals[35]. E-waste is a source of many precious metals like copper, aluminum, nickel, cadmium, lead, gold, palladium, silver, indium and plastics. Therefore, if this e-waste is properly recycled and if the precious metals are extracted fully, there won't be a need to extract these precious metals through mining which adversely affects the environment through emissions of greenhouse gases.[36]

If e-waste is not disposed off properly it degrades the environment and also causes loss of secondary materials. If e-waste is properly recycled, it not only saves the natural resources but also reduces the greenhouse gas emissions. Many electronic goods like air conditioners and refrigerators contain substances that damage the ozone layer. If these are not recycled in an environmentally sound manner, they increase global warming and in turn, affect the climate.

2.1.4.1 Hazardous Components of E-waste:

a. Toxic Substances: E-waste contains hazardous substances such as lead, mercury, cadmium, brominated flame retardants, and polyvinyl chloride (PVC). Improper disposal can lead to the release of these substances into the environment, posing significant risks to ecosystems and human health[37].

b. Leaching and Contamination: When e-waste is disposed off in landfills or incinerated, toxic substances can leach into soil and water, contaminating groundwater and affecting nearby communities. Proper disposal methods are necessary to prevent contamination and the spread of pollutants[38].

2.1.4.2 Importance of Safe Disposal:

Safe disposal of e-waste is very necessary for a healthy environment.

a. Environmental Protection: Safe disposal methods, such as recycling or appropriate treatment technologies, minimize the release of hazardous substances into the environment. This helps to protect ecosystems, water sources and biodiversity from pollution caused by e-waste[39].

[35] Perrine Chancerel, Christina E.m.meskers, Christian Hageluken and Vera Sussane Rotter, '*Assessment of Precious Metal Flows during preprocessing of waste Electrical and Electronic Equipment*', Journal of Industrial Ecology, Vol.13, No.5, 2009.
[36] Ibid
[37]United Nations Environment Programme (UNEP). (2015). *Waste Crime - Waste Risks: Gaps in Meeting the Global Waste Challenge*. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/9311/Waste_Crime.pdf.
[38]Golev, A., et al. (2016). *Sustainable Recovery of Metals from Printed Circuit Boards: A Review*. Waste Management, 57, 205-218. doi: 10.1016/j.wasman.2016.07.019.
[39]Schluep, M., et al. (2013). *Recycling - From E-Waste to Resources*. United Nations Environment Programme (UNEP). Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/30888/EWaste_Report_2013..

b. Human Health Protection: Unsafe disposal practices expose individuals, including waste collection workers and nearby communities, to harmful substances through air, water and soil pollution. Safe disposal reduces the health risks associated with exposure to toxic components of e-waste[40].

2.1.4.3 Challenges in E-waste Disposal:

Theoretically the rules say that safe disposal of e-waste is very much essential for maintaining quality environment and protection of human health. However, the safe disposal also is facing many challenges.

a. Informal Disposal: Inadequate infrastructure and lack of awareness lead to informal disposal practices, such as open burning, unregulated landfilling, or improper dismantling of e-waste. These practices contribute to environmental pollution and health hazards[41].

b. Limited Disposal Facilities: Insufficient recycling and disposal facilities pose challenges in managing e-waste effectively. The lack of specialized facilities and appropriate technologies hinders the safe disposal and treatment of e-waste[42].

c. Regulatory Compliance: Ensuring compliance with e-waste management regulations is a significant challenge. Monitoring and enforcement measures are necessary to promote responsible disposal practices and hold stakeholders accountable for their e-waste management responsibilities[43].

3. Suggestions and Conclusion:

a. Authorized Recycling Facilities: E-waste should be disposed off at authorized recycling facilities that have the necessary infrastructure and expertise to handle and treat e-waste in an environmentally sound manner[44].

b. Proper Dismantling and Treatment: Safe disposal involves proper dismantling of e-waste to separate hazardous components from recyclable materials. Hazardous substances should be treated using appropriate technologies to prevent their release into the environment[45].

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c. Public Awareness and Education: Raising public awareness about the importance of safe e-waste disposal is crucial. Educational campaigns and programs can promote responsible consumer behavior and encourage individuals to use designated collection centers or recycling facilities[46].

Safe disposal of e-waste requires the implementation of appropriate disposal methods like biological treatment, incineration and deposition in secured landfills, the establishment of proper recycling facilities and the enforcement of regulations. By addressing these challenges and promoting responsible practices, the adverse environmental and health impacts of e-waste can be mitigated.

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