



Emerging challenges in technology transfer and commercialization: A case study on precious metal recovery

Nitesh Kumar^{1*}, Vinod Kumar², Jaynath Kumar³, Chandra Kant⁴, Rajesh Kumar⁴

¹ Department of Chemistry, S.N.S. College, Motihari (A Constituent Unit of B.R.A. Bihar University, Muzaffarpur), Bihar, India

² Department of Chemistry, M.J.K. College, Bettiah (A Constituent Unit of B.R.A. Bihar University, Muzaffarpur), Bihar, India

³ Department of Chemistry, Dr. R.M.L.S. College, Muzaffarpur (A Constituent Unit of B.R.A. Bihar University, Muzaffarpur), Bihar, India

⁴ P.G, Department of Chemistry, R.D.S. College, Muzaffarpur (A Constituent Unit of B.R.A. Bihar University, Muzaffarpur), Bihar, India

Abstract

The generation of e-waste around us has increased considerably attention around the world as a result of the growth of information and communication technology (ICT) based instruments. This has made recycling of E-waste in an environment-friendly manner a crucial issue; thereby increasing the importance of technologies that might assist in reusing e-waste in an environment-friendly manner. The current case study arrangements with such a innovative technology aimed to recover gold from a scrap of mobile phones and other electronic equipment and reduce the e-waste into a manageable mass. The study highlights the underlying challenges in putting such technologies into production. Detailed discussions with the stakeholders involved in technology development, commercialization, and production were held. These included scientists involved in the development of technology, industrial units receiving the technology, and officials of the Central Pollution Control Board (CPCB). The important points emerging from the discussions included the threat emerging from unauthorized e-waste recyclers using hazardous technologies for e-waste recycling. A possible remedy for this may be the Government's effort to make these unauthorized e-waste recyclers use standardized, environment-friendly, and affordable e-waste recycling technologies. Another issue that cropped up during the case study was of the procedural delay in getting approval from the Government departments for starting manufacture. Some of the Government departments are facing a crunch of manpower in dealing with the applications received from private sector companies for environmental clearances.

Keywords: electronic waste, technology transfer, recycling, science commercialization, environment

Introduction

E-waste consists of redundant electronic appliances which are not supposed to be used anymore. The term e-waste is used to shelter all the components which go into the making of electronic and electrical equipment (EEE) and its portions that have been rejected by its owner as waste without the intent of reuse (Step Initiative 2014). It is estimated that the global quantity of e-waste produced in 2014 was 41.8 million metric tonnes (Mt) which is predicted to enhance to 50 Mt of e-waste in 2018. (The global e-waste monitor – 2014, United Nations University, IAS – SCYCLE, Bonn, Germany). The rapid growth and utility of information and communication technology (ICT) products such as television sets, computers, mobile phones, etc. have resulted in an enormous increase in the extent of e-waste generated in the country. As India is focusing on the application of ICT in various spheres of life through its Digital India initiative, the possibility of the generation of e-waste is very high. Various reports have also raised concerns about the generation, handling, and accumulation of e-waste in India ^[1-2, 3, 4]. Since mobile telephones have a strong tendency to go out of use because of their short life span they make a vast section of E-waste. Printed Circuit Boards (PCBs) of these mobile phones contain many hazardous metals like nickel, cadmium & mercury; and, significant metals like copper, gold, and platinum. E-waste recycling refers to the disassembly of E-waste, separating precious metals from it and reducing the remaining matter to a manageable mass. (https://en.wikipedia.org/wiki/Computer_recycling) This recycling is important because if left on itself e-waste can lead to the release of toxins and carcinogens into the environment. At present majority of E-waste is being recycled in an unscientific way by burning the material to separate components and recovering precious materials. This method generates furans, polycyclic aromatic hydrocarbons (PAHs), dioxins, polyhalogenated aromatic hydrocarbons (PHAHs), and hydrogen chloride. Initially such type of recycling results in only localized contamination but later this spreads to waters and food chains. Workers who are involved in the unscientific processing of E-waste also suffer bad health effects via inhalation and skin contact, this goes on to expose a large section of the population to impurities via drinking water, smoke, food, and dust. Evidence also suggests that impurities from E-waste might be present in some agricultural or manufactured products for

distribute (Robinson, 2009). Therefore, technologies which can recycle e-waste in an environmentally friendly manner and recover precious material from it are highly desirable.

Background for the Technology Development

In India, the informal sector recycles about 95% and the formal sector recycles only 5% of the e-waste. As the major percentage of e-waste is being recycled by the informal sector in an unscientific manner it causes the emission of furan, dioxin, and other poisonous gases along with the discharge of harmful elements like lead, cadmium, mercury, etc. during the extraction process which is seen as a serious threat to the environment. Therefore, a need was felt to evolve a zero-discharge method for the extraction of valuable metals from e-waste which can be very helpful in the effective recovering and disposal of e-waste (Jha et al., 2011).

During the last 20 years, recycling of printed circuit boards (PCBs) has been based on pyrometallurgical processes which involve the application of heat resulting in the emission of highly polluting gases, carcinogenic compounds, and low recovery rate of metals; because of these disadvantages, researchers are shifting towards the hydrometallurgical processes as they are more predictable and easily controllable (Cui and Zhang, 2008).

One such bench-level technology was developed by the Council of Scientific and Industrial Research (CSIR-NML) at Jamshedpur.^[5] The technology was successfully developed and tested at the Metal Extraction and Forming (MEF) unit of the National Metallurgical Laboratory (NML) Jamshedpur and then transferred to ADV Metal Combination Pvt. Ltd., New Delhi.^[6] In the technology developed by CSIR-NML, the mounted components of the PCBs are removed by assistance of screwdrivers and other technique, this is followed by shredding of the scrap by the metal cutter, which turns the waste into small granules. This is followed by hydrometallurgical processing which consists of leaching – transferring wanted components into solution using halides or acids as leaching agents, purification of the leach solution to eliminate contaminants via ion exchange, solvent extraction, or adsorption, then recapture of base and valuable metals from the solution by the electro refining process, chemical reduction, or crystallization (Kamberović *et al.*, 2009). After that absorption/cementation with subsequent heat treatment is used to recover gold. The major raw material used for this technology is mobile phone PCBs, scrap parts of various equipment, leaching, adsorbent, etc.

The sequential development of technology is shown below:

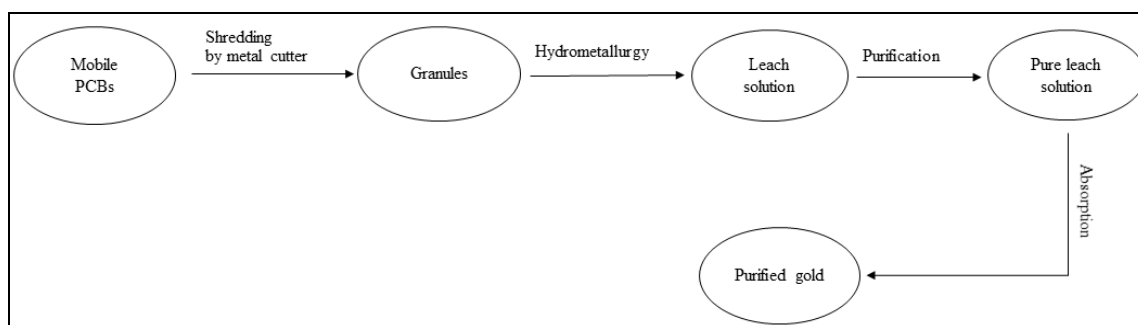


Fig 1: Recovery of Gold from PCBs

Government initiatives for technology commercialization

Commercialization of bench-level technologies developed in Government research/R&D institutions is extremely crucial for taking benefits of research to society. To achieve this, these technologies are to be transferred to the private sector industry where they can be up-scaled and put into production. The transfer of science-based knowledge and capabilities from one entity (person, group, organization) to another for the purpose of further development and commercialization is called technology transfer. (Swami Dass & Vulasa, 2009; Lane, 1999)

Technology transfer is also referred to as converting the technology being generated in scientific research institutions into applications aimed at solving a pressing problem or earning commercial profit for stakeholders.^[7]

Most of the Government research institutions have established in-house technology transfer units which are dedicated to dealing with the transfer of these technologies and their commercialization by the industrial units to whom these technologies are transferred.

Government research institutions can become significance and attractive sources of technology for the industry provided they are able to convert their research-based scientific knowledge into technologies that can be put into production by the private sector industry. To achieve this both Government research organisations and industry need to effort together to recognize and address issues related to technology transfer and its commercialization. But this is not easy to achieve as the objectives and work cultures of Government research institutions and industry are quite different from each other. But the collaboration between the two can be mutually beneficial for each other. On one side it can help the research institution to achieve more visibility and gain commercial benefits; on the other hand, the industry is able to earn profits with the help of indigenously available scientific expertise by converting their research-based knowledge into commercially viable products and services. Finally, all this can contribute to enhancing the quality of life for the end consumer.^[8] Various stages of this technology transfer process are shown in Fig 2.

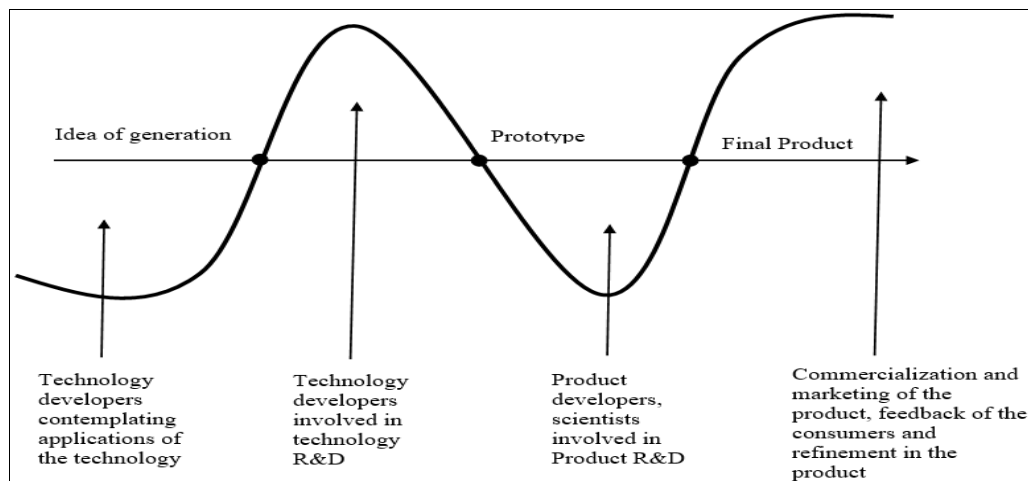


Fig 2: Adopted from Lane, J. P. (1999) Understanding technology transfer. *Assistive Technology*, 11(1), 5-19.

The government of India has put a lot of emphasis on converting the scientific knowledge into technology which can be used for producing commercially viable products and services. To achieve this aim the Government has set up a variety of institutions like National Research Development Corporation (NRDC) in 1953 to commercialize indigenously developed scientific knowledge.^[9] Department of Science and Technology (DST) also established National Science & Technology Development Board (NSTEDB) in 1982 to stimulate knowledge driven and technology intensive enterprises, through the creation of Technology business incubators and technology parks at IIT Kharagpur, IIT Chennai, IIT Kanpur, IIT Delhi, IIT Mumbai, Delhi University and IT-BHU Varanasi.^[10]

Society for Technology Management (STEM) was set up at Hyderabad in 2005. STEM is a non-profit organization was set-up to provide a platform for all the professionals/stakeholders to create a synergy in the industry through sharing of their expertise.^[11] Technology Development and Demonstration Programme (TDDP) was set-up by Department of Scientific and Industrial Research (DSIR) with the view to create linkages between industry, R & D establishment and academic institutions thereby helping in the conversion of innovative ideas into products and subsequent commercialization of these products.^[12] In order to encourage public-private partnerships in R&D, the Government of India has set up the New Millennium India Technology Leadership Initiative (NMITLI), which is being monitored through the CSIR.^[13] More recently CSIR established CSIR-Tech in 2011, a private initiative to commercialize intellectual property and technical know-how generated from public & private R&D labs and academic institutions.^[14]

At the policy level Government of India has taken a lot of initiatives in IPR policy, the transparent tax regime for protecting the IPRs of all innovators and to encourage the public-private partnership (PPP) model to increase investments in infrastructure.^[15]

Challenges of technology transfer in India

Commercialization of scientific research is a complex process and needs many inputs like research and development (R&D) resources, intermediary facilitators, infrastructure, entrepreneurial incentives, seed capital, leadership, and culture. A lot of effort has been done by Indian Government for the improvement in the commercialization of technology from research institutions to private sector industries. However, the following issues need to be addressed:

- Difference in interest and objectives of private sector industry and government research institutions.
- Research institution lacks dedicated technology transfer offices (TTO) which plays a crucial role in technology transfer.^[16]
- Lack of economic feasibility analysis before undertaking the technology development by the scientist and after the commercialization of the technology.
- Lack of continuous monitoring of the development and transfer process.
- Differences in the time scale of technology at the lab scale and industrial scale.
- Geographical distances between research institutions and private sector industrial enterprises.

The case studies

The present case study deals with the technology “Recovery of Gold from scrap of mobile phones and other electronic equipment”. The technology was developed by CSIR-NML and was successfully transferred to ADV Metal Combine Pt. Ltd. New Delhi.

Discussions were held with the scientist and industrial unit to understand the overall process from the development of the technology to its transfer and commercialization. Discussion with officials of the Central Pollution Control Board (CPCB) was also held to understand the regulation and prospective scenario of e-waste. The technology is claimed to be helpful in dealing with e-waste by minimizing the harmful discharge during the recovery of precious metals from e-waste.

About the technology

The rapid growth and use of information and communication technology (ICT) products such as television sets, mobile phones, computers, etc. have resulted in an enormous increase in the quantity of e-waste generated around the world. As India is focusing on the application of ICT in various spheres of life through its Digital India initiative, the possibility of the generation of e-waste is very high. Various reports have also raised concern about the generation, treatment, and accumulation of e-waste in India. Therefore, safe recycling of e-waste in accordance with the existing environmental norms for hazardous waste disposal is very important from an environmental safety point of view.

The e-waste from ICT pieces of equipment contains many toxic and hazardous elements such as lead, nickel, cadmium, mercury chromium, etc. These metals can have an adverse effect on human health as well as on the environment. However, the e-waste also contains various precious and valuable metals such as gold, silver, platinum, palladium, etc.

Table 1: The percentage-wise metals present in PCBs of mobile phones are shown below.

Elements	Weight (w/w %)	Elements	Weight (w/w %)
Cu	56.68	Ag	0.1
Al	1.42	Pd	0.01
Ca	1.61	Au	0.021
Fe	0.24	Resin material	38.29
Sn	1.40	Mn	0.005
Zn	0.22		

Source: Abhishek Tripathi *et al.*: Leaching of Gold from the Waste Mobile Phone Printed Circuit Boards (PCBs) with Ammonium Thiosulphate.

Recovery of these variable metals from e-waste has become widespread industrial activity. At present, both the informal and formal sectors are engaged in the recycling of e-waste through the recovery of various metals from e-waste. In India, the informal sector recycles about 95% and the formal sector recycles only 5% of the e-waste. As the major percentage of e-waste is being recycled by the informal sector in an unscientific manner it causes the emission of dioxin, furan, and other harmful gases along with the discharge of harmful elements like lead, cadmium, mercury, etc. during the extraction process which is seen as a serious threat to the environment. Therefore, a zero-discharge method for the extraction of various metals from e-waste can be very helpful in the effective recycling and disposal of e-waste.^[17]

In the last 20 years, recycling of printed circuit boards (PCBs) has been based on pyrometallurgical processes but due to the emission of highly polluting gases, carcinogenic compounds, and low recovery rate of metals, researchers are shifting towards the hydrometallurgical processes as they are more predictable and easily controllable.^[18]

In the technology developed by CSIR-NML, the mounted components of the PCBs are removed by screwdrivers and other technique, this is followed by shredding of the scrap by the metal cutter, which turns the waste into small granules. This is followed by hydrometallurgical processing which consists of leaching – transferring desirable components into solution using halides or acids as leaching agents, purification of the leach solution to remove impurities by ion exchange, adsorption or solvent extraction, then recovery of base and precious metals from the solution by the electro refining process, chemical reduction, or crystallization.^[19] After that absorption/cementation with subsequent heat treatment is used to recover gold. The major raw material used for this technology is mobile phone PCBs, scrap parts of various equipment, leaching, adsorbent, etc.

Analysis and Discussion

1. Discussion with Scientists

Discussion with scientists who developed the technology was held broadly on the following points

- The source of idea for developing the technology
- Time taken to develop the technology and the challenges faced during the process of development, additional requirement, development of the protocol
- How the technology got noticed by the industry
- Environmental considerations
- Unique features of the technology and testing
- Suggestion for enhancing technology transfer
- How the technology will help society

Since India is a major consumer and importer of gold, recovering gold from printed circuit boards (PCBs) of mobile phones can reduce the dependence on imports. This was the main driving motive behind developing the technology. Subsequently, the task of developing the process to recover gold was undertaken. After initial research, a prototype was developed. Initially, there were challenges when other metals also got dissolved in the solution that was used for the recovery of gold. Another problem was effluents being generated during the process. The gold had to be separated from the solution. To achieve this, leaching conditions were optimized in

terms of various parameters such as concentrations of copper sulfate and ammonium thiosulfate; pH, and pulp density. Typically, one could extract 350 g of gold from 1000 kg of PCB from mobile phones. The quantity of recovered gold also depends on the type of mobile phone. A more sophisticated mobile phone having the latest features and good connectivity for the communication system might have more amount of gold and obviously, be costly too. Scientists claimed that “The extracted gold is more than 99.99% pure”. In terms of additional resources, equipment, funding, and raw materials in-house resources were found to be sufficient. After development, the technology was tested for:

- a. Economic Feasibility
- b. Purity
- c. Environmental aspect

Anticipated Benefits of Technology

From the scientists’ point of view, the technology will help in the effective recycling of e-waste generated from equipment like mobile phones PCBs, and scrap parts of various equipment. Since this e-waste is known to contain various toxic elements such as cadmium, lead, chromium, mercury, nickel, etc. which have an adverse impact on our environment, its effective recycling will be extremely helpful in protecting the environment. It will also help in achieving national missions like “Swachh Bharat” by helping in tackling the problem of e-waste. [20]

2. Discussion with Industry

Discussion with the industry was held broadly on the following points

- The raw materials required for production and their source
- How industry came to know about the technology
- Formal agreements with NML for using the technology
- Time is taken for the technology transfer
- Difficulties faced during the technology transfer process from NML
- Suggestion to enhance collaborations between Government institutions and industry

The industrial unit ADV Metal Combine Private Ltd., New Delhi came to know about the technology through a conference on waste recycling held in Guangzhou, China. The industrial unit was impressed by the idea contained in the technology. They conducted a detailed market study to assess the potential of the technology. After convincing themselves about the market potential of the technology the industry contacted CSIR-NML through email and made a visit to CSIR-NML after receiving an invitation. Subsequently, they applied to get an exclusive license of the technology, the whole process was completed in three months with the Business Development Unit of CSIR-NML playing a crucial role. However, the industrial unit felt that the charges were somewhat high for a small entrepreneur like them for getting the exclusive license of the technology. After receiving the technology industrial unit made changes to the technology which they thought were necessary for mass-scale production and to make it economically feasible. The industry used its full-flagged lab facility and outsourced the testing of the technology for improvement. During the modification process, all the required support was provided by the CSIR-NML. The industrial unit shows its satisfaction towards CSIR-NML and said “NML is the great resource point” for getting such technologies. After successfully upgrading the technology, the industrial unit applied with Delhi Pollution Control Committee (DPCC) for clearance to launch the production process, the clearance is still awaited. The whole process was shown in Figure 3.

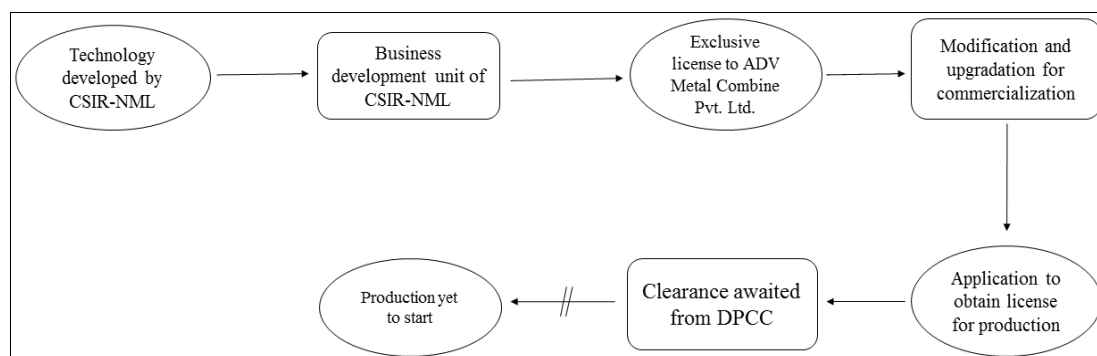


Fig 3: Overall Flow of Technology

Since the raw material used in this technology is mobile phone PCBs, and scrap parts of various equipment so the industrial unit needs authorization for recycling and dismantling of e-waste. This requires approval from DPCC. The point about unauthorized e-waste recyclers also emerged which constitute a major portion of e-waste recycling. The industrial unit feels that the challenge posed by unauthorized recyclers is huge because of the rather unscientific process used by them causing a lot of emissions during the recycling process. In addition to regulatory challenges faced by authorized recyclers.

3. Discussion with Central Pollution Control Board (CPCB) Officials

Discussion was held with CPCB officials broadly on the following points

- Process followed by the State Pollution Control Board (SPCB) or Pollution Control Committee for grant of authorization for e-waste recycling
- Timeline for licensing process of the e-waste recycling/dismantling
- Regulatory requirement for recyclers/dismantlers
- Problems associated with unauthorized e-waste recyclers
- How Government deals with unauthorized e-waste recyclers
- Suggestion for the improvement in the existing regulatory
- Current research areas where Indian Government research agencies should focus in order to deal with e-waste effectively

The government of India has come up with a regulation known as e-waste (Management and Handling) Rules, 2016 announced and notified on 23rd March 2016. For the recycling/dismantling the industrial firms must follow the guidelines in accordance with the notified rules and regulations. The CPCB has made some regulatory requirements for recycling and dismantling of e-waste, to be followed by the recyclers/dismantlers. When an industrial firm applies for recycling/dismantling of e-waste to the concerned SPCB or Pollution Control Committee, the concerned authority must complete the entire process within ninety days in accordance with rules and regulations. Also, there is no fee for applying for such licenses. If an industrial firm does not get any response within the specified time period, then they may approach to the appellate authority or the chairman the clarification So in order to get the license faster the industrial firm needs to follow up with the authorities. CPCB is also concerned with unauthorized e-waste recyclers which pose a threat in terms of emissions but on the other hand, there are socio-economic aspects as the livelihood of many these recyclers depends on the profession. So, in that direction, the Government is planning to take up certain initiatives the at district level like providing them a common facility or area so that they can come and set up their processing plants for recycling/dismantling. The Government is also trying to minimize the supply of e-waste to unauthorized recyclers marketing the formal system more robust.

Conclusions

The industrial unit came to know about the technology only through a seminar and that too outside the country. It was more of a coincidence that the industrial unit came to know about the technology rather than an organized and proactive effort on the part of a government research institution. The Government should also make adequate efforts to publicize the technologies available with Government research institutions. The other important issue that came up is the cost of such technologies. Most of the bigger industrial corporations can source the technology from outside the country but the small and medium enterprises (SMEs) which form a bulk of industrial units in the country are not able to afford imported technologies, so Government research institutions may be a significance source of indigenously developed affordable technologies. In the present case, as pointed out by the industrial unit the cost of the technology as charged by the Government research institution was on the higher side, a point that may well be considered by Government research institutions keeping in mind the financial constraints faced by SMEs. What can be done is that, instead of charging a one-time fee for exclusive licensing from the industrial unit, a small amount may be charged at the time of licensing the technology and the rest may be recovered through royalty charged on a year-to-year basis depending upon the profit earned by industrial unit from the technology. This will reduce the financial burden on the SMEs and it will also keep the research institution interested in the follow-up of the modifications done by the industrial unit in the technology and the efforts undertaken to sell the product based on the technology.

But the challenge emerged when it came to acquiring a license for production from Government regulatory authority. The industrial unit had submitted papers but the response was still awaited. As confirmed from informal resources there is a complete ban grant of license for e-waste recycling in Delhi because of master plan consideration. The industrial unit seemed to be unaware of this provision. As a final step in the commercialization of technology Government research institutions may also help the industrial unit to obtain necessary clearances from various ministries and departments. In some select cases, the Government research institution can also be authorized to scrutinize the environment-friendliness of the production process. This can form the basis for further evaluation by concerned Government departments or ministries like CPCB/SPCB to grant licenses for production.

An association of technology transfer executives working in Government research institutions can prove to be an ideal platform for the exchange of ideas.

State Pollution Control Board or Pollution Control Committee and other concerned Government departments have their own problems in dealing with the applications received from industrial enterprises. In some cases, they are not fully equipped with sufficient manpower and that needs to increase. They may also be equipped with technology helping them to deal with governance-related issues.

References

1. Mor RS, Sangwan KS, Singh S, Singh A, Kharub M. E-waste Management for Environmental Sustainability: and Exploratory Study. *Procedia CIRP*,2021;98:193–198. (b) E. Markl, M. Lackner.

- Industrial Engineering Management-THE key skill for the Digital Age International. *Journal of Industrial Engineering and Engineering Management*, 2019, 8(3), 08-22. (c) S. I. Mohammed. E-Waste Management in Different Countries: Strategies, Impacts, and Determinants. *Advances in Green Electronics Technologies* 2022. (d) G. Twagirayezu, O. Irumva, A Uwimana, J. C. Nizeyimana, J. P. Nkundabose. Current Status of E-waste and Future Perspective in Developing Countries: Benchmark Rwanda. *Energy and Environmental Engineering* 2021, 8(1), 1-12. (e) O. Osibanjo, I.C. Nnorom, The challenge of electronic waste (e-waste) management in developing countries. *Waste Management & Research: The Journal for a Sustainable Circular Economy*.2007, 25(6), 489-501. (e) Z. He, Y. Yue, Y. Wang, The hazards, treatment measures and sustainable development of electronic waste. *Earth and Environmental Science* 2022, 1011, 012023. (f) D. Blanco, E. M. Rubio, R. M. Lorente-Pedreille. *Encyclopedia (mdpi), Lightweight Structural Materials in Open Access: Latest Trends. International Journal of Lightweight Materials and Manufacture*, 2021, 14(21), 6577.
2. "WHO | Electronic waste,"<http://www.who.int/ceh/risks/ewaste/en/>, 2020.
 3. He Z, Yue Y, Wang Y. The hazards, treatment measures and sustainable development of electronic waste. *Earth and Environmental Science*,2022:1011:012023.
 4. Marconia M, Favia C, Germania M, Mandolinia M, Mengarel M. A collaborative End of Life platform to favor the reuse of electronic components. *Procedia CIRP*,2017:61:166-171.
 5. National Metallurgical Laboratory (NML) is one the constituent laboratory of Council of Scientific and Industrial Research (CSIR) which has core competency in Minerals, Metals and Material related research. <http://www.nmlindia.org/>
 6. Established in 1997, ADV Metal Combine Pvt. Ltd.is a company promoted by a group of technocrats with focus on manufacturing and marketing. ADV Metal is a member of ADV Group head quartered at Delhi is registered with Govt. Organization and holding various licenses from Govt. of India and State Govt. for carrying out imports, exports and indigenous manufacturing and trading businesses.
 7. Estep J, Daim T. Multiple perspectives of technology transfer: Technology transfer from government labs. In *Technology Management in the IT-Driven Services (PICMET), 2013 Proceedings of PICMET'*,2013:13:2378-2391. IEEE.
 8. Corillon C, Mahaffy P, Scientific relations between academia and industry: building on a new era of interactions for the benefit of society. In *International Workshop on Academia-Industry Relations*, 2011.
 9. About us, <http://www.nrdcindia.com/english/index.php/about-us/about-nrdc>, accessed on 02/02/2016
 10. Objectives, <http://www.nstedb.com/>, accessed on 02/02/2016
 11. Technology management <http://stemglobal.org/index.htm>, accessed on 04/02/2016
 12. Particulars of organization and functions, <http://dsir.csir.res.in/webdsir/>, accessed on 04/02/2016
 13. New Millennium India Technology Leadership Initiative; <http://csir.res.in/External/Heads/collaborations/Nmitli.htm>, accessed on 08/02/2016
 14. Company profile, <http://www.csirtech.com/about.php>, accessed on 10/02/2016
 15. Modi promises IPR policy, transparent tax regime, <http://www.thehindu.com/news/national/modi-promises-ipr-policy-transparent-tax-regime/article7904406.ece>
 16. Saraf CU. Elements of managing transfer of technology from laboratory to industry: Technology Transfer Management (TTM). *Journal of Scientific & Industrial Research*,2014:73:704-710.
 17. Jha MK, Kumar A, Kumar V, Lee JC. Prospective scenario of e-waste recycling in India. *Recycling of Electronic Waste II: Proceedings of the Second Symposium*, 2011, 73-80. Metallurgy Laboratory, Jamshedpur.
 18. Cui J, Zhang L. Metallurgical recovery of metals from electronic waste: A review. *Journal of hazardous materials*,2008:158(2):228-256.
 19. Kamberović Ž, Korać M. Ivšić D, Nikolić V, Ranitović M. Hydrometallurgical process for extraction of metals from electronic waste, Part I: Material characterization and process option selection. *Metalurgija, M*,2009:15(4):231-243.
 20. Swachh Bharat should look at managing its electronic waste, http://articles.economictimes.indiatimes.com/2015-02-23/news/59423364_1_e-waste-management-attero-recycling-informal-recycling-sector.