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# The Management of Hazardous Solid Waste in India: An Overview

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**Abstract:** Due largely to economic development, industrialization, and changing lifestyles, quantity of hazardous waste in India is rising significantly. This is particularly true in mega cities, where populations are large and growing. Due to a range of factors including limitations in governance systems, inadequate treatment facilities, limitations in compliance and regulation, and limited trained and skilled stakeholders, the management of hazardous solid waste in the country is largely ineffective. One exception to this is the State of Gujarat, which has sought to implement a number of strategies to better manage the rising quantities of hazardous solid waste being produced. This article highlights the management of solid waste in the country for an effective mitigation of various hazards. Further, this article focused on adaptive technologies for the hazardous waste management all over the country more specifically in the state of Gujarat.

**Keywords:** hazardous waste; treatment: management hazards; compliance; regulations; India

## 1. Introduction

Ineffective solid waste management is a significant problem in India, especially in urban centres [1,2]. As urbanization increases, the problems of solid waste management in the mega cities are also rising [3]. The population was 1252 million in 2013, compared with 1028 million in 2001 [4]. About a third of the population lives in urban areas. By 2050, it is expected that about 50% of India's population will be living in urban areas, and waste generation will grow by 5% per year [5]. It is anticipated that by 2021, 2031, and 2050, waste arising will be around 101 million metric tons (MMT), 164 MMT, and 436 MMT per year, respectively. The rise in the generation of solid waste is mainly due to population growth, economic development, and changing lifestyles. Municipal solid wastes which are hazardous are often simply collected, transported, and dumped without treatment or processing. Thus a substantial amount of waste remains unattended at collection centers, roadsides, and riverbanks, with many small scale and large scale industrial units disposing of their waste mainly in open spaces and adjacent to water sources, resulting in environmental pollution and risks to public health [2]. Thus despite significant socio-economic development, solid hazardous waste management systems in India have remained relatively unchanged and are inefficient. The 3Rs (reduce, reuse, and recycle) are seldom used, despite being part of the country's policy framework. Various pieces of legislation have been introduced by the Ministry of Environment and Forests (MoEF & CC) to address some of these issues.

However, compliance is variable and limited. Options for effectively managing the hazardous waste are therefore urgently required. However, treatment and disposal facilities are not adequate to meet the huge volume of such toxic waste [6]. The demand for storage, transport, treatment, and disposal of ascending waste generation has created an urgent need for environmental regulations and standards to ensure public safety. The present regulations and standards are insufficient to regulate and manage hazardous wastes (HW), thus imparting critical environmental problems. However, the problems and challenges of HW management in India can be overcome with an integrated and coordinated effort by the government, the private sector in general, and the community in particular. In this article, the existing HW management system has been discussed in detail, emphasizing the policy issues, problems and challenges, and future strategies for improvement in HWM system. The country also announced to develop an environmental infrastructure with which more resource conscious management practice can be demonstrated with an introduction of advanced technologies.

## 2. Methods

For classification of any waste as hazardous, it is usually evaluated based on its attributes such as nature, composition, and inherent characteristics. After identifying the HW-generating sources, the inventory of the data pertaining to HW generation was developed by conducting academic surveys and followed by field visits for data verification. The desk study was undertaken, during April–May 2018. It is essential that the data that are obtained from the preceding options be verified from secondary data (either published data or available for another industry producing similar products). HW generation rates estimated from plant capacity in Indian industries are available and will help in identifying any misappropriate data and corrections in the database [7]. The following were the main search engines used: Sciencedirect, PubMed, and ResearchGate, as these are the key sources of academic information on waste management, and environmental and public health risks. In addition, the website of the Ministry of Environment, Forest and Climate Change (MoEF), which is the main government agency with responsibility for environmental management in India, was also searched. The websites of key newspapers (e.g., the Hindu), and industry sources (e.g., the Indian Waste Management Association), were also searched. The key words used were 'India', 'hazardous waste management', and 'risk'. Over 10,000 articles were initially found. Publications that were more than five years old were excluded from the search, to ensure that the material was as current as possible. Only credible and verifiable sources were focused upon (e.g., Government sources). Gujarat was already known to the authors as a best practice case study. As the aim was to use this State as a best practice case study, 'Gujarat' was used as a secondary term to narrow the initial search. The initial list was then reduced to 45 articles. However, some of these contained duplicated information. Finally, a total of 28 articles were used.

## 3. Hazardous Waste Management in India

Hazardous waste is a waste with properties that make it dangerous or potentially harmful to human health or the environment. Hazardous waste in India is defined as "any substance, excluding domestic and radioactive wastes, which because of its quantity and/or corrosive, reactive, ignitable, toxic and infectious characteristics causes significant hazards to human health or environment when improperly treated, stored, transported and disposed" [8].

The absence of adequate infrastructure, as well as limitations in enforcement for managing hazardous waste has resulted in ineffective management of the waste in India [2]. Burning in landfills is still one of the most common methods of disposal, resulting in harm to human health and the environment. Waste contractors collecting hazardous waste are mostly ill-equipped, untrained, and poorly paid, and the high temperature treatment infrastructure in India is inadequate [1,9].

Hazardous waste is being produced due to the rapid industrial development in the country. Indeed, industrialized states such as Gujarat, Maharashtra, Tamil Nadu, and Andhra Pradesh face problems relating to rising quantities of hazardous waste [5,10,11]. For example, Gujarat is one of the

fastest-growing states for industrial development in India, with an increasing number of chemical, petrochemical, medicines and pharmaceuticals, textiles, pesticides, paper, and fertilizer industries. As a result, it is one of the highest producers of hazardous waste in the country. Untreated waste from these factories is the main cause of pollution in the state.

Up to date and accurate figures are difficult to obtain, however, India produces approximately 51.1 MMT of waste annually, with around 7.46 MMT of hazardous waste generated from 43,936 industries [10]. Approximately 3.41 MMT (46%) is landfilled, 0.69 MMT (9%) is incinerated, and 3.35 MMT (45%) is recycled. Gujarat is the highest producer with some 7751 hazardous waste generating facilities contributing to 28.76% of waste generation in the country. Around 10–15% of industrial waste is hazardous. Quantities of solid hazardous waste are rising at around 2–5% annually [10]. Coal ash from thermal power stations accounts for more than 70% of all industrial hazardous waste.

The management of HW is complicated by the fact that HW is still not a well-defined term [12]. The term HW is applied to any waste that exhibits, or is contaminated with, hazardous material, including explosive substances, flammable substances, oxidizing agents and peroxides, toxic substances, substances causing disease, radioactive substances, mutation-causing substances, and other substances, chemicals or otherwise, that might cause injury to persons, animals, plants, properties, or environments [12].

### *3.1. Policies and Regulations*

The Ministry of Environment and Forests (MoEF & CC) and the pollution control boards: Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) together form the regulatory and administrative core of the waste management sector in India [13] (Table 1). At the state level, the management of solid waste is the responsibility of Urban Local bodies. Industries generating hazardous wastes must seek permission from the respective SPCB. A key issue is that municipal authorities do not possess the budgets to adequately cover the costs associated with developing effective waste management systems. The lack of strategic plans, as well as systems for governance (particularly waste collection/segregation), and regulation are major barriers to achieving effective Solid Waste Management (SWM) in India [1].

**Table 1.** The responsibilities of agencies for the Hazardous Waste Rules in India.

| Activity | Authority | | | |
|---|---|---|---|---|
| | **MoEF & CC** | **SG** | **SPCB** | **CPCB** |
| Survey and inventorisation of hazardous waste generators and processors | | | x | |
| Grant authorisation for handling hazardous waste to sites and operators | | | x | |
| Inspect facilities/infrastructure/technical capabilities in hazardous waste units | | | x | |
| Suspend/refuse/can authorisation for handling hazardous waste | | | x | |
| Identify and notify sites for hazardous waste treatment/disposal facilities | | x | x | |
| Facilitate environmental impact assessment studies before identifying sites | | x | x | |
| Collect, collate and publish list of abandoned hazardous waste dump sites | | x | | |
| Establish a system for filing annual returns and reporting accidents by hazardous waste facilities and operators | | | x | |
| Process and grant permits for the import of hazardous waste to sites in India | | | x | |
| Examine and permit/refuse exporters' requests for the importation of hazardous waste into India | x | | | |
| Issue instructions to hazardous waste importers | | | x | |
| Inform port authorities to take appropriate steps for the safe handling of hazardous waste at ports | x | | x | |
| Inspect records of imports | x | | x | x |
| Process appeals | | x | | |

Source: CPCB (Central Pollution Control Board); MoEF & CC (Ministry of Environment, Forests and Climate Change); SG (State Government); and SPCB (State Pollution Control Board). Adapted from [14].

Various pieces of legislation covering the management of hazardous waste exist. The fourty-second amendment to the Indian Constitution that was adopted in 1976, and came into effect on 3 January 1977, dictated the state to protect and improve the environment to safeguard public health, forests, and wildlife. The Directive Principles of State Policy (Article 47) in the Constitution require not only that the state protects the environment, but also that it improves polluted environments. Until 2016, hazardous waste was imported from countries such as Saudi Arabia and Malaysia. However, this practice was discontinued with the enactment of the Hazardous and Other Wastes (Management and Trans-boundary Movement) Rules 2016 that banned the import of solid plastic waste, edible fats, animal oils, and household waste. The rules also require State governments to allocate lands for recycling sheds for hazardous waste, ensure proper registration, skill development, equipment supply, and payment for workers engaged in the collection of hazardous waste, and the establishment of monitoring agencies to check the production and recycling of hazardous waste from each state. Another key piece of legislation is the Environment (Protection) Act in 1986, which is umbrella legislation to protect and improve the environment and to regulate the management and handling of hazardous substances and chemicals. There are also various rules under this Act including:

- the Hazardous Waste (Management and Handling) Rules, 2008 (these are the primary regulations governing the management of hazardous waste in India)
- the Biomedical Waste (Management and Handling) Rules 1998
- Manufacture, Storage and Import of Hazardous Chemical Rules 2001
- E-Waste (Management and Handling) Rules 2010

Figure 1 illustrates the responsibilities of the producers of the hazardous waste to ensure that damage to the environment and to public health is minimized. These measures include adequate labeling, containment, transport of the waste, and the provision of an audit trail to follow the waste from generation to treatment.

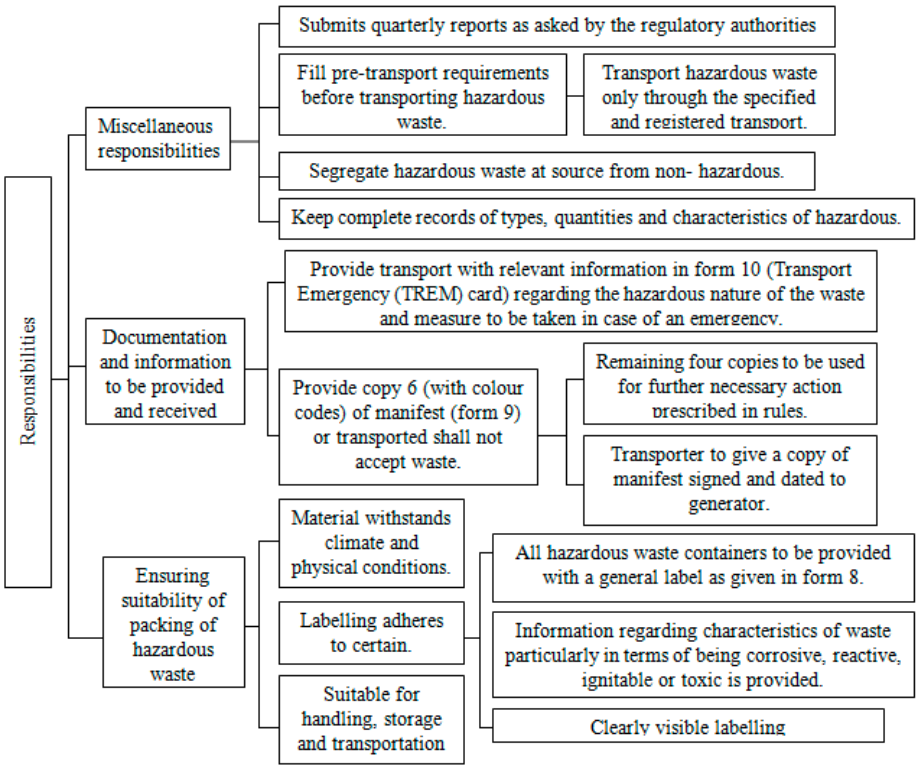


**Figure 1.** The responsibilities of the generator of the hazardous waste Source: ELI (2014) [1].

However, despite the existence of these legislation and guidelines, limitation in their enforcement is a major challenge [13]. Other key challenges include lack of financial resources, a shortage of staff, a lack of standardized protocols, and a lack of authority [1]. The Hazardous and Other Wastes (Management and Trans-boundary Movement) Rules 2016 state that owners of hazardous waste disposal facilities are liable to pay financial penalties if the rules of transportation, storage, and recycling of such waste are not complied with, and may even be imprisoned due to negligence. The rules also specifically direct the state governments to identify locations for the construction of hazardous waste treatment facilities. However, no new sites have been built since the new rules came into effect. Many states like Karnataka, Kerala, Punjab, and Orissa do not have hazardous waste treatment facilities [10].

### 3.2. Treatment Technologies

There is significant shortage in treatment capacity across the country, particularly in Class II cities (Table 2).

**Table 2.** Hazardous Waste treatment capacity in India [15].

| | Class I (0.1–1 Million People) | Class II (50,000–99,999 People) | Total |
|---|---|---|---|
| Waste water generated (mld) | 35,558 | 2697 | 38,255 |
| Waste treatment capacity (mld) | 11,554 | 234 | 11,788 |
| Required capacity (mld) | 24,004 | 2463 | 26,467 |
| Untreated waste (%) | 68 | 92 | 70 |

Around 88 hazardous waste incinerators, as well as 220 recycling facilities exist in the country, along with two engineered landfills (both in the State of Gujarat) [14]. However, Table 3 illustrates that there is a significant shortage of high temperature treatment technologies.

**Table 3.** Hazardous waste treatment facilities in India, by state [2].

| State | Biomethanisation | Pelletisation | Waste to Energy |
|---|---|---|---|
| Andaman and Nicobar | | | |
| Andhra Pradesh | | 11 | 2 |
| Assam | | | |
| Chandigarh | | 1 | |
| Chattisgarh | | | |
| Delhi | | | 3 |
| Goa | | | |
| Gujarat | | 6 | |
| Himachal Pradesh | | | |
| Jammu and Kashmir | | | |
| Jharkhand | | | |
| Kerala | 10 | 1 | 1 |
| Madhya Pradesh | | 2 | |
| Maharashtra | 5 | 5 | 2 |
| Meghalaya | | | |
| Nagaland | | | |
| Orissa | | | |
| Punjab | | | |
| Sikkim | | | |
| Tamil Nadu | | 3 | |
| Tripura | | | |
| West Bengal | | | |
| TOTAL | 15 | 29 | 8 |

The above Table 3 clearly posturizes the least count on high temperature treatment facilities available in the country, which is to be developed in more efficient way for an effective hazardous waste management. Most of the treatment facilities that do exist have not worked effectively due to various operational and design problems [2]. For example, the first large scale MSW incinerator built at Timarpur, New Delhi in 1987 failed because of poor waste segregation, seasonal variations in waste composition and properties, inappropriate technology selection, and operational and maintenance issues [9].

## 4. Best Practice Examples of Managing Hazardous Waste from Gujarat

Gujarat was the first state to address hazardous waste issue and brought about a novel concept of common treatment stabilization and disposal facility (TSDF) for clusters of industries. It has eight of the 27 TSDF sites in India [11]. It utilizes online live tracking of the transport and disposal of hazardous waste is undertaken through the extended Green Node (XGN) List of Registered industries and daily quantity (MT) by all TSDFs, with more than 18,000 facilities including treatment plants and recyclers), and handlers and registered recyclers included in XGN. In the State, there has been a focus on use of waste as a resource, including for energy generation through co-processing, in line with the Hazardous Waste (Movement, Handling & Trans boundary Movement) Rules, 2008. Co-processing is the use of waste as raw material, as a source of energy, or both to replace natural mineral resources and fossil fuels such as coal, petroleum and gas (energy recovery) in industrial processes, mainly in energy intensive industries such as cement, lime, steel, glass, and power generation. In Gujarat, the utilization of hazardous waste as alternative fuel and input material in cement kilns increased by 35 times between 2009/2010, from 15,693 tons per annum, to 543,569 TPA in 2013/2014. In 2013/2014, the quantity of waste utilized by cement plants rose by 185% from 190,707 TPA in 2012/2013.

## 5. Treatment, Processing, and Disposal Facilities in Gujarat

Although there are large numbers of industries generating HW, housed in a number of industrial estates located in many states of India, few industrial and HW treatment facilities have been established. The issue of waste treatment is complex and needs comprehensive study. The selection of treatment technologies requires a great deal of waste characterization, and depends on affordability and the need for environmentally sound technology [16]. Though there is established separation, storage, collection, and transportation guidelines for HWs generated from industrial or nonindustrial sectors, these wastes still find their way to public landfills, nearby dump sites, or waterways, raising serious environmental concerns. In addition, there are insufficient HW collection, treatment, and disposal services for small-scale waste producers who do not have their own treatment facilities. HWs from these sources are collected and disposed of with municipal wastes. Following the regulations to contain HW in secure sites, large stocks of hazardous or partially treated HW are stockpiled in the vicinity of industrial sites. These wastes must be disposed of appropriately. Failing to manage such wastes leads to groundwater pollution, resulting in a health hazard to members of the public, who use groundwater as the source of their domestic water supply and for irrigation.

## 6. Role of Gujarat Government in Hazardous Waste Management

Gujarat Pollution Control Board plays a highly efficient role in the management of hazardous waste in Gujarat.

1. Gujarat was the first state to address hazardous waste issue and brought about a novel concept of common treatment stabilization and disposal facility (TSDF) for the cluster of Industries. Gujarat is leading the country in development of TSDF sites. Among 27 TSDF sites in country Gujarat has eight TSDF sites.
2. Common Hazardous Wastes Incineration Facility (CHWIF): Certain non-biodegradable waste water and liquid hazardous waste (toxic) are advisable to dispose-off in environmentally sound manner. Process of detoxification for the treatment of non-biodegradable waste water

is economically not viable. In late 1990, the concepts of individual common incinerators for safe disposal of toxic hazardous waste were adopted. As of now, State is having five common hazardous incineration facilities and 83 individual incineration facilities.

3. Realizing the importance of waste management: Gujarat pollution control board with an Indian industry jointly with "Klynveld Peat Marwick Goerdeler" (KPMG) organized a 2-day summit and expo for 4R principle of hazardous waste management in vibrant Gujarat event.
4. Xtended Green Node (XGN): Online live tracking of transportation and disposal of hazardous waste has been made by the extended Green Node (XGN) List of Registered industries & daily quantity (MT) by all TSDFs (being generated through XGN). More than 18,000 Industries, Common Effluent Treatment Plants, TSDFs-Hazardous Waste Handlers and Registered Re-cyclers are covered under XGN. Unloading of trucks only after respective industry (for large & medium scale) generates Manifest from XGN. While in the case of small scale units, manifest entry on behalf of the industry being done by TSDF. Manifest register and party wise summary from XGN is verified by concerned TSDF and submitted to Regional Office.
5. Waste Minimization through Co-Processing: The concept on "Utilization of Hazardous Waste" as a supplementary resources or for energy recovery, or processing in line with Hazardous Waste (Movement, Handling & Trans-boundary Movement) Rules, 2008. Central Pollution Control Board (CPCB) has been empowered to accord approval for utilization of different categories and type of Hazardous Waste Co-processing recovers energy, recycles and conserves materials and contributes to reduced environmental footprint. It represents a sustainable solution for many waste streams which can't be recycled and shouldn't be land filled. It offers significant potential for reducing pollution and landfill space caused by the waste disposal. Co-processing is thus a preferred solution in the waste management hierarchy.
6. Clean up of Old Waste Dump Sites in Gujarat: Gujarat Pollution Control Board had taken on hand the problem of old dump sites and its impact on environment Board had carried out Inventory of illegal dumpsite and undertook Clean up activity of such Sites in the year 2004. Subsequently 34,395.40 MT of Hazardous waste was lifted and shifted to landfill site (TSDF). The Board continues cleanup of illegal dump sites across the State; shifting about 9172 MT of illegally dump waste.
7. Public private partnership Common TSDFs have come up: The common sites in Gujarat are remarkable examples of public private partnership. Common TSDFs have come up with capital investment subsidy provided by the State Government and in some cases with assistance from the Government of India. Land at concessional rates allotted by State Industrial Development Corporation and financial participation by industrial units and institutional financial support helped this development.
8. Alang Ship Breaking Yards: Environmentally Sound Management Facilities the ship breaking industry performs two major roles. It adjusts ship tonnage for the shipping industry by way of disposal of old ships and it also supplies substantial quantities of re-rollable and scrap steel. It also increases the availability of some finished material which otherwise would have to be produced by the iron and steel industry using the natural ore. Thus, the ship breaking industry helps in conservation of natural resources. Also it reduces the environment pollution compared to the steel industry, which can be concluded from following data. Alang Sosiya Ship Recycling Yard developed by Gujarat Maritime Board in 1982 is amongst the largest ship recycling yards across the globe. 169 plots are spread over a 10 km stretch along the coast of Alang aligned from NE to SW direction. The beaching method is employed to dismantle about 400 ships per year. This generates about 3.5 million tons of steel that can be re-rolled per annum. Before January-2006, ship recyclers were sending their wastes to TSDF operated by Naroda Enviro Protection Ltd., Ahmedabad—Hazardous waste quantity handled about 3873.049 MT.
9. Common effluent treatment plants (CETP): In Gujarat CETP treatment is divided into two stages first initial in which raw effluents of the waste from small and medium industries is treated.

Then that waste is treated in final effluent treatment plant. There are total 34 CETPs in Gujarat in which 28 are in operational and six are proposed. Of these CETPs, 15 are in Gujarat Industrial Development Corporation (GIDC) estates and 19 are outside the GIDC estates.

10. Green industries formation in Gujarat: A list of 100 small and cottage Industries having no pollution potential was published under the circular of the Gujarat Pollution Control Board. These industries are exempted from obtaining NOC (No Objection Certificate) from the Board for establishing such industries and for conversion of land to 'non-agricultural' use.

## 7. Discussion

The rise in economic development in India within recent decades has resulted in a significant increase in the generation of hazardous waste [5,10]. These wastes are posing a significant and growing risk to the environment and public health in the country to the ineffective management of the waste [2]. While there are various pieces of legislation in place in the country that dictate the need for effective governance structures and treatment facilities (e.g., Article 47 of the Constitution, the Hazardous and Other Wastes (Management and Transboundary Movement) Rules 2016, there are also a number of other factors that are limiting the effective management of hazardous waste in India. These factors include limitations in adequate treatment facilities, governance systems, compliance, and adequate training and skills [1,2,5].

As noted in [15], limitation in implementation of plans is a key issue that is restricting the effective management of hazardous waste in India. More effective hazardous waste regulations could drive innovation not only within the sector, but also within the economy as a whole through the recovery of value from the waste and the reduction in pollution. Indeed, the State of Gujarat has sought to implement a number of strategies to manage its hazardous waste including the use of co-processing, TSDFs, and online tracking [11]. This approach has served to recover energy, conserve resources, and reduce the impacts on the environment. The use of an online, real time tracking system has helped to reduce illegal dumping and facilitate increased compliance. A more wide spread use of a GPS-based tracking system for the collection and transport of all types waste, potentially linked to the use of smart phones as for example, is done for municipal waste in Chennai, would serve to improve practice.

These approaches should be adopted more widely across the country, particularly in the mega cities where industrialization is rapidly developing, but the waste treatment infrastructure is limited or in most cases, does not exist. Often the state agencies do not possess the budget to cover the services [1]. It is vital that there is investment in infrastructure to meet the growing population and waste being generated. This will be important to ensure that the waste is effectively managed and that some value can be recovered. This would lead not only to reduced impacts on public health and the environment, but would also deliver economy value, create skills development, and create jobs.

Funding for adequate infrastructure might be raised from waste producers through a waste tax, with the most polluting entities paying more. The central and state governments could also look at the use of fiscal incentives to develop the sector (e.g., exemption/reduction in excise duty and from taxes, and customs duty concessions on the import of components and equipment). There should also be penalties (e.g., fines) placed on facilities that do not comply with the necessary legislation and regulations. The use of public and private sector partnerships to collect and sustainably manage the waste might also be considered.

There is an urgent need to develop the knowledge, skills and competencies of key stakeholders in the sector (e.g., within the CPCBs and SPCBs), to enable them to undertake their roles more effectively.

Finally, there is a need for more up to date and efficient systems for the collection and analysis of data. This would enable the development and effective implementation of policies and systems to more effectively manage the waste. In many cases, the available data are unreliable and not up to date. This therefore makes informed decision-making difficult.

## 8. Conclusions

In summary, it can be said that in the developing countries, the thrust on economic development is often given priority to production costs than the best available technology and this result in more waste generation. It is difficult to develop alternative technology for total elimination of hazardous waste generation, yet we can take measures for using alternative resource as solar energy, wind energy in the production process instead of using the electricity for the production, as that can cause less emission of hazardous waste there by moving towards green—non pollution. With that we can formulate policies and strategies towards prioritizing waste reduction and minimization rather than mere disposal. Remediation strategy needs to focus on the 'polluter pays principle' with the polluter being asked to pay penalty as well as costs of cleaning up the pollution. Industries causing pollution repeatedly should be blacklisted. Where polluters are not traceable, a dedicated fund needs to be created by State Pollution Control Board/Pollution Control Committee (SPCB/PCC) for remediation. With that Waste Exchange Banks/Collection Centres should be developed to provide information on wastes as on the types of waste and the methods to manage waste, to provide information on wastes, and promote reuse, recovery, and recycling technologies which upscale the quality of resource recovery.

India's growing economic development and industrialization poses significant risks to the environment and to public health, due to the resulting generation of hazardous waste, and its ineffective management. However, as has been demonstrated by the State of Gujarat, effective management can lead not only to improvement in the environment and public health, but also to resource security. If effective strategies are not put in place, urgently, the anticipated rise in industrialization and hazardous waste will lead to major problems in India.

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