

Current practices for the management of sludge generated from common effluent treatment plants - A review

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Sludge management in common effluent treatment plants (CETPs) is a highly complex, difficult and expensive task that, if done incorrectly, might jeopardies the environment and sanitary advantages expected in the treatment systems. The sludge generated from the CETPs may contain hazardous waste that poses substantial or potential threats to public health and the environment. Hazardous wastes are frequently dumped directly into the environment in many developing and underdeveloped nations, which puts human health and the ecosystem at risk. The processing, managing and disposal of hazardous sludge is a major challenge in this technological era and it is very crucial to pick a sludge treatment and disposal system that is both practical and affordable from a technological & environmental standpoint. This review article discusses the current practices of hazardous sludge management, collection & transportation, recycling and reuse and various treatment techniques.

Keywords: Common effluent treatment plants (CETPs), Hazardous waste, Sludge management, Treatment and disposal of sludge

Introduction

The rapid obsolescence of goods and the pervasive trend toward wastefulness in today's society, along with industrial and commercial growth, technical advancements, and higher living standards, all contribute to the continuous production of solid wastes. Wastewater contains wide variety of contaminants like microorganism, biodegradable & non-biodegradable contaminants, organic and inorganic contaminants. These contaminants lead to turbidity, dissolved solids, algae, colloids and precipitated solids^{1,2,3}. As the global population grows and industrialization accelerates, there has been a significant increase in the utilization of natural resources. This surge in consumption has led to a widespread impact on our natural resources, primarily caused by the discharge of industrial wastewater into water streams^{4,5}. About 45% of industries contribute to major manufacturing output and employment in India, where majority of industries are classified into small and medium scale⁶. Unfortunately, half of the total hazardous waste produced in India are due to these industries⁷. Such industries require immediate action and efficient management to prevent degradation of natural resources. Industrial effluent containing hazardous waste can cause several health issues^{8,9}. In various parts of

India common effluent treatment plants (CETPs) have been installed for the treatment of industrial wastewater and are in operation at numerous industrial clusters¹⁰. Hence, optimum working conditions for treatment of effluent to be at par with discharge standards is a major mandate for any CETP¹⁰. For collective treatment of wastewater generated from small and medium scale industries CETPs are the most reliable option¹¹. Biological treatment process in wastewater treatment plants (WWTPs) is used in order to reduce the concentration of organic & inorganic compound, suspended & dissolved solids to produce by-product in the form of biomass and are also called as sludge¹². However, chemical treatment is also widely used in WWTPs such as aluminium, iron and calcium metal salts to reduce heavy metals and phosphorus from wastewater. Excessive amount of sludge production, pH neutralization and high operating cost are some the major drawbacks of chemical treatment methods¹³. The primary treatment method in CETPs involves a chemical treatment process, which separates various contaminants by forming a chemical precipitate that can be easily removed through sedimentation or filtration. CETP works on the principle of physicochemical treatment process or both physicochemical treatment and

biological treatment process. Major CETP units include inlet chamber, screens, equalization tank, flash mixer, flocculation tank, secondary clarifier, tube settler, dual media filter, activated carbon filter, chlorine contact tank, aeration tank and sludge drying beds¹⁴. Most of the CETPs produce solid waste while processing industrial waste water, which requires a significant capital to dispose of the resulting sludge safely. This includes costs associated with loading, transporting, and unloading the waste at a secure landfill facility¹⁵. Dumping sludge in landfills can harm soil fertility and change its chemistry, further it also pollutes surface and groundwater, putting public health at risk. Therefore, traditional sludge management methods like land filling and incineration need to be replaced with new approaches that turn sludge into nutrient-rich products or can be utilized as construction materials. One of the solutions for stabilizing industrial sludge is the composting process¹⁶.

Construction material manufacturing by utilizing CETP sludge is a favourable approach towards sustainable development. By utilizing sludge as construction material like gravel, blue metal, and sand does not alter the characteristics or strength of the concrete are reported by many studies. The present review examines the current practices and challenges for disposal of hazardous waste from the CETPs and highlights the innovative techniques to recycle and reuse. The review also provides guidelines and focuses on finding the loop holes for further research in this area. Furthermore, the paper explores novel approach for collection & transportation of hazardous sludge from CETP facilities and discusses recent advances that could be implemented. The review also

highlights potential improvements in existing methods and finally, up to date various treatment technologies for sludge treatment are discussed, providing insights about processing, handling, treatment and disposal.

Current generation, management and disposal practices of sludge from WWTPs

With rapid urbanization and migration from rural to urban areas has led to a surge in the demand for resources such as water, energy, and food in cities. Consequently, human kind is also experiencing lots of health and environment related issues due to production of solid/hazardous waste from wastewater treatment plants. Rise in the production of sludge from WWTPs has emerged a new challenge in today's modern world causing various social, economic, and environmental problems. Although, there have been several new emerging technological advancements in recent years but effectively managing and disposing this solid waste is still intricate and challenging. Disposal of sludge often leads to serious environmental concern related to contamination of soil, water and air. Hence, it is necessary to treat and manage it with great care to meet public health standards. As the production of sludge continues to increase, demand for innovative research technique and robust technology shall also increase. Current treatment practices of sludge treatment may be enhanced to create economically viable alternatives for circular economy to reduce the socio-economic and environmental problems¹⁷. Mixture of semi-solid and muddy materials containing both liquid and solid by-products generated from various stages of industrial processes, wastewater treatment, drinking water treatment, and on-site sanitation systems are referred as "sludge". Fig. 1

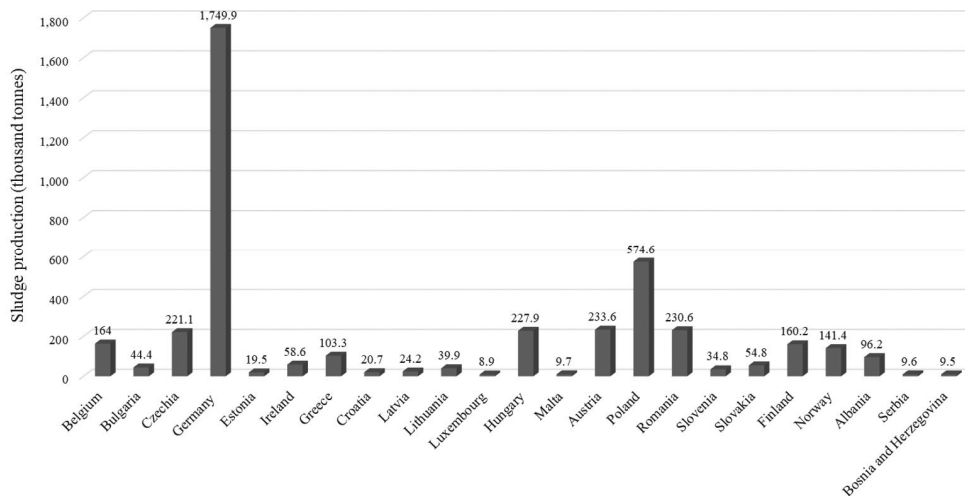


Fig. 1 — Sludge production in different countries in the year 2019¹⁸

depicts the sludge production by different countries from urban WWTPs in the year 2019¹⁸.

Sludge management and disposal can vary significantly based on the surrounding circumstances. They can be collected and disposed of without any beneficial use. Sludge contains contaminants such as pesticides, chemicals, heavy metals, and other hazardous materials. It is therefore crucial to properly process, treat and store in a manner that safeguards public health and avoids additional environmental issues and repercussions¹⁹. Rising demand of net zero carbon emission technologies and renewable energy sources green technologies like organic waste in the form of sludge could serve as a viable and sustainable option for locals. Emerging technologies are focusing on utilizing sludge from WWTPs as an alternative for heat, energy and power production. Current practices of sludge handling and land filling can be replaced with reusing sludge which is both economically feasible and environmentally sustainable. Circular economy of wastewater from start to end provides an approach that could serve as the foundation for developing a new sludge management strategy. This concept allows for the achievement of multiple objectives, including sludge disposal, as well as the recovery of energy, nutrients, and other valuable resources. By integrating these new strategies with the trend of eco-innovation and waste management, hierarchy of "reduce, reuse, recycle, and recover" is developed as a modern approach for sustainable development. The demands of the modern world

require a sustainable approach to waste management that goes beyond the traditional linear approach. Instead, a circular approach that aims to minimize waste and emissions should be adopted. Sludge from WWTPs should be considered as a valuable source of biomass and nutrients rather than a waste product. Both wastewater and sludge are the part of wastewater treatment cycle, hence new treatment technologies should focus on the solution of both as future perspectives²⁰. The treatment and disposal of sludge are complex and it is an important step towards the protection of mother Earth. Various health related issues were observed due to hazardous sludge from the CETPs which contain residual organic pollutants, toxic metals, and pathogenic microorganisms²¹. Although, sludge treatment requires significant amount energy which is approximately half of WWTPs operational costs^{22,23}. By utilizing the concept of circular economy many researchers observed that it can reduced around 40% of total greenhouse gas emission^{24,25} (Fig. 2).

Today different methods for sludge disposal are 27% for incineration, 14% for land filling, 42% for agricultural purposes and 17% for other industrial application²⁸. In Europe, sludge is utilized mainly for agricultural purposes in place of disposal. Approximately 37% of the total sludge produced is used for agricultural purposes²⁹. Conversely, in several European countries, the use of incineration has increased significantly due to its thermal efficiency and huge reduction in sludge volume³⁰.

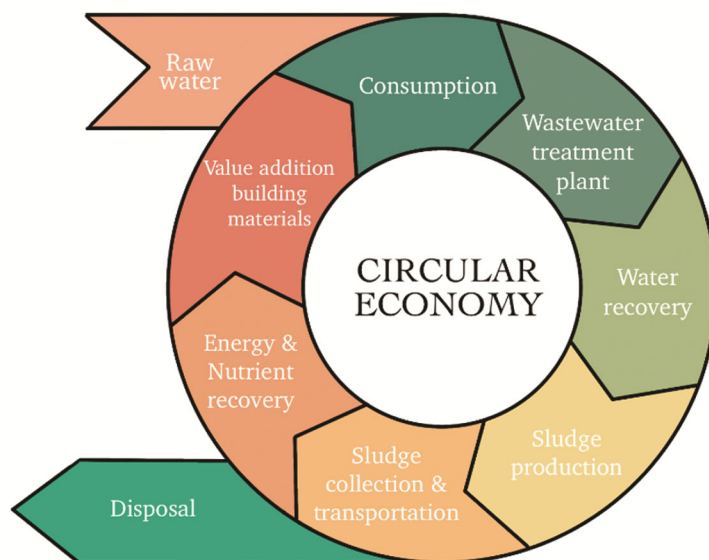


Fig. 2 — Circular economy concept^{26,20,27}

Sludge disposal methods (like direct use for agricultural purposes, composting, incineration and land filling) in EU-15 countries are analyzed and it was found that incineration is becoming more popular in Germany and the Netherlands with increasing trend of 28% and 16%, respectively, and 22% and 12% decreasing trends, respectively, in Denmark and Belgium³¹ (Fig. 3).

Sludge from common effluent treatment plants (CETPs)

Nowadays, industries are facing lots of challenges while disposing their industrial sludge due to high sludge stabilization reactor cost, dewatering of sludge and transportation to their respective sites. Hazardous sludge produced in common effluent treatment plants (CETPs) contains high BOD, COD, TDS, TSS and heavy metals which cannot be used and the only way is to be disposed of in landfills. However, due to land filling various problems like gradual decrease of soil fertility, land degradation, groundwater and surface water pollution are the current challenges of human health safety. In recent years, researchers have shifted their studies from traditional methods of sludge disposal such as incineration and landfill to nutrient recovery like converting sludge into nutrient-rich products³². CETP sludge for agricultural purposes is permissible only if it does not contain any hazardous elements. Due to its constituents falls under regulatory guidelines, primary sludge must be disposed of in a common hazardous waste treatment, storage and disposal facility (TSDF). Conversely,

secondary sludge from biological treatment generally has nutrients and can be utilized as manure for dry land or forest disposal, provided that the concentration of the components falls within acceptable limits. However, this needs to be assessed on a case-by-case basis and with approval from the regulatory authorities. Both primary and secondary sludge must undergo dewatering process to reduce the amount of water content from the sludge. Any sludge suspected of containing harmful substances must be disposed of in a proper TSDF after the necessary analysis, and if required, should be stabilized before land disposal³³.

Characterization, disposal & treatment practices of sludge in WWTPs

Sludge characterization

To make water safe for consumption, a conventional CETP uses various processes like coagulation, flocculation, sedimentation, filtration, and disinfection. These processes result in the production of significant amounts of sludge or waste material. An average water treatment facility generates around 100,000 tons of sludge annually³⁴. India is also generating large quantity solid & hazardous waste on a daily basis from its WWTPs i.e., sewage treatment plants (STPs), effluent treatment plants (ETPs) and CETPs that needs to be managed and disposed of properly. However, due to a lack of effective sludge management strategies and less sludge storage capacity (in most CETPs in India)

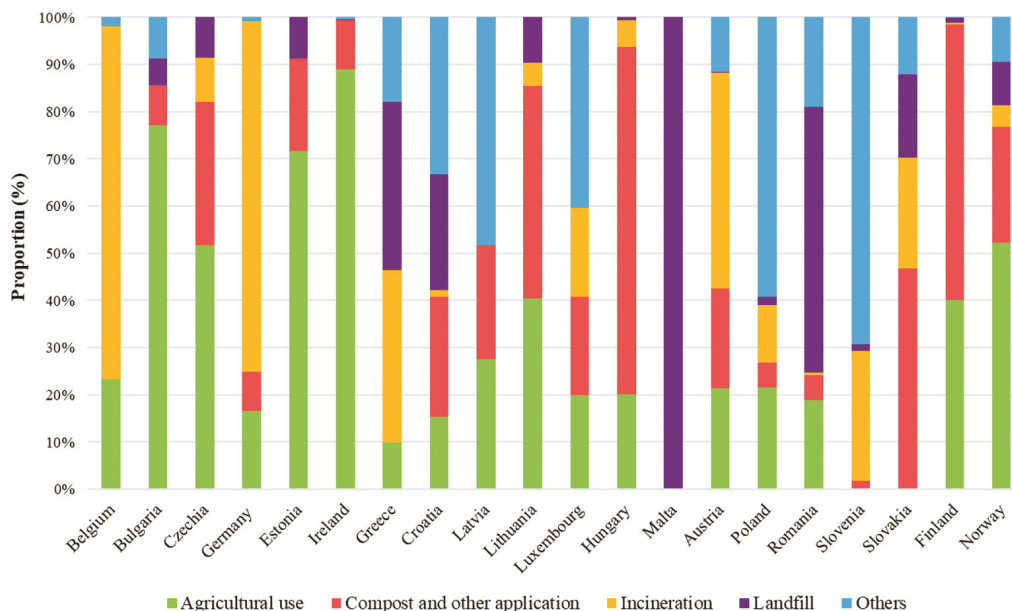


Fig. 3 — Comparison of different sludge disposal methods in European countries in 2019¹⁸

results in degradation of soil fertility and pollution of water bodies³⁵. Primary treatment of wastewater that include screening, sedimentation, grit removal, precipitation and flotation generally produce primary sludge that contains oil & grease, silts and sediments^{30,36,37}. Approximately 2%-9% solids were found in primary sludge and the remaining 90% is water³⁷. During secondary treatment, biologically treated wastewater contains activated sludge and physiochemically treated wastewater contains sludge having hazardous or heavy metal content. Total sludge produced during secondary treatment is in between 0.8%-3.3%^{26,38,36}. Chemically treated wastewater contains chemical sludge that are produced by coagulation and flocculation. The properties of the sludge, both in terms of quality and quantity, are determined by the type and amount of reagent used during treatment. Commonly used reagents include inorganic coagulant like lime, aluminium chloride ($AlCl_3$), ferric chloride ($FeCl_3$), aluminium sulfate ($Al_2(SO_4)_3$), ferric chloride ($FeCl_3$), ferric sulphate ($Fe_2(SO_4)_3$) and inorganic polymeric coagulants like polyaluminum chloride (PAC), polyferric sulfate (PFS), etc.³⁹.

Potential use of sludge and sludge treatment

Various biological, chemical and physical techniques have been developed to manage and reduce the production of sludge^{40,41,42}. The most commonly used techniques for disposal, treatment and utilization of sludge include ocean dumping, land filling, incineration^{22,21}, reuse for agricultural purpose (composting method) and reuse for building material like cement blocks, bricks and asphalt^{43,44,45}. To choose the appropriate sludge treatment and disposal methods, it is important to determine the amount and quality of the sludge that needs to be treated. The various steps involved in this process can be grouped into four main categories: conditioning, thickening, stabilization, and dewatering. In addition, storage, transportation, and final disposal are also important considerations.

The treatment of sludge may vary depending on the disposal location and future use. Nevertheless, the primary objectives of sludge treatment remain the same, which are:

1. To stabilize the organic matter present in the sludge.
2. To decrease the volume of sludge by dewatering for disposal.

3. To eliminate harmful microorganisms.
4. To obtain by-products that can be utilized or reused to overcome the expenses associated with sludge treatment.
5. To dispose of the sludge in a manner that is safe and visually pleasing.

When evaluating different options for treating and disposing of sludge, it is essential to take into account all the steps required for the ultimate disposal of the treated sludge. Fig. 4 provides an overview of most of the available processes for sludge disposal and treatment.

Hazardous sludge treatment and disposal practices

Use of CETP sludge for agriculture purpose is appropriate only if it does not contain hazardous components. The constituents of primary and secondary sludge (physicochemical treatment) typically require proper disposal in TSDF due to toxic, hazardous and heavy metal content. The secondary sludge, resulting from biological treatment, mainly contains nutrients and can be utilized as manure for dry land or forest areas at regulated levels, provided that its constituents are within permissible limits. Both primary and secondary sludge should undergo dewatering to reduce its volume. Sludge containing hazardous material must be appropriately analyzed and disposed of in a TSDF after stabilization³³. Facilities where hazardous waste is treated, stored or disposed of is termed as TSDF. The term "facility" encompasses all land, structures, and related components that are used for these purposes⁴⁸.

- "Treatment" refers to any process that enhances the hazardous waste's physical, chemical, or biological properties to make it less harmful, easier to transport, store, or dispose of, or suitable for resource recovery.
- "Storage" is the temporary holding of hazardous waste until it can be treated, disposed of, or transferred elsewhere.
- "Disposal" refers to the proper placement of hazardous waste on land or water, whether by dumping, spilling, or other means.

About 12.35 million metric tons (MT) of hazardous waste is generated in India during the year 2021-22. Fig. 5 illustrates the breakdown of hazardous waste generation by category. Out of total 12.35 million metric tons of hazardous waste generated, 46.46% is utilizable hazardous waste, 22.90% is classified as recyclable hazardous waste, 24.72% is landfill able

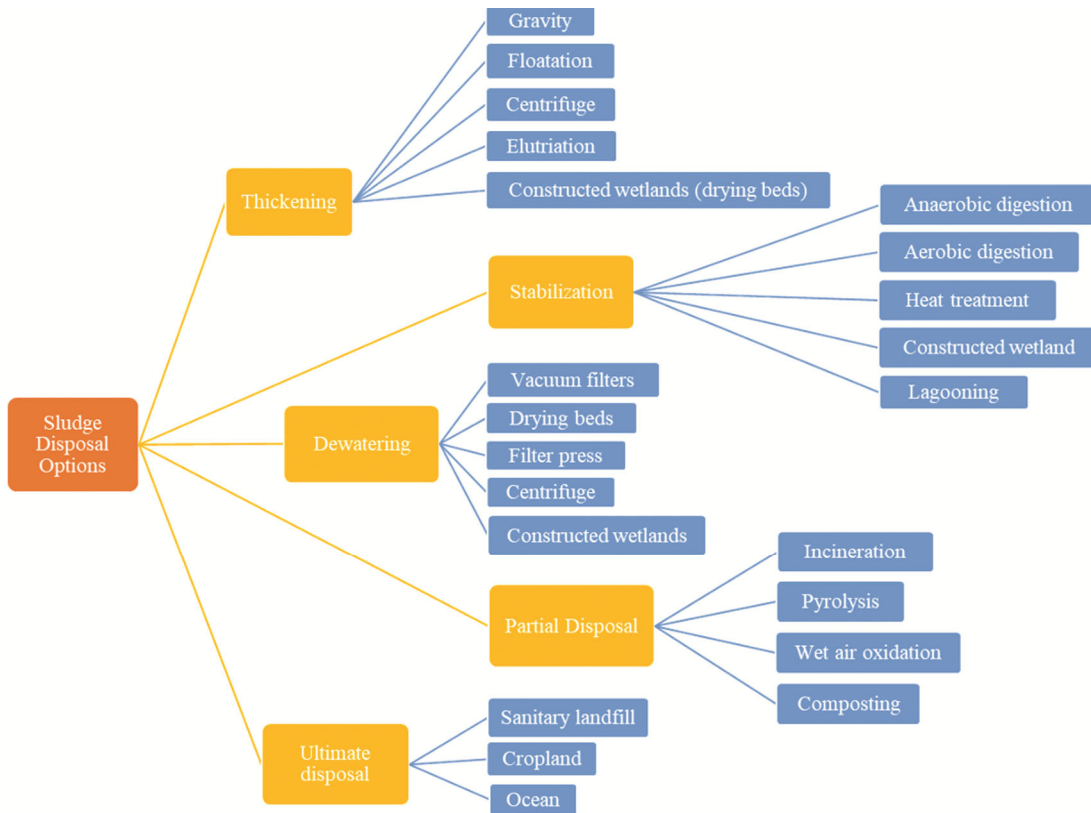


Fig. 4 — Sludge treatment and disposal option for WWTPs^{46,47}.

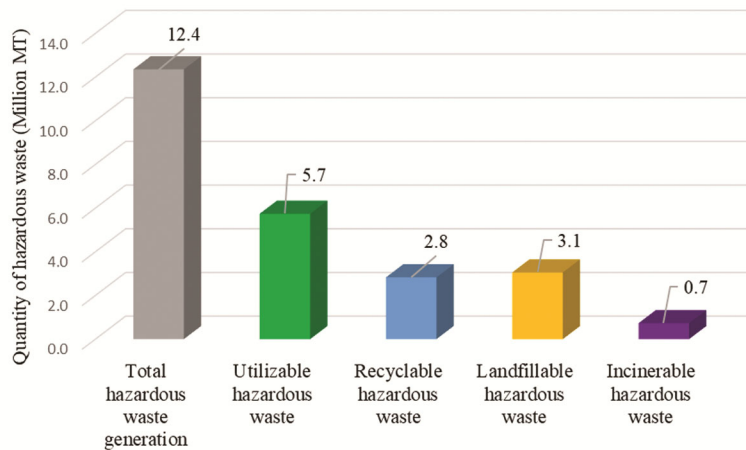


Fig. 5 — Total hazardous waste generation in India and different category wise classification⁴⁹

hazardous waste, and 5.92% is incinerable hazardous waste⁴⁹.

Hazardous waste which cannot be utilized in any way are typically disposed of either in secure landfills or burnt out in an incinerator. In India, there are around 50 facilities that handle hazardous waste and among that 20 have both secure landfills and incinerators, 19 have only secure landfills, and 11

have only incinerators. Recently, new facilities were built in Delhi and Goa for hazardous waste disposal. Fig. 6 depicts the total number of current operational TSDFs in India (state-wise)⁴⁹. Table 1 shows several CETP’s sludge storage, handling and disposal facilities in India.

Fig. 7 shows of the hazardous waste disposal through secure landfills (SLF) and incinerators in

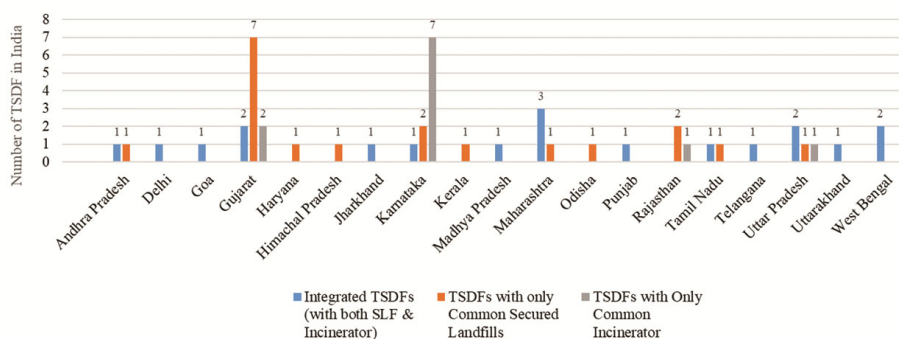


Fig. 6 — State-wise TSDF facilities in India⁴⁹

Table 1 — Sludge storage, handling and disposal facilities in India³⁵

Name of CETPs in India (state-wise)	Capacity (MLD)	Type of industries	Sludge generation from CETP (MT/day)	Sludge Storage facility	Sludge Disposal
Telangana					
Jeedimetla common effluent treatment plant	5.0	Chemical, Dye & dye intermediate	2-2.5	CETP Premises	
Pattancheru common effluent treatment plant	7.5	Leather, Pharmaceuticals, Steel, Chemical, Pesticides			SLF
Bollaram common effluent treatment plant	0.25	Chemical, Pharmaceuticals		CETP Premises	
Delhi					
Wazirpur common effluent treatment plant	24.0	General and Pickling		CETP Premises	
Mangolpuri common effluent treatment plant	2.4	General		CETP Premises	
Mayapuri common effluent treatment plant	12.0	General		CETP Premises	
Lawrence Road common effluent treatment plant	12.0	General & Food processing		CETP Premises	
Jhilmil common effluent treatment plant	16.8	General & Engineering		CETP Premises	
Badli common effluent treatment plant	12.0	Pickling		CETP Premises	
Okhla Industrial Area common effluent treatment plant	24.0	Textile & General		CETP Premises	
GTK Road common effluent treatment plant	6.0	General		CETP Premises	
SMA common effluent treatment plant	12.0	General		CETP Premises	
Nangloi common effluent treatment plant	12.0	General & Rubber products		CETP Premises	
Narela common effluent treatment plant		General		CETP Premises	
Gujrat					
Naroda common effluent treatment plant, Ahmedabad	3.0	Pharmaceuticals, Textile & Chemicals Dyes	5		SLF
Vatva common effluent treatment plant, Ahmedabad	16.0	Chemicals Rolling mills, Dyes, Textile, Pharma	8		SLF
Odhav common effluent treatment plant, Ahmedabad	1.2	Textiles, Dye & dye intermediate	1.2		SLF
Vapi common effluent treatment plant, Vapi, Valsad	55.0	Engineering, Chemicals, Paper mills, Dyes, Pharma	10.0-13.3		TSDF
Nandesari common effluent treatment plant, Vadodara	5.5	Dyes & dye intermediate, Chemical, Organic chemicals	2		TSDF
Ankleshwar common effluent treatment plant	1.0	Pharma, Dyes & dye intermediate, Chemical, Pesticides	103.3		TSDF
Sachin common effluent treatment plant- I, Sachin, Surat	0.5	Dye intermediate & Dyes			TSDF
Sarigam common effluent treatment plant, Sargam, Valsad	0.4	Dye intermediate & Dyes, Chemical, Pharma	0.2		TSDF
Dharieswar common effluent treatment plant, Jetpur	0.15/.055	Textile printing units	0.03		TSDF
Sanand common effluent treatment plant, Paldi, Ahmedabad	0.2	Petroleum, Pharma, Chemical, Pharma, Dyes, Pesticides	3		SLF

(Contd.)

Table 1 — Sludge storage, handling and disposal facilities in India³⁵ — (Contd.)

Name of CETPs in India (state-wise)	Capacity	Type of industries	Sludge generation from CETP	Sludge Storage facility	Sludge Disposal
Jetpur common effluent treatment plant, Jetpur	20	Textile printing units	0.07		TSDF
Panoli common effluent treatment plant, Bharuch	1	Dyes, Pharma, Chemical	0.83		TSDF
Padra common effluent treatment plant, Sachin, Surat	2.3				
Sachin common effluent treatment plant-II, Sachin, Surat	50.0	Printing units & Textile dyeing	35-40		TSDF
GVMSAV Odhav common effluent treatment plant, Ahmedabad	1.0	Dye & Dye intermediate			
Narol common effluent treatment plant, Ahmedabad	0.1				
Haryana					
Kundli common effluent treatment plant	1.1	Textile, rubber, leather, Milk/ food processing,		CETP Premises	
Karnataka					
Pai & Pai common effluent treatment plant	0.3	Metal finishing			
LidkarBanglorecommon effluent treatment plant	1.0	Tannery	0.11	CETP Premises	
Maharashtra					
Dombiveli common effluent treatment plant Phase-I	14.0	Textile industries	3.33		TSDF
Dombiveli common effluent treatment plant Phase-II	1.5	Organic/ inorganic chemicals, Dyes, Metal coating Pharmaceutical	4		TSDF
Thane Belapur common effluent treatment plant	12.0	Pigments Paints, Textile, Chemicals, Pharmaceutical, Dye	8		TSDF
Tarapur common effluent treatment plant	2.0	Dyes, Engineering, Pharmaceutical, Chemical	0.2		TSDF
Taloja common effluent treatment plant	10.0	other industries & Pharma	0.07		TSDF
Ambarnath common effluent treatment plant	0.3	Chemical & Dyes	0.15		SLF
Jaisingpur common effluent treatment plant	1.0	Auto parts, Batteries, Textile, Dairy Chemicals,	0.3		SLF
Patalganga common effluent treatment plant	15.0	Dyes & Dye intermediate Petrochemical, Chemical, Pharma	0.33-0.37		TSDF
Mahad common effluent treatment plant	7.5				
Badlapur common effluent treatment plant	8.0	Chemicals & Dyes, Textiles, Engineering			
Butibari common effluent treatment plant					
Madhya Pradesh					
Govindpura common effluent treatment plant, Bhopal	0.9	Industries (Not categorised)			
Punjab					
Phillore common effluent treatment plant	0.0	Tanneries		CETP Premises	
Jalandhar common effluent treatment plant	1.5	Allied industries & Tanning			
Rajasthan					
Balotra common effluent treatment plant Unit I	6.0	Printing & Textile dyeing		CETP Premises	
Jasol common effluent treatment plant	2.5	Printing & Textile dyeing		CETP Premises	
Jodhpur common effluent treatment plant	20.0	Textile dyeing and printing & Stainless-steel pickling		CETP Premises	
Bhiwadicommon effluent treatment plant	6.0	Sewage & Industries			
Pali common effluent treatment plant Unit I	5.2	Textile unit sewage for Unit I&II	10		
Pali common effluent treatment plant Unit II	8.4		10		
Pali common effluent treatment plant Unit III	9.0	Sewage & Textile units	10		
Machhericommon effluent treatment plant, Jaipur	0.6	Tannery			

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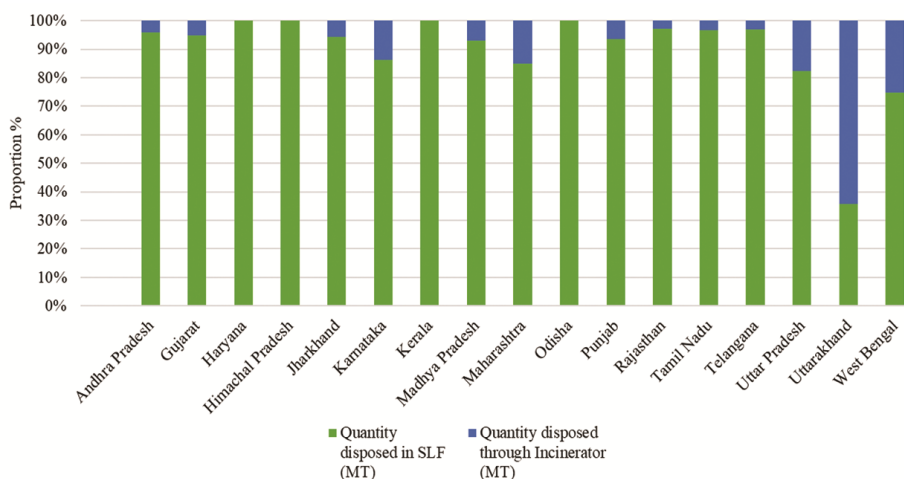
Table 1 — Sludge storage, handling and disposal facilities in India³⁵ — (Contd.)

Name of CETPs in India (state-wise)	Capacity	Type of industries	Sludge generation from CETP	Sludge Storage facility	Sludge Disposal
Tamil Nādu					
Mannarai common effluent treatment plant, Tirupur	4.2	Dyeing & Textile bleaching	4.9	CETP Premises	
Kasipalayam common effluent treatment plant, Tirupur	4.0	Dyeing & Textile bleaching	2	CETP Premises	
Veerapondi common effluent treatment plant, Tirupur	10.0	Dyeing & Textile bleaching	10	CETP Premises	
Manickapuram Pudur common effluent treatment plant, Tirupur	1.6	Dyeing & Textile bleaching	1	CETP Premises	
Kunnangalpalayam common effluent treatment plant, Tirupur	4.3	Dyeing & Textile bleaching		CETP Premises	
Andipalayam common effluent treatment plant, Tirupur	5.0	Dyeing & Textile bleaching	2.5	CETP Premises	
Angeripalayam common effluent treatment plant, Tirupur	8.5	Dyeing & Textile bleaching	2.5	CETP Premises	
Chinnakkarai common effluent treatment plant Ltd., Tirupur	5.0	Dyeing & Textile bleaching	2.5	CETP Premises	
Andakovil common effluent treatment plant, Karur				CETP Premises	
KS common effluent treatment plant, Karur				CETP Premises	
KKEL common effluent treatment plant, Karur	1.3	Dyeing & Textile bleaching	2.7	CETP Premises	
Sellandi Palayam common effluent treatment plant, Karur				CETP Premises	
Thiruvai common effluent treatment plant, Karur	2.1	Dyeing & Textile bleaching	1	CETP Premises	
Valandi Dyeing common effluent treatment plant, Karur				CETP Premises	
Taluk Dye & Bleaching common effluent treatment plant, Karur				CETP Premises	
Amaravathi Poll Tech common effluent treatment plant, karur	2.4	Dyeing & Textile bleaching	1	CETP Premises	
TALCO Vaniyambadi, Valayampet, common effluent treatment plant, Vellore	2.8	Tannery	9	CETP Premises	
TALCO Vaniyambadi, Udayendiram common effluent treatment plant, Vellore	0.2	Tannery	0.2	CETP Premises	
TALCO Pernambut common effluent treatment plant	0.9	Tannery	10	CETP Premises	
TALCO Ambur Thuthipet common effluent treatment plant, Vellore	2.0	Tannery	3	CETP Premises	
Visharam common effluent treatment plant, Melvisharam Vellore	3.4	Tannery	2	CETP Premises	
TALCO Ranipet common effluent treatment plant, Vellore	4.0	Tannery	4	CETP Premises	
Melpudupet common effluent treatment plant, Ambur, Vellore					
Ambur Mallgalthope common effluent treatment plant, Vellore	1.1	Tannery	1	CETP sludge yard	
SIDCO Ranipet common effluent treatment plant, Vellore	2.5	Tannery	3	CETP Premises	
SIDCO phase II common effluent treatment plant Ranipet, Vellore					
TALCO Dindigul common effluent treatment plant	2.5	Tannery	1.5	CETP Premises	
TALCO Madhavaram common effluent treatment plant, Chennai	0.4	Tannery	0.35		
Pallavaram common effluent treatment plant, Chennai	3.0	Tannery	10	CETP Premises	

(Contd.)

Table 1 — Sludge storage, handling and disposal facilities in India³⁵ — (Contd.)

Name of CETPs in India (state-wise)	Capacity	Type of industries	Sludge generation from CETP	Sludge Storage facility	Sludge Disposal
Uttar Pradesh					
Kanpur common effluent treatment plant	36.0	Sewage & Tanneries			SLF
Unnao common effluent treatment plant	2.2	Tanneries		CETP Premises	
Mathura common effluent treatment plant	6.3	Printing & Textile dyeing		CETP Premises	
West Bengal					
Calcutta Leather Complex common effluent treatment plant	6.0	Tanneries processing		CETP Premises	SLF

Fig. 7 — State wise hazardous waste disposal methods in India⁴⁹

various states of India. It was observed that hazardous waste disposal through incinerator is widely used in the states of Uttarakhand, West Bengal and Uttar Pradesh.

Resource recovery from sludge

In addition to various contaminants, wastewater also contains substances that can be considered valuable products such as nutrients, salts, metals, chemicals, fuels, and energy^{50,51}. Textile industries perform wet operations such as scouring, bleaching, and dyeing, which require the handling of significant amounts of salts. Consequently, the effluent produced from these processes contains high levels of total dissolved solids (TDS) in addition to organic matter. To address this issue, common effluent treatment plants (CETPs) utilize lime, ferrous sulphate, and polyelectrolytes to conduct physicochemical treatment that removes color from the effluent. As a result, large quantities of lime sludge are generated. In a study⁵² conducted on utilizing textile sludge for building material, it was observed that it may be feasible to utilize up to 30% of Textile ETP sludge as a substitute for cement in the production of non-structural building materials. This

approach could serve as an alternative approach to disposal, providing a practical solution for the use of Textile ETP sludge in these applications. Sewage sludge (Biological treatment) contains significant amounts of nutrients, specifically around 0.5-0.7% phosphorus and 2.4-5.0% nitrogen, in the form of proteinaceous material that can be utilized as a fertilizer for plants³⁷. Heavy metals like Ni, Hg, Cd, Zn, Pb, Cr and Cu are generally found in sludge which can contaminate soil and groundwater which can cause adverse effect on environment and human health³⁷. To recover heavy metals from sludge, different researchers have explored different methods. Ultrasonication process for heavy metal recovery is gaining more popularity in recent years. About 0.5%-2.0% heavy metal concentration is found in sludge⁵³.

Conclusions and suggestion for further research

Today production of huge amount of hazardous sludge from common effluent treatment plants (CETPs) is a great concern for many CETP operating authority. Also, the performance of CETPs is not achieving its optimum level due to various factors (like receiving low influent with respect to design

capacity, improper operation, low chemical dosing and inappropriate sludge handling and management). Thus, various advancements in sludge treatment, handling and management are area of research to be focused. Further studies shall focus on sludge treatment technologies that can provide better efficiency, sustainable and more reliable than conventional treatment methods and these methods shall be discussed in detail. In the context of the circular economy, sludge is viewed as a valuable resource for energy and material recovery rather than waste. Various studies are done on CETP sludge utilization like building construction material, recovery of nutrients and recovery of heavy metals. Overall, the present review discussed some of the shortcoming of the sludge handling, disposal and treatment techniques which can be utilized to replace the existing conventional methods.

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