Potential of Municipal Sludge - A Cradle to Cradle Approach Towards Circular Economy

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Abstract - *India is a rapidly growing economy and now it is the fourth largest in the world. As per the report by United Nations, it is anticipated that India will overtake China to become the most populous country in the world by 2027. India's utilization of natural resources is already in a stress and there will be a scarcity of them by 2050. Therefore, with this growing population and rapid urbanization, India must take advantage of the creative economy and move towards the optimum utilization of Natural resources i.e. towards the circular economy. Circular economy solutions are embedded in the concept of generating zero waste and hence, developing innovations that can utilise discarded materials to produce reusable and recyclable products. As per Government of India, Countries 40% of urban population is serviced with sewerage system only, while the remaining 60% of the urban population is still dependent on sub-optimally regulated On-site Sanitation systems. Further, in onsite sanitation systems, limited attention has been accorded to proper construction, operation and maintenance, and treatment & disposal of municipal sludge. Municipal Sludge is facing many issues and societal stigma towards its utilization after recycling, as an alternative resource for other purposes. Recycle and reuse of Municipal Sludge in India is always a topic of contradictions. This paper presents a study on the various practices and policy interventions in other developed countries compared to India on recycle and reuse of Municipal Sludge.*

***Key Words*: Circular Economy, Faecal Sludge, Municipal Sludge, Wastewater**

1. Introduction

Currently, we take raw materials from the Earth, make products from them, and eventually throw them away as waste – this economy process is called as linear economy. While as per European Parliament, the circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is also extended.[1]

The idea of Circular Economy (CE) has been gaining global popularity in various fields, including in solid and liquid waste management. CE integrates economic activity and environmental well-being in a sustainable way. A typical linear economy approach adopts a 'take-make-waste' approach, whereas CE places emphasis on recycling of materials, which contribute to more sustainable business models, while also reducing emissions and increasing efficient use of natural resources. CE-based development approach is one of the key strategies in achieving the 2030 Agenda for Sustainable Development Goals (SDGs).

Sewage sludge originates from wastewater treatment processes. It is the by-product produced during the primary (physical and/or chemical), the secondary (biological), and sometimes the tertiary (additional to secondary, often is disinfection) treatment.[2] While, Faecal sludge is raw or partially digested combination of excreta which comes from onsite sanitation systems. Characteristics depends on the duration of storage, temperature & soil condition.

Sludge has for long been seen as a resource rather than merely as a by-product of liquid waste, since it contains valuable nutrients (nitrogen, phosphorus, potassium and other minerals, organic matter and moisture) that promote the growth of crops. Parallely, the potential contribution of sludge management to greenhouse gas emissions also needs to be kept in mind. Hence, sustainable sludge management and reuse strategies that are both economically and technically sound and environmentally feasible need to be developed.

1.1 Composition of Sludge

Approximately 60% of India's population is dependent on on-site sanitation systems, the balance 40% being covered with off-site systems.[3] Sludge is generated from both systems and needs to be managed appropriately, with minimal adverse effects on the environment. Sewage sludge originates from wastewater treatment processes, while faecal sludge from routine desludging of septic tanks. However, in contrast to on-site sludge, off-site sludge might contain heavy metals, industrial waste, kitchen waste, run-off, emerging contaminants etc. that would require special attention while using the treated sludge.

Raw sludge (i.e. untreated sludge prior to stabilization) comprises primary, secondary and tertiary fractions in any given mixture that occur at a sewage treatment plant. Sewage sludge which is stabilised primary, secondary or tertiary, occurs in a mixture at the end of the treatment process contains plant nutrients such as nitrogen and phosphorous, as well as harmful substances such as pathogens, endocrine disrupters and heavy metals.[4]

1.2 Importance of Treated sludge and its reuse

Sludge has for a long time been seen as a resource rather than merely as a by-product for disposal, owing to the fact that it contains valuable nutrients like nitrogen, phosphorus, potassium and other minerals that promote the growth of crops. The presence of organic matter and moisture is also of potential value. In combination, these ingredients are highly beneficial when applied to land, and its use on agricultural land is the most common outlet in a number of countries. Biosolids can be applied to the surface of the land in many ways. For ex. as a liquid, dewatered cake or dried material, or injected as a liquid into soils.[5]

2. India's current status of sludge recycle & reuse

India, currently one of the fastest growing economies in the world, is likely to continue at this fast pace in the coming decades. As per Census 2011, the total urban population of the country was at 37.7 crore and is projected to touch 60 crores by the year 2030. By the year 2050, it is expected that 50% of the country's population (approximately 81.4 crores) will be urban. The fast pace of urbanization is resulting in increased sludge generation which is posing environmental threat and health hazards, therefore, necessitating short term and long-term solutions to beneficially recycle and reuse sludge generated in urban India.

As per the CPCB report on National Inventory of Sewage Treatment Plants (2021), sewage generation from urban centres is about 72,368 MLD. However, there are only 1,093 Sewage Treatment Plants (STP) operational at present, with combined operational capacity of 26,869 MLD covering 35 States/UTs. Of this, the actual utilization is only 20,235 MLD. Further, another 274 STPs of 3,566 MLD combined capacity are under construction and 162 STPs with combined capacity of 4,827 MLD are being proposed across urban areas of the country.

2.1 Regulatory Measures in India

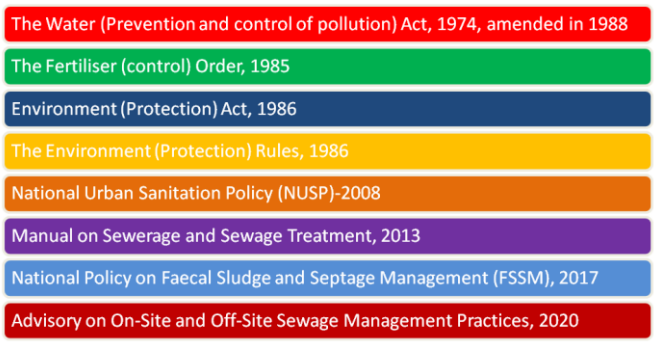

Fig -1: Some Key Regulatory Measures related to Municipal Sludge Management in India

During the last few years, a lot of development has taken place in India in terms of Regulations in the Solid & Liquid Waste Management Sector. Government of India has released many Acts, Rules, Polices, Guidelines, and Orders in managing offsite & onsite sanitation systems. Some of them are listed above. However, a comprehensive dedicated regulatory framework for recycle and reuse of municipal sludge is yet to develop in the country.

2.2 Beneficial utilisation of sludge in India

There was hardly any formal system for using treated sludge in a beneficial manner in India. Majority of septic tanks were desludged only when they were completely filled up, and often led to choking of the on-site system. Similarly, sludge from STPs were often dumped or used in agricultural fields without any regulation. Currently, around 80% of sludge is being utilised in India.[6] Moreover, there are cases where cities in India are recycling or reusing the sewage sludge after treatment.

Chennai Metropolitan Water Supply & Sewerage Board anaerobically digests sludge to produce bio-gas from it. The average electrical energy production from bio-gas is about 2 KWh / m^3 of bio-gas. Energy cost savings through power production per year is 373.50 lakhs (9 months/ year) through 4 STPs in Chennai. [7]

Table-1: The non-conventional Energy Production in 4 STPs in Chennai

Location of STP	Capacity (MLD)	Capacity Of Gas Engine (KW)	Power production per month (KWh)	Cost savings / month @ Rs.3.50 / KWh
Kodungaiyur (Zone - I&II)	110	1064	4,50,000	15.75 Lakhs
Koyambedu (Zone - III)	60	625	2,25,000	7.90 Lakhs
Nesapakkam (Zone – IV)	40	469	1,50,000	5.25 Lakhs
Perungudi (Zone – V)	54	1064	3,60,000	12.60 Lakhs
Total	**264**	**3222**	**11,85,000**	**41.50 Lakhs**

Ahmedabad converts city sludge to Bio-fertilizer, and utilises an integration of two technologies – irradiation, and Bio-NPK to produce a novel product. The plant is loaded with 150 kCi of Co-60 and was inaugurated in February 2019. [8]

Faecal Sludge from septic tanks also contains resources such as organic substances, plant nutrients and energy that can be recovered to offer monetary gain for the treatment plant. There are plenty of examples where faecal sludge is being treated in Faecal Sludge Treatment Plant (FSTP) or co-treated in STP and then being reused either in the form of manure, pellets. The share of nutrient/energy recovery from various FSTPs in India is shown in the figure below. [9]

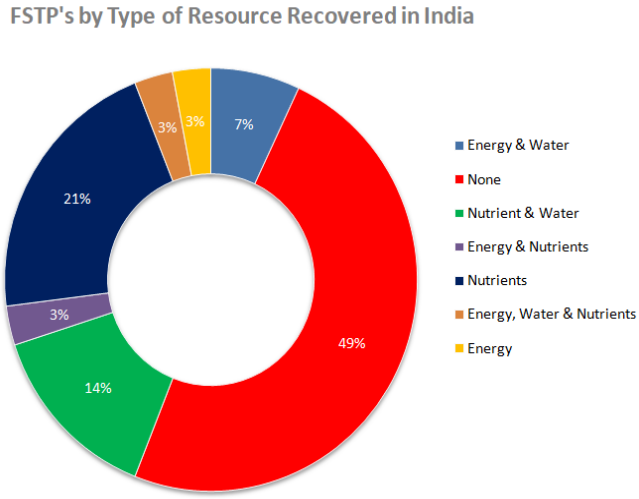

Fig -2: Nutrient/energy recovery from various FSTPs

Furthermore, Ministry of Petroleum & Natural Gas, Government of India has recently launched an initiative titled "Sustainable Alternative Towards Affordable Transportation (SATAT)" aiming at providing Compressed Bio-Gas (CBG) as an alternative to CNG in automobiles. It is planned to roll out 5,000 CBG plants across India by 2025. [10]

3. International Approaches for Sludge Management and Utilisation

For years, sewage sludge treatment has been considered a secondary concern compared to main wastewater treatment. However, the importance of sludge management is increasing nowadays due to the fast increase of sludge generation in view of sewage network extensions, new installations, and upgrading of facilities. United States, Europe and East Asia are leaders in sludge utilisation. [11]

3.1 Approach for sludge utilisation in USA

As per United States Environment Protection Agency (USEPA), guidance and regulations are the best way to promote good practices for sludge reuse, recycle and disposal that minimize the potential adverse impacts on public health and the environment and maximize the potential benefits. The benefits potentially gained through sludge use include energy and nutrient recovery, soil improvement, and conservation of valuable natural resources.

There were several laws (e.g. Clean Water Act; Clean Air Act; Resource Conservation and Recovery Act: Marine Protection, Research and Sanctuaries Act: Toxic Substances Control Act: and the National Environmental Policy Act) which laid emphasis on environmentally sound management of municipal sludge and several of these laws stressed the need for sludge utilization and reuse. The final edition of part 503 'Standards for the Use or Disposal of Waste water sludge' was regulated on 25 November 1992.

3.2 Approach for sludge utilisation in European Union

The biggest amounts of sewage sludge in the EU are generated in Germany, the UK, and France. Comparatively less sewage sludge is generated by Italy and Spain (each country generates more than 700,000 t DM per year). These five countries together generate nearly 75% of the total amount of sewage sludge in the EU. [12] According to Fytili and Zabaniotou (2008), sewage sludge generation in the EU has increased by 50% since 2005. Therefore, the optimization of sewage sludge management represents a key element in the sector of wastewater treatment.

EU has given various directives to the Member States for sludge management, as given below:

i. Urban Wastewater Treatment Directive (91/271/EEC)

ii. Directive on Protection of the Environment, and in particular of the Soil when Wastewater sludge is used in Agriculture (86/278/EEC)

iii. Directive on Waste Disposal (99/31/EC)

iv. Directive on Incineration of Waste (94/08/20)

3.3 Approach for sludge utilisation in Germany

The legal initiatives of Germany are tabulated below. [13]

Table-2: Laws / Regulations

KrW-/AbfG	Act for Promoting Closed Substance Cycle Waste Management	promotion of closed substance cycle economy, resource protection, environmentally sound waste disposal
AbfKlärV	Sewage Sludge ordinance Fertilizer Ordinance/ Ordinance on the Principles of Good Professional	sludge application to agricultural land (limiting values for quantities, soil, sludge parameters and

DüMV/DüV	Practice During the Application of Fertilizers	nutrient demand)
BBodSchV	German Federal Soil Protection and Contaminated Sites ordinance	additionally for sewage sludge used in landscaping, recultivation and land reclamation
TASi	Technical Instructions on Waste from Human Settlements	landfilling of sludge

4. Conclusions

In recent years, the concept of circular economy has gained increasing prominence across the world as an approach that presents solutions to some of the world's most pressing sustainable development challenges[14], including that of waste management.

Based on the literature review, it has been found that following issues or gaps need to be addressed in order to achieve circular economy in the sector.

i) Research to be done in enriching the by-products with additional nutrients by adding other wastes and microorganisms in the products

ii) There is a lack of dedicated standards on discharge of sewage sludge, recycle and reuse

iii) National policy or Guidelines on sludge reuse & recycle is absent

iv) Lack of monitoring framework on recycle and reuse of sludge

v) Lack of incentives on products generated from treating sludge

vi) Shortfall in imposition of tax or fine on dumping sludge in landfills or open land

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