

MAINSTREAMING GOVERNANCE ON WASTEWATER TREATMENT, WATER RE-USE AND RESOURCE RECOVERY:

LEARNINGS FROM INDIA AND THE EUROPEAN UNION

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Cover photos

Left Photo: Sludge Recirculation Clarifier Solid Contact Sedimentation Tank, Central Photo: Irrigation canal at Kishanpur village, Kanpur (2020), Right photo: Aerial view of the Schilde WWTP (near Antwerp, Belgium) with a conventional activated sludge (CAS) lane (max flow 34 MLD) and membrane bioreactor (MBR) lane (max flow 14 MLD)

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1. BACKGROUND

India's water resources are severely overexploited and polluted. Discharge of untreated wastewater has resulted in contamination of 75% of all surface water bodies in India (CPHEEO, 2012). Over the years, the need for wastewater treatment, recycle and reuse has been emphasized in several policies, laws and programs. Various attempts have been made for interventions on wastewater recycle and resources recovery and reuse (RRR), at different scales with varying level of completion and success. However, owing to diverse bottlenecks related to technological adequacy and upscaling, policy and law convergence, lack of robust financial and incentive mechanisms, lack of adequate capacities and awareness amongst stakeholders, the interventions are yet to make a significant impact at a large scale in India. As India grows and urbanizes, meeting the ever-increasing water demand amidst water scarcity and pollution scenarios necessitates a major impetus on wastewater treatment and RRR through mainstreaming of various related policies, laws and programs leading to a governance framework. This policy paper is derived out of the PAVITRA GANGA project (a joint India-EU project; https://pavitra-ganga.eu/en) that focuses on developing and piloting robust treatment and reuse technologies along with policy interventions to address some of the existing challenges and promote wide scale wastewater treatment and RRR systems in India.

1.1 State of wastewater treatment, resources recovery and reuse in India

The total sewage generated by urban areas in the country was estimated to be about 61,948 million litres per day (MLD) (in 2015), as against the available installed sewage treatment capacity of only 23,277 MLD (i.e. about 37% of the sewage generated) (MoEFCC, 2018), illustrating a huge gap in sewage treatment, while also suggesting a significant volume of untreated/partially treated sewage finding its way into water bodies resulting in pollution. Figure 1 indicates the wastewater generation and treatment scenario in different classes of cities in India. The wastewater treatment infrastructure overall performs poorly due to frequent electricity break-downs, deficient

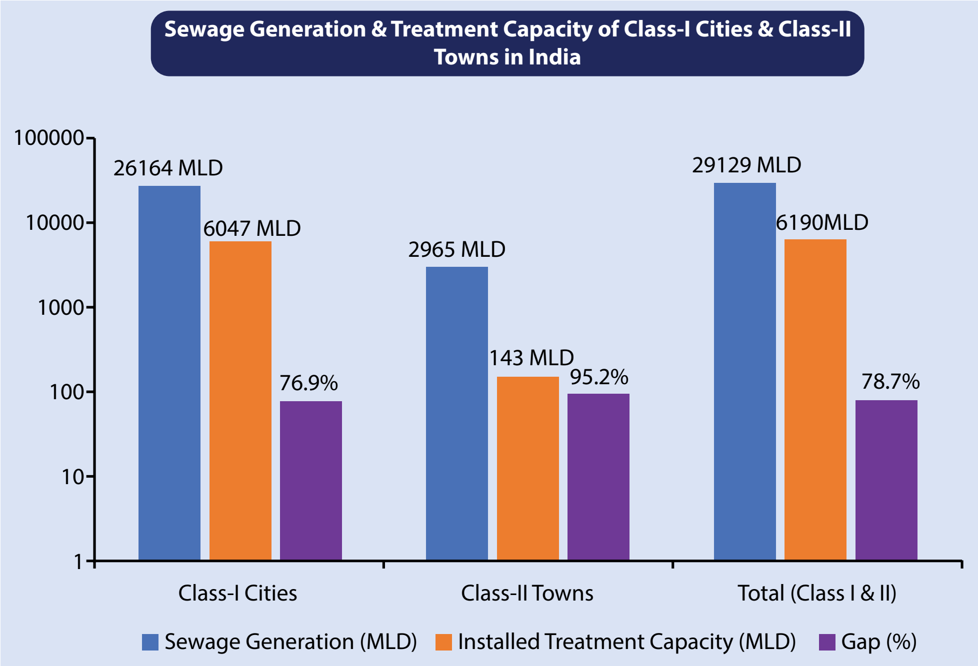

Figure 1: Sewage generation and treatment scenario of Class-I cities & Class-II towns of India (log-scale with % gap in treatment)

(Data Source: CPCB, 2017)

operation and maintenance, inadequate sewerage networks and technology designs not matching the wastewater characteristics (Never, 2016, CPCB 2007). Latest estimations by the Central Pollution Control Board (CPCB) show that 20% of sewage treatment plants (STPs) are non-functional and about 39% of the STPs do not meet the discharge standards prescribed under the Environment (Protection) rules for discharge into streams (CPCB, 2017).

Moreover, untreated wastewater (in the absence of any other source of water) is widely used in agriculture for irrigation and as source of nutrients, which result in increased health risks and leads to water and soil pollution (Kaur et al. 2012). So far, the reuse of treated wastewater from centralized schemes is limited to a few places in India and restricted to agriculture and horticulture (Amerasinghe et al., 2013; WSP and IWMI, 2016) and some industries for cooling (PwC, 2016; Lahnsteiner et al., 2015). Examples for these two reuse schemes are given in Chapter 3 of this policy brief, where enabling factors and barriers for water reuse are further discussed. Zero-liquid discharge (ZLD) guidelines were introduced for four industrial sectors (textile, distilleries, pulp and paper and tanneries) by CPCB in 2015 and promoted in nine states along the Ganga river basin (CPCB, 2015) setting the stage for increased on-site water reuse by industries in the near future.

Recent assessments of small-scale treatment systems in Karnataka showed that these fail to treat wastewater up to the desired water reuse standards (due to insufficient nutrient and pathogen removal) and that reuse of treated water is hampered by a lack of opportunities and demand in the vicinity (Ulrich et al., 2018). However, decentralized wastewater treatment solutions are commonly perceived as solutions for underdeveloped areas (e.g. peri-urban and rural settings) and have several advantages (e.g. less energy use, easier management of wastewater reuse, better adaptation to local conditions, better affordability, etc.) over centralized treatment systems (Starkl et al., 2013).

Besides the wastewater, sludge management in Indian STPs is of general concern due to a lack of or poorly operated treatment infrastructure (Kaur et al., 2012). Untreated or partially treated sludge is discharged into water streams or dumped on landfills. Adequately treated and processed sewage sludge is a nutrient-rich organic material and valuable organic soil improver (Kumar et al., 2017). Ahmedabad Municipal Corporation (AMC) has launched India's first full-scale automatized sludge hygienization plant in 2019 that can convert 100 tons/day of dry sludge into a safe fertilizer by radiation technology and NPK treatment (Varshney, 2016). Unfortunately, lack of conducive policy guidelines for nutrient recovery from sewage limits the application of treated sludge on a larger scale (Gujarat Cleaner Production Centre, unknown). Anaerobic treatment of sludge reduces the amount and results into a more stabilized material, but also leads to the production of biogas which can be recovered and used. The Ministry of New and Renewable Energy (MNRE) estimates an energy production potential of about 225 MW from sewage in India. However, growth of the waste to energy sector has been limited in India due to reasons such as high cost of installation and the dependence on import of commercial technologies (Gujarat Cleaner Production Centre, unknown). The lack of specific regulations for sewage sludge discharge until 2016 and the low feed-in tariffs for biogas (no economic returns) led to few implemented biogas systems in the Indian wastewater sector up to now (Kaur et al. 2012; Never 2016). Some Urban Local Bodies (ULBs) and state water boards such as the Chennai Metro Water Supply and Sewerage Board, Nagpur Municipal Corporation, Delhi Jal Board have engaged with private entities to implement waste to energy projects in public-private partnerships (Indian infrastructure, 2019). Two examples for such energy recovery schemes are given in the Indian case study section of this document (see chapter 3), where enabling factors and barriers for biogas recovery are further discussed. Under some of the national programs such as the Swachh Bharat Mission-Urban, Waste to Energy production of 61.0 MW has been achieved till date. Under Atal Mission for Rejuvenation and Urban Transformation (AMRUT)[1], about 60 Faecal Sludge Treatment Plants (FSTPs) of 32 kilo litres per day (KLD) are being implemented in major cities in Uttar Pradesh that have a potential to generate about 13,200 tons per year of compost, and a revenue of about INR 4 crore per annum.

Thus, some attempts have been made in India at treatment of sewage sludge and recovery of resources (water, energy and nutrients) from STPs. However, India is yet to exploit in full potential, the Circular Economy opportunities for wastewater resource recovery from STPs.

India's water crisis requires a paradigm shift of current water

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[1] AMRUT is a Government of India (Ministry of Housing and Urban Affairs) program to provide basic services (e.g. water supply, sewerage, urban transport) to households and build amenities in cities to improve the quality of life for all, especially the poor,

governance practices, moving from today's linear **'take-use-waste'** approach to a **circular water management.** This requires, amongst others, introducing appropriate pollution control and following the multi-barrier-principle of the World Health Organization to safeguard environmental and public health. Proper access to safely managed sanitation remains a problem for millions of people in India, and untreated sewage introduces serious health risks for a large part of the population, making the SDG6 targets important focus points of policy as well as of technological and social innovation.

About this policy brief

The PAVITRA GANGA project was initiated to contribute to the Indian policies, laws and programs and fulfilment of Sustainable Development Goal (SDG) 6, by unlocking the environmental and economic potential of municipal wastewater treatment, reuse and resources recovery solutions for urban and peri- urban areas in India. The core aim of this policy brief is to bring together the learnings from successful and unsuccessful case studies from India and EU with an analysis of the Indian and EU policy and regulatory frameworks. Together with relevant stakeholders from Central, State and local level for the two selected technology test sites (Delhi and Kanpur), it intends to formulate recommendations to support the existing and future policy and law reforms in India.

1.2 European shift from wastewater treatment to wastewater reuse and resources recovery

Europe is experiencing growing water stress, both in terms of water scarcity and deteriorating quality. Approximately half of the European countries, representing almost 70% of the population, are facing water stress issues. Some European countries such as Belgium and Spain are high (above 40%) on the water stress index[2], emphasizing the need to work on comprehensive governance of water resources, of which one is the reuse of wastewater (see Figure 2).

The European Union (EU) has been tackling water pollution and scarcity for a long while now. Core policy instruments are the Urban Waste Water Treatment Directive (UWWTD, 91/271/ EEC), the Water Framework Directive (WFD, Directive 2000/60/EC) and the Groundwater Directive (GWD, Directive 2006/118/EC).

The UWWTD aims to protect the environment from discharges of urban wastewater, in particular by requiring that cities, towns and other population centres meet minimum wastewater collection and treatment standards by stipulated deadlines. Under the UWWTD, there have been billions of euros invested across Europe to collect and treat urban wastewater from agglomerations ≥ 2000 p.e. to remove harmful microorganisms, oxygen-consuming substances and nutrients (European Commission, EC, 2017). Industry sector specific regulations and guidelines, including EU BREFs (Best available techniques reference documents) further ensure that water quality norms are followed. The WFD aims to protect surface and groundwater in EU river basins through specific milestones and operational steps to be undertaken by all EU countries. It establishes measures to prevent or limit the inputs of pollutants into surface and groundwater and thus mitigates the deterioration of water resources. The GWD provides detailed regulations to prevent, control and address groundwater pollution and established groundwater quality standards. To facilitate the compliance with European UWWDT requirements for collection, secondary and more stringent treatment, the EU allocate EUR 14.8 billion of the European Regional Development Fund (ERDF) and the Cohesion Fund to water related interventions mainly wastewater treatment and as drinking water supply for the period 2014-2020.

Water reuse practices in EU Member States are mainly driven by the demand for additional water resources and evolve under quite diverse national legal regimes. Mostly agricultural uses are permitted but some countries also have quality standards for urban, industrial, recreational and environmental applications (Breitenmoser and Hochstrat, 2019). One of the factors preventing the uptake of water reuse includes the lack of common environmental and health standards for water reuse across the EU, plus the potential obstacles to the free movement of agricultural products irrigated with reclaimed water (European Parliament 2020). Increasing efforts in recent years have been put to promote water reuse as a possible solution to water scarcity problems.

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[2] The water stress index is defined as the ratio (%) of a country's total water withdrawal to its total renewable freshwater resources

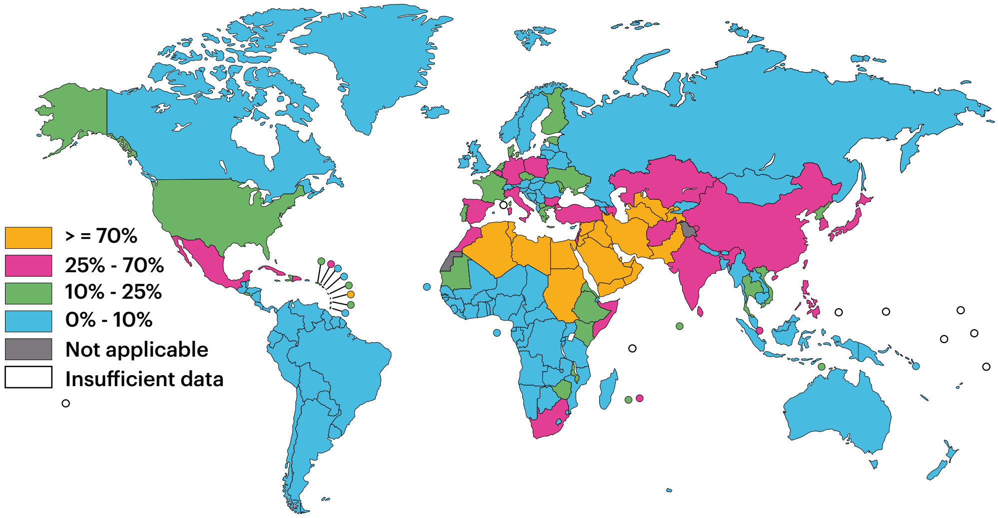

Figure 2: Level of Water Stress in Different Countries

(Source: United Nations (2018). Sustainable Development Goal 6 Synthesis Report 2018 on Water and Sanitation. New York.)

In 2015, the European Commission (EC) presented the new circular economy package (EC, 2018) with one of the actions to develop a regulation on the 'minimum requirements for water reuse', expected to be adopted in 2020. The regulation aims to stimulate the uptake of water reuse by offering a sustainable, alternative water supply for irrigated agriculture. The EC has recently announced its New Green Deal package providing a roadmap to 'boost the efficient use of resources by moving to a clean, circular economy while restoring biodiversity and cutting pollution' (EC, 2020a).

Sludge management is a challenging issue for EU Member States, which is exacerbated by the fragmented EU legislation (Kelessidis and Stasinakis, 2012; Fytili and Zabaniotou, 2008; Wisniowska et al., 2019). The 28 EU Member States generate more than 10 million tons of sewage sludge (dry matter) from municipal wastewater treatment plants annually (Bianchini et al., 2016). Germany, the UK, Spain, France and Italy produce more than 55-65% of the total sewage sludge amount generated (Collivignarelly et al., 2019).

Several EU legislations relevant to sludge management have evolved over time. These include the UWWTD (91/271/EEC)-related to disposal in general, the Sewage Sludge Directive (86/278/EEC) and its amendment (2018/851/EC)-related to sewage sludge reuse (organic fertilizer), the Directive on industrial emissions (2010/75/EC) and the Directive on the promotion of energy from renewable sources (2009/28/EC)- related to sewage sludge for energy recovery) and the Landfill Directive (1999/31/EC) and its amendment (2018/850/EC)-related to landfilling of sewage sludge.

The political choices for sludge recovery/disposal routes are strongly influenced by the availability of agricultural land, the population density, the costs of treatment options and the acceptance by farmers and the public in EU Member States (Collivignarelli et al., 2018). Therefore, each EU Member State has developed distinct national guidelines and standards for sewage sludge treatment and disposal. Some EU Member States have implemented stringent limit values for pathogens and organic micropollutants if treated sludge is reused for agriculture (e.g. Denmark, Finland, Sweden, Netherlands, Austria, Belgium, France and Germany). Other EU member states (e.g., Italy) have additionally included maximum amounts of treated sewages sludge to be applied on soil while distinguishing between different soil types (pH, cation exchange capacity).

The most favoured routes for sludge disposal in EU Member States is the reuse of sewage sludge in agriculture (ca. 5 million tons; 50%), followed by incineration (ca. 3 million tons, 28%) and landfilling (2 million tons, 18%) (Bianchini et al., 2016, Collivignarelly et al., 2019, Wisniowska et al., 2019). Further, there has been a shift towards phosphorous (P) recovery from sewage sludge (recycling mineral fertilizer). In 2014, the EC classified phosphate rock as critical raw material (EC, 2014). Several EU countries (i.e., the Netherlands, Denmark, Switzerland and Belgium) have started to recover P from sewage sludge and authorized the use of recovered struvite/phosphates as fertilizers. Under the New Green Deal package, the EC is currently working on an Integrated Nutrient Management Action Plan (INMAP) with criteria for phosphate salts and struvite, biochar and pyrolysis materials, and ashes. (EC, 2020b).

2. POLICY AND REGULATORY LANDSCAPE SUBSUMING WASTEWATER TREATMENT, RESOURCES RECOVERY AND REUSE IN INDIA

2.1. Key Policies at Central Level

2.1.1. The National Water Policy 2012

The National Water Policy (NWP) (2012) emphasizes on water conservation, recycle reuse, water demand management, sectoral water use efficiency, water pricing, provision of water supply and sanitation facilities and enhancing water availability. It stresses on river basin management approach, transboundary water management, Integrated Water Resources Management (IWRM) as well as adaptation to climate change amongst others.

While some states have drafted a state water policy based on the central policy recommendation, weak enforcement, lacking monitoring mechanisms and unclear responsibilities as well as inter-sectoral conflicts among water related ministries hinder any significant impact on improving India's water management practices (Pandit and Biswas, 2019; Jain, 2019).

Though the objectives of the policy calls for recycle and reuse of water, the lack of clear frameworks/action plans to operationalize the policies and bring about transformational changes on ground are a recurring issue.

2.1.2. The Water (Prevention and Control of Pollution) Act 1974

The Water (Prevention and Control of Pollution) Act aims to prevent and control water pollution by establishing Central and State Pollution Control Boards (the CPCB and SPCBs) to enforce the regulations relating to the treatment and disposal of sewage and trade effluents. The CPCB develops water quality management plans involving, amongst others, setting water quality goals, monitoring water quality, controlling pollution; wastewater recycling and resource recovery, use of clean technologies, and setting wastewater discharge standards and charges for residual pollution (CPCB, 2008). The SPCBs plan comprehensive programs for prevention, control and abatement of water pollution and secure its execution at state level, as well as advise the State Government on water pollution.

Though, the Act details the function of various agencies to look at prevention and control of water pollution, it depends on 'end of the pipe' treatment systems and lacks emphasis on cleaner production. There is also a lack of provision for public participation, in matters related to water pollution.

2.1.3. The Environment (Protection) Act 1986

The Environment (Protection) Act empowered the Central Government to make rules to regulate environmental pollution. Concerning water, the environmental rules prescribe standards for quality of surface water for various purposes (irrigation, domestic, industrial, recreation, etc.) and the effluent discharge standards, with permissible limits of concentration of various parameters in wastewater for discharge over different areas (inland surface, public sewers, land for irrigation and marine coastal areas, etc.).

In 2017, an amendment was made to the Environment (Protection) Act to specify the standards for the discharge (into water bodies and land) of the treated effluent from the sewage treatment plants (STPs). However, these standards were scrapped by the Order of the National Green Tribunal (NGT), stating that the diluted and differential standards will affect the existing pollution load of water bodies and will further negatively impact a large section of the population. The NGT in its 2019 order made the sewage discharge standards much more stringent and emphasized that the benefit of such standards is to achieve all-purpose non-potable reuse quality effluent. It states that each STP is to be treated as a source of water for reuse and recycling, helping in mitigating drought/ climate change in the country (NGT Order, 2019).

2.2 Key Policies in NCT Delhi and Uttar Pradesh

2.2.1 Key Policies in NCT Delhi

The Delhi Jal Board Act (1998) was to establish the Delhi Water Board to undertake the responsibilities related to water supply, sewerage and sewage disposal and drainage within the National Capital Territory (NCT) of Delhi. The Draft Water Policy (2016) notes various emergent policy issues that needs to be addressed in Delhi such as shifting emphasis from supply side to demand side management, prioritization in water allocation and adjusting to climatic changes. It also aspires to treat and reuse 25% of total sewage produced, by 2017, and increase the same to 50% by 2022, and to 80% by 2027. The DJB also developed a Sewerage Master Plan for Delhi-2031 for effective implementation and operations of wastewater services.

2.2.2 Key Policies in Uttar Pradesh

The Uttar Pradesh State Water Policy (1999) emphasizes on preservation of scarce water resources by optimized utilization of available resources and inclusion of user participation and decentralization of authority to improve water quality. The UP Water Supply and Sewerage Act (1975) aims at the establishment of a corporation, authorities and organizations for the development and regulation of water supply and sewerage services and for matters connected therewith. The State currently seeks to adopt the Draft policy on wastewater recycle and reuse in urban local bodies, which touches upon various aspects of wastewater collection and treatment, reuse of treated effluent and sludge and public acceptance and awareness. It calls for updating and development of standards and practices for substituting fresh water used in irrigation and industry by treated wastewater after blending it, to increase surface water utilization for municipal uses and the implementation of centralized wastewater collection and treatment systems.

2.3. Key Government Programs at Central Level

2.3.1. Programs to Clean River Ganga

The key flagship programs launched by the Government of India with an aim to clean River Ganga have been the Ganga Action Plan (GAP) launched in 1985 and the current flagship program of Namami Gange launched in 2014 (Figure 3 below).

Despite creating considerable STP infrastructure, the Ganga Action Plan was not able to achieve its overall objectives due to multiple factors including inadequate institutional and policy framework between central, state and local Government bodies to implement schemes, inadequate technological designs, significant delays in project execution, lack of funds in urban local bodies (ULBs) for adequate operation and maintenance of STP infrastructure, improper mass awareness and weak monitoring network .

Namami Gange: The Government of India's flagship Namami Gange programme (launched in 2014) is an ongoing program with a broader scope of effective abatement of pollution, conservation and rejuvenation of National River Ganga. Activities are underway for creating sewerage capacity of 1,187.33 MLD including two recently launched projects based on Hybrid Annuity PPP Model at Haridwar and Varanasi.

Besides, the government has also initiated Public private partnerships (PPP) through financial models like DBOT (design, build, operate and transfer), DBO etc. and support to infrastructure projects through Viability Gap Funds (VGF).

2.3.2. Recent Government initiatives to improve wastewater treatment and management

The Government of India has recently initiated or renewed several programmes to improve un-sewered and sewered sanitation. Under these programmes, applicants from municipal and private sectors are offered grants, subsidies and loans for investments. An overview of these initiatives is provided in Table 1.

GANGA ACTION PLAN - I	GANGA ACTION PLAN - II	NAMAMI GANGE
Focus on pollution abatement, interception & diversion (I&D) as well as treatment of domestic sewage, to prevent toxic and industrial chemical wastes from identified grossly polluting units from entering in to the river GAP phase-I involved a sanctioned cost of INR 462.04 crores of which about INR 433.3 crores was spent on 25 class-I towns in Uttar Pradesh, West Bengal and Bihar About 868.69 MLD of sewage treatment capacity was created	Involved laying sewers, construction of new sewage treatment plants and rehabilitation of existing sewerage systems amongst others activites Under GAP phase-II, about INR 3402.43 Crores (until February 2014) capacity was spent on for Ganga and its tributaries About 1757.23 MLD of sewage treatment capacity was created	Key activities of the Namami Gange are the creation of sewage treatment infrastructure, river front development, cleaning of river surface, conservation of bio-diversity and conservation of identified priority species, afforestation and public awareness. The program has an approved budget of INR 20000 crore Treatment capacity of about 328 MLD have been created until 2019

Figure 3: Ganga cleaning programs

Table 1: Overview of Government initiatives to improve wastewater treatment

Initiative	Ministry	Period	What is financed	Available funds	Reference
Swachh Bharat (Clean India) Mission	MoHUA/ MoDWS	2014-2019	Toilet construction in households, communities and public spaces in all 4041 statuary towns	9 billion USD	http://swachhbharaturban.gov.in/
AMRUT Mission	MoHUA	2015-2023	Water supply and sewerage connections, wastewater treatment facilities and septage management; as well as storm drainage systems (500 cities)	7 billion USD	http://amrut.gov.in/content/
Smart City Initiative	MoHUA	2017-2023	Sanitation and wastewater treatment and management in 100 Indian cities	7 billion USD	http://smartcities.gov. in/content/

Source: MoHUA = Ministry of Housing and Urban Affairs, MoDWS= Ministry of Drinking Water and Sanitation

2.4 Policies to promote water reuse and resources recovery from sewage treatment plants

Water reuse is promoted in the 2012 National Water Policy and the 2017 amendment of the Environment (Protection) Act 1986 for STP effluents considers discharge for land irrigation and inland surface waters. The National Urban Sanitation Policy as well promotes the recycle and reuse of treated wastewater for non-potable applications and encourages technological developments (MoUD, 2008) However, there are no clear national water and wastewater reuse standards or rules in India which specify reuse applications (Schellenberg et al., 2020). Several Indian States such as Karnataka, Gujarat, Jharkhand, Haryana and Punjab have developed state water reuse policies (Schellenberg et al., 2020, Reymond et al., 2020). The Ministry of Housing and Urban

Affairs (MoHUA) has recommended norms for different uses of treated sewage in its Manual on Sewerage and Sewage Treatment Systems (CPHEEO, 2013).

Waste-to-energy technologies such as anaerobic digestion (biogas), gas recovery from landfills or incineration with heat utilization and gasification can play a role in diversifying India's energy supply (Breitenmoser et al., 2019). Under the 'Waste to Energy' program, the Ministry of New and Renewable Energy (MNRE) has been financing large-scale Waste to Energy (WtE) systems, such as biogas plants (> 1 MW) since 2006. The Solid Waste Management Rules, 2016, regulates post processing of sewage sludge and set quality standards to be used in agriculture (Wisniowska et al., 2019; CPHEEO, 2016). The Initiative of Sustainable Alternative Towards Affordable Transportation together with the release of the IS standard for biogas for automotive applications and piped network (IS 16087) (BIS 2013, Ministry of Petroleum and Natural Gas, 2018), sets a target of 15 million tons compressed natural gas produced annually from organic waste sources such as sewage treatment plant sludge by 2023. The National Policy on Faecal Sludge and Septage Management (FSSM) issued by the Ministry of Urban Development (now Ministry of Housing and Urban Affairs) in February 2017 promoted small scale WtE systems and nutrient recovery from onsite faecal sludge treatment systems (septic tanks and pit latrines).

Though there are certain policies, laws and programs by the Government that endorses wastewater treatment, reuse and resources recovery, the availability of clear guidelines and specific standards with a defined implementation framework for wastewater treatment and RRR is lacking. There is the need to dovetail existing water and wastewater policies and programs into a National Water Framework as an umbrella of general principles governing water issues by the national government, the state governments and the local governing bodies. This should lead the way for essential legislation on water and sanitation governance in the entire country. Such a framework should recognize the importance and mainstream the wastewater treatment and RRR systems in India.

3. ANALYSIS OF SUCCESSFUL AND UNSUCCESSFUL EXPERIENCES WITH WASTEWATER TREATMENT, RESOURCES RECOVERY AND REUSE TECHNOLOGIES IN INDIA AND EUROPE

Globally, the uptake of wastewater treatment and RRR systems has been slow despite its various benefits towards sustainable production and consumption systems (Otoo & Drechsel, 2018). The past experiences on wastewater treatment, and RRR practices have demonstrated both the benefits and the challenges related to sustainable planning and operation of technologies. A review of various initiatives in India and the EU (case studies, Section 3.1) and stakeholder consultation (Section 3.2) provide an in-depth understanding of water governance factors (Section 3.3.) that successfully or unsuccessfully contributed to delivering improved wastewater treatment and RRR systems. These form the base for policy recommendations towards enhancing water governance on wastewater treatment and RRR in India.

3.1. Experiences from full-scale technology applications case studies

In total thirteen case studies on wastewater reuse (agricultural and industrial) and resource recovery from sewage sludge (nutrients and biogas) in India and the EU were analyzed to determine water governance factors influencing the planning and operation of wastewater treatment and RRR systems. Water governance factors comprise the political, legal, socio-economic and institutional systems in place to manage water resources. Short descriptions of eight of the case studies are presented below, highlighting policy interventions, technological designs and the main enabling factors and barriers of water governance arrangements. Additional information and further analyses of each of the case studies can be found on the Pavitra Ganga project website: https://pavitra-ganga.eu/en

Agricultural reuse

Case 1: Kanpur (Jajmau), India

Background: Kanpur city in Uttar Pradesh is situated on the banks of river Ganga. The estimated sewage generation of Kanpur city is about 339 MLD, while its industrial tannery cluster produces 26 MLD of highly polluted wastewater.

Policy intervention: The introduction of the Ganga Action Plan (GAP) aimed to improve the water quality by interception, diversion and treatment of domestic sewage and toxic and industrial chemical wastes from polluting tannery units.

Treatment technologies: Under GAP-I, three sewage treatment systems were commissioned at Jajmau, viz. a 130 MLD sewage treatment plans (STP) based on the activated sludge process; a 36 MLD combined effluent treatment plant (CETP) based on upflow anaerobic sludge blanket (UASB) as well as a 5 MLD pilot plant based on UASB. Treated effluents from STPs and CETP are now mixed and provided for irrigation through an irrigation canal.

Enabling factors and barriers: Technological design of the CETP did not take into account a long-term development of the area and hence increased volume of effluent against created treatment capacity, frequent electricity breakdowns, inter-institutional conflicts and lack of cost-recovery resulting in low quality irrigation water (exceeding standards for BOD, COD, Cr, Pb, Zn and Cu). The deterioration of the quality of the effluent caused a decrease in crop yields and led to the contamination of soil and groundwater (IWMI 2013).

To address the bottlenecks, several interventions have been recently initiated under the Namami Gange Program involving various stakeholders (viz. NMCG, Australian AID, IIT Kanpur, VA Tech Wabag, UP Jal Nigam, Jajmau Tannery Effluent Treatment Association (JTETA) etc.) that includes diversion of major Sisamau drain to Jajmau STP (60 MLD) and Bingawan STP (80 MLD) to prevent direct discharge into Ganga river, and creation of 20 MLD CETP to treat tannery effluent.

Agricultural reuse	Case 2: Barcelona, Spain	**Background:** The water supply source of the Barcelona Metropolitan Area viz. the Llobregat River was intensively exploited for urban, industrial and agricultural uses, resulting in water quantity deficits and water quality deterioration due to agricultural runoff and disposal of industrial and urban treated effluents in most of the areas supplied from the River. **Policy intervention:** Spanish water reuse guidelines were established in 2007 for different uses of treated wastewater including urban, agricultural irrigation, and recreational purposes including parameters such as suspended solids, turbidity, E.coli, and intestinal nematodes eggs. The national water reuse guidelines and competing freshwater demands fostered the development and implementation of different wastewater reuse technologies. **Treatment technologies:** Technology designs were driven by reuse purpose and wastewater characteristics ('fit-for-purpose treatment') and based on a participatory stakeholder dialogue to meet the particular water quality needs of each reuse purpose at additional costs and demand. The wastewater treatment plant of El Prat de Llobregat is an activated sludge system. About two-thirds of the secondary treated water is discharged into the Mediterranean Sea, while one-third undergoes, depending on demand, tertiary treatment for reuse, by coagulation-flocculation and lamella settling, filtration through a microscreen followed by UV disinfection. Oxygen is injected into the system to ensure a saturated dissolved oxygen concentration. A smaller part of the flow undergoes reverse osmosis (RO). **Enabling factors and barriers:** The close proximity of the farmers to the wastewater treatment system limited pumping costs of the treated water and provided farmers an economic incentive over freshwater sources for irrigation, especially during times of scarce freshwater supply. Another driver of success was the leadership and involvement of one single agency providing greater flexibility and ease for negotiating with farmers.
Industrial Reuse	Case 3: Nagpur, India	**Background:** Nagpur city in Maharashtra has witnessed high demands for freshwater due to rapid population growth and economic development during the last decades. The Maharashtra Generation Company Limited (MahaGenCo) needed large volumes of cooling water (309 MLD) for expanding production capacity of its thermal power plant (TPP) against an allocated 205 MLD by the Irrigation Department of the Maharashtra Government (SANDRP 2014). As an alternative to freshwater, the use of treated sewage was explored to meet the additional water requirements. **Policy intervention:** In 2005 the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was launched to facilitate the development of infrastructure projects with water supply, sewerage and treatment. As a result, a Memorandum of Understanding (MoU) was signed in 2008 between Nagpur Municipal Council and MahaGenCo for the supply of 110 MLD treated sewage from Bhandewadi STP to be further used in the cooling towers of the thermal power plant located in Koradi (Ade et al., 2018). In order to complement the efforts achieved with the JNNURM, the state of Maharashtra adopted its wastewater reuse policy in 2017. **Treatment technologies:** Bhandewadi STP is a sequencing batch reactor system followed by chlorination and deep-bed multimedia filtration. The tertiary treated wastewater is of acceptable quality for further use as process water at the thermal power plant. **Enabling factors and barriers:** The strong contractual agreement backed by Government policies and regular monitoring of delivered water quality resulted in a sustainably operated treatment system. MahaGenCo experienced economic advantages over sourcing freshwater, while Nagpur Municipal Council was able to cover the O&M costs through the revenues by the industry.
Industrial Reuse	Case 4: Schilde, Belgium	**Background:** The potential role of treated wastewater reuse as an alternative source of water supply is being more and more acknowledged in Belgium, which ranks 23 out of 164 countries experiencing water scarcity (World Resources Institute, 2019). **Policy intervention:** The 2003 Flemish Integral Water Policy Decree has been launched in response to the European Urban Waste Water Treatment Directive (UWWTD, 91/271/EEC), the Water Framework Directive (2000/60/EG) and the Groundwater Directive (2006/118/EC). **Treatment technologies:** The WWTP of Schilde, located in the province of Antwerp, was retrofitted with an MBR system. It runs in two treatment lanes, one with a conventional activated sludge system and the other with the MBR. The MBR lane is intended to meet more stringent water quality norms. MBR effluents further undergo nanofiltration and are used as source water for breweries. **Enabling factors and barriers:** The increasing freshwater demands and water stress combined with policy interventions and large investments in developing, implementing and operating wastewater treatment infrastructures are key enabling factors for successful water reuse systems in Belgium.

Resource Recovery – Biogas and electricity production

Case 5: Kodungaiyur, Tamil Nadu, India

Background: Kodungaiyur STP of 110 MLD capacity was commissioned in 2006 to treat sewage of Manali and Chinnasekkadu regions of Tamil Nadu. The contract for commissioning the STP was assigned to VA TECH WABAG by Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB), on Design-Build-Operate (DBO) mode. The plant is equipped with an advanced sludge treatment process which is capable of producing about 750 kW-h electricity to run the entire plant. About 36 MLD wastewater from the STP is reused in Petrochemical and Fertilizer Industries of Chennai Petroleum Corporation Ltd. (CPCL).

Policy intervention: The "Waste to Energy" program by MNRE offers support to utilities and operators for setting up large-scale Waste to Energy (WtE) green power generation units (> 1 MW) inside wastewater treatment plant since 2006. The Government Order (GO) No. 116, issued in Tamil Nadu in 2013, encourages reuse of wastewater in industries.

Resource recovery: The raw sludge generated from the STP is hydrolyzed and decomposed in the anaerobic digesters. The STP produces about 12,500 m3 of biogas per day from which, about 13 MW of electricity is generated per day.

Enabling factors and barriers: The DBO contract with a private entity has ensured optimal project implementation. Further, reuse of treated wastewater has been driven by water scarcity in Chennai. The industry buys treated wastewater of the city to be used in industrial application, which serves as a reliable supply of water for plant operation. The STP has achieved about 98% self-sufficiency in terms of power consumption (WABAG, n.d.). An amount of approximately INR 20 million is saved annually by using the on-site generated electricity.

Case 6: S Flanders, Belgium, Belgium

Background: To cater to clean water demand and strict regulations contained in the 91/271/EEC Council Directive (EC 1991), the Flanders Regional Government accelerated connections to urban wastewater treatment plants and implemented a 10 year digester renovation programme not only to reduce heavy burden on disposal costs but also to reduce GHG emissions and reach renewable energy targets.

Policy Intervention: The European Energy and Climate Policy, including successive Renewable Energy Directives have enabled support mechanisms to be introduced to promote biogas and electricity production from sewage sludge and drastically improve efficiencies. Stringent regional norms for heavy metals, plus the fact that Flanders is in a Nitrates Vulnerable Zone have meant that treated sewage sludge is effectively banned from land spreading in the region.

Resource recovery: Part of the sludge produced during biological treatment is anaerobically digested to produce biogas, which is used to generate electricity or enhanced to be used as an energy source for cars.

Enabling factors and barriers: Production of biogas is a benefit to the wastewater treatment company. It is the driver to motivate investment funds to support in "green" and environmental assets. It also reduces the volume of sludge and costs involved in final sludge disposal. However, energy recovery from digesters only becomes cost-efficient if there are at least 85,000 inhabitants connected to the treatment plant. Hence, in rural regions of EU with fragmented populations, alternative strategies to transport sludge to a large central digester are implemented. Meeting renewable energy and GHG emissions targets have driven innovation to improve digester efficiencies and returns on investment.

Case 7: Rithala, Delhi

Background: Rithala STP consists of two STPs, of 181 MLD capacity each, commissioned in 1989 and 2002 respectively. It receives sewage from North-West Delhi. Treated wastewater from the STPs are reused for gardening and in thermal power plants of Tata Power Delhi Distribution and Pragati Power Corporation Limited. In STP-II, designed and built by SUEZ, biogas generated during the treatment process is used for electricity production, which is utilized in the treatment plant.

Policy Intervention: Delhi Jal Board (DJB)'s policy on utilization of treated wastewater for horticulture has backed water reuse for gardening in Delhi. The Tariff Policy (2016) by the Ministry of Power mandating use of treated sewage in thermal power plants located within 50 km radius of an STP, has promoted water reuse in industrial applications. Government subsidy offered for generation of power in wastewater treatment plant, through the "Waste to Energy" policy by MNRE, has aided biogas production in STPs.

Resource Recovery: In Rithala STP-II, biogas is produced though anaerobic digestion of sludge and resulting biogas is used as on-site energy source to produce electricity. In 2015, STP-II generated 20,000 kWh of biogas daily, which helped meet about 30% - 35% of the electricity demands of the STP-II (More to Bio-Gas than Hot air, 2015).

Enabling factors and barriers: The cost of the biogas to electricity production unit was about INR18 crore and was covered under contractual agreement between DJB and SUEZ. Monetary savings due to captive electricity production is estimated to be INR 56.6 million per annum (@ INR 5/kWh of the electricity supplied by the grid) (JICA 2005). Thus, cost savings incurred due to the use of captive electricity was effective enabler for resource recovery. Resource recovery can also be encouraged though Government assisted programs.

Resource recovery - Struvite

Case 8: Flanders, Belgium

Background: Phosphate is a finite mineral resource and in order to meet its continuously increasing need phosphate recovery is needed that is best done in WWTPs where large amounts of phosphate are (relatively) concentrated. A possible technique that can be used is the precipitation of phosphate in the form of struvite ($MgNH_4PO_4 \cdot 6H_20$).

Policy intervention: Inorganic fertilisers need to comply with the Belgian legal requirements as per the Royal Decree (2013) for marketing and use of fertilizers. Struvite being not included in this Decree, the Federal Public Service (FPS) Health, Food Chain Safety and Environment can grant exemptions for the trade of struvite products as fertilizers. The Flanders Environmental Law (VLAREMA) sets conditions for waste to raw material and the Flanders Waste Agency (OVAM) issues a Resource Declaration.

Phosphorous recovery technology: Studies by Aquafin showed the possibility of phosphorus recovery in the form of struvite from sludge water after dewatering of sludge. Based on tests, a P-removal of 85% was achieved for the WWTP Antwerpen-Zuid. Further, through NuReSys-P, struvite precipitation technique, a maximum P-removal potential of about 30kg P per day, (15% of the incoming P) was achieved. Thus, the introduction of struvite process resulted in 50% reduction in P load in the centrifuge effluent, from typically 30 kg P per day to 15 kg P per day.

Enabling factors and barriers: The main driver to produce phosphorus from digestate is the reduction of disposable phosphorus in sludge. The recovered product can be re used as a fertiliser in agriculture. The main barrier is the difficulty to receive certification from the OVAM as it requires the struvite to meet the maximum content of pollutants, which is difficult as phosphate is produced from sludge. Also, the phosphate production technology is complex and sensitive to sewage water quality. The stringent controls on the quality of struvite are a barrier to its overall introduction to the market, as it is difficult and costly to guarantee.

3.2. Experience from stakeholder workshops

Water sector reforms and development of effective policies and regulations require multi-stakeholder partnerships and regular stakeholder engagement to enhance acceptability and sustainability of identified interventions. Participatory stakeholder engagement is also fundamental to achieving the Sustainable Development Goals (SDGs) including amongst others, supporting and strengthening the participation of local communities in improving water and sanitation management (Goal 6.B), as well as- ensuring responsive, inclusive, participatory and representative decision making at all levels (Goal 16.7). A stakeholder engagement process was employed as an important pillar to elucidate the challenges on the ground, discuss feasible solutions from users' and managers' perspectives and also to validate the findings from the case study analyses (Section 3.1). Two stakeholder consultation workshops were held in New Delhi and Kanpur.

The two stakeholder consultation workshops provided the opinions and views of diverse stakeholders on core challenges and opportunities of wastewater treatment and RRR in India. The stakeholders highlighted that the key challenges faced by STPs in India are: (i) high load variations of incoming sewage; and (ii) complexity of the sewage composition which affects the treatment efficiency. Another key issue that was brought out in the workshops was the dearth of faecal sludge treatment systems to handle high volumes of sludge generated which can result in re-contamination of the local environment. Further, operation, maintenance and pricing issues were also discussed as major barriers to wastewater management. The participants of the workshop in New Delhi stated that the high costs of transportation of treated sewage from STPs to reuse sites and low demand for treated wastewater are major constraints. Absence of guidelines with well-defined quality criteria and standards for reuse of treated wastewater as well as treated sewage sludge for different purposes (agriculture, horticulture, landscaping etc.) are other barriers to wastewater and sewage sludge reuse.

Stakeholders in Delhi workshop

- Ministry of Jal Shakti
- National Water Mission
- Central Pollution Central
- Board National Mission for
- Clean Ganga Delhi Jal Board
- Technology Providers
- Research Institutions

Stakeholders in Kanpur workshop

- Uttar Pradesh Jal Nigam
- Uttar Pradesh Pollution Control Board
- National and State Mission for Clean Ganga
- Solidaridad Asia
- Researchers from CSIR Indian Institute of Toxicology Research, Lucknow
- Harcourt Butler Technical University Kanpur and IIT-Kanpur

Opportunities of treated wastewater reuse for irrigation, forestry and other non-potable uses were reflected upon in both workshops. The consensus was that the wastewater has to be treated to acceptable limits before any further reuse. Some participants of the workshops also mentioned that there should be public awareness regarding wastewater management and segregation of waste. Stakeholders from Delhi also indicated that the market for treated sludge is limited and that there is a need to establish a market for the resource through a business model that allows effective cost-recovery. The Kanpur stakeholders suggested that the tannery sludge could be converted to useful products such as bricks, while STP sludge could be converted into bio-compost. Suggestions were made to shift from Public Private Partnership (PPP) models to Public, Private and Community Partnerships (PPCP). This would help improving wastewater management with the involvement of the community as a key stakeholder. The participants also highlighted that even though in most cases rules and regulations are already in place, it is imperative that their enforcement and implementation is done effectively.

3.3. Lessons learnt from case studies and stakeholder consultation

The case studies and stakeholder consultation in India highlighted that the state Governments have been taking important steps to tackle - to some extent – the problems of water pollution and water scarcity. However, the lack of overarching and clearly-defined guidelines from the Central or State Governments, along with the lack of an established legal framework for safe and sustainable reuse of treated wastewater and sewage sludge with clear market and incentive/ disincentive mechanisms still poses a major barrier towards sustainable wastewater treatment and RRR systems. Further, the choice of technology to treat and recycle/reuse domestic wastewater has to be guided by the physical constraints as well as the intended use of the treated wastewater (fit-for purpose treatment). In India, resource recovery techniques of generating biogas and using it further for electricity production has the possibility to reduce operational costs in wastewater treatment plants. It highlights that policy and regulatory intervention can create successful models for wastewater treatment, resource recovery and reuse. Sewage sludge treatment can also be a promising business model for large municipalities through bio-fertilizer production and promotion of its usage among farmers.

The case studies from the EU show that there has been an increased utilization of wastewater in recent years, for many different purposes including agriculture, industry and drinking, especially in water scarce countries. The recent development of water governance arrangements such as dedicated economic instruments and the set-up of water reuse guidelines are expected to foster water reuse in the EU in the years to come. Case studies on resource recovery have shown that European countries have benefited from applying treated sewage sludge on agricultural land through improved crop productivity and enhanced soil fertility. The adverse effects on the environment can be mitigated by establishing stringent limit values for different contaminants of concern. Countries without P deposits, can also recover P from municipal wastewater plants to change their dependency on other countries to import P.

Table 2 below summarizes the water governance factors that influence (positively (+) or negatively (-) the development and implementation of wastewater treatment and RRR systems in India and EU. Water scarcity, seasonal variations in freshwater availability, unreliable electricity supply, environmental concerns related to the quality of resources recovered, acceptability of treated wastewater and treated sewage sludge by user communities, cost/benefits for wastewater and sewage sludge treatment/reuse and biogas production, water and energy pricing systems and treated wastewater supply mechanisms, are some of the factors driving the success or failure of a wastewater treatment and RRR initiative.

Table 2: Enabling factors (+) and barriers (-) affecting current wastewater treatment, resources recovery and reuse practices in Europe and India

Water Governance Factors

(a) Wastewater treatment and reuse

Enabling Factor/ Barriers	Europe	India
Legislation/policies	(+) UWWTD regulates wastewater management in EU Member States (+) Non-compliance followed up by warnings then financial penalties → drives investments in wastewater treatment infrastructure	(+) Water Pollution (Prevention and Control of Pollution) Act 1974 in place (+) CPCB standards for STP and CETP effluents in place (incl. quality parameters for irrigation on landscape) (-) low rate of enforcement of pollution controls (-) Lack of 'umbrella directive' for integrated water resources management
	(+) WFD provides an integrated water resources management framework for European river basins and cross-sectorial water management	(+) Introduction of river protection plans (e.g. Ganga Action Plan; Namami Gange)/Government programs (e.g. JNNURM) enhancing municipal wastewater treatment infrastructure
	(+) Some EU Member States with individual water reuse norms legislations (e.g. Spain, Portugal) this provides confidence for farmers and consumers	(-) No India-wide regulation or norms on water reuse quality parameters. Only proposed norms by CPHEEO, 2013 (+) Some Indian states with individual water reuse legislation/norms (e.g. Maharashtra, Gujarat, Punjab)
	(+) EU BREFs (Best available techniques reference documents) ensure water quality norms are followed	(+/-) zero-liquid discharge policy of CPCB (2015) for four industrial sectors in 9 Indian states in the Ganges river. However, ZLD is expensive, requires a lot of energy and produces a lot of solid waste
		(+) Tariff Policy 2016 mandates thermal power plants located within 50 km radius of STPs to use treated sewage water
New legislative initiatives/ revisions	(+) Circular economy package under Europe's New Green Deal including legal instrument for minimum water quality requirements for agriculture (expected 2020)	(+) National Green Tribunal (NGT) has directed the Ministry of Environment and Forests and Climate Change (MoEFCC) to issue stricter norms for effluent discharge from sewage treatment plants (STPs)
Water scarcity issue/ Decreased water availability	(+) drives diversification to alternative water supplies, more local supply / semi-closed water cycles, increased cross-sectorial water management (domestic-industry-agriculture)	
Wastewater treatment and reuse infrastructure	(+) Reuse purpose and wastewater characteristics decide on technology design (fit-for purpose treatment)	(-) Technology designs not matching resource context and not taking long term development plans of the area into account
	(+) technology design matching resource contexts	(-) Prescribed standard technologies in tender processes
Operation and maintenance	(+) high degree of automation	(-) Unreliable power supply (-) Financial constraints
	(+) skilled operators	(+/-) Some plant operators have developed skills and capacities
		(-) outdated O&M on installations

Enabling Factor/ Barriers	Europe	India
Cost recovery	(+) high cost recovery for wastewater treatment in EU15 Member States (-) low cost recovery for wastewater treatment in EU 13 Member States	(-) in general low cost recovery for wastewater treatment (-) Lack of rational pricing in water & wastewater management services affecting cost efficacy of interventions
	(+) economic incentive of using treated wastewater over freshwater systems, when freshwater is scarce (industrial reuse examples) (-) difficult for low revenue applications such as irrigation, not always suitable for cash crops, e.g., vegetables	
Public financing strategies for wastewater treatment and reuse	(+) ERDF Cohesion funds essential for EU 13 Member States to reach UWWTD compliance (-) high investments needed for wastewater treatment and reuse (+) fit-for-purpose treatment at the design stage reduces capital expenditure compared to retrofitting	(+) Government support/initiatives (e.g. Swachh Bharat Mission, Namami Gange, AMRUT, JNNURM etc.) (+) Promotion of PPP through financial models of BOOT, DBOOT etc. Recent launch of Hybrid Annuity Model (HAM) for PPP in wastewater treatment schemes (+) Public private partnerships (+) Creation of Viability Gap Funds (VGF) to support infrastructure projects
	(+/-) charges for wastewater services influenced by socio-cultural norms and political interests	
Institutional arrangements	(+) public private partnership/clear allocation of roles and leadership	(-) Multiplicity of organizations/stakeholders with lacking collaborative efforts (+) Creation of Special Purpose Vehicles (SPVs) to assist better execution of infrastructure projects on ground.
Acceptance	(+/-) perceived risks by public/farmers related to treated wastewater quality and quality of wastewater irrigated products. Sometimes the perceived risks lead to not using wastewater even if possible. (+) on-site treatment and reuse (industrial reuse)	

(b) Sludge Treatment and Resource Recovery

Enabling Factor/ Barriers	Europe	India
Legislation/policies	(+) EU Directives promote safe disposal and reuse of treated sewage sludge for agriculture or energy recovery. Agricultural reuse of untreated sewage sludge is prohibited. (+) National/regional regulations on sewage sludge treatment and reuse by individual Member States with even stricter limits for heavy metals, pathogens and organic pollutants (+) attractive pricing for energy from biogas through specific legislation in some EU Member States	(+/-) Solid Waste Management Rules 2016 obliges municipalities to postprocess sewage sludge and promotes reuse in agriculture. But there is weak enforcement of the rules. (+/-) CPHEEO manual 2013 guides on sewage sludge processing technologies. Few standardized (BIS standards) technologies. (+) Waste to energy technologies (anaerobic digestion, incineration, gasification etc.) promoted under WtE program of MNRE. (-) WtE programmes by MNRE. Programme does not entail promotion of market relevant aspects (cost recovery, demand for products)

<table>
<tr><th>Enabling Factor/ Barriers</th><th>Europe</th><th>India</th></tr>
<tr><td>New legislative initiatives/under revisions</td><td>(+) new EU circular economy package under the European New Green Deal promotes RRR
(+) Amendment of waste directives, requiring EU Member States to reduce landfilling of sewage sludge (driver for increased digestion of sludge)
(+) Increased national regulations on mandatory P recovery from sewage sludge and authorization of recovered phosphate products as fertilizers
(-) Stringent standards on derived P fertilisers from sewage sludge are not reciprocated for mineral P fertilisers, meaning that there is not a level playing field.</td><td>(+) Draft amendments to the 2016 National Tariff Policy and draft amendments to the 2015 central motor vehicle rules (could act as future driver for energy recovery from sewage sludge)
(+) Indian Standards (BIS) for biogas/biomethane use in automotive applications/piped network
(+) Policy on promotion of city compost in 2016</td></tr>
<tr><td>Environmental and socio-economic aspects</td><td>(+/-) Land spreading of treated sewage sludge can enhance the fertility of soils. Heavy metal accumulation is of concern and thus land spreading is banned in some EU Member States
(-) EU Directives do not distinguish between soil types for land application. Different soil types can react differently to the same load of pollutants., with lighter soils being a higher leaching risk than heavier soils.
(-) Lack of good agricultural practices and regulations for spreading increase risks of pollution
(+) Phosphate rock categorized as critical raw material with limited global supply. It is price sensitive and is a driver for recovered P fertiliser products</td><td>(-) Current sludge management in Indian STPs is of general concern due to a lack of or poorly operated treatment infrastructure. Untreated or partially treated sludge accumulates at the STP sites and leach into streams and groundwater or are dumped into landfills
(+/-) informal low-cost reuse of untreated sewage sludge (high nutrient properties vs. environmental and public health risks)</td></tr>
<tr><td>Financing/Cost recovery</td><td>(+) Land application of sewage sludge (where permissible) is a cheaper alternative to incineration or landfill disposals
(+) Digestion of sludge reduces volumes of residual sludge for incineration / landfill disposal</td><td>(-) feed-in tariffs for biogas production are too low to encourage investment and increase production
(+) PPP for waste-to-energy projects (investors)</td></tr>
<tr><td></td><td colspan="2">(-) high investments needed for sludge treatment technologies
(+) On-site energy production through biogas brings cost savings for operational activities
(-) complex, high-tech and expensive technologies for P recovery</td></tr>
<tr><td></td><td colspan="2">(-) Incentives (legal, financial) for the use of high-quality biosolids in agriculture are needed</td></tr>
<tr><td>Acceptance</td><td colspan="2">(-) Market for recovered P products still needs to be established</td></tr>
<tr><td></td><td colspan="2">(+/-) Acceptance of treated sludge among farmers is key. This is not always the case.</td></tr>
</table>

4. WAY FORWARD

India has been taking important steps to create an enabling environment for tackling the issues of water pollution and water scarcity. There are still some challenges that impede advancement in the wastewater and RRR sector. Based on lessons learnt from the policy and regulatory framework analysis (Section 1.1 and 2), the consultation workshops with stakeholders (Section 3.2) and the case studies' analysis (Section 3.1 and 3.3) from India and the EU, the following recommendations are deduced to encourage and mainstream wastewater treatment and RRR in India:

4.1. Need for target-based regulations, defined national reuse standards for treated wastewater and sewage sludge and effective enforcement strategy.

Target-based regulations, clearly defined national reuse standards for treated wastewater and sewage sludge, as well as water safety planning and risk mitigation measures are imperative interventions for enhancing RRR in India. Guidelines and frameworks should not only include targets but also detail out the legislative, regulatory and financial measures needed to achieve them.

Further, regulations and guidelines need to be supported by effective monitoring, enforcement and follow-up strategies. Enforcement mechanisms for polluters need to be established in order to reduce the pressure on end-of-pipe treatment systems.

A model policy on water reuse and resources recovery from sewage sludge is required to be formulated at the national level, which can be adopted by the States. Essential components of this model policy should include different types of water reuse opportunities as well as sewage sludge application routes, public acceptance and generation of awareness regarding wastewater treatment and RRR and capacity building of various stakeholders alongside the wastewater value chain.

4.2. Policy and guiding frameworks need to establish detailed guidance on wastewater and sewage sludge treatment and reuse technologies (fit-for-purpose treatment)

The choice of technology to treat and recycle wastewater and sewage sludge has to be guided by the physical and socio-economic constraints as well as the intended uses of the treated wastewater (fit- for-purpose treatment). Decentralized systems should be suitably promoted to facilitate and enhance wastewater reuse in peri-urban and rural areas with openness to new technologies and configurations that allow for different degrees of treatment for different water uses as well as for different resource recovery possibilities (nutrients, energy) from sewage sludge. For this purpose, enhanced government support and investments into research and development for innovative technologies for wastewater treatment and RRR is required. A robust implementation framework involving last mile connectivity of solutions will help in better upscaling and optimisation.

Reuse of treated wastewater and/or treated sewage sludge is still in its nascent stage in India. Most State Governments lack a wastewater management and reuse policy and/or law. Only a few states (Gujarat, Jharkhand, Karnataka, Haryana and Punjab) have formulated policies and/or laws to improve wastewater treatment and encourage the reuse of water. However, there is limited capacity to enforce regulations that are already in place.

There is a requirement of clearly-defined guidelines from the Central or State Governments, along with an established framework for safe and sustainable RRR of treated sewage sludge. Regular and planned engagement of key stakeholders in policy formulations and implementation; and community mobilization, awareness and capacity building are important and collaborative action is needed to create demand for the end-products from the STPs.

4.3. Need of effective financing mechanisms (funds, taxes, tariffs) that permit sufficient cost- recovery for long-term operation and maintenance of wastewater and sewage sludge treatment infrastructure.

Although public funds are available for treatment infrastructure, most utilities are unable to recover cost of treatment, especially for low cost applications such as water reuse and treated sewage sludge in agriculture. To boost industrial reuse, several industries and bulk water users will need to look towards wastewater as an economically viable option to meet their water requirements. Thus, treated wastewater should be cost-competitive as compared to alternative options available to industries.

Circular economy initiatives to increase RRR require robust business models that ensure cost recovery. Effective financial incentive and disincentive mechanisms for water reuse and resources (nutrients and energy) recovery with economic advantages for entities (e.g. exemptions/ rebate in GST charges, incentives to recycle/reuse by-products, tax incentives for "green" energy and favourable loan facilities for green investments) will increase utilization of treated wastewater, promote resource recovery and facilitate market uptake.

Policies and regulations are needed to support more effective water- and wastewater-pricing systems, electricity fed-in tariffs and use of recycled products from STPs that permit sufficient cost recovery, ensure adequate investments and support long-term operation and maintenance. The willingness to pay for water reuse is clearly linked to the non-availability of conventional water sources i.e., surface and or groundwater. In-house energy generation through biogas from sewage sludge increases cost-recovery (if it is used as a replacement of mains electricity) and avoids dependency of conventional electricity supply. Hence, adequate permitting systems need to be in place to control or prevent groundwater extraction, thus safeguarding long term supplies for drinking water and promoting alternative water sources such as treated wastewater. In areas where cost recovery is low, there is a need to provide public budget transfers.

4.4. Strengthening of institutional and monitoring capacity

Improvements are needed in the institutional framework for water supply, distribution, sewage treatment, reuse and resources recovery at the national and state levels with clearly defined roles and responsibilities supported by adequate infrastructure, manpower and finances. SPCBs have limited human resources to monitor water quality, and limited organizational capabilities to pursue legal action against violators of pollution control (Kumar and Tortajada, 2020). Thus, capacity enhancement of the SPCBs will enable in establishing a better pollution monitoring and prevention system. Furthermore, RRR technologies are complex and proper training programs for engineers and operators are needed to ensure that potential recovery efficiencies are attained.

Regular and planned engagement of key stakeholders in policy formulations and implementation; community mobilization, awareness and capacity building are important for collaborative action which is needed to create demand for the end-products from the STPs. Acceptance of recycled products among potential customers is key for viable business models.

The number of monitoring stations in water bodies are inadequate and many of them are not located in cities or immediately downstream of sources of pollution, due to which, a realistic picture of the extent of water pollution in the country does not surface (Kumar and Tortajada, 2020). Substantial investments in monitoring stations and monitoring capacity are needed to better identify the sources and pathways of pollutants into water bodies and ensure total confidence for the end users such as farmers in the safety of using treated wastewater or treated sewage sludge.

As a way forward, it is fundamental to rethink wastewater treatment and RRR governance in India and continue to design, implement and enforce robust policy and regulatory frameworks - taking inspiration from recent developments in water governance and best practices in India, the EU and beyond. The research and development of innovative, cost effective, and sustainable technologies and establishment of monitoring mechanisms have an important role to play in achieving this titanic task and PAVITRA GANGA aims to make a contribution to these endeavours.

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PAVITRA GANGA: A Joint India-EU initiative towards innovation in water technology

The potential role of treated wastewater reuse as an alternative source of water supply is well acknowledged and embedded within international, European and Indian strategies. UN Sustainable Development Goal on Water (SDG 6) specifically targets a substantial increase in recycling and safe reuse globally by 2030.

The PAVITRA GANGA project has as one of its key objectives to develop and pilot robust, cost-effective water treatment technologies for the Indian context with a focus on reuse. The project envisages to pilot test an array of innovative wastewater treatment technologies with a potential for application and upscaling that might have a significant impact on wastewater treatment in India and as such shall contribute to improving water quality and overall rejuvenation of the River Ganges. The novel technologies are that will be tested are the following:

- The Andicos™ technology (combined anaerobic treatment of organic waste and sewage), a modular treatment step that can be addition to existing treatment plants, and/or applied as a new stand-alone facility. It consists of filtration through membranes, the membrane concentrate is processed through a digester, producing biogas and a nutrient-rich digestate that can be used as a fertilizer. In case of water reuse the effluent can be treated by a CWplus designed to remove micro-pollutants and pathogens. Structured adsorbers can be used in case of river flow augmentation.
- The SFD-MBR, a self-forming dynamic membrane bioreactor, is based on integration of conventional activated sludge and 'non-membrane' surface filtration. It is robust, resilient and cost-effective compared to ultrafiltration membranes, offering a decentralised wastewater treatment solution that has both low energy and maintenance requirements, also making it suitable for small-scale applications and for installation in remote areas. In case of water reuse the effluent can be treated by CWplus or by structured adsorbers in case of river flow augmentation.
- The PAS, a photo activated sludge system, is a merger of the high rate algae ponds (HRAPs) and activated sludge systems, combining the advantages of simple natural systems making use of sunlight and technologically advanced activated sludge systems, suitable for small-scale applications and for installation in remote areas needing little maintenance.
- The structured adsorbers, low-cost inorganic granulated sorbent materials for chromium or phosphorous removal and recovery, show a high sorption capacity, fast kinetics and good mechanical and chemical stability, allowing for the recovery and reuse of the valuable metals and nutrients.
- CWplus, a modified constructed wetlands, combine vertical flow constructed wetlands composed of several layers consisting of gravel, sand, and sorbents planted with local vegetation. The sorbents are based on e.g. granular activated carbon for enhanced heavy metal removal.

All these technologies consider the Indian wastewater composition and allow for simple operation and maintenance procedures. The efficiency in removing bulk pollutants as well as micro-pollutants and pathogens shall be tested. Challenges with respect to health will remain a focus, therefore protocols shall be developed for designing water reuse safety plans to promote health and safety as well as to demonstrate an innovative, easy to use water quality and quantity monitoring platform to improve operation and maintenance. The success of the application of the technologies are strongly affected by water governance arrangements and stakeholder's engagement. The PAVITRA GANGA project and these technologies is being piloted at two pilot sites in India viz. Delhi (Barapullah) and Kanpur (Jajmau) which face significant challenges of pollution from domestic sewage and industrial effluents. The project also comprises key stakeholder engagements and analysis of policy & regulatory frameworks necessary for success of potential interventions.