Policy brief on determinants of successful and unsuccessful urban wastewater treatment, water re-use and resource recovery models

Deliverable D2.1

WP2 Water Governance, stakeholder engagement and policy support
Task 2.1 Analyse successful and unsuccessful water governance systems across India and internationally for delivering improved wastewater treatment, water re-use and resource recovery solutions

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Date of approval	31/07/2020
Approved by Project Coordinator	Paul Campling
Date of approval	31/07/2020
Due date of deliverable	31/07/2020
Actual submission date	31/07/2020

Project number (EU)	821051 (H2020-SC5-2018)
Project number (India)	BT/IN/EU-WR/39/AJ/2018
Project coordinator	Paul Campling
Scientific coordinator	Anshuman
Project web site	https://www.pavitra-ganga.eu/en

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

Dissemination level		
PU	Public	X
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R	Document, report	X
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DEC	Web sites, patent fillings, videos, etc.	
OTHER	Software, technical diagram, etc.	
ETHICS	ETHICS	

History			
Version	Date	Reason	Revised by
0.1	31/05/2020	First Draft	Gabriela Cuadrado Quesada
0.2	31/07/2020	Final Version	Gabriela Cuadrado Quesada

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SUMMARY

Background: Globally, the uptake of wastewater treatment and resource recovery and reuse (RRR) technologies and practices has been slow despite the known benefits to prevent surface water pollution and contribute to sustainable production and consumption systems. In India, only 37% of the wastewater generated receives treatment. The reuse of treated wastewater and sewage sludge for agriculture and biogas recovery from centralized schemes is limited to a few places. Even in the European Union (EU), where important improvements in wastewater treatment infrastructure have been made, only about 2.4% of treated urban wastewater is being reused. Also the sewage sludge management is a challenging issue for EU Member States due to technical-operational and environmental considerations of different treatment and disposal routes. To achieve a circular economy, a new approach to water and wastewater management, which includes innovative technologies and business models supported by legislation, policies, society and financing structures, is crucial. PAVITRA GANGA aims to enhance wastewater treatment and RRR from wastewater treatment plants through demonstration of innovative technologies and business models. Therefore, this document investigates governance factors, which influence the sustainability and market uptake of sustainable wastewater treatment and RRR systems in India and beyond.

Methodology: The analysis of governance factors is based on (i) a thorough literature review on the status of wastewater treatment and RRR (water, energy, nutrients) from wastewater treatment plants in India and the EU (Chapter 1), (ii) a content analysis of the key Indian water policy and legal frameworks (Chapter 2); (iii) two consultation workshops with different stakeholders in India to understand their opinions and views on core challenges and opportunities of wastewater treatment and RRR in India (Chapter 3); and (iv) an analysis of 13 case studies in India and the EU regarding the enabling and disabling governance factors for wastewater treatment and RRR technologies for different end uses (Chapter 4 and 5). Finally, the different elements of the analysis result in policy recommendations for enhancing wastewater treatment and RRR governance in India (Chapter 6).

Results and Discussion: Overall, this document illustrates that important steps have been taken by the Indian Government to create an enabling environment for tackling the issues of water pollution, water scarcity and resource recovery. However, the lack of an overarching and clearly-defined policy or law from the Central government is a key limiting factor to enhance wastewater treatment and RRR in India. This barrier is evident from the fact that most state governments lack a wastewater management and RRR policy and/or law. Some states in India (e.g. Maharashtra, Gujarat, Punjab) have formulated policies/laws to improve wastewater treatment and encourage RRR practices, yet, their enforcement is challenged by inappropriate pollution control measures and a lack of clear market incentive/ disincentive mechanisms. The choice of technology to treat and recycle/reuse municipal wastewater has to be guided by the physical constraints as well as the intended use of the treated wastewater (fit-for purpose treatment). Resource recovery from sewage sludge, such as generating biogas and using it further for electricity production has the possibility to significantly reduce operational costs in wastewater treatment plants. Sewage sludge treatment can also be a promising business model for large municipalities through bio-fertilizer production and promotion of its usage among farmers. Nevertheless, moving to a circular wastewater management requires a multi-barrier approach, as promoted by the World Health Organization, to safeguard environmental and public health, to increase confidence in the quality of recovered resources and ultimately to create a market demand.

Conclusions and recommendations: Policy and regulatory interventions can create successful business models for wastewater treatment and RRR but need effective monitoring, enforcement

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and follow-up at all governance levels (central, national and local governing bodies). The following policy recommendations are deducted from the governance analysis:

(i) Target-based regulations, defined national reuse standards for treated wastewater and sewage sludge and effective enforcement strategy needs to be developed;

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

(iii) Effective financing mechanisms (funds, taxes, tariffs) that permit sufficient cost- recovery for long-term operation and maintenance of wastewater and sewage sludge treatment infrastructure should be established; and,

(iv) Institutional and monitoring capacity needs to be strenghtened and engagement of key stakeholders tackled to increase acceptance of waste-recycled products.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACA	Catalonian Water Agency
AMRUT	Atal Mission For Rejuvenation And Urban Transformation
Bio-CNG	Bio Compressed Natural Gas
BIS	Bureau of Indian Standards
BOD	Biochemical Oxygen Demand
BOT	Build Operate Transfer
CAS	Conventional Activated Sludge
CEC	Contaminants of Emerging Concern
CETP	Common Effluent Treatment Plant
CFF	Contact-flocculation Filtration
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
Cr	Chromium
Cu	Copper
CWplus	Constructed Wetland Plus
DBT	Department of Biotechnology
DJB	Delhi Jal Board
DO	Dissolved Oxygen
DPR	Detailed Project Report
EC	European Commission
EDR	Electrodialysis Reversal
EEC	European Economic Community
EPA	Environmental Protection Agency
ETP	Effluent Treatment Plant
EU	European Union
FAO	Food and Agricultural Organization
FC	Feacal Coliform
FOEN	Federal Office for the Environment
GAP	Ganga Action Plan
HRAP	High Rate Algae Ponds
ICLEI	International Council for Local Environmental Initiatives
IIT	Indian Institute of Technology
INR	Indian Rupee
IWMI	International Water Management Institute
IWP	India Water Partnership
IWRM	Integrated Water Resources Management
IWVA	Intercommunale Waterleidingsmaatschappij van Veurne-Ambacht
JICA	Japan International Cooperation Agency
JnNURM	Jawaharlal Nehru National Urban Renewal Mission

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KNN	Kanpur Nagar Nigam
MahaGenCo	Maharashtra State Power Generation Company
MBR	Membrane Bioreactor
MIS	Management Information System
MoDWS	Ministry of Drinking Water and Sanitation
MoEFCC	Ministry of Environment Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoJS	Ministry of Jal Shakti
MNRE	Ministry of New and Renewable Energy
MoU	Memorandum of Understanding
MPD	Master Plan for Delhi
NGT	National Green Tribunal
NMC	Nagpur Municipal Council
NRAP	National River Action Plan
O&M	Operation & Maintenance
PAS	Photo Activated Sludge
Pb	Lead
PPCP	Public, Private and Community Partnerships
PE	Population Equivalent
PPP	Public Private Partnership
RO	Reverse Osmosis
SANDRP	South Asia Network on Dams, Rivers and People
SBR	Sequential Batch Reactor
SDG	Sustainable Development Goals
SFD-MBR	Self-Forming Dynamic Membrane Bioreactor
SPCB	State Pollution Control Board
STP	Sewage Treatment Plant
Sq. Km	Square Kilometer
TDS	Total Dissolved Solids
TERI	The Energy and Resources Institute
TSS	Total Suspended Solids
TPP	Thermal Power Plants
UA	Urban Agglomeration
UASB	Up-flow Anaerobic Sludge Blanket
UF	Ultrafiltration
ULB	Urban Local Body
UN	United Nation
UP	Uttar Pradesh
UPJN	Uttar Pradesh Jal Nigam

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UPPCB	Uttar Pradesh Pollution Control Board
UV	Ultra violet
UWWTD	Urban Waste Water Treatment Directive
VMM	Flemish Environment Agency
WASH	Water, Sanitation and Hygiene
WFD	Water Framework Directive
WHO	World Health Organization
WP	Work Package
WtE	Waste to Energy
WW	Wastewater
WWAP	World Water Assessment Programme
WWTP	Wastewater Treatment Plant
WWTP-WRP	Water Water Treatment Plant- Water Reclamation Plant
Zn	Zinc

LIST OF UNITS

m^2	Square meter
m^3	Cubic metre
km	kilometre
km^2	Square kilometre
kVA	Kilo volt ampere
kGy	Kilo Gray
KWh	Kilo Watt hour
mg/l	Milligram per litre
µm	micrometre
µg/l	Microgram per litre
mg/kg	Milligram per kilogram
MLD	Million Litres per day
MGD	Million Gallons per day
MPN	Most Probable Number
MW	Mega Watt

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CHAPTER 1 WATER GOVERNANCE IN INDIA AND EUROPE

1.1 ANALYTICAL APPROACH

India's water resources are under severe stress resulting from overexploitation and pollution. The Indian government has started the Namami Gange programme in line with the sustainable development goals (SDGs), to protect its water resources including the improvement of resource recovery and reuse (RRR). This has come along with the development of a number of water governance arrangements. The PAVITRA GANGA project links directly to these programmes and builds on existing cooperation between EU/India, supported by national governments.

Governance arrangements such as polices, plans, laws and regulations that exist in the water sector (See Figure 1) can significantly influence the activities carried out in that sector. Regulatory functions involve ensuring adherence to rules during formulation and implementation of the sectoral decisions to objectively promote public interest. It is understood that a strong institutional and regulatory framework for water and RRR governance should addresses the concerns of all the relevant stakeholders.

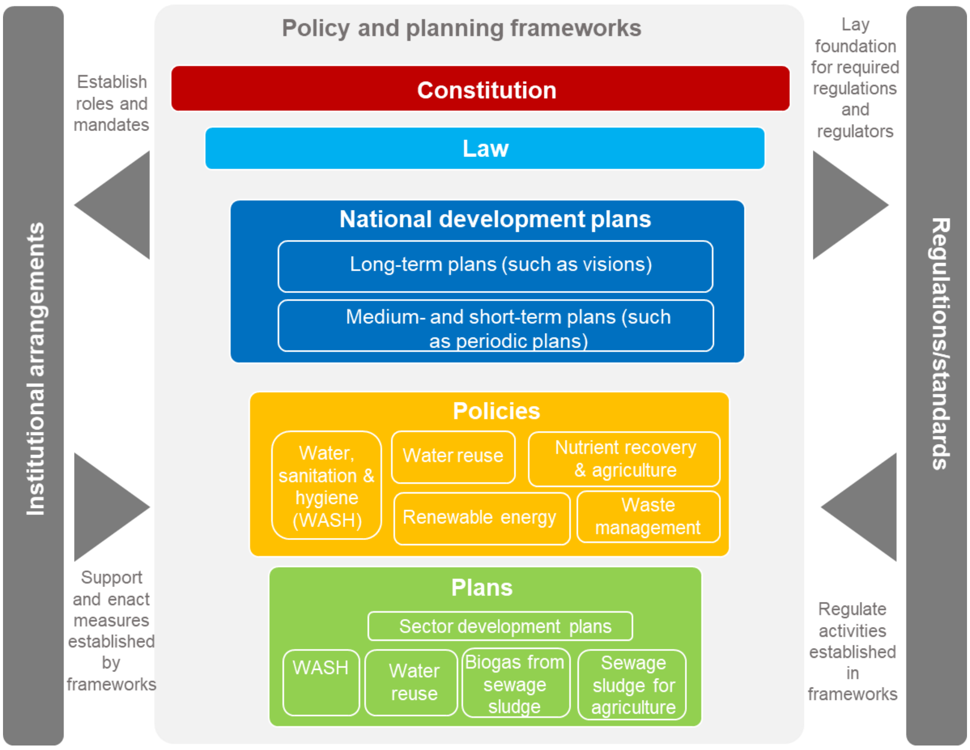

Figure 1: Overview of elements of water and RRR policy and planning frameworks
Source: Adapted from (WHO 2019).

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Wastewater treatment plants (WWTPs, also called sewage treatment plants, STPs[1]) will not only safeguard human health and protect the environment but we also know that wastewater is also an opportunity to reclaim and recover water, energy and nutrients for other uses (WWAP, 2017; IWA, 2018). The concept of circular economy in the water and wastewater sector has become a popular and important issue in environmental governance worldwide. The European Commission (EC) has only 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). The circular economy requires a new approach to water and wastewater management including innovative technologies and business models supported by legislation, policies, society and financing structures (Smol et al., 2020). PAVITRA GANGA aims to enhance the potential for resource recovery and reuse (RRR) from WWTPs through demonstration of innovative technologies and business models. Therefore, a holistic understanding of the governance factors, which influence the sustainability and market uptake potential of sustainable wastewater treatment and RRR systems, is needed.

The key objectives of this document are: firstly, to describe the Indian and EU policy and legal frameworks of wastewater and RRR; and, secondly, to analyse wastewater and RRR governance systems across India and the EU that have successfully or unsuccessfully contributed to delivering improved wastewater treatment and RRR solutions. For the purpose of this document we focus on case studies related to full-scale applications of water, energy and nutrient recovery from municipal WWTPs. This analysis is the basis for formulating recommendations to further assist policy and law in India.

The methodology used to conduct this analysis includes: (i) literature review on the status of wastewater treatment and RRR in India and the EU (Chapter 1) (ii) content analysis of the key Indian wastewater and RRR policy and legal frameworks (Chapter 2); (iii) two consultation workshops with different stakeholders in India to understand their opinions and views on core challenges and opportunities of wastewater treatment and RRR in India (Chapter 3); (iv) analysis of 13 case studies in India and the EU regarding the enabling and disabling governance factors for wastewater treatment and RRR technologies for different end uses (Chapter 4 and 5); and, (v) key recommendations based on the above (Chapter 6).

1.2 WASTEWATER TREATMENT, WATER RE-USE AND RESOURCES RECOVERY IN INDIA

1.2.1 WASTEWATER GENERATION AND TREATMENT

India's water resources are severely overexploited and polluted. India is a groundwater-dependent nation. Groundwater overexploitation in India has led to multiple impacts, the most obvious being the fall in water levels and reduced well-yields. As a consequence, many people in India suffer from water scarcity (Kulkarni, Shah and Vijay Shankar 2015). In India about 91% of the households in rural areas and about 96% of the households in the urban areas have access to a latrine (Bharat et al., 2020; UNICEF and WHO, 2019). It is estimated that only 30% of the sewage from major cities and 60% of the industrial wastewater, mostly from large-scale industries, receives treatment (Kaur et al. 2012). Discharge of untreated wastewater has resulted in contamination of 75% of all surface water bodies in India (CPHEEO, 2012). Moreover, untreated wastewater (in the absence of any other source of water) is widely used in agriculture for irrigation and as

[1] Throughout the document the terms WWTP and STP are used interchangeably. While in Europe mostly the term WWTP is used, STP is common in India.

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source of nutrients creating health risks and leading to pollution of the fields and other water resources in the area (Kaur et al. 2012).

As the PAVITRA GANGA Project focusses on unlocking wastewater treatment and RRR opportunities for urban and peri-urban areas, this document highlights wastewater related challenges in urban regions. According to the Census of India (2011), about 32% of the population (380 million people) lives in urban areas. A town or urban agglomeration (UA) with a population of 100,000 or above is categorised as Class I, while Class II towns/UAs have between 50,000 and 99,999. Around 70% of India's urban population lives in Class I towns/UAs. There are 468 Class I towns/UAs, 53 of which have a population of one million or above and house about 43% of the urban population. Greater Mumbai UA (18.4 million), Delhi UA (16.3 million) and Kolkata UA (14.1million) have more than 10 million people and are known as mega-cities. As the population of India continues to rise, the proportion of people living in urban areas is also rising. It is expected to grow by 404 million by 2050, to around 780 million (United Nations, 2014). While the population growth in the mega-cities has slowed considerably in the past decade, the population is expected to grow faster in smaller towns and cities and the newly created towns.

On average, 80% of the freshwater supplied to a city or town gets converted into wastewater. There is a wide variation between states and between cities in per capita availability of piped water supply and sewerage networks. A better sewerage network ensures that all the wastewater generated is collected, increasing the quantum of wastewater as a proportion of the water supplied. A smaller proportion of the water supplied is collected by the sewerage system in metropolitan cities (around 70%) than in Class I and II cities (79.4% and 80%, respectively). This might be because in some metropolitan areas, like Mumbai, many of the people living in slums do not have sewerage connections, though they can access water from common public sources (Kumar and Tortajada, 2020).

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 compared to the available installed sewage treatment capacity of 23,277 MLD (MoEF&CC, 2018). The total available installed treatment capacity stood at about just 37% of the domestic sewage generated illustrating a huge gap between the sewage generated and treated, also suggesting that a significant volume (about 63%) of untreated/partially treated sewage finds its way into the water bodies to become a major cause of pollution. It may also be noted that if the treatment efficiencies of the existing STPs is taken into account the gap between sewage generated and treated will be further pronounced. Figure 2 gives an indication of the wastewater treatment needs in different classes of cities in India. The extent of treatment of collected sewage is much higher in metros (around 71%) than in Class I and II cities. It is least in Class II cities, where only 13% of the collected wastewater is treated.

The wastewater treatment infrastructure is overall poorly performing due to frequent electricity break-downs, poor operation and maintenance, inadequate sewerage networks and technology designs not matching the wastewater characteristics (Never, 2016). Latest estimations by the Central Pollution Control Board (CPCB) show that 20% of 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).

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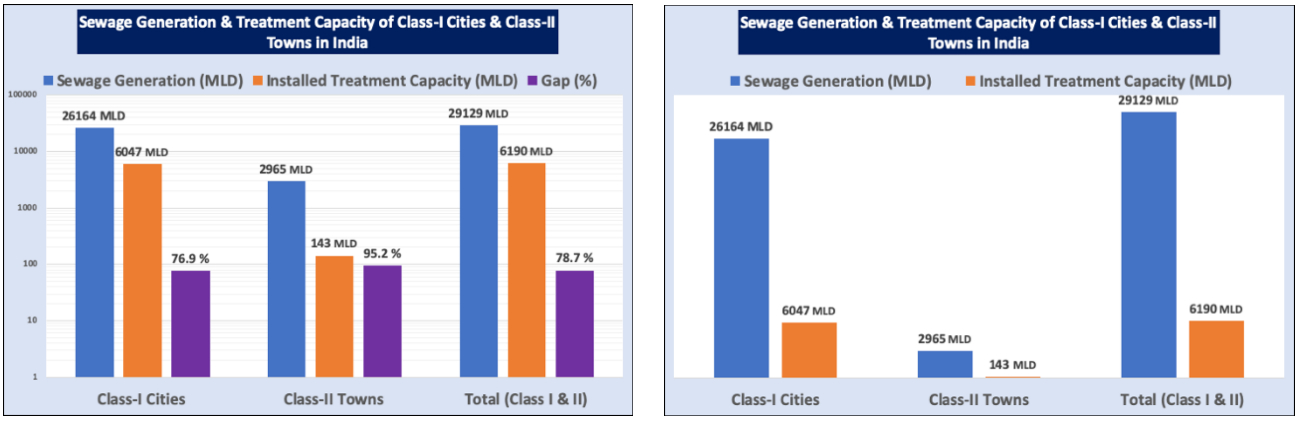

Figure 2: Sewage generation and treatment scenario of Class-I cities and Class-II towns of India (left graph: log-scale with % gap in treatment) *Source: (CPCB, 2017)*

In India, the following types of wastewater treatment processes are defined: effluent treatment plant (ETP), sewage treatment plant (STP) and common and combined effluent treatment plant (CETP). An ETP is a plant where the treatment of mainly industrial effluents is done. A STP treats municipal sewage. The Ministry of Environment and Forest, Government of India has launched the CETP in order to make a cooperative movement of pollution control especially to treat the effluent, emanating from the clusters of compatible Small-Scale Industries.

The technologies used by most STPs under state responsibility are two-stage treatment processes consisting of 1) primary settling, followed by activated sludge process; 2) up flow anaerobic sludge blanket and polishing pond; or a series of waste stabilization ponds. The STP technology landscape differs between Indian states (Figure 3) in the Ganga River Basin as a result of the resource contexts, stakeholder preferences for technological options and government support. Centralized solutions are generally perceived as conventional norms by political actors and engineers, while wastewater treatment technology designs are often prescribed in tender processes leaving little room for innovative solutions (PwC, 2016; Never, 2016; Wankhade, 2015).

1.2.2 WATER REUSE FROM SEWAGE TREATMENT PLANTS

At present, a significant portion of partially treated and untreated sewage is used by farmers for irrigation given the lack of a freshwater alternative and the fertilizing properties (high N and P contents) of sewage (Kaur et al., 2012). These practices entail hazards to human health and the environment, as untreated sewage contain pathogens, heavy metals and, if mixed with industrial wastewater, further persistent and toxic chemicals (Banerjee, year unknown).

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). Two examples for these two reuse schemes are given in Chapter 4, where enabling factors and barriers for treated water reuse and resource recovery are further discussed.

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Zero-liquid discharge (ZLD) guidelines were recently 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.

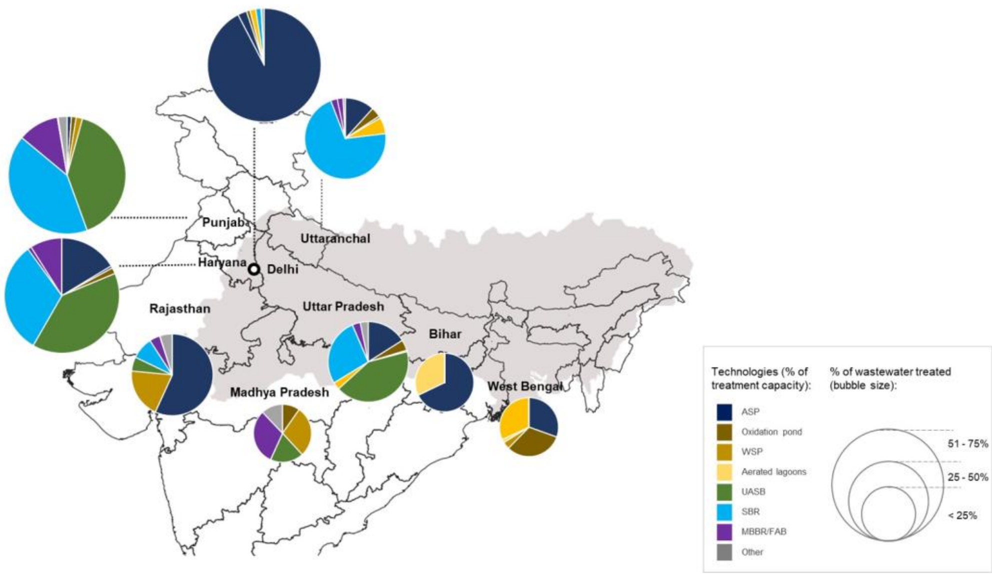

Figure 3: STP technologies and total treatment capacity installed and planned in Indian states located in the Ganga river basin (grey area)

While centralized treatment schemes are under the responsibility of Indian states, around 20000 small-scale and decentralized wastewater treatment units have been constructed by private investors driven by zero liquid discharge (ZLD) policies and regulations in several Indian states (Ulrich et al., 2018; Kuttuva et al., 2018). The southern Indian state of Karnataka has introduced a ZLD state policy in 2004 requiring 100% wastewater treatment and on-site reuse for apartment complexes above a certain size (Kuttuva et al., 2018). Since then, around 2200 residential and commercial complexes have installed decentralized wastewater treatment units within their premises in the capital of Bangalore, Karnataka (KSPCB, 2012). Recent assessments show that most small-scale treatment systems fail to treat wastewater up to the desired water reuse standards (lack of nutrient and microbial removal processes) 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 how several advantages (e.g. less energy use, easier management of wastewater reuse, better adaptation to local conditions and better affordability) over centralized treatment systems (Starkl et al., 2013). In India, decentralized wastewater treatment would benefit from i) a clear policy framework including technical specifications and design standards as well as reuse-specific quality standards; ii) systematic capacity building and training for plant operators; iii) an efficient monitoring system; and iv) governmental financial incentives (Ulrich et al., 2018).

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1.2.3 Energy and nutrient recovery from sewage sludge

Sewage sludge, or biosolids, are semi-solid residues arising during sewage treatment. Adequately treated and processed sewage sludge is a nutrient-rich organic material and valuable organic soil improver (Kumar et al., 2017). Its high organic carbon contents make it a promising source for energy recovery (biogas) through anaerobic digestion (Kaur et al., 2012).

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 partly treated sludge is led into water streams or dumped on landfills. Given its high nutrient properties, sewage sludge from sludge drying beds of some STPs is used on agricultural lands as organic fertilizer (Kaur et al., 2012; Banerjee, yearunknown; Varshney, 2016). In absence of adequate treatment, the dried sludge can contain high levels of heavy metals and pathogens with adverse effects on soil, plants and water bodies, posing hazards to human health (Kumar et al., 2017; Saha et al., 2018). According to the Ministry of New and Renewable Energy (MNRE), there exists an energy production potential of about 225 MW from sewage in India. However, growth of the waste to energy sector has been limited due to reasons such as high cost of installation, the dependence on import of commercial technologies and lack of conducive policy guidelines for nutrient recovery from sewage (Gujarat Cleaner Production Centre, unknown).

Energy recovery from sewage sludge at centralized STPs is restricted to a few cases in India. The lack of specific regulations for sewage sludge discharge until 2016 and the low feed-in tariffs for biogas (insufficient return on investment economic returns) has led to few implemented biogas systems in the Indian wastewater sector up until now (Kaur et al. 2012; Never 2016). The examples of resource recovery from STPs in India generally includes biogas based energy producing systems to generate electricity. Energy recovery in STPs in India is primarily driven by the need to limit operational breakdown due to power supply interruption from electricity grid (Yagnaprasad, 2019).

Some Urban Local Bodies (ULBs) 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 partnership basis (Indian infrastructure, 2019). Two examples for such energy recovery schemes are given in the Indian case study section of this Deliverable (see chapter 4.4 and 4.5), where enabling factors and barriers for biogas recovery are further discussed. Ahmedabad Municipal Corporation (AMC), in Gujarat State, has launched India's first full-scale automatized sludge hygienization plant in 2019. The plant set up at Pirana can convert 100 tons/day of dry sludge into fertilizer by radiation technology and NPK treatment (Varshney, 2016). The case study is further discussed in section 4.6.

Under the Swachh Bharat Mission-Urban, Waste to Energy production of 61.0 MW has been achieved till date. Under AMRUT, about 60 Faecal Sludge Treatment Plants (FSTPs) of 32 KLD are being implemented in major cities in Uttar Pradesh. From these cities, there is a potential of about 13,200 tons/annum of compost generation, with a potential to generate a revenue of about INR 4 crore per annum. Other examples of RRR in India include FSTPs in Sakhipur, Uttar Pradesh where dried faecal sludge and solid waste are co-composted to generate 24 metric tons of compost every year, and Waste to Energy plant in Nashik, Maharashtra where food waste collected from hotels and septage from public toilets are co-digested in a 2:1 ratio to produce biogas and organic fertilizer (Gupta et al., 2020).

Therefore it is pertinent to say that some attempts have been made in India at reuse of sewage sludge and recovery of resources from STPs. However, India is yet to exploit in full potential, the Circular Economy opportunities for RRR from STPs.

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1.3 WATER POLICIES IN EUROPE AND THE SHIFT FROM WASTEWATER TREATMENT TO WASTEWATER REUSE AND RESOURCE RECOVERY

Like India, Europe is also experiencing growing water stress, both in terms of water scarcity and quality deterioration. 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 at the highest on the water stress index (defined as the ratio (%) of a country's total water withdrawal to its total renewable freshwater resources). These countries are above 40% stress, making it clear that they need to work on a comprehensive governance of water resources, of which one is reuse of wastewater (see Figure 4).

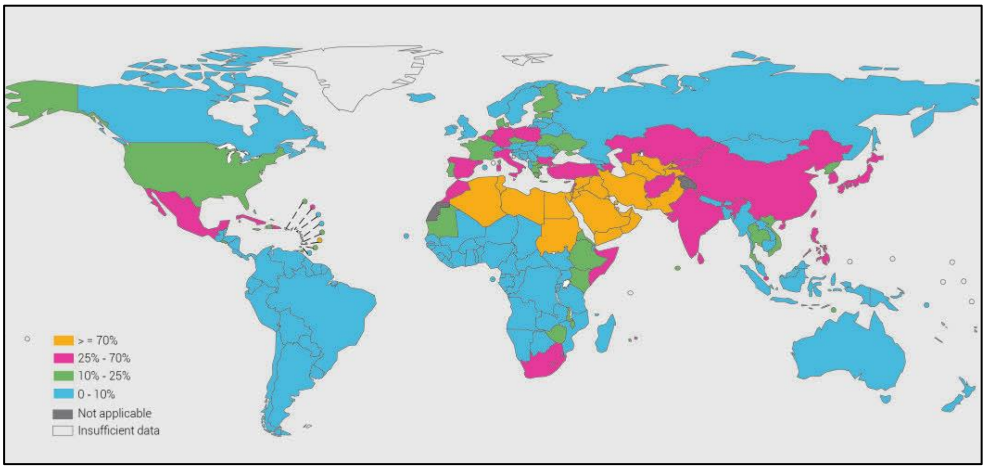

Figure 4: Level of Water Stress in Different Countries
Source: United Nations (2018). Sustainable Development Goal 6 Synthesis Report 2018 on

1.3.1 WASTEWATER TREATMENT AND WATER RESOURCES GOVERNANCE

The EU has been tackling its water related problems for a long while now. Core policy instruments in this sense are the Urban Waste Water Treatment Directive (UWWTD, 91/271/EEC), the Water Framework Directive (WFD) (Directive/2000/60/EC) and the Groundwater Directive (Directive 2006/118/EC).

The 1991 UWWTD played a key role in improving EU water quality. It 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 (Art 3) and treatment standards (Arts 4 and 5) by deadlines stipulated in the directive. Industry sector specific regulations and guidelines, including EU BREFs (Best available techniques reference documents) ensure water quality norms are followed. The 2000 WFD has been considered by many scholars as a holistic piece of regulation as it involves land-use planning, agricultural policy, environmental management and governance, and other policy areas on a river basin scale (Fried, Quevauviller and Vargas-Amelin 2018). Water management and governance by river basins, the natural geographical and hydrological units, instead of administrative and political boundaries require cooperation and joint-objective setting across EU Member States and establishment of River Basin Management Plans (EC, 2019).

The WFD establishes the protection of surface and groundwater in order to achieve 'good status' objectives per river basin. The 'good status' objectives include quantity and quality concerns. It is based on specific milestones and operational steps which have to be undertaken by all EU Member States. The WFD

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establishes that all Member States have to implement measures necessary to prevent or limit the input of pollutants into surface and groundwater and to prevent the deterioration of the status of all water resources. This means that all countries have to protect, enhance and restore water systems, ensure a balance between extractions and recharge capacity, this with the overarching aim of achieving good qualitative and quantitative status of water. Furthermore, the WFD requires the implementation of measurements required to reverse concentration of pollutants resulting from human activities in order to progressively lessen water contamination.

The 2006 Groundwater Directive provided detailed regulations in order to prevent, control and address groundwater pollution. In order to achieve this, the Groundwater Directive establishes the concept of 'groundwater quality standard', which means an environmental quality standard expressed as the 'maximum concentration' permitted of a particular pollutant, group of pollutants or indicator of pollution in a groundwater body (Directive 2006/118/EC, Art 2). This Directive also establishes 'quality criteria' that take account of local characteristics and allow for further improvements to be made based on monitoring data and new scientific knowledge.

Under the UWWTD, there have been billions of euros invested across Member States to collect and treat urban wastewater from agglomerations ≥ 2000 p.e. to remove harmful microorganisms, oxygen-consuming substances and nutrients (EC 2017). Compliance rates with the UWWTD are generally high for EU-15 Member States constituting the EU until 2004 (Figure 5): 94.7% of wastewater of wastewater is collected, 88.7% treated with secondary processes and 84.5% with more stringent treatment methods. Major compliance gaps are still found in Member States that joined the EU after 2004. Romania, Bulgaria, Slovenia and Cyprus, for example, lack behind with collection rates of < 70%. Secondary treatment compliance is as a low as 20% in Malta, Bulgaria, Slovenia while compliance levels with tertiary treatments need to be improved in Bulgaria, Malta, Ireland and Romania (< 25% compliance) (EC, 2016).

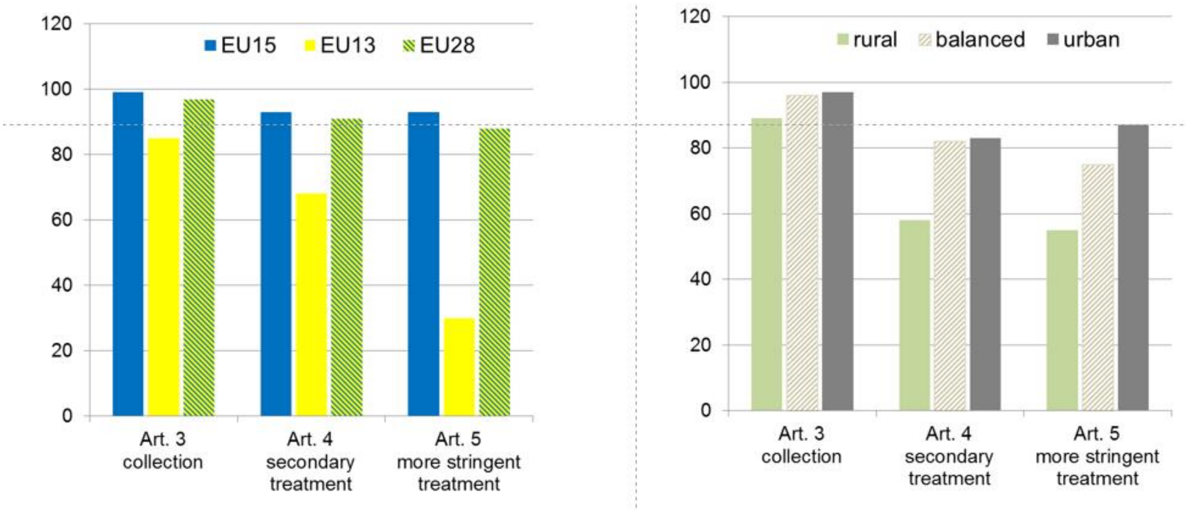

Figure 5: Compliance with UWWDT requirements for collection, secondary and more stringent treatment

Source: (EC, 2016)

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The 'distance to compliance' calculated using 2014 data, shows the nature and size of the remaining challenges regarding wastewater treatment in the EU (EC, 2017a):

- *11 million p.e. are not properly collected (1.8 % of total EU load). The p.e. not properly collected are not properly treated either;*
- *41 million p.e. do not meet the performance requirements of secondary treatment (7.2 % of the total EU load that requires this treatment);*
- *45 million p.e. do not meet the performance requirements of more stringent treatment (11.9 % of the total EU load that requires this treatment).*

To tackle these implementation and compliance challenges, the EU allocated EUR 14.8 billion of the European Regional Development Fund and the Cohesion Fund to water related interventions mainly wastewater treatment and as drinking water supply for the period 2014-2020. These investments are spent in Member States with less developed water infrastructure (EC, 2017a). The largest share of the available budget, about EUR 10 billion, goes to wastewater treatment infrastructure, including the construction or upgrading of plants and sewerage networks, with some funding also going to sludge management (EC, 2017a).

Even though Europeans are constantly improving their quality of their drinking water or local waterways (EEA, 2016, 2017b), there are concerns about contaminants of emerging concern (CECs) that are not dealt with by standard treatment methods (Heo et al., 2020).

Only recently the EC (2017b) has updated its Roadmap for a strategic approach to pharmaceuticals in the environment. It identifies knowledge gaps and figures out options to address environmental (and human health) protection. The current revisions of UWWTD and the WFD also seek to better integrate options to mitigate micropollutants in the European water cycle (Breitenmoser and Hochstrat, 2019).

In Europe, Switzerland is currently the only country which has revised its legislation to include the mandatory removal of organic micropollutants from municipal wastewater (BAFU, 2017a). In Germany, individual federal states introduced a fourth treatment step in WWTPs without explicit legal requirements (Kompetenzzentrum Mikroschadstoffe NRW, 2015).

1.3.2 Water reuse from wastewater treatment plants

Increasing efforts in recent years have been put to promote water reuse as a possible solution to water scarcity problems. Water reuse should be considered as the core of an integrated water management approach to save costs, recover materials and demonstrate environmental stewardship.

Water reuse practices in Europe are mainly driven by the demand for additional water resources and evolve under quite diverse national legal and policy regimes. Mostly agricultural uses are permitted but some countries also have quality standards for urban, industrial, recreational and environmental applications (e.g. Spain) (Breitenmoser and Hochstrat, 2019). Agricultural reuse dominates, especially in arid regions in the southern European countries (Bixio et al., 2006) as highlighted by case studies from Spain in Chapter 4 of this document. Currently, only about 2.4% of treated urban wastewater is reused in Europe, even though it is considered to have a lower environmental impact than water transfers and desalination. Southern Member States such as Spain, Italy, Greece, Malta and Cyprus and northern Member States like Belgium, Germany and UK already have in place several initiatives regarding water reuse for irrigation, industrial uses and aquifer recharge (EC, 2019) (Figure 6). One of the factors preventing the uptake of water reuse include the lack of common environmental and health standards for water reuse across the EU, plus the potential

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obstacles to the free movement of agricultural products irrigated with reclaimed water (European Parliament, 2020).

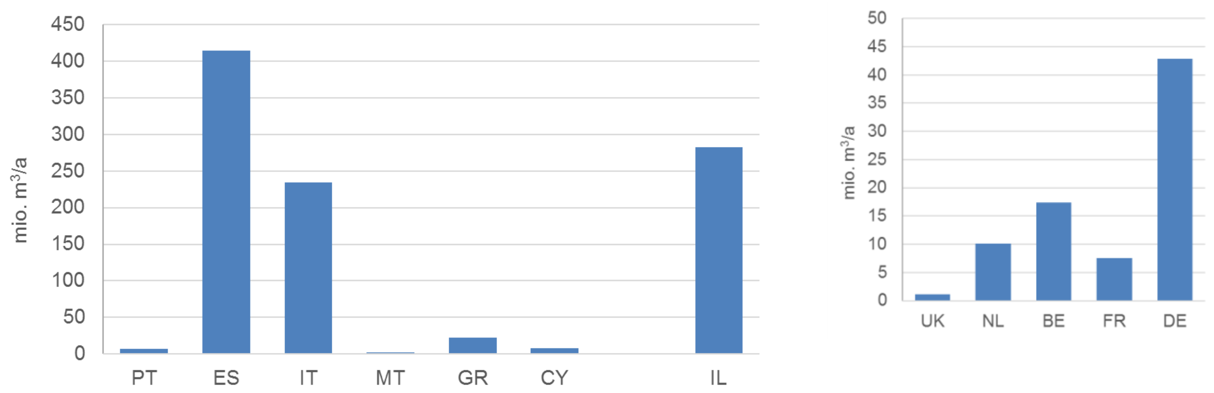

Figure 6: Amounts of reused water from municipal wastewater treatment plants in different EU countries. Numbers reflect the status of the year 2005, except for Spain (2010) and Portugal (2017) ***Source: (Breitenmoser and Hochstrat, 2019)***

In 2015, the EC presented the new circular economy package. In particular, it committed to develop a number of actions to promote further uptake of wastewater treatment and water reuse at EU level. These actions focus on overcoming the main barriers to the untapped potential for water reuse wherever it is cost-efficient and safe for health and the environment. These actions include:

- Reuse in integrated water planning and management
- Minimum quality requirements for water reuse in irrigation and aquifer recharge
- Water reuse in industrial activities
- Support to research and innovation in water reuse
- EU funds for investments in water reuse.

The action has led to new measures to reduce the risk of shortages of water for irrigation in the form of a regulation on the 'minimum requirements for water reuse', which is expected to be adopted in 2020 (Table 1).

Table 1: Water reuse quality requirements for agricultural reuse/irrigation (Source: Alcade Sanz and Galwik, 2017)

Parameter	Water quality class A	Water quality class B	Water quality class C	Water quality class D
E.coli (CFU/100mL)	≤ 10	≤ 100	≤ 1000	≤ 10000
Helminth eggs per L	≤1	≤1	≤1	≤1

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Legionella ssp (CFU/L)	<1000	<1000	<1000	<1000
BOD (mg/L)	≤ 10	<25	<25	<25
COD (mg/L)		<125	<125	<125
TSS (mg/L)	≤ 10	<35	<35	<35
Turbidity (NTU)	≤ 5			
	Class A: all food crops, including root crops consumed raw and food crops where the edible part is in direct contact with reclaimed water- all irrigation methods	Class B: Food crops consumed raw where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops to feed milk- or meat-producing animals - all irrigation methods	Class C: Food crops consumed raw where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops to feed milk- or meat-producing animals - drip irrigation only	Class D: Industrial, energy, and seeded crops - all irrigation methods

The regulation aims to stimulate the uptake of water reuse by offering a sustainable, alternative water supply for agricultural irrigation. It will help to ensure that enough water is available for the irrigation of fields, in particular during heatwaves and severe droughts as a result of climate change, so preventing crop shortfalls and food shortages. Because the geographic and climatic conditions vary greatly across Member States, they are free to decide whether it is appropriate to use reclaimed water for agricultural irrigation. Member States may also decide to use reclaimed water for other uses such as industrial water. The regulation contains strict requirements for the quality of reclaimed water and its monitoring to protect human and animal health as well as the environment. It is developed as a permit system which is based on a 'Water Risk Management Plan' that entails compliance checks, monitoring, and information and awareness. The adoption of common environmental and health standards for water reuse across the EU is an essential strategy, with a robust permitting, monitoring and compliance platform, to promote public confidence in agricultural products irrigated with reclaimed water and prevent potential barriers to the free movement of agricultural goods.

The EU Circular Economy roadmap has been renewed in 2020 under the New European Green Deal strategy (EC, 2020a). The new circular economy action plan introduces legislative and non-legislative measures promoting circular economy processes and fostering sustainable consumption in the electronics and IT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food as well as water and nutrient sectors (EC, 2020b). Water and wastewater governance are acknowledged as significant part to the EU circular economy due to water being a carrier of materials such as nutrients like P and N as well as energy (Smol et al., 2020).

1.3.3 Energy and nutrient recovery from sewage sludge

Sewage sludge from WWTPs contains biodegradable and recalcitrant organic compounds, pathogens, heavy metals and other inorganic constituents. Sewage sludge from industrial WWTPs can further contain toxic compounds and environmentally persistent chemicals. If properly treated, sewage sludge can be considered a source of nutrients and energy which could be recovered.

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EU Member States generate more than 10 million tons of sewage sludge (dry matter) from municipal WWTPs (sewage sludge) annually (Bianchini et al., 2016). Germany, the UK, Spain, France and Italy produce more than 55-65% of the total sewage sludge amount generated in the 28 EU Member States (Collivignarelly et al., 2018). 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).

Among the most important EU legislations in the context of sludge management are the following:

Related to disposal in general

- The **UWWTD (91/271/EEC**) obliges EU Member States to safely dispose sewage sludge (dumping to surface waters is forbidden) and to reuse sludge whenever appropriate. Sewage sludge disposal routes should be designed coherently with waste hierarchy outlined in the Waste Framework Directive (2008/98/EC) and its amendment (2018/851/EC), i.e. prevention (e.g. minimization techniques), preparing for reuse (e.g. biological stabilisation such as anaerobic digestion), recycling (e.g. matter recovery), other recovery (e.g. energy recovery such as incineration) and as final, but an undesired option, landfilling.

Related to sewage sludge reuse (organic fertilizer)

- The **Sewage Sludge Directive (86/278/EEC) and its amendment (2018/851/EC)** encourages the use of treated sewage sludge in agriculture. Treated sludge refers to sewage sludge that has undergone biological, chemical, heat, long-term storage or any other appropriate process to reduce its fermentability and the health hazards occurring from its use. Standard treatment technologies are aerobic or anaerobic digestion, thermal drying, alkaline stabilization, composting or acid oxidation/disinfection (Collivignarelly et al., 2018). The use of untreated sludge in agriculture is prohibited.

To further protect against potential health risks from residual pathogens, treated sludge should only be applied to soils where:

- no fruit and vegetable crops are grown or less than ten months before these crops are to be harvested;
- grazing animals are not allowed to access land where treated sludge has been applied;
- rules for the sampling and analysis of sludge and soils are also specified; and,
- limit values for heavy metal concentrations in sewage sludge for agricultural use and sludge-treated soils are defined (EC, 2020c).

In 2014, the Sewage Sludge Directive was evaluated for its effectiveness (EC, 2014a). The evaluation showed, among other positive outcomes, that the Directive had successfully increased the amount of treated sludge used in agriculture and promoted the recovery of biogas from sewage sludge for renewable energy generation over the last 30 years. Nevertheless, the changing EU policy landscape (e.g. the EU action plan for the Circular Economy), the availability of new innovative and cost-effective sludge treatment technologies, and the awareness of the occurrence of organic pollutants (e.g. halogenated organic compounds, polycyclic aromatic hydrocarbons) mean that the Directive is currently outdated. A new evaluation is currently on-going, which might lead to a proposal to the EC to revise the Directive (EC, 2020c).

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Related to sewage sludge for energy recovery

- The **Directive on industrial emissions (2010/75/EC)** lays down the norms and rules for the incineration of wastes (including sewage sludge) as well as emissions standards.
- The **Directive on the promotion of energy from renewable sources (2009/28/EC)** indicates compulsory energy levels, such as biogas, to be recovered from renewable sources, such as sewage sludge.

Related to landfilling of sewage sludge

- The **Landfill Directive (1999/31/EC) and its amendment (2018/850/EC)** obliges the EU Member States to reduce the amounts of biodegradable wastes (such as 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, based on the EU directives outlined above. Some EU Member States have implemented even more 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).

The treatment and disposal techniques (Table 2) thus vary significantly between and within EU Member States (EC, 2020c) (Figure 7). The way sewage sludge is disposed can also greatly differ between regions within a country. Italy, for example, has drafted additional regional guidelines based on the Italian national legislation to regulate the reuse of treated sewage sludge to agricultural lands (see case study Lombardy, Italy in Chapter 4.12).

Table 2: Overview of sludge treatment and disposal steps and some available technologies (Source: adapted from Kelessidis and Stasinakis, 2012)

Sludge treatment/disposal steps	Available technologies
Thickening	Drainage drum
	Gravitation thickener
	Lamellar decanter
Stabilisation	Chemical (e.g. conditioning with lime)
	Anaerobic digestion
	Thermal hydrolysis
	Aerobic stabilization
	Composting
Dewatering	Centrifuge
	Drying bed
	Belt filter press
	Filter press
	Screw press
Drying	Solar drying
	Thermal drying
Storage	Storage tank
	Laguna
	Decanter

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Disposal/final use	Land application Incineration Landfilling Cement plant

The treatment technologies applied in EU Member States relate to their final disposal practices and the size of WWTPs (Kelessidis and Stasinakis, 2012). Anaerobic and aerobic digestion are the most popular stabilization methods. These are applied in 24 and 20 Member States (out of 28 EU Member States), respectively. Especially, Spain, UK and other northern EU Member States apply anaerobic digestion for energy generation and/or sludge stabilization for further reuse in agriculture (see case studies on Belgium in chapter 4.11) (Wisniowska et al., 2019). Chemical stabilization, with lime or other chemicals, is generally of minor importance. Sludge composting is applied to achieve sludge hygienization for land use and is commonly applied in 25 out of 28 EU Member States (Kelessidis and Stasinakis, 2012; Wisniowska et al., 2019). Sludge dewatering seems to be an important step in sludge management in most EU Member States with mechanical dewatering being preferred to drying beds. Thermal drying is in many cases the first step before incineration units and is applied in all EU Member States (Kelessidis and Stasinakis, 2012).

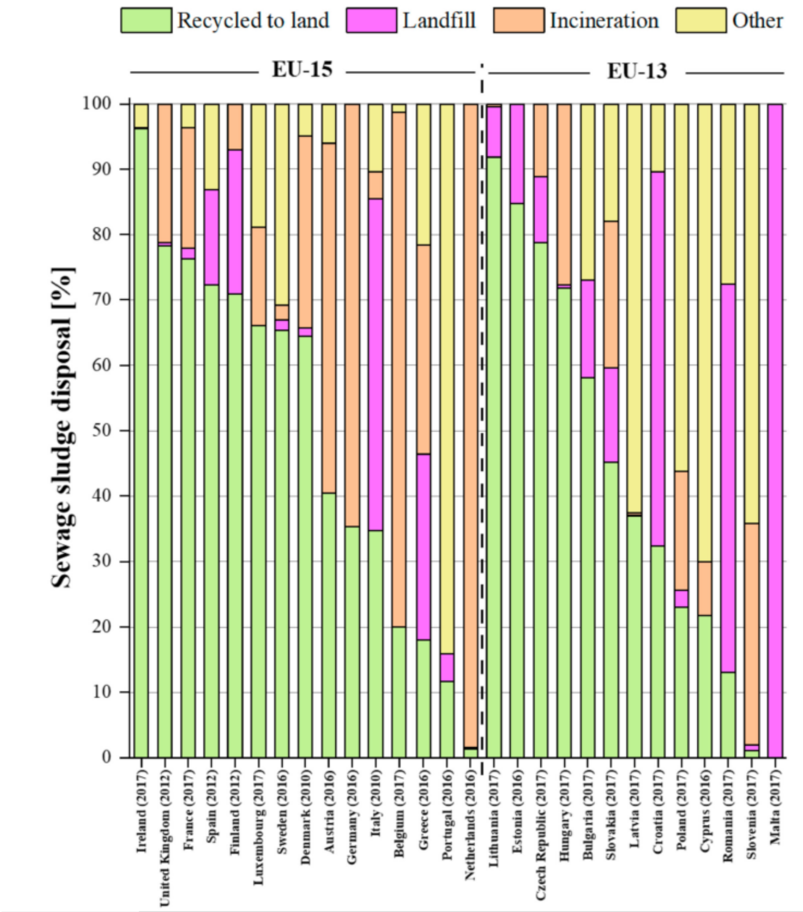

Figure 7: Main sewage sludge recovery routes in Europe (Collivignarelli et al., 2018)

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The most favored 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., 2018, Wisniowska et al., 2019). In northern EU Member States with low availability of soils for the spreading of treated sewage sludge (e.g. Germany, Belgium, Austria), incineration is the primary recovery route. Land application of sludge is widespread in Ireland, France, Spain, Finland, the Czech Republic, Lithuania, Estonia and Hungary. In Spain and France more than 65% of produced sewage sludge is used as fertilizer in agriculture. On the other hand, in the Netherlands, Switzerland (see Chapter 4.14) and several parts of Germany, sludge applications to land are prohibited. Landfilling is practiced mainly in Italy, Greece, Spain, Croatia, Romania and Malta (Collivignarelly et al., 2018, Wisniowska et al., 2019).

Related to P recovery from sewage sludge (recycling mineral fertilizer)

In 2014, the EC classified phosphate rock as critical raw material (EC, 2014b). P is an essential nutrient in fertilizer and livestock feed products in agriculture. Several EU countries have started to recover P from sewage sludge and authorized the use of recovered struvite/phosphates as fertilizers (i.e. the Netherlands, Denmark and Belgium). Few countries (i.e. Switzerland, Germany, Austria and Sweden) have proposed and/or introduced national level legislation on mandatory P recovery from sewage sludge. Two case studies on P recovery from sewage sludge (Belgium and Switzerland) are presented in Chapter 4.13 and 4.14 respectively.

Moreover, 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, 2020d).

1.4 Overview of PAVITRA GANGA's approach to water technology and innovation

Water overexploitation and pollution are major causes of water depletion. Main pressures from water consumption are concentrated on irrigation and domestic demand. Water scarcity and drought events are likely to be more severe and more frequent in the future due to climate change and increasing population. Over the past few decades, droughts have dramatically increased in number and intensity around the world, including in India (WWAP 2020).

The potential role of treated wastewater reuse as an alternative source of water supply is well acknowledged and embedded within international, EU and Indian strategies. UN SDG 6 on water specifically targets a substantial increase in recycling and safe reuse globally by 2030. Moreover, when compared to alternative sources of water supply such as desalination or water transfer, water reuse often turns out to require lower investment costs and energy, also contributing to reduce greenhouse gas emissions.

Water reclamation can be considered a reliable water supply for different uses such as drinking, agriculture and industry. Water reuse is independent from seasonal drought and weather variability and able to cover peaks of water demand. This can be particularly beneficial to agricultural activities that can rely on reliable continuity of water supply during the irrigation period, consequently reducing the risk of crop failure and income losses. Appropriate consideration for nutrients in treated wastewater could also reduce the use of additional fertilizers resulting in savings for the environment, farmers and wastewater treatment.

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. When the pilots are successful, upscaling and application of the technologies might have a significant impact on wastewater treatment in India and as such will contribute to considerable water quality improvement and overall rejuvenation of the Ganga River. The novel technologies that will be tested are the following:

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- The Andicos™ technology (combined anaerobic treatment of organic waste and sewage), a modular treatment step that can be added to existing treatment plants, and can also be applied as a new stand-alone facility in more rural areas. Andicos™ 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 will be treated by a CWplus designed to remove micro-pollutants and pathogens. Structured adsorbers will be used in case of river flow augmentation.
- The SFD-MBR, a self-forming dynamic membrane bioreactor, a novel wastewater treatment technology based on the integration of conventional activated sludge and 'non-membrane' surface filtration. It is robust, resilient and cost-effective compared to ultrafiltration membranes, offering a decentralized 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 will 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. It will be considered as post treatment step after anaerobic treatment, the effluent will be used for river flow augmentation.
- 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, 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 and zeolites for enhanced heavy metal and trace organics removal.
- All technologies take into account the Indian wastewater composition and allow for simple operation and maintenance procedures. The efficiency in removing bulk pollutants but also micro-pollutants and pathogens will be tested. Challenges with respect to health will remain a focus, therefore protocols are 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.

As the PAVITRA GANGA project has its two pilot sites in Delhi and Kanpur, the particularities of water supply and wastewater treatment facilities in these two cities is explained below. Moreover, as the pilot sites are located in the national capital territory of Delhi and the state of Uttar Pradesh the analysis of policy interventions and regulatory frameworks (Chapter 2) is focused on these two states.

Delhi

Delhi is located in a semi-arid zone and depends largely on imported water for meeting its water needs. Delhi receives raw waters from the Ganga basin, Yamuna basin, and Indus-basin. Additionally, groundwater resources are tapped to meet leftover demand. The Delhi Jal Board (DJB) is responsible for the production and distribution of potable water and the treatment of wastewater.

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As of March 2018, against the overall water demand of 4315 million litres per day (MLD), the installed raw water treatment capacity is about 3420 MLD. The total sewage generation in Delhi is about 2725 MLD and the capacity exists to treat about 2278 MLD. However, due to operation and maintenance constraints, only 1669 MLD (61%) is treated. Out of this, about 337 MLD (20%) is reused (DJB, 2016).

Kanpur

The city of Kanpur is the tenth most populous city in India and one of the key urban and industrial conglomerations on the banks of the Ganga river. The city is heavily dependent on the river for meeting its water needs and it also acts as a sink for most of the sewage generated in the city. As per the estimates from the Municipal Corporation, Kanpur city has a domestic water requirement of about 600 MLD but the existing infrastructure can supply only about 385 MLD. The gap in the supply and the entire industrial water requirement is met by tube wells and hand pumps. However, due to over extraction, groundwater is being depleted and most of the wells tapping shallow aquifers do not give sustained yield during peak summers. Also, both surface and groundwater resources in the city are heavily polluted.

As per the latest figures (June 2019), the city produces about 408 MLD of sewage and the capacity exists to treat about 457 MLD (Uttar Pradesh Jal Nigam, 2019). Overall there are six functional STPs. However, actual treatment is about 75% of the sewage generated due to the operational constraints of the STPs. Further, there is one CETP that treats about 68% of the wastewater coming from the tanneries. The rest of the untreated sewage and untreated or partially treated effluents from the industries (leather, textile, jute and chemical) is disposed directly on land or in the river which is resulting in pollution of surface and sub-surface water. The average total coliform count in the stretch of Ganga river in Kanpur was observed to be as high as 240,000 MPN/100ml in summer months (CPCB, 2013). Furthermore, traces of heavy metals such as Cd, Cr, Cu, Fe, Pb, As, Zn, and Mg have also been observed in both surface and groundwater.

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CHAPTER 2 WATER AND WASTEWATER POLICY INTERVENTIONS AND REGULATORY FRAMEWORKS IN INDIA

2.1 NATIONAL POLICY AND REGULATORY FRAMEWORK

2.1.1 THE INDIAN CONSTITUTION

The Indian Constitution in its Article 246 places water resources in the legislative jurisdiction of the states. In terms of what is placed under the control of the states, 'water' encompasses 'water supplies, irrigation and canals, drainage and embankments, water storage and water power'. However, shipping and navigation of mechanically propelled vehicles in inland waterways which are declared as National waterways by the Parliament and regulation and development of Inter-State rivers are under the jurisdiction of the Central Government. Article 248, dictates that any policy matter not explicitly granted to the states is reserved for the central government. Among the first major changes in the water sector came from the Supreme Court. Examples of this trend include: (i) the Bandhua Mukti Morcha v. Union of India case, where the Supreme Court expressed a pattern of liberal interpretations to broaden fundamental rights and recognized the deprivation of clean drinking water as a violation of the Article 21: right to life (Bandhua Mukti Morcha v. Union of India A.I.R. 1984 S.C. 802); (ii) In A.P. Pollution Control Board II v. Prof. M.V. Nayudu, the Constitutional Court held in more explicit language that the 'right to access to drinking water' was a part of the fundamental right to life (A.P. Pollution Control Board II v. Prof. M.V. Nayudu (2001) 2 S.C.C. 62). The Supreme Court has yet to give definitive rulings on how far the Article 21 rights extend for water provision for agricultural and commercial purposes.

Noteworthy is to mention that there are no provisions in Article 246 of the Constitution that grant the States power to legislate on environmental matters. This is an area of law reserved for the Central Government via Article 248 (Government of India, 1974a). Delegating the States the jurisdiction over water and the Central Government with jurisdiction over environmental matters allows for dual federal and state water and wastewater regulations. As a result of this, today's system sees many duplicative functions and institutions by the States and the Central Government.

2.1.2 THE NATIONAL WATER POLICY

The Ministry of Water Resources (now Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti), Government of India formulates the National Water Policy in India. The first National Water Policy was formulated and adopted in India in September 1987. The policy was reviewed and update once in 2002 and again later in 2012 as the National Water Policy (Ministry of Water Resources, 2012).

Following the steps of the Constitutional Court, the National Government approved in 2012 the National Water Policy. This Policy highlights as follows: 'public policies on water resources need to be governed by certain basic principles. These basic principles are:

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(i) Planning, development and management of water resources need to be governed by common integrated perspective considering local, regional, State and national context…
(ii) Principle of equity and social justice must inform use and allocation of water.
(iii) Good governance through transparent informed decision making is crucial to the objectives of equity, social justice and sustainability…
(iv) Water needs to be managed as a common pool community resource held, by the state, under public trust doctrine…
(v) Water is essential for sustenance of eco-system, and therefore, minimum ecological needs should be given due consideration.
(vi) Safe water for drinking and sanitation should be considered as pre-emptive needs, followed by high priority allocation for other basic domestic needs (including needs of animals), achieving food security, supporting sustenance agriculture and minimum eco-system needs…
(vii) All the elements of the water cycle…, are interdependent and the basic hydrological unit is the river basin, which should be considered as the basic hydrological unit for planning.
(viii) Given the limits on enhancing the availability of utilizable water resources and increased variability in supplies due to climate change, meeting the future needs will depend more on demand management…
(ix) Water quality and quantity are interlinked and need to be managed in an integrated manner…,
(x) The impact of climate change on water resources availability must be factored into water management related decisions…' (Government of India, Ministry of Water Resources, 2012).

The Constitutional rulings as well as the 2012 National Water Policy illustrate a paradigm shift in water use, management and governance as the perception that freshwater is an abundant resource has changed to that of water being scarce, threatened by pollution and recognising the need of sustainable use. 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 ministries hinder any significant impact on improving India's water management and governance 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 plan to operationalize the policies and bring about transformational changes on ground is a recurring issue.

2.1.3 The Water (Prevention and Control of Pollution) Act

The Water (Prevention and Control of Pollution) Act of 1974 (amended 1988) aims to prevent and control water pollution and to maintain and restore the wholesomeness of water by establishing Central and State Pollution Control Boards (the CPCB and SPCBs) to monitor and enforce the regulations. The act defines the composition of the boards and the terms and conditions of service of their members. This act sets effluent standards and penalties for non-compliance for effluent-discharging bodies (Government of India, 1974b).

The CPCB advises the government on any matter concerning the prevention and control of water pollution, coordinates pollution control activities and provides technical assistance and guidance. The CPCB and SPCBs collect, compile and publish technical and statistical data relating to water pollution and the measures devised for its effective prevention and control. They prepare manuals, codes and guidelines relating to the treatment and disposal of sewage and trade effluents and disseminate information related to the same.

Water quality monitoring is a prerequisite for assessing the status of maintenance and restoration of water bodies as well as the extent of pollution. Water quality monitoring is performed by the CPCB and the SPCBs with the following objectives:

- *Rational planning of pollution control strategies and their prioritization*

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- *Assessing the nature and extent of pollution control needed in different water bodies*
- *Evaluating the effectiveness of pollution control measures already in place*
- *Analysing water quality trends over time*
- *Assessing the assimilative capacity of a water body to make pollution control cost-effective*
- *Understanding the environmental fate of different pollutants*
- *Assessing the fitness of water for different uses.*

As of 2019, the water quality monitoring network in India had 4022 stations in 28 states and 6 Union Territories spread over the country. The monitoring network covers 2017 rivers, 341 lakes, 138 tanks, 105 ponds, 73 creeks/marine/sea/coastal, 58 canals, 77 drains, 10 water treatment plants (raw water) and 1153 groundwater stations. (CPCB, 2019). The inland water quality monitoring network is operated under a three-tier programme: the Global Environmental Monitoring System, the Monitoring of Indian National Aquatic Resources System and the Yamuna Action Plan (Bhardwaj, 2005). In addition to general parameters, and core parameters such as pH, dissolved oxygen (DO) and biochemical oxygen demand (BOD), biological monitoring and monitoring of trace metals and pesticides are undertaken (CPCB, 2019).

A CPCB water quality management plan covers setting water quality goals; monitoring water quality; identifying the nature and magnitude of pollution; inventorying the sources of pollution; collating water quantity information; selecting technologies for pollution control; financing waste management; maintaining sewage treatment plants; and controlling industrial pollution, including recycling and resource recovery, use of clean technologies, and setting wastewater discharge standards and charges for residual pollution (CPCB, 2008).

The CPCB has developed a concept of 'designated best use'. According to this concept, out of several uses a water body is put to, the use which demands highest quality of water is termed as "designated best use", and accordingly the water body is designated." It is the classification of the inland surface waters into five best use categories (A to E) according to the quality of the water in those water bodies (http://www.cpcb.nic.in/Water_Quality_Criteria.php). This classification helps water quality managers and planners set water quality targets and design suitable restoration programmes for various water bodies. The five designated best uses and the criteria are depicted in Table 3:

Table 3: Water Quality Criteria
Source: Central Pollution Control Board (CPCB, http://www.cpcb.nic.in/Water_Quality_Criteria.php)

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1.Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C, 2mg/l or less
Outdoor bathing (Organised)	B	1. Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C, 3mg/l or less

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Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C, 3mg/l or less
Propagation of Wildlife and Fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N), 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25°C, micro mhos/cm, maximum 2250 3. Sodium absorption Ratio Maximum 26 4. Boron Maximum 2mg/l

The CPCB suggests that a major part of the cost of waste management should be borne by the urban population, according to the 'polluter pays' principle, which can be applied to domestic and industrial dischargers to induce waste reduction and treatment and can provide a source of revenue to finance investments in wastewater treatment.

2.1.4 The Environment (Protection) Act

The Environment (Protection) Act of 1986 empowers the central government to make rules to regulate environmental pollution. It contains discharge standards for STPs and CETPs (Government of India, 1986).

Concerning effluent discharge standards, the environmental rules prescribe maximum allowable limits of concentration of various pollutants in water for discharge over different areas (land, surface water bodies, marine coastal areas, etc.) Table 4 shows selected parameters for STP discharge. Overall 40 parameters including heavy metals, radioactive substances, and pesticides are considered. Further, the rules specify the procedure as per which samples of water for the analysis to be taken.

Table 4: Overview of Indian STP discharge standards over time. (Source: Schellenberg et al., 2020)

	Parameters	General norms[g] 1986				Draft norms Nov. 2015**	MoEF & CC notification, Oct. 2017**	NGT order 2019**
		Inland surface water	Public sewers	Land irrigation	Marine coastal areas			
1	BOD [mg/l]	30	350	100	100	10	30 20 (metro cities)[h]	10
2	COD [mg/l]	250	–	–	250	50	–	50
3	TSS[i] [mg/l]	100	600	200	100 (process water)	20	100 50 (metro cities)	20
4	pH	5.5–9	5.5–9	5.5–9	5.5–9	6.5–9	6.5–9	5.5–9
5	TN[j] [mg/l]	100	–	–	100	10	–	10
6	Ammonical Nitrogen as N [mg/l]	50		–	50	5[k]	–	–
7	Free NH3 [mg/l]	5			5	–	–	–
8	Nitrate [mg/l]	10			20	–	–	–
9	Diss. PO4 as P [mg/l]	5	–	–	–	–	–	1[l]
10	Fecal Coliform [MPN/100ml]	–	–	–	–	<100	<1,000	<230

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The established STP standards have changed considerably over the past years regarding the limits and list of overall parameters but also the decision to just use one fixed set of standards for all envisaged end uses (Schellenberg et al., 2020). The stringent draft norms in 2015 were replaced by the 2017 amendment that relaxed the standards for the discharge of treated effluent from STPs. Revised standards considered only the four parameters: pH, Bio-chemical Oxygen Demand (BOD), Total Suspended Solids (TSS) and Faecal Coliform (FC). The National Green Tribunal (NGT) resolution from 2019 aims to introduce more stringent standards through the implementation of a Best Available Technology approach (NGT, 2019; Schellenberg et al., 2020).

2.1.5 The National Ganga River Basin Authority

The National Ganga River Basin Authority (NGRBA) was constituted in February 2009 under section 3 (3) of the Environment Protection Act. It was established for a planning, monitoring, financing, implementing and coordinating authority with the objective to ensure effective reduction of Ganga river pollution and conservation by adopting a holistic river basin approach (Press Information Bureau, 2012). Environmental and Social Management Framework (ESMF) of NGBRA by MOEF intended to facilitate the management of environmental and social issues of the project. The World Bank has been supporting the Government of India in its efforts of NGRBA project. The World Bank scheme has two major phases; Phase-1 with 200 million dollar loans to supports the institutional development that includes water quality monitoring, a stakeholder engagement program, environmental regulations and the operationalization of institutions at the central and state level. Phase-II with 800 million dollar loans involves the wastewater collection and treatment, solid waste management, control of industrial pollution and riverfront development (World Bank, 2015).

2.1.6 The Ganga Action Plan

The Ganga Action Plan (GAP) was launched in 1985 with the major aim of pollution abatement, to improve the water quality by interception and diversion (I&D) as well 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 [2] of which about INR 433.3 crores was spent on 25 class-I towns in Uttar Pradesh, West Bengal and Bihar. New technology of sewage treatment, Up-flow Anaerobic Sludge Blanket (UASB) was successfully developed. Under GAP phase-I, about 868.69 MLD of sewage treatment capacity was created.

Further, Ganga Action Plan Phase-II was implemented from 1993 largely as an extension of the previous work on Ganga and its tributaries that covered 95 towns in five states. GAP-II mainly involved the laying of sewers, construction of new sewage treatment plants and the rehabilitation of existing sewerage systems. Under the GAP-II, about 1757.23 MLD of sewage treatment capacity was created with investments of about INR 3402.43 crores (until February 2014) for the Ganga and its tributaries (NMCG, 2020).

The Ganga Action Plan, however, was not able to achieve its 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; the lack of funds in urban local bodies (ULBs) for adequate operation and mantainance (O&M) of STP infrastructure, improper mass awareness, weak monitoring network etc.

[2] 1 crore = 10.000.000 INR

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2.1.7 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 5:

Table 5: Overview of government initiatives to improve wastewater treatment

Initiative	Ministry	Period	What is financed	Available funds	Reference
Swacch 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://swachhbharat urban.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.go v.in/content/
Namami Gange (Clean Ganga) Mission	MoJS	2014-2023	Wastewater treatment facilities and septage management in Ganga River Basin	3 billion USD	https://nmcg.nic.in/

MoHUA = Ministry of Housing and Urban Affairs, MoDWS= Ministry of Drinking Water and Sanitation, MoJS= Minsitry of Jal Shakti (merged Ministry of Water Resources, River Development & Ganga Rejuvenation and Ministry of Drinking Water and Sanitation)

There is the need to dovetail existing water and wastewater laws into a National Water Framework as an umbrella of general principles governing water issues by the Central 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 framework should recognise the importance of wastewater treatment and RRR.

As discussed in the stakeholder's workshop there is already an initiative in those lines, as the Central Government has started a process for drafting a policy related to reuse of water at national level. Some participants of the workshops also mentioned that there should be mass awareness regarding wastewater treatment, separation of waste and possible ways to recover different resources and materials. In absence of guidelines for some new and emerging contaminants, the World Health Organisation (WHO) guidelines can be used as broad directives, and depending on local situations, new norms should be developed.

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2.1.8 POLICIES TO PROMOTE WATER, ENERGY AND NUTRIENT RECOVERY FROM SEWAGE TREATMENT PLANTS

Reuse of treated wastewater: Water reuse is promoted in the 2012 National Water Policy (chapter 2.1.2) and the 2017 amendment of the Environment (Protection) Act 1986 for STP effluents considers discharge for land irrigation and inland surface waters. However, there are no national water 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 wastewater reuse applications in their Manual on Sewerage and Sewage Treatment Systems (CPHEEO, 2012) (Table 6).

Table 6: Recommended norms of treated sewage quality for different uses according to CPHEEO, 2012. All units in mg/L unless specified. (Source: Schellenberg et al., 2020)

Parameter	Toilet flushing	Fire protection	Vehicle exterior washing	Non-contact impound-ments	Landscaping, horticulture & agriculture			
					horticulture, golf courses	Crops		
						Non-edible crops	Edible crops	
							Raw	Cooked
Turbidity (NTU)	<2	<2	<2	<2	<2	AA	<2	AA
SS	nil	nil	nil	nil	nil	30	nil	30
TDS				2100				
pH				6.5 to 8.3				
Temp. (°C)				Ambient				
Oil and Grease	10	nil	nil	nil	10	10	nil	nil
Minimum Residual Chlorine	1	1	1	0.5	1	nil	nil	nil
Total Kjeldal Nitrogen	10	10	10	10	10	10	10	10
BOD	10	10	10	10	10	20	10	20
COD	AA	AA	AA	AA	AA	30	AA	30
Dissolved Phosphorus as P	1	1	1	1	2	5	2	5
Nitrate	10	10	10	5	10	10	10	10
Fecal Coliform/ 100 ml	nil	nil	nil	nil	nil	230	nil	230
Helminthic eggs/liter	AA[m]	AA	AA	AA	AA	<1	<1	<1
Color	Colorless	Colorless	Colorless	Colorless	Colorless	AA	Colorless	Colorless
Odor				Aseptic (Not septic and no foul odor)				

AA = as arising when other parameters are satisfied

Energy recovery from sewage sludge: In 2017, the Ministry of Power, proposed a new Draft National Energy Policy (Ministry of Power, 2017) with four key objectives: energy access at affordable prices, improved energy security and independence, greater sustainability and economic growth (Ministry of Power; International Energy Agency 2020). The Draft Policy has a clear focus on energy technology innovation. It aims to increase the share of renewable energies through international cooperation for cleaner energies as well as through infrastructure expansion and upgrading for modern and sustainable energy services (Ministry of Power, 2017; Breitenmoser et al., 2019a). The government of India targets to raise renewable energy production capacity from 36 GW in 2017 to 175 GW by 2022 from alternative energy sources hydro-power, wind, solar radiation and biomass (Ministry of New and Renewable Energy, MNRE, 2015). India's agreement at COP 21 Paris Climate Convention states that India will satisfy 40% of its energy requirements from non-fossil sources to reduce carbon emissions by 2030.

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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., 2019a). The MNRE estimates a potential of 120 MW to be produced from untapped industrial, agricultural and urban wastes (including wastewater) (MNRE, 2016). MNRE has been financing large-scale Waste to Energy (WtE) systems, such as biogas plants (> 1 MW), under the 'Energy Recovery from Urban, Industrial and Agricultural Waste Programme (WtE programme) since 2006. The CPCB had sent a circular to all State Pollution Control Boards in 2007 mandating green power production from methane present in biogas produced through anaerobic digestion of sludge. The Tariff Policy Amendment by the Ministry of Power in 2016, the release of the IS standard (biogas/biomethane for automotive applications and piped network (IS 16087), the amendment of the Central Motor Vehicles Rules (1989/2015), to allow the usage of compressed biogas (bio-CNG) in motor vehicles, as well as the National Policy on Biofuels (Ministry of Petroleum and Natural Gas, 2018a), have been designed on a national level to increase the utilisation of biofuels recovered from urban, agricultural and industrial wastes in the energy and transportation sector (Breitenmoser et al., 2019a).

Also relevant for energy recovery from sewage sludge is the related Initiative of Sustainable Alternative Towards Affordable Transportation (Ministry of Petroleum and Natural Gas, 2018b), which sets a target of 15 million tons compressed natural gas (bio-CNG) produced annually from organic waste sources such as sewage treatment plant sludge by 2023. Small-scale waste to energy (WtE) systems (mainly biogas systems) from faecal sludge are further promoted in the National Policy for Faecal Sludge and Septage Management 2017 (MoHUA, 2017).

Nutrient recovery from sewage sludge: A research initiative under MNRE in 2008 promoted medium-sized mixed-feed biogas fertilizer plants with a strong focus on demonstrating benefits of AD digestate as organic fertilizer (Breitenmoser et al., 2019a). The Ministry of Housing and Urban Affairs (MoHUA) has published recommendations for sludge disposal in 2013 in their Manual on Sewerage and Sewage Treatment Systems (CPHEEO, 2013). Sewage sludge is usually categorized as non-hazardous substance and thus regulated by Municipal Solid Waste Management Rules. The New Waste Management Rules, introduced in 2016 (Solid Waste Management Rules, 2016; CPHEEO, 2016), regulates the post processing of sewage sludge. The legally binding rules guide on treatment options (e.g., anaerobic digestion and post-composting) and set quality standards for sewage sludge (such as organic compost) used in agriculture (Wisniowska et al., 2019; Solid Waste Management Rules, 2016; Table 7). The Policy on the Promotion of City Compost by the Ministry of Chemicals and Fertilizers from 2015 aims to promote market development for municipal organic fertilizers/compost (Chander, 2016; Breitenmoser et al., 2019a).

Table 7: Specifications for organic compost quality (Solid Waste Management Rules, 2016)

Parameters	Units	Limit values for organic compost
Arsenic	mg/kg	10.0
Cadmium	mg/kg	5.0
Chromium	mg/kg	50.0
Copper	mg/kg	300.00
Lead	mg/kg	100.00
Mercury	mg/kg	0.15
Nickel	mg/kg	50.00
Zinc	mg/kg	1000.00
C/N ratio		<20
pH		6.5-7.5
Moisture	% by weight, maximum	15.0-25.0

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Bulk density	g/cm^3	<1.0
Total organic carbon	% by weight, minimum	12.0
Total nitrogen (as N)	% by weight, minimum	0.8
Total Phosphate (as P2O5)	% by weight, minimum	0.4
Total Potassium (as K2O)	% by weight, minimum	0.4
Colour		Dark brown to black
Odour		Absence of foul odour
Particle size		Minimum 90% material should pass through 4.0 mm IS sieve
Conductivity	dsm-1	4.0

Regarding un-sewered sanitation (septic tanks and pit latrine) the National Policy on Faecal Sludge and Septage Management (FSSM) issued by Ministry of Urban Development (now Ministry of Housing and Urban Affairs) in February 2017 sets the context, priorities, and direction for, and to facilitate, nationwide implementation of FSSM services in all Urban Local Bodies (ULBs) to achieve safe and sustainable sanitation. A key outcome that is expected from the widespread adoption of the FSSM policy is nutrient recovery where treated sludge is reused as fertilizer in farmlands, parks, gardens, etc. The FSSM Policy also looks at septage and faecal sludge as a potential source of energy to be adopted if feasible, as one of the productive uses (MoHUA, 2017).

2.2 Policy and regulatory framework of the National Capital Territory of Delhi

2.2.1 The Delhi Jal Board Act

The 1998 Delhi Water Board Act core aim is to establish the Delhi Water Board to undertake the responsibilities of water supply, sewerage and sewage disposal and drainage within the National Capital Territory of Delhi, excluding the areas under the New Delhi Municipal Council and Cantonment area. The Delhi Water Board has the following main functions:

- *Treat, supply and distribute water for household consumption or other purposes to those parts of Delhi where there are houses, whether through pipes or by other means;*
- *Plan for, regulate and manage the exploitation of ground water in Delhi in consultation with Central Ground water Authority and also give advice in this regard to the New Delhi Municipal Council, the Delhi Cantonment Board or any other local authority, except with the prior approval of the central government;*
- *Promote measures for conservation, recycling and reuse of water;*
- *If directed by the Government or the Central government, take over and carry out any functions relating to the management and regulation of sewerage and ground water or the drains of any area, hitherto being carried out by the Government, the Delhi Development authority or any other agency;*
- *Collect, treat and dispose-of sewage from any part of Delhi and carry out works connected with sewerage, sewage treatment and sewage disposal including the planning, design, construction, operation and maintenance of works…;*

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- *Take up or promote any other measures necessary for or ancillary to the functions of the Board laid down under this Act, including negotiations with other Boards or similar authorities, or the central or any state government, and entering into agreement with them, or the formulation and implementation of schemes, or research and development works;*
- *Make provision for unfiltered water supply.*

2.2.2 THE DRAFT WATER POLICY

The 2016 Draft Water Policy has as prime objective to ensure the long-term water security of the National Capital Territory of Delhi even under conditions of external flux. According to the Draft Water Policy the emergent policy issues that need to be addressed in Delhi are:

- Shifting the emphasis from supply side to demand side management
- Priority in Water Allocation – where the priorities will come into play in a situation where there is a shortage of water. Delhi needs to determine its order of sector priorities in a situation of scarcity
- Legal Issues
- Adjustment to Climate Change
- Recycled Water Resource – important is to highlight that the draft water policy has acknowledged that wastewater will have to be treated and recycled even up to drinking water level to reduce dependence on variable freshwater resources.

In this regards the Draft Water Policy notes critical actions to be taken such as:

- Recycled wastewater use target to be framed for 2019/2022/2027
- Recycled water usage to be encouraged to reduce freshwater imprint
- Norms of treated wastewater to be upgraded to at least tertiary levels
- Industries, power plants, large scale users in transport sector to changeover their water use to recycled water to the extent possible
- Promote use for irrigation, large gardens, flushing
- Use to be promoted by inductive tariffs or by regulation
- Use for indirect groundwater recharge and for water bodies maintenance
- Rebates may also be given for decentralized wastewater treatment where the same is put to reuse and curtails freshwater requirement. Decentralized STPs should be encouraged so that the resource loop can be closed near the point of generation. The bylaws in this regard may be strengthened
- In areas proposed for urban extensions in MPD 2021 the land use policy should provide for decentralized STPs
- Detergents: phosphate content in detergents is a major bane in pollution treatment as it is very difficult and costly to remove from the water stream. Many countries have acted to reduce the phosphate content in soaps from 14% to 5% thereby improving the quality of STP effluent. This again can be accomplished by tax instruments and discussion with manufacturers. The use of natural cleansers such as 'reetha' (Sapindus Mukorossi), would be promoted to decrease phosphate content and water used in laundry
- Further, treatment technology of existing STPs should be improved to get tertiary level output wherever possible. Thereafter, a command/influence area plan should be

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created for each STP. Targets for recycle and reuse would need to be fixed on a bi-annual basis

In Delhi, the Delhi Jal Board Act is of great importance, which since 1998 has provided guidelines to treat, supply and distribute water as well to promote measures for conservation, recycling of water; and reuse of water. It is pertinent for Delhi to approve the Draft Water Policy in order to provide an umbrella instrument where critical aspects regarding water and sanitation are unified and take into account long-term water security. Many participants of the workshops reflected on the importance of having this Draft Water Policy approved soon. They also highlighted the importance of better enforcement mechanisms when it comes to water pollution.

In the Draft Water Policy Delhi has aspired to treat and reuse 25% of total sewage produced by 2017, and increase the same to 50% by 2022, and to 80% by 2027. However, the Delhi Jal Board officials who participated in the workshop also highlighted that the market for treated wastewater is limited indicating that there is a need to establish a market for the resource through a business model that allows effective cost-recovery for the ULB.

2.3 The policy and regulatory frameworks of Uttar Pradesh

2.3.1 The Uttar Pradesh State Water Policy

The core objectives of the 1999 Water Policy for Uttar Pradesh (UP) are as follows:

- To ensure preservation of the scarce water resources and to optimise the utilization of the available resources;
- To bring about qualitative improvement in water resource management which should include user's participation and decentralization of authority;
- To maintain water quality, both surface and underground, to established norms and standards;
- To promote formulation of projects as far as and whenever possible on the concept of basin or sub-basin, treating both surface and the ground water as a unitary resource, ensuring multipurpose use of the water resource. This would include the following main uses:
    - Drinking and domestic use
    - Irrigation
    - Hydro power generation within the constraints imposed by other users.
    - Industries including agro-industries
    - Navigation, recreation, health and for other uses
- To ensure ecological and environmental balance while developing water resources;
- To promote equity and social justice among individuals and groups of users in water resource allocation and management;
- To ensure self-sustainability in water resource development;
- To ensure Flood Management and drainage as integral part of water resource development;
- To provide a substantive legal framework for management;
- To provide a Management Information System (M.I.S.) for effective monitoring of policy implementation;
- To promote research and training facilities in the water resource sector;
- To provide mechanism for the resolution of conflicts between various users.

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2.3.2 The Uttar Pradesh Water Supply and Sewerage Act

The 1975 Water Supply and Sewerage main aim is the establishment of a corporation, authorities and organisations for the development and regulation of water supply and sewerage services and for matters connected therewith. The created corporation is the Uttar Pradesh Jal Nigam, which has as main functions, the following:

- *'The preparation, execution, promotion and financing the schemes for the supply of water and for sewerage and sewage disposal;*
- *To render all necessary services in regard to water supply and sewerage to the State Government and local bodies…;*
- *To prepare State plans for water supply, sewerage and drainage on the directions of the State Government;*
- *To review and advise on the tariff, taxes and charges of water supply in the areas of Jal Sansthans and local bodies…;*
- *To assess the requirement for materials and arrange for their procurement and utilisation;*
- *To establish State standards for water supply and sewerage services;*
- *To perform all functions…, which were being performed by the Local Self-Government Engineering Department…;*
- *To review annually the technical, financial, economic and other aspects of water supply and sewerage system of every Jal Sansthan or local bodies…;*
- *To establish and maintain a facility to review and appraise the technical, financial, economic and other pertinent aspect of every water supply and sewerage scheme in the State;*
- *To operate, run and maintain any waterworks and sewerage system…;*
- *To assess the requirements for manpower and training in relation to water supply and sewerage services in the State;*
- *To carry out applied research for efficient discharge of the functions of the Nigam or a Jal Sansthan;*
- *Any other functions entrusted to the Nigam by or under this Act…'.*

This Act also stipulates that if the State Government considers necessary it can also create organisations called Jal Sansthan. These organisations will be created if local conditions or expedient for the improvement of water supply and sewerage services, in any particular area, are needed. The main functions of a Jal Sansthan are as follows:

- *'To plan, promote and execute schemes of and operate an efficient system of water supply;*
- *Where feasible, to plan, promote and execute schemes of, and operate, sewerage, sewage treatment and disposal and treatment of trade effluents;*
- *To manage all its affairs so as to provide the people of the area within its jurisdiction with wholesome water and where feasible, efficient sewerage service;*
- *To take such other measures, as may be necessary, to ensure water supply in times of any emergency;*
- *Such other functions as may be entrusted to it by the State Government…'*

2.3.3 The Draft policy on wastewater recycle and reuse in urban local bodies

In the 12th schedule of the Indian constitution, it is a function of municipalities to provide the safe water supply and hygienic sanitation facilities to urban citizens. Municipalities are performing this function of the

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supply of safe drinking water as per their capacity in municipal areas. However, about 80% water used by the urban community comes out of houses in the form of wastewater which unless properly collected, conveyed, treated and safely disposed of may eventually pollute the water resources and cause environmental degradation and disease-causing pathogens. The volume of wastewater generation, combined with the decreased volumes of fresh water available for drinking water supply, irrigated agriculture, and industries caused the state of UP to consider the adoption of source substitution and wastewater reuse, recycle policy.

Therefore, currently the state of UP seeks to adopt a new policy on wastewater reuse and recycle. According to the draft policy the rationale behind adopting this wastewater reuse and recycle policy entails the following:

- *'Coping with the water scarcity situation;*
- *Protecting the public health and the environment;*
- *Water allocation and movement among sectors also need to be driven by economic motives;*
- *Applying the Integrated Water Resources Management (IWRM) approach and best practices;*
- *Considering the Policy as part or mitigation measures of the effect of climate change;*
- *Increasing the amounts of treated wastewater (WW) and considering it as a potential water and revenue source'.*

Among the main objectives of this draft policy are as follow: (i) to direct the water sector towards more efficient use of water resources. It details the intention to reuse treated wastewater in irrigation that enables freeing fresh water to be utilized for municipal uses. It also provides for using the treated wastewater in other economic activities. It calls for expanding collection and treatment of wastewater, updating and development of standards and practices for substituting fresh water used in irrigation and industry by treated wastewater after blending it. (ii) to increase surface water utilisation for municipal uses and thus decreasing the strain on ground water. (iii) the implementation of centralized wastewater collection and treatment systems.

This draft policy is quite comprehensive and touches upon many different aspects. These include as follows:

- *Substitution priorities*
- *Institutional and Administrative Arrangements*
- *Resource Management*
- *Resource Development*
- *Legislation and Institutional arrangements*
- *Public acceptance*
- *Public awareness*
- *Technology, research and development*
- *Wastewater collection and treatment*
- *Reuse of treated effluent and sludge*
- *Wetland and river/stream flow augmentation*
- *Constructed wetlands*
- *Reuse of recycled water*
- *Pricing financing and investment*
- *Standard, regulations and quality assurance*
- *Human resource development and research and development*
- *Selected priority issues*
- *Operation and maintenance*

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- *State level implementation strategy*
- *Monitoring and evaluation*
- *Incentive*
- *Demand profiling*
- *Policy evaluation*
- *Power of state government*

2.3.4 Uttar Pradesh Water Management and Regulatory Commission Bill

The 2008 UP Water Management and Regulatory Commission Bill establishes the UP Water Management and Regulatory Commission. This commission aims are: (i) to regulate water resources within the State; (ii) to facilitate and ensure judicious, equitable and sustainable management, allocation and optimal utilization of water resources for environmentally, economically sustainable development of the State; (iii) to fix the rates for water use for agriculture, industrial, drinking, power and other purposes and cess on lands benefited by flood protection and drainage works from the owners of lands benefited through appropriate regulatory instruments according to State Water Policy.

The Commission has the following powers and perform the following functions:

- *To approve the Integrated State Water Plan/Basin Plans developed by State Water Resources Agency to ensure sustainable management of water resources within the parameters laid down by State Water Policy;*
- *To determine the allocation and distribution of entitlements for various category of use of water at utility, project level and also between various water user entity within the parameters laid down by the State Water policy on such terms and conditions as may be prescribed for such a distribution;*
- *To lay down the criteria for modifications in the entitlements for the diversion, storage and use of surface and ground water of the State;*
- *To review and accord clearance to new water resources projects proposed at the river basin/sub-basin level by the concerned entity ensuring that the proposal is in conformity with Integrated State Water Plan specially with respect to the water allocation of each entity, that is economically, hydro-geologically and environmentally viable;*
- *To establish a system of enforcement, monitoring and measurement of the entitlements for the use of water to ensure that the actual use of water, both in quantity and type of use are in compliance with the entitlements as issued by the Commission;*
- *To monitor conservation of environment and facilitate the development of a framework for the preservation and protection of the quality of surface and ground water resources as per established norms and standards;*
- *To withdraw the entitlement or take any action as deemed necessary in case any water user entity pollutes or causes to pollute any surface or ground water source of water and thereby infringes the maintenance of established norms and standards for water quality;*
- *To impose penalty on any organization or agency, whether government or private, any individual or a group of individuals who changes, alters or cause to change or alter the status of any surface or groundwater resources without the specific sanction or approval of the Commission.*
- *To periodically review the entitlement as and when considered necessary;*
- *To register and monitor bulk water entitlement by the Commission or its duly authorized representatives,*
- *To promote competition, efficiency and economy in the activities of the water and wastewater sector to minimize wastage of water;*

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- *To promote better water management techniques;*
- *To enforce rain water harvesting to augment ground water recharge;*
- *To fix and regulate a water tariff system and charges for the use of water after due consideration to all costs including administration, operation, maintenance, depreciation, and subsidies.*
- *To review and revise the tariff/ water charges periodically;*
- *To determine and fix the rate of cess to be charged from owner of lands benefited by flood protection and drainage works implemented under new projects.*
- *To enforce the decisions or orders issued under this Act by a suitable agency authorized by the Commission or empower to any existing agency for this purpose;*
- *To aid and advise the State Government on any matter referred to the Commission by the State Government.*

UP has managed to design and have in place significant regulatory instruments in regard to water protection and water supply and sanitation. However, it is still in dearth of clear provisions and guidelines regarding wastewater recycle and reuse.

Many participants of the workshops reflected on the importance of improving and updating sewage systems in UP as the impacts from poor or non-existent sewage systems is seriously polluting water resources all over the state. As it was the case in Delhi, the attendees of the workshops stressed the need of better enforcement mechanisms when it comes to water pollution.

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CHAPTER 3 STAKEHOLDER ENGAGEMENT AND RESPONSES

3.1 INTRODUCTION

Water sector reforms and development of effective policies and regulations requires multistakeholder partnerships and regular stakeholder engagement to gather responses critical for enhanced acceptability and sustainability of identified interventions. Participatory stakeholder engagement is also fundamental to achieving 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) (United Nations, 2015).

PAVITRA GANGA project employs stakeholder engagement as an important pillar for the project outcomes. In collaboration with local stakeholders and supported by industrial partners PAVITRA GANGA is working further with the pilot site established at the Barapullah Drain (New Delhi) and developing a new pilot site at the Jajmau STP (Kanpur). It is important to understand the current wastewater situation in New Delhi and Kanpur, what the past experiences are with wastewater treatment and RRR and how we can envisage the future of wastewater treatment and RRR for India.

Entrusting this, two stakeholder consultation workshops were held at the initial stage of the project, one in New Delhi and one in Kanpur. The innovative wastewater treatment and reuse technologies that are being developed and piloted in the Pavitra Ganga Project in Delhi and Kanpur were presented. Stakeholders' responses were attempted from the two sites involving key questions related to the following:

1.Opportunities/constraints of the existing policy, regulatory and institutional set up currently dealing with wastewater/excreta disposal treatment systems and reuse
2. Opportunities/ constraints of the existing technology landscape for the wastewater and excreta disposal treatment practices.
3. Past experiences with wastewater reuse as well as resource recovery.

(See Annex 1 and 2 for the agenda for New Delhi and Kanpur respectively. See Annex 3 and 4 for the list of participants of the workshop at New Delhi and Kanpur respectively).

3.2 KEY RESPONSES FROM DELHI STAKEHOLDERS' CONSULTATION

The stakeholder consultation workshop in New Delhi was attended by key actors spanning national, state, local levels, NGO's and companies including representatives from from Ministry of Jal Shakti, National Water Mission, CPCB, Delhi Jal Board, Technology Providers, Research Institutions and NGOs. Some of the key responses that evolved out of consultation process are as discussed below.

3.2.1 POLICY, REGULATORY AND INSTITUTIONAL

The participants discussed the current policy and regulatory framework {such as Environment Protection Act 1987; Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016; Guidelines on Implementing Liabilities for Environmental Damages due to Handling and Disposal of Hazardous Waste and Penalty 2015; Environmental Notification 2017 – CPCB; Environment Compensation Policy}, as well as

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relevant institutional framework {related to key agencies such as CPCB, DJB, NMCG, etc.}. Following constraints and the potential opportunities emerged from the discussions.

Constraints

- The existing policies are often implemented in silos – loads and volumes.
- Faecal sludge treatment is important however only draft regulations exists.
- There is little or no penalty for small and medium scale industries.
- Sewage connection and water connection are mostly free of charge, although there are charges in water connection in some places. Free provision of water and no sewerage charge was seen as another constraint for the efficient operation and maintenance of water and wastewater infrastructure.
- Demand for reclaimed water is very low.
- Conveyance of the treated wastewater is the main problem in its reuse. Since the STP's are far away from irrigation fields, their cost is high as compared to fresh water (groundwater) which is almost free of charge.
- Rational water pricing policy is mostly lacking. Free of cost water is likely to be more wasted.
- There should also be a zero liquid discharge for industries where they can efficiently use their treated wastewater within their premises without discharging their wastewater in nearby water bodies.
- Awareness campaigns are vital and needed to promote the wastewater reuse interventions. Schools could be the starting level.
- An integrated pollution load and concentration based planning of sewage systems is lacking.

Opportunities

- Use of reclaimed water for gardening purposes. Also treated sewage water can be used in power generation and production processes.
- There should be a detailed planning and survey before establishing any treatment plant in an area to gauge the load and concentration of the sewage which will be treated by the particular plant to increase its efficiency.
- After wastewater treatment a minimum amount of water should be discharged in the water bodies (rivers) so as to maintain their minimum natural flow and to balance the river ecosystem, to improve the overall sustainability of water resources.
- Rational pricing of water and wastewater services for efficient use and O&M.
- Community awareness and collaborative action is needed to create demand for the end-products from the STPs. Incentives should be provided to ensure reuse of treated wastewater.

3.2.2 Technology landscape for wastewater treatment and disposal

In Delhi there are two types of wastewater treatment processes. The authorized establishments are covered under 100% sewerage system out of which 99% are conventional STPs and 1% decentralized systems. In unauthorized colonies, septic tanks are present for sewage disposal. The open drains have no flow during summer systems. An interceptor system has been developed to pump sewage from septic tanks and transport it to the STPs for treatment.

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Constraints

- Laying of new sewage collection pipelines in unauthorized establishments is difficult due to lack of space.
- Most of the STPs are equipped with an Activated Sludge Process (ASP), which are expensive in operation and maintenance and need skilled labour that is not readily available.
- The STPs are overloaded, resulting in reduced efficiency. Failure of wastewater treatment systems may also be attributed to the failure of operation and maintenance process after implementation of technologies.
- Faecal coliforms and heavy metals have been detected in vegetables irrigated with raw sewage. At present, STPs test quality of effluent only once a week. Continuous monitoring system for effluents before discharge is required.
- There is no faecal sludge treatment system. Also, the sludge generated from conventional STPs has very few users.
- In peri-urban areas open drains are present through which sewage flows, which allow for other municipal solid waste to be dumped which affects the performance of STPs.
- Industrial as well as pharmaceutical waste might be present in the sewage.
- There is little acceptability for the concept of "toilet to tap".

Opportunities

- Treated wastewater can be used (preferably) for river augmentation.
- Pricing models should be created for freshwater and treated wastewater to encourage reuse of wastewater and valuation of freshwater.
- A combination of conventional and (cheaper) decentralized system of wastewater treatment seems the way to go.
- Step-wise upgrading of the STPs is necessary, to manage the increasing population and subsequent pollution load in Delhi.
- Optimisation of technology and scale is required for decentralized plants so that they can be maintained well on the site.
- STPs should be developed taking cost recovery into account.

3.2.3 Experiences on wastewater reuse and resource recovery

In the context of past experiences with wastewater reuse and RRR in Delhi, the following points were highlighted:

- In Delhi, there is reuse of treated wastewater to some extent. Treated wastewater from Okhla and Keshopur STPs are used in various gardens around India Gate.
- Currently only about 15% of treated wastewater is actually reused in horticulture. Delhi Jal Board would like to bring it up to 70%.
- Wastewater reuse as well as resource recovery is influenced by the under as well as over-capacity of the STPs. This is caused because of unplanned urban growth and lack of service provision/connectivity.
- Drinking water standards require about 64 parameters to be met that was felt to be not realistic as first step. Further, treatment for 'drinkable purpose' requires approval of other agencies besides the DJB. There was a felt need to start with low hanging fruits in order to learn about reuse first and then potentially 'step up' to potable reuse.

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- Cities downstream indirectly use wastewater of other cities for potable purposes via surface water dependent drinking water production facilities.
- Need to identify and define water reuse indicators and develop policy/standards to achieve that. Standards from EU and USA may be considered.
- Wastewater reuse is constrained with lack of transportation network, long distance between STPs and agricultural fields, poor quality of treated effluents and poor monitoring systems. Framework of treated wastewater reuse needs to look at who bears the cost of transportation of the treated wastewater to the users and who are the responsible actors/entities/contributors.
- There is very little use of the sludge. There are no agricultural lands within or in the periphery of the city due to which people are not interested in taking sludge from STPs despite it being provided completely free.
- There should be stringent norms/ clarity on norms/ certified quality system with respect to parameters of wastewater use in agriculture. MoEF&CC 2017 norms are present for wastewater reuse. But enforcement and monitoring is required.
- Decentralized systems are required to be established in larger number for reuse of wastewater in peri-urban and rural areas.
- Advisory board on wastewater reuse should engage at grass-root level for mobilization and capacity building.

3.3 Key responses from Kanpur stakeholders' consultation

The stakeholder consultation workshop for Kanpur was held at the Indian Institute of Technology, Kanpur campus. The workshop saw participation from state and city level agencies, NGOs and academic institutions including experts from Uttar Pradesh Jal Nigam, Uttar Pradesh Pollution Control Board, National and State Mission for Clean Ganga, Solidaridad Asia, and Researchers from CSIR Indian Institute of Toxicology Research, Lucknow, Harcourt Butler Technical University Kanpur and IIT-Kanpur.

3.3.1 Policy, regulatory and institutional

The participants discussed the current policy, regulatory and institutional framework in the context of state and the city, and the following major responses emerged from the discussions:

- NGT has published revised norms for wastewater disposal. Earlier Central Pollution Control Board had given different norms for metropolitan cities and other cities. But NGT rejected the same stating dual norms cannot be implemented.
- With the current infrastructure, it will take time to achieve such standards. The design parameters of existing SPTs have also to be revised to achieve such standards. The new standards can possibly be achieved in projects which are under implementation.
- For achieving the stipulated norms of wastewater treatment, support from public and other stakeholders is required. At present, the Government of Uttar Pradesh has started a scheme to connect every house to sewerage network.
- Inadequate load handling is a major cause of inefficient performance of STPs. Decentralized technologies like in situ treatment of drains can be implemented to reduce transportation and other associated costs of wastewater treatment.
- There should be research and collaboration between research institutions and technology providers to scale up and work towards feasibility of the technological and institutional setup.

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- There should be some People Private Partnership for operation and maintenance of these systems. Working capacity of STPs should be monitored, as it has been usually observed that STPs work over capacity, so they have to bypass the raw sewage.
- Unauthorized colonies have to apply to be authorized. But after authorization, treatment of sewage from these colonies has to be incorporated in planning and policies for the cities.
- Due to industrial ingression sewage has mixture of toxic discharges from industries. So meeting norms at discharge is difficult. There should be a system to separate industrial water and sewage, and policies so that industries which discharge effluent to sewerage system, should maintain industrial discharge norms.
- Jajmau STP (treats about 170-180 MLD) producing large amount of solid waste which is hazardous. A TSDF is being planned to be constructed for disposal of hazardous waste. Safe disposal of solid waste has to be considered and planned as volume and toxicity of these wastes will increase in future.

Reflections on the regulations for reuse of treated wastewater

- There are no regulations for reuse of treated wastewater for agriculture. A Memorandum of Understanding has been signed with railways to reuse treated wastewater.
- There is a policy for Thermal Power Plants to reuse treated sewage if it is located within 50 km of an STP. Industries have their own standards for usage of water in various processes, but they have to be incentivized to reuse their wastewater.
- Incentives should be in term of monetary benefits. A policy can be developed wherein GST charges may be exempted from environment friendly industries.
- The volume of industrial wastewater is less, but more toxic compared to sewage. Smaller industries cannot invest in high cost technologies. So suitable low cost technologies should be in place for smaller industries.
- There should be mass awareness regarding segregation of waste. In absence of guidelines, WHO standards can be used as broad guidelines, and depending on local situations, new norms should be developed.

3.3.2 Technology landscape for wastewater treatment and disposal

Regarding the wastewater and excreta disposal treatment practices, the main themes discussed included the following:

- The STP in Jajmau has UASB technology. A new STP has been commissioned. Septic tank sludge is discharged in local drains, enforcement to pay for this is required.
- No faecal sludge treatment plant (FTP) is being constructed in Kanpur.
- There are proper treatment technologies present but the by-product sludge is of concern, requiring other treatment technologies or valorisation of sludge. For example, Solidaridad (Kanpur) converted lime sludge of tanneries to bricks.
- The complexity of the wastewater and disposal of toxic sludge from STP at Jajmau were perceived by the participants to be major constraints in wastewater treatment and reuse in Kanpur.
- There should be mass awareness regarding separation of waste. In absence of guidelines, the World Heath Organization standards can be used as broad guidelines, and depending on local situations, new norms should be developed.

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3.3.3 Experiences on wastewater reuse and resource recovery

In the context of past experiences with wastewater reuse and resource recovery in Kanpur, following points were highlighted:

- Currently, treated wastewater is being reused in tanneries, as well as for irrigation and in future it may be potentially reused for railways, Thermal Power Plants (TPP), forestry, non-agricultural irrigation.
- Water reuse is being promoted in tanneries to reduce the money for extracting water from ground (in terms of electricity fee).
- There is use of untreated wastewater in irrigation since 1989 in the Jajmau area, which has deteriorated the quality of soil and groundwater. Proposal for zero liquid discharge in the CETP-STP was not implemented due to high cost of O&M. Treated wastewater from the canal is readily available to be used by farmers. The farmers from the nearby villages are not financially well to do and not everyone can afford to buy drinking water cans which costs about INR 1 per litre of water. Due to groundwater contamination, deeper bore well has to be installed to pump water. There is no alternative to treated wastewater in the region.

Opportunities

- Zero liquid discharge in could be adopted in a phase wise manner.
- Technology upgradation is required which can treat wastewater to safe levels, without posing threat to the environment or health of people.
- Decentralied systems can be used. For example, drains are treated in situ and treated wastewater is supplied to the area in the vicinity of drains.
- There should also be research and collaboration between research institutions and technology providers to scale up and work towards feasibility of the technological and institutional setup.

Constraints to wastewater reuse

- Assurance of quality and quantity of reuse water is lacking.
- Water Quality Index (good or bad) for different uses is needed.
- Higher cost of treated wastewater as compared to groundwater which is not adequately priced.
- Inadequate or lack of mechanism and infrastructure and high cost of transportation of treated sewage from STPs to users.
- Adequate pricing of the resource and infrastructure services is required.

Resource Recovery

- Sludge from tanneries usually is sent to landfill. sludge contains 12g/kg of chromium. Brick making could be an option.
- There are pilot projects to explore possible usage of tannery by-products. For example from raw trimmings, whips can be manufactured.
- Sludge should be converted to usable product, e.g., bio-compost. Bio composting can be promoted in areas where organic farming is practised.
- Government should provide some incentives to recycle by-products. Incentives can also be provided to industries using cleaner technology for production.

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- Regulations for solid waste management and recycle are available in Solid Waste Management Rules 2016.

Economic viability

- A PPP Model should be created wherein the capital cost is invested by the Government and O&M costs are borne by private companies.
- The villagers cannot pay INR 1 per litre for availing water, the current price. Hence economic sustainability of projects should be considered.

3.4 CONCLUSIONS

To sum up, the two stakeholder consultation workshops allowed the PAVITRA GANCA team to understand the opinions and views of diverse stakeholders on core challenges and opportunities of wastewater treatment and RRR in India, particularly in Delhi and Kanpur. Therefore, this chapter provided the key elements of the narrative synthesis that stemmed from both workshops.

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CHAPTER 4 ANALYSIS OF SUCCESSFUL AND UNSUCCESSFUL EXPERIENCES WITH WASTEWATER TREATMENT AND RESOURCE RECOVERY TECHNOLOGIES IN INDIA AND EUROPE

4.1 ASSESSMENT CRITERIA

Globally, the uptake of wastewater treatment technology and RRR systems have been slow despite its various benefits towards sustainable production and consumption systems (Otoo and Drechsel, 2018). Recent international experiences, i.e. Lautze et al., 2014, WWAP, 2014, Otoo and Drechsel, 2018, show that the sustainability and scaling-up of wastewater treatment and RRR systems is affected by the political, technical-operational, environmental, economic, socio-cultural and policy-legal-institutional settings ('enabling environment') that influence RRR management and governance. The enabling environment for wastewater treatment and RRR has been recently analyzed for the broader Indian context by Breitenmoser et al., (2019a; 2019b) using selected assessment criteria affecting technology sustainability and scaling-up.

The analyzes found that technology selection in India is generally influenced by political preferences, regulations and tender processes but often fail to consider the long-term development perspective. Land, water and energy scarcity are triggers to alternative solutions, including wastewater treatment and RRR technologies and are promoted in current national policies and initiatives (Breitenmoser et al., 2019a; 2019b).

The enabling environment for wastewater treatment and RRR systems varies between and within countries, thus, potential barriers for the sustainability and market uptake of innovative technologies need to be addressed and investigated deeper in specific case studies. Therefore, learning from current practices facilitate a better understanding of favorable conditions for governing wastewater technology and RRR systems in India and beyond (Lautze et al., 2014).

In order to analyze, compare and contrast different experiences in wastewater treatment and RRR governance arrangements in India and the EU, an adapted version of the assessment framework developed by Breitenmoser et al., (2019b) is used. With regard to the aim of this assessment, wastewater treatment and RRR governance is defined as political, socio-economic and institutional systems in place that influence their management and delivery in a given context. Therefore, the subsequent discussion of 13 selected case studies (Table 8) focusses on **policy and law factors** to exemplify the role of national/state policies and laws in triggering wastewater treatment and RRR systems, i.e. water, energy and nutrients recovery for agricultural, industrial or urban reuse. Further, **technical-operation factors** that may positively (enablers) or negatively (barriers) affect wastewater treatment and RRR systems are identified. Therefore, different treatment technology designs and their operation and maintenance requirements are discussed. Wastewater treatment and RRR governance arrangements such as the role (enabling factor/barrier) of socio-economic and institutional factors are also outlined. This analysis will provide important insights for the operational sustainability and market uptake of Pavitra Ganga technologies.

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Table 8: Case study overview (with chapter and section number)

Resource recovery sewage treatment plants	India	Europe
Water reuse for agriculture	• Jajmau, Kanpur (4.2)	• Alicante, Spain (4.7) • Barcelona, Spain (4.8)
Water reuse for industry	• Nagpur, Maharashtra (4.3)	• Schilde, Flanders, Belgium (4.9)
Water reuse for other purposes (managed aquifer recharge)		• Wulpen, Flanders, Belgium (4.10)
Biogas from sewage sludge for electricity production	• Kodungaiyur, Tamil Nadu (4.4) • Rithala, New Delhi (4.5)	• Flanders, Belgium (4.11)
Sewage sludge for agriculture (organic fertilizer)	• Amehdabad, Gujarat (sludge irradiation; 4.6)	• Pavia, Lombardy, Italy (4.12)
Phosphorous recovery from sewage sludge (mineral fertilizer)		• Flanders, Belgium (4.13) • Zurich, Switzerland (4.14)

4.2 Indian context, Jajmau, Kanpur, Uttar Pradesh Case Study (agricultural reuse)

Introduction

The city of Kanpur covers an area of 1,040 km^2 and about 22 km of the river Ganga falls within its city limits (Singh, 2006). It is one of the major industrial cities in North India. The estimated sewage generation of Kanpur city is about 339 MLD (Bassi et al., 2019). Two sewage treatment plants (STPs; 5 and 130 MLD) and one common effluent treatment plant (CETP; 36 MLD) located in Jajmau (North-East part of Kanpur, right bank of river Ganga) treat about 50% of the generated sewage.

This region experiences variable rainfall and is not connected to any irrigation canal network (Singh, 2006). Therefore, treated effluent from STP and CETP are mixed and provided for irrigation through an irrigation canal (Figure 8). Until 1986, freshwater from Ganga was used to dilute raw sewage in the irrigation channel and then provided to farmers. The diluted sewage was a reliable source of water for farmers. Wastewater was lifted from the drain and used for irrigation of agricultural fields lying at the vicinity of the drain. A study by IWMI (2013) reports that farmers gained higher income on farming food crops and fodder with sewage as compared to groundwater (Amerasinghe et al., 2013). This was because farmers did not have to pay for wastewater but also because of a reduced need for fertilizers due to high nutrient content of sewage.

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Figure 8: Irrigation channel of partially treated effluent from the Jajmau CETP and STP (© M. Phukan)

However, after the introduction of the Ganga Action Plan (GAP) and subsequent construction of the STP and CETP, treated sewage mixed with tannery effluent was supplied through the drain (Singh, 2006). Technological design of the CETP, not taking into account long-term development of the area, has resulted in low quality irrigation water not meeting requirements as defined by the Food and Agricultural Organization (FAO). The deterioration of quality of wastewater caused decrease in crop yield and lead to contamination of soil and groundwater (Amerasinghe et al., 2013).

POLICY INTERVENTIONS

Introduction of river protection plans enhancing municipal wastewater treatment infrastructure

The introduction of the GAP has had some positive effect on the development of wastewater technologies and creation of STPs for pollution abatement. It sought to improve the water quality by interception, diversion and treatment of domestic sewage and toxic and industrial chemical wastes from identified polluting units. Under GAP-I, the three WWTPs (5 MLD UASB, 36 MLD UASB and 130 MLD ASP) were constructed at Jajmau at Kanpur. Though GAP had some positive effects in terms of development of wastewater technologies and creation of STPs for pollution abatement, the overall experience with GAP however has been that it was not able to completely achieve its objectives due to multiple factors including inadequate technological designs that could not adequately treat the mixed toxic discharges from industrial and domestic sources.

Currently the state of Uttar Pradesh (UP) does not count with a specific policy that aims to incentivize the reuse of treated water. There is only a draft policy as discussed in Chapter 2.

WASTEWATER TREATMENT TECHNOLOGY DESIGNS

A short description of the treatment technologies (Pandey and Deb, 1999; JICA, 2005) used in the STP and the CETP in Jajmau region are given below:

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A 130 MLD STP commissioned in January 1999 based on the activated sludge process

Primary treatment: the inlet chamber receives the raw sewage. In a screen channel floating matters are trapped and removed, and grit is removed in grit chamber. Thereafter the sewage is conveyed to primary clarifier.

Secondary treatment: after primary settling in the clarifier, sewage is treated using the activated sludge process. The wastewater from aeration tank is sent to secondary clarifier where the settleable solids are settled. A part of the settled solids are recirculated back to the aeration tank and excess sludge is removed.

Tertiary treatment: the treated sewage goes from the secondary clarifier to chlorine disinfection unit. The sludge from primary and secondary clarifier are mixed together and conveyed to gravity thickener after which sludge is digested in a digester system where biogas is produced.

A 36 MLD CETP commissioned in 1993 based on Upflow Anaerobic Sludge Blanket (UASB) (as well as a 5 MLD pilot plant commissioned in 1989)

Primary treatment: the system of conveyance of wastewater is partly underground and partly open. A 12 km conveyance system consisting of 4 pumping stations is used for pumping the wastewater from tanneries to the CETP. Each pumping station is equipped with a grit chamber and a screen to remove the suspended matter from the wastewater. Domestic sewage is pumped through a pumping station to the treatment plant, which also passes through a screen and grit chambers. Industrial wastewater (9 MLD) and domestic sewage (25 MLD) are mixed in the equalization tank to achieve a homogeneous stream of wastewater. The mixed effluent is fed to the UASB reactors for treatment.

Secondary treatment: UASB is a high rate and compact anaerobic process requiring an average retention time of about 8 hours wherein organic pollutants are broken down through bacteriological processes.

Post treatment: the treated effluent from the UASB reactors is subjected to aerobic treatment in order to further reduce the BOD.

Finally, the effluent is then mixed with the treated wastewater from the 130 MLD sewage treatment plant and discharged for irrigation via a canal. Sludge is further processed and pumped to the sludge thickener for thickening. The thickened sludge is then gravitated to the sludge drying beds for dewatering.

TECHNICAL-OPERATIONAL DRIVERS AND BARRIERS

Poor quality of treated effluent (irrigation water)

A report by CPCB (2016) submitted to the National Green Tribunal (NGT) showed that the CETP treated wastewater did not meet the irrigation water use standard and the standards for effluent discharge on land for irrigation as prescribed by EPA and MoEFCC for parameters such as BOD, COD, Suspended Solids, Chlorides, Oil and Grease (Table 9). Additional studies have monitored elevated chromium (Cr) levels and other heavy metals (Pb, Zn, Cu) as a result of industrial activities (CPCB, 2016). Out of the 220 tanneries using chrome for tanning of hides, only 88 have installed chrome recovery units (Singh, 2006). Due to high operating cost of chrome recovery, only a few tanneries are able to operate these units. Therefore, chrome finds its way to the irrigation channels and subsequently to the agricultural fields. The effluent flowing through the irrigation canal was black in colour, emitting foul odour. Black sludge was also seen accumulating near the drain. Also study by CPCB observed that the primary treatment including chrome recovery by the member units was not satisfactory and the pre-treated wastewater received at CETP contains excessively high concentration of chromium (77.20 mg/l against desired characteristic of 2 mg/l) and suspended solids. (CPCB, 2016).

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Inadequate technological design and capacities

The UASB technology was designed in 1993 to co-treat the industrial wastewater from tanneries (9 MLD) and domestic sewage (25 MLD) (in 1:3 ratio) in order to make the mixed wastewater more amenable for biological treatment. The CETP was designed considering effluent flow from 175 tanneries. However, by the year 2015, the number of tanneries operating in the region increased to 350 and the volume of tannery effluent increased to 26 MLD. Though the volume of effluent from tanneries increased, there was no optimization of the treatment capacity of the CETP. Out of 26 MLD, 13.5 MLD was sent to the CETP, making treatment inefficient, while remaining 12.5 MLD is discharged untreated to the irrigation canal.

UASB is highly land and energy intensive and has constraints while treating sewage with varying loads of Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and coliform. It is incapable to remove pathogen and coliforms effectively. Discharge of partially treated wastewater is acceptable only if there is substantial flow in river or treatment plants are operated with full capacity. The less volume of water in the river is not adequate for dilution of wastewater. Hence, STPs and ETPs in the Ganga Basin should not have a bypass mode.

Coupled with these were the frequent electricity break-downs (power shedding of about 5-6 hours every day) causing disruption and discharge of untreated/partially treated sewage leading to contamination of soil and groundwater in the region and reduction in yield of food crops (e.g. wheat and rice), due to the use of wastewater from irrigation drain (IWP, 2012).

Table 9: Results of monitoring of samples collected from CETP. All units in mg/L unless specified. (Sampling date: 28.11.2015) Source (CPCB, 2016)

Parameter	CETP Inlet	CETP Outlet	Irrigation Channel	EPA Standards for Irrigation	Max. Permissible Values for CETP treated Effluents (on land for Irrigation)*
pH	8.25	8.05	8.06	5.5-9.0	5.5 – 9.0
Oil and Grease	86.6	16.1	21	10	10
Suspended Solids	1081	199	83.8	200	100
Total Dissolved Solids	5876	3362	1870	2100	-
BOD	601	201	64.5	100	100
COD	1203	423	212		250

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Faecal Coliform (MPN/100 ml)	2.2 x 106	1.7 x 106	1.4 x 106	-	-
Chloride as Cl-	2614	1825	572	600	1000
Sulphate as SO4-	1086	111	208	-	1000
Phosphate as P	0.367	0.631	0.643	-	-

*Environment Protection Amendment Rules dated 1st January, 2016

#The study by CPCB (2016) during 2015, reports the content of Total Chromium (Cr) in the outlet of the CETP as 23.4 mg/l and Cr in the irrigation channel is reported as 1.98 mg/l.

OTHER DRIVERS AND BARRIERS

Inter-institutional coordination issues and lacking cost-recovery

Besides the technical and operational barriers, there has been also a difference of opinions amongst the tannery owners, UP Jal Nigam (UPJN), Kanpur Nagar Nigam (KNN) and UP Pollution Control Board (UPPCB) (Singh, 2006). These differences exist in relation to the leather industry's measures to reduce pollution; replacement of existing technology and defunct machinery due to low finances; failure in collecting O&M charges for maintenance of the CETP; low cost recovery in low revenue applications such as agricultural irrigation; poor maintenance of the CETP. The multiplicity of organizations involved in the process has issues of accountability and it is difficult to provide a decisive direction towards the problem (Singh, 2006).

CONCLUSIONS

Kanpur case may not have been a very successful experience of wastewater treatment and reuse as the planning process of developing and implementing the technology turned out to be inadequate to consider the growth of the city and the industrial cluster in Jajmau. The case study reveals how the technology was of poor design and implementation as the capacity of the treatment system has proven to be lower than the requisite capacity leading to poor quality of treated wastewater that could not fully comply to the desired standards and was not suitable for irrigation use. Similarly poor operation and maintenance, disrupted power supply also affected the overall performance for Jajmau STP.

Moreover, this experience shows two broader concerns regarding technology: (i) it is not only about developing and implementing the technology but to update it and maintain it – where of course funding and monitoring play a fundamental role; (ii) treated sewage water from domestic uses should not be mixed with industries' treated sewage water as their effluents cannot be treated with the same technology, which poses an additional challenge.

Even though there was a policy intervention, the GAP, which led to the introduction of the treatment technologies, the technical design and implementation turned out to be inadequate.

To address the bottlenecks, however, several interventions have been recently initiated under the Namami Gange Program involving various stakeholders (viz. NMCG, Autralian AID, IIT Kanpur, VA Tech Wabag, UP Jal Nigam, Jajmau Tannery Effluent Treatment Association (JTETA) etc.) that includes tapping of major Sisamau drain and diverting it to Jajmau STP (60 MLD) and Bingawan STP (80 MLD) to prevent direct

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discharge into the Ganga river and creation of 20 MLD CETP to treat tannery effluent. Thus, Government agencies with the support of local stakeholder groups including multilateral organizations and research institutions have planned various interventions to improve wastewater treatment in recent times.

Targeting wastewater treatment, management and river cleaning is a continuous process. Hence, it is expected that these steps along with continued efforts by various agencies will yield progressive results in Jajmau region of Kanpur.

4.3 INDIAN CONTEXT, NAGPUR, MAHARASHTRA CASE STUDY (INDUSTRIAL REUSE)

INTRODUCTION

The city of Nagpur is the largest city in Central India and has high prominence in historical, political and educational front in the state of Maharashtra. Due to rapid population growth and economic development, the city witnessed a high demand for freshwater during the period of 1998-2008 (ICLEI, 2010).

In 2006, Nagpur was selected as one 63 mission cities under the Jawaharlal Nehru National Urban Renewal Mission (JnNURM). During 2006-2007, Nagpur Municipal Council (NMC) conducted audit of the water sector and submitted a Detailed Project Report (DPR) for availing funds to implement the recommendations. The DPR (2006-2007) also consisted of a proposal for commissioning a 110 MLD STP to treat the sewage generated by the city. During 2008-2009, the NMC supplied 530 MLD of water to the city, which generates about 425 MLD of sewage . There was only one STP with treatment capacity 100 MLD during the period (2008-2009) (ICLEI, 2010).

Large volume of water was required by the Maharashtra Generation Company Limited (MahaGenCo) for production of electricity in its thermal power plants (TPP). In 2008, MahaGenCo planned for expansion of the capacity of its TPPs to meet the rising demand for electricity, which increased its water requirement for cooling to 309 MLD. However, the Irrigation Department of the Government of Maharashtra allocated 205 MLD to the company which was not sufficient to meet the water requirement (SANDRP 2014). As an alternative to freshwater, the use of treated sewage was explored to meet the additional water requirement. A Memorandum of Understanding (MoU) was signed in 2008 between NMC and MahaGenCo for supply of 110 MLD sewage for treatment at Bhandewadi STP, which will further be used in the cooling towers of the thermal power plant located in Koradi (Ade et al., 2018).

POLICY INTERVENTIONS

Government programs supporting urban wastewater and sanitation (public funding)

The JnNURM aims 'to encourage reforms and fast track planned development of identified cities'. The focus of the mission is to improve the efficiency in urban infrastructure and service delivery mechanisms, increased community participation, and improve the accountability of ULBs/ Parastatal agencies towards the people living in the cities under this mission. The main thrust of the Sub-Mission for Urban Infrastructure and Governance (administered by the Ministry of Urban Development) is on infrastructure projects associated with water supply and sanitation, sewerage, and solid waste management. The other Sub-Mission for Basic Services to the Urban Poor looks to provide utilities to the urban poor. This is envisaged to be done through projects for the integrated development of slums for providing shelter, basic services and other related civic amenities.

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Maharashtra wastewater reuse policy 2017 fosters industrial water reuse projects and aims for public private partnerships

The wastewater reuse policy adopted by the State of Maharashtra in 2017 is also instrumental in encouraging reuse of wastewater in the region. The policy is to reuse treated municipal wastewater for cooling in thermal power plants and in industrial estates for non-potable purposes. It allocates responsibility to the municipalities for reuse of treated wastewater and directs the urban local bodies to draft an action plan within a year and commission treatment plants within next three years. The policy states that permission for extraction of freshwater from reservoirs for industrial areas and power plants located with 50 km of municipal corporations, for non-potable purposes, will be withdrawn once the treated wastewater is made available. The government also approved public funding for setting of the STPs as well as permitted private funding model (Ashar, 2017).

WASTEWATER TREATMENT TECHNOLOGY DESIGNS

The project comprised of intake facility of raw sewage from the Nag Nala with a pumping station of 130 MLD, a 2.3 km transmission pipeline to the treatment facility, a proposed STP (110 MLD) at Bhandewadi with primary, secondary and tertiary treatment, a 16.2 km transmission pipeline from the STP to one day storage reservoir at the power plant (World Bank Group, 2019).

Primary treatment: the raw sewage is lifted and screened using mechanical bar screens to remove garbage up to 50 mm in size. Then sewage is transmitted to Bhandewadi STP where screen and grit chamber further removes suspended materials. Parshall flume is an open channel device used to measure the flow of effluents. Ferric alum is used as a coagulant and four clarifiers are used for settling of solids (MAHAGENCO, n.d.).

Secondary Treatment: sequential batch reactors (SBR) are used for aerobic treatment of sewage, operated on a fill-and draw basis. Each tank is filled during a discrete period of time and then operated as a batch reactor. One tank undergoes aeration to reduce the BOD while the other tank will be in decant mode to settle the sludge (IWA n.d.). The decanted water is subjected to chlorination.

Tertiary Treatment: the chlorine treated wastewater is pumped to the deep bed multimedia filters. These filters have an arrangement of different sized filter media and with different density such that the larger size contaminant particles get trapped near the top of the media bed and smaller particles gets retained deeper in the media. This aids in efficient removal of organic matter and microorganisms (PURETEC, n.d.). The tertiary treated wastewater is received at storage reservoir and further used as process water.

Sludge handling: sludge from the clarifiers are conveyed to a sludge thickener and further subjected to anaerobic digestion in a digester. The biogas produced in the process is collected in a gas holder. Digested sludge is dewatered and dried in sludge drying beds. At present, efforts are being made to explore market possibilities to utilize sludge for gardening and agriculture (MAHAGENCO, n.d.).

TECHNICAL-OPERATIONAL DRIVERS AND BARRIERS

Acceptable quality of treated wastewater for industrial reuse (cooling towers)

110 MLD of tertiary treated wastewater from Bhandewadi STP is used in cooling towers in the power plant. The STP produces treated wastewater of the quality as given in the table below:

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Table 10: Quality of treated effluent at Bhandewadi STP

Source: (MAHAGENCO, n.d.)

Parameter	Raw Sewage Quality (mg/l)	Tertiary Treated Sewage Quality (mg/l)
pH	6.8-7.8	7.3
TSS	300	<5
BOD	250	<5
COD	500	<30
Total Nitrogen	45	<10
Total Phosphorus	8	<0.5
Total Alkalinity	220	<200
TDS	735	<200

OTHER DRIVERS AND BARRIERS

Public-private-partnership model fostering project ownership

The project was executed through a Public Private Partnership (PPP) model wherein a Build Operate Transfer (BOT) contract for 30 years was signed between MahaGenCo and NMC. NMC was required to provide the raw wastewater and MahaGenCo was responsible for treatment and transportation of the wastewater. The contract ensured a regular and reliable supply of wastewater to the industry with regular monitoring. It also established project ownership and management as MahaGenCo was the only end user of the treated wastewater (World Bank Group, 2019).

Economic incentives

The capital cost of the project was INR180 crores. NMC provided INR 90 crores from JnNURM Grant and the land for construction of the STP. MahaGenCo provided remaining INR 90 crores (Sharma, 2013). MahaGenCo would pay INR 15 crores/ year for 110 MLD raw sewage. For volume of sewage exceeding 110 MLD, the industry was liable to pay INR 2.3 per m^3 of raw sewage. Through this financial arrangement, MahaGenCo had to pay about INR 3.4 per m^3 of treated wastewater. It helped the industry avoid the higher cost of sourcing freshwater from irrigation or municipal projects (about INR 9.6 per m^3). On the other hand, the contact helped NMC gain revenue to cover the operation and maintenance cost of other wastewater treatment projects (World Bank Group, 2019).

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CONCLUSIONS

In summary, the process of providing treated wastewater in Nagpur, Maharashtra can be considered as a successful experience of wastewater treatment and reuse for cooling towers in a thermal power plant. Regarding policy and regulatory intervention, this case study illustrated that with the help of a strong contractual agreement backed by government policies it is easier to create successful models for wastewater treatment and reuse systems. This business model allowing for cost-recovery for O&M results in successfully operating sewage treatment plants.

4.4 INDIAN CONTEXT, KODUNGAIYUR, TAMIL NADU CASE STUDY (RESOURCE RECOVERY)

INTRODUCTION

Kodungaiyur STP of 110 MLD capacity was commissioned in 2006. The sewage produced from the areas of Manali and Chinnasekkadu will be conveyed and treated in the Kodungaiyur STP. Kodungaiyur Plant is one of the largest STPs in India which focuses on sewage treatment as well as resource recovery. The plant is equipped with an advanced sludge management process which is capable of producing adequate amount of electricity to run the entire plant. In the mode of Design-Build-Operate, the contract was assigned to VA TECH WABAG in the year 2003 by the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB). Sludge collected from the primary and secondary treatment processes has been used to generate biogas by way of sludge digestion, which has been used as fuel to generate electricity. Thus generated electricity has been employed to operate the STP. About 750 kW-h electricity is produced from the STP. This process reduces the carbon emissions to the atmosphere by way of methane capture from raw sludge.

POLICY INTERVENTIONS

Central and national recommendations and regulations promote water reuse for industries

The Ministry of Housing and Urban Affairs (MoHUA) has recommended as a part of the service level benchmarks that the 'extent of reuse and recycling of treated wastewater' should be at least 20% as an indicator of sustainability (MoUD 2014). Further, the announcement made in 2013 by Tamil Nadu Chief Minister under Rule 110 (Government Order (GO) No. 116) empowers the community and local bodies in planning and implementation of their responsibilities on all aspects of Solid and Liquid Waste Management. This GO encourages the reuse of wastewater in Tamil Nadu and various industries are using the treated wastewater supplied from sewage treatment plants (MoUD, 2014).

Tamil Nadu has also come out with a comprehensive programme for providing a sewerage network in Chennai city and the district headquarters with appropriate financing and user charges for sewerage connections. The model comprises of financing of sewerage projects through an aggregation of user deposits, loans and government grants with user charges to manage debt servicing and operation and management charges is being adapted to provide sewerage schemes across the state (Water Aid, 2019).

The Environment (Protection) Act, 1986 and CPCB Environmental Standards have established guidelines that emissions and discharges from the facilities to be created, refurbished, or augmented are required to comply with the notified standards and wastewater disposal standards.

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Government subsidies for large-scale waste-to-energy plants under Ministry of New and Renewable Energy

The Ministry of New and Renewable Energy (MNRE) had estimated that 120 MW production potential can be produced from untapped industrial, agricultural wastes and urban wastes (including wastewater) (MNRE, 2015). The Energy Recovery from Urban, Industrial and Agricultural Waste Programme ('Waste to Energy' (WtE)) by MNRE offers support to utilities and operators for setting up large-scale WtE green power generation units (> 1 MW) inside wastewater treatment plant since 2006. Central financial assistance is provided in the form of capital subsidy and grants-in-aid for production of biogas in sewage treatment plants (MNRE, 2015).

WASTEWATER TREATMENT TECHNOLOGY DESIGN

Kodungaiyur STP comprises primary and secondary wastewater treatment processes. In preliminary and primary treatment process, raw sewage after passing through manual screen materials of 25 mm size will be screened. Settleable solids like grit and inorganic matter in the raw sewage are settled and removed. Hereafter the sewage goes to the primary clarifiers provided with central driven scrapper mechanism to settle the solids on the floor of the clarifier which is scrapped to the central pit and surface scum is collected in the scum box.

In the secondary treatment process, the conventional activated sludge biological treatment is used. For continuous aeration, slow speed fixed type aerators are fixed in 4 rows. The over flow of the primary clarifier and return sludge is sent to the aeration tank. The circular type secondary clarifiers receive the mixed liquor from the aeration tanks, settle down all the biomass at the conical bottom and the supernatant (treated sewage) is separated.

RESOURCE RECOVERY

The raw sludge generated from the STP is hydrolyzed and decomposed in the anaerobic digesters (Figure 9). Feeding pattern for digester is 2 hours feeding followed by 2 settling and followed by 4 hours will be mixing. By the recirculation process, the entire sludge is systematically mixed with the sludge mixing pump sets. The biogas with methane, hydrogen sulphide and carbon dioxide is produced during the digestion process. The solids retention time in the digester is 15 days. The produced biogas is utilized to operate the STP with a biogas engine of 1064 kVA available in Kodungaiyur STP (CMWSSB, 2018).

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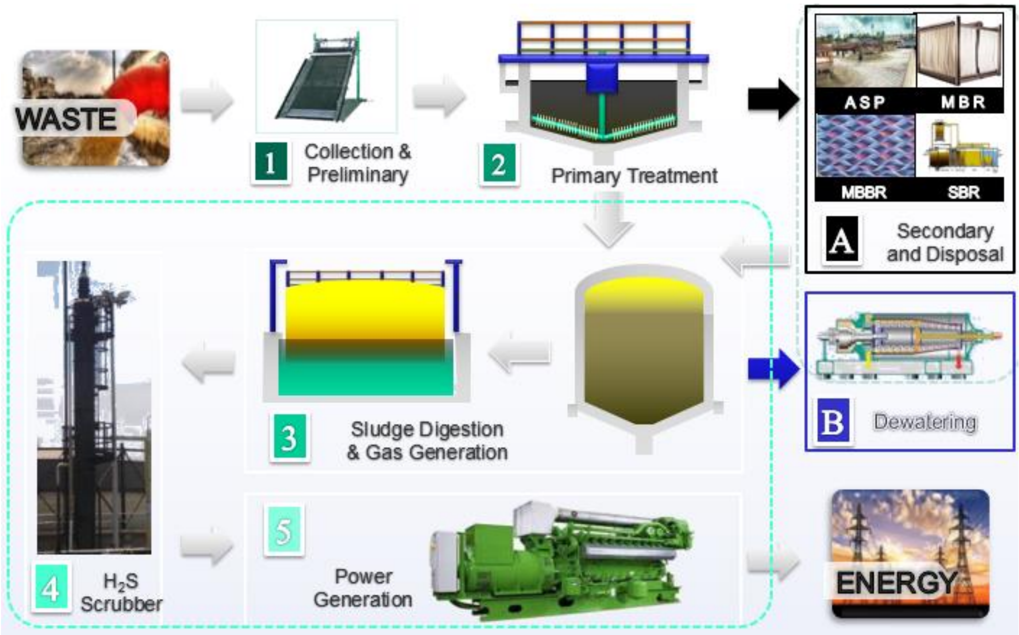

Figure 9: The produced Biogas
Source: IWA, Energy from wastes

OTHER DRIVERS AND BARRIERS

On-site electricity generation reduces operational treatment costs

In the STP, emphasis has been on sludge treatment and generation of power from biogas, utilizing the same to run the treatment process efficiently and reducing the amount of electricity required from the State Electricity Grid. Kodungaiyur STP produced about 12,500 m^3 of biogas per day. Power generated from STP Biogas Engine is about 13 MW/day and an amount of approximately Rs. 20 million is saved annually by using the on-site generated electricity (CMWSSB, 2018). The O&M cost is reduced by 80% due to savings in electricity cost. Further, the STP is almost completely (98%) self-sufficient in terms of power consumption.

Water scarcity drives industrial water reuse

During the late 1980's, CPCL curtailed few of its refineries' operations because of the severe water shortage. In this context, the water scarcity in Chennai posed an enormous challenge to the CPCL's success. The management of CPCL made a significant investment in buying the treated wastewater from CMWSSB for low cost and used for industrial operations in the refinery. In this regard, about 36 MLD of treated wastewater from Kodungaiyur STP is being supplied at the cost of INR 8.75 per kilo litre to nearby industries viz., 23.0 MLD to Chennai Petro Chemicals Limited, 11.5 MLD to Madras Fertilizer Ltd and 1.5 MLD to Manali Petro Chemicals. Through the sale of treated wastewater to the industries, about INR 10 crores revenue is being produced annually (CMWSSB, 2018). Remaining treated wastewater is being discharged to the nearby Buckingham canal to help reduce the pollution load in the canal.

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Design-Build-Operate model enables a continuing reliable wastewater treatment service

The mode of Design-Build-Operate, helps to leverage on the significant technical and economic capabilities of VA TECH WABAG to guarantee optimal project implementation and efficient operations and maintenance of the plant. The operation and maintenance of the plant was contracted to VA TECH WABAG by the CMWSSB which ensured a regular and reliable water supply of treated wastewater to the stakeholders. The treated effluents from Kodungaiyur STP also meet the disposal standards as per the Consent to Operate under Water Act and Air Act issued by Tamil Nadu Pollution Control Board (TNCPB). The average BOD of the treated effluent during the year 2016-17 is around 15 mg/L, which is within the TNPCB norms.

CONCLUSIONS

The process of providing treated wastewater in Kodungaiyur, Tamil Nadu can be considered as a successful experience of wastewater treatment and reuse. Further, opting for a resource recovery model not only ensures successful plant operation but also reduces the operational expenditure by installation of a bio energy mechanism which has a lucrative payback period of 3-4 years. It also saves on the operational costs of transporting sludge to distant landfills. Regarding policy and regulatory intervention by the government, this case study creates successful models for wastewater treatment and reuse systems and as well as resource recovery.

4.5 INDIAN CONTEXT, RITHALA, NEW DELHI CASE STUDY (RESOURCE RECOVERY)

INTRODUCTION

Rithala Sewage Treatment Plant (STP) has a combined capacity of 80 MGD (ca. 363.6 MLD). It consists of two STPs, commissioned in 1989 and 2002 respectively. It receives sewage from North-West Delhi, from areas like Karol Bagh, Ashok Vihar, Pitampura etc. STP-I receives about 13 MGD (ca. 50 MLD) sewage and STP-II receives about 30 MGD (ca. 130 MLD) of sewage (CPCB 2012). A part of the treated sewage is supplied for gardening in DDA Japanese parks and to power plants of Tata Power Delhi Distribution (Previously North Delhi Power Distribution – NDPL) and Pragati Power Corporation Limited (PPCL).

POLICY INTERVENTIONS

Central and national recommendations and regulations to promote water reuse for industries

Due to concerns over depleting groundwater levels in Delhi, the NGT directed all urban municipalities to use treated wastewater for horticulture in 2017 (Alley, Maurya, and Das, 2018). The policy by DJB on utilization of treated wastewater for horticulture and other purposes is also a major initiative in enabling wastewater reuse in gardens and parks of Delhi.

The 2015 Delhi Draft Water Policy suggests reuse of treated water for various non-domestic uses such as horticulture, forestry, road flushing, fire-fighting and use in industrial processes. Provision of incentives through a well-planned tariff system is also mentioned in the draft policy as well as promotion of

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decentralized treatment and alternative treatments systems. There are policy targets to increase wastewater reuse to 25% by 2017, 50% by 2022 and 80% by 2027 (Water Policy for Delhi, 2016).

The Tariff Policy dated 28th January, 2016, issued by the Ministry of Power mandates that the thermal power plants including existing plants, which are located with 50 km radius of a sewage treatment plant of a Municipality or Local Body, shall use treated sewage produced by these bodies.

Government subsidies for large-scale waste-to-energy plants under MNRE

The WtE policy by the MNRE offers subsidy to utilities and operators for setting up green power generation units inside wastewater treatment plant. As mentioned befoe, economic assistance is provided in the form of capital subsidy and grants for production of biogas in sewage treatment plants (MNRE, 2015).

WASTEWATER TREATMENT AND BIOGAS RECOVERY TECHNOLOGIES

The Technology of Rithala-I STP is based on the activated sludge process while Rithala-II STP utilizes high rate aeration with bio-filtration technology for treatment of wastewater. In the pre-treatment stage screening and de-gritting of raw sewage removes floating and coarse matter. The sewage is then transferred to a primary settling tank, followed by aeration where microorganisms (activated sludge) remove the organic content in sewage. The next step involves settling of the microorganisms and particulate organic matter in the final settling tank. A part of the activated sludge is pumped back to the aeration tank and remaining sludge along with sludge from the primary settler is transferred to the anaerobic digester, where the complex organic compounds decompose to form biogas which is collected in a gas holder. The digested sludge is transferred to sludge drying beds (Sharma, 2013)

In Rithala-II STP, the activated sludge process is followed by treatment using Bio-Filtration technology (BIOFOR). The fine floating materials in the sewage are first intercepted using a screen. Then, the sewage is passed through biological filters where sewage is treated aerobically. The treated wastewater is subjected to chlorination for disinfection. The sludge is used to produce biogas which generates electricity (DTE, 2015).

Reuse of wastewater: About 32 MGD (ca.145 MLD) of treated wastewater from Rithala is supplied for gardening and horticulture at DDA Japanese Park and to be used in cooling towers in PPCL - Bawana Power Plant and NDPL at Rohini (DJB, 2016). Remaining wastewater is released to a Supplementary drain, which ultimately discharges to Yamuna River in Delhi.

Resource Recovery: The Rithala-II STP which was designed and built by SUEZ, in 2002, has a high level of energy self-sufficiency, as the biogas is used as on-site energy source to produce electricity for utilization in the plant.

According to a report by JICA (2005), the average energy consumption of the STP is about 32,500-36000 kWh/day. Average biogas production is about 89 m^3 per MLD of sewage treated. The cost of the biogas to electricity production unit was about INR18 crore and was covered under contractual agreement between the Delhi Jal Board and SUEZ. The 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).

In 2006, Rithala STP-II produced biogas of about 7,556 m^3 per day, which was subsequently stored in gas holders and electricity of about 17,000 kWh/day had been generated as energy. By 2015, the plant generated 20000 kWh of biogas daily, which helped to meet about 30% - 35% of the electricity demands of the Rithala STP-II (Daily Pioneer, 2015).

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Other Drivers and Barriers

Use of advanced wastewater treatment technology to produce good quality of treated wastewater

The use of advanced technology enables treatment of wastewater to produce better quality of treated effluent. Rithala STP is designed to produce effluent quality with BOD < 15 mg/l, TSS< 20 mg/l (Table 11). These technologies also utilizes less land area than natural systems

Table11: Quality of treated wastewater (date of Sampling 03.11.2012). All units in mg/L unless specified.
Source: (CPCB, 2012)

Name of STP	BOD Inlet	BOD Outlet	COD Inlet	COD Outlet	TSS Inlet	TSS Outlet
Rithala-I	143	6	392	27	307	17
Rithala-II	143	6	392	20	307	28

Policy driven actions have backed wastewater reuse in industrial operations

Policies mandating the use of treated wastewater in horticulture and in industrial process have initiated reuse of treated wastewater from the Rithala STP. The use of treated wastewater in cooling towers and other operations in the Bawana and the NDPL Plant is a direct result of the policy mandate by Ministry of Power. While the Draft Water Policy for the state of Delhi mentions different usages of treated wastewater and has targets to increase reuse, it is required to be finalised by the State Government for full utilization of these targets. It also requires to be complemented with guidelines and quality standards for different kinds of reuse mentioned in the draft policy.

Funding mechanisms through government program has encouraged resource recovery from sewage treatment plants

The WtE program has the capacity to encourage installation of resource recovery units, such as biogas production in STPS, by providing financial assistance in the form of incentives. This promotes the STPs to achieve self-sustainability in terms of energy production.

Cost savings due to captive production of electricity

The Delhi Jal Board incurs cost saving in electricity bills of grid power supply, by utilizing electricity produced from biogas generated during the sewage treatment process. This serves as an effective enabler for resource recovery.

Conclusions

Use of latest and upgraded technology has been successful in treating sewage to superior quality standards in Rithala STP. Reuse of good quality treated wastewater can reduce freshwater extraction for non-potable use. Policies backed by clear guidelines can help in creating wastewater reuse models in urban settings as well as in industrial sites. Resource recovery can be encouraged through government assisted programs.

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4.6 INDIAN CONTEXT, AHMEDABAD, GUJARAT (SEWAGE SLUDGE TREATMENT FOR REUSE IN AGRICULTURE)

INTRODUCTION

The city of Ahmedabad is the largest city and former capital of the state of Gujarat. It is the administrative headquarters of Ahmedabad district. As per the Census of India (2011), Ahmedabad's population of 5,633,927 makes it the fifth most populous city in the country. It is located on the banks of the Sabarmati River, 23 km from Gandhinagar, the state capital. Ahmedabad has had major economic and industrial development in the last few decades, therefore, the city has witnessed a high demand for freshwater as well as a high requirement to adequately treat wastewater.

Ahmedabad city produces a large amount of sewage sludge every day. In absence of adequate treatment and disposal, this sludge can contaminate soil and water and may also result in health risk due to the potential presence of infectious agents. However, sewage sludge also contains essential micro and macro nutrients, which can enhance soil productivity. Treated sludge can be an efficient organic manure for horticulture and agricultural applications. The disposal of sludge from sewage in cities is a serious problem for urban authorities as it contains a high load of potentially infectious agents that can pose a serious threat to public health. In many regions in India, sludge is usually sent to a landfill which may not be able to effectively contain the pollutants or is provided to farmers in an unregulated manner. This could potentially result in spread of diseases, groundwater and soil contamination thereby negatively impacting the environment and health. In 2015, Bhabha Atomic Research Centre (BARC) (Scientific and technical support) in collaboration with Ahmedabad Municipal Corporation (AMC) (provided the funds required for the plant) took the lead to set up a sludge hygienization plant to treat 100 tons sludge per day and produce manure using a fully automatic process and Cobalt-60 gamma radiation technology which allows to hygienize the sludge reliably and affordably while protecting public health and the environment. Additionally, the hygienized sludge is also inoculated with useful bacteria and converted it into carbon, nitrogen and phosphorous rich manure for agricultural use. This technology is effective, simple, economic and reproducible, and degrades chemical contaminants such as Zinc, Lead, Chromium, etc. to make sludge safer for use (Varshney, 2016).

Prior to this BARC in collaboration with Vadodara Municipal Corporation had been operating sewage sludge hygienization research irradiator (SHRI) to treat 110 m^3 of sewage sludge in Vadodara since 1994. In this process high energy gamma radiation coming from Cobalt-60 source is used to hygienize sludge with heavy microbiological load and pathogens. The sludge is converted into manure and used by local farmers for agricultural use. (Department of Atomic Energy, 2016)

POLICY INTERVENTIONS

In India sewage sludge is normally categorized as non-hazardous substance and thus regulated by Municipal Solid Waste Management Rules. In 2012, the Ministry of Housing and Urban Affairs (MoHUA) published recommendations for sludge disposal in their Manual on Sewerage and Sewage Treatment Systems (CPHEEO, 2012).

The New Waste Management Rules, introduced in 2016 (Solid Waste Management Rules, 2016; CPHEEO, 2016), regulates the post-processing of sewage sludge. The legally binding rules guide on treatment options (e.g., anaerobic digestion and post-composting) and set quality standards for sewage sludge (as organic compost) used in agriculture (Wisniowska et al., 2019; Solid Waste Management Rules, 2016).

State Government of Gujarat announced the *Urban Sanitation and Cleanliness Policy* in 2018 for streamlining solid and liquid waste management in urban regions of the State. As per the policy, all waste and wastewater

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produced by Urban Local Bodies will undergo treatment process as per the standards of Central Public Health and Environment Engineering Organization (CPHEEO) for the purpose of re-use and recycle (Kapil, 2018).

In addition to the policies on sludge management, the nationwide sanitation movement of Swachh Bharat Abhiyan has been instrumental in reducing open defecation from several towns and villages across India, and creating nation-wide awareness in terms of sanitation and cleanliness.

SEWAGE SLUDGE TREATMENT TECHNOLOGY DESIGNS

Radiation Technology for sewage sludge

Ionizing radiation emitted by radiation source such as Cobalt-60 interacts with the critical molecules like DNA, proteins and water present in the cell and result in the inactivation of microorganisms. As a result of irradiation, besides pathogens, other unwanted constituents like weeds, chemicals, etc. are also degraded, making the sludge safer for use. Based on microbiological inactivation, radiation technology is already established world over for sterilizing medical products, food safety and food preservation. Sludge hygienization can be carried out in the similar manner (Varshney, 2016).

As per the established norms in India, the STP sludge should be hygienized before it can be applied on land or provided in container/bags to the users. Lime stabilization, heat pasteurization, composting, mesophilic and thermophilic digestion are some of the methods currently practised. Treatment by these methods converts the sludge to 'Biosolid A', which does not invite several restrictions required otherwise for use of untreated sludge. Sludge as such is very difficult to characterize in terms of microbiological and chemical loads which keep changing. Irradiation ensures that sludge does not contain pathogens. Other solid wastes can also be hygienized using the process of dry sludge irradiation (Varshney, 2016).

TECHNICAL-OPERATIONAL DRIVERS

An average radiation dose of 8-10 kGy is required to hygienize dry sludge. The dry sludge containing about 75% solid is brought to irradiation facility in dumpers and poured into the crushers. The crushed sludge is carried by conveyor belt to aluminium tote boxes and filled. The tote boxes are irradiated at 8 - 10 kGy. The hygienized powder sludge is inoculated with useful bacteria through automated spray unit containing the liquid bio-fertilizer. The inoculated sludge is filled in 50 kg bags at bagging station and sealed. Quality assurance is done by batch wise measuring microbiological population and heavy metal concentration in the sludge before and after irradiation. Re-growth possibility of pathogens in hygienized dry sludge in sealed bags is negligible (Varshney 2016).

OTHER DRIVERS AND BARRIERS

Ecological and socio-economic advantages of radiation technology to treat sewage sludge

The advantages of treating sewage sludge with this technology are its social and environmental benefits. Radiation treatment reduces microbial population in the sludge. So the health risk associated with the use of untreated sludge decreases.

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Post irradiation, the sludge is subjected to inoculation, where beneficial microorganisms are sprayed to the sludge. This improves the nutrient and organic carbon content of sludge. This sludge can be used as bio-fertilizer.

The use of the treated sludge also presents the opportunity to use the nutrients of the sludge, which otherwise is discarded and also helps in reducing the additional pollution load to the environment. This can also lead to economic gain through savings on more expensive fertilizer which would otherwise be required to be applied (Varshney, 2016).

Radiation technology to treat sewage sludge is simple, economic, reproducible and scalable

It is based on the process of radiation sterilization which is well established now in India. It has been easy to integrate with conventional sewage treatment facilities. The fully automatic process seems to be effective to avoid manual handling of contaminated sludge and therefore preventing public health problems (Varshney 2016). This technology also degrades chemical contaminants such as polyaromatic hydrocarbons (PAHs) by producing high-energy excitation and ionization of molecules, and formation of free radicals which create strong oxidation conditions in the sludge matrix. Studies have found that gamma irradiation doses of 2 to 10 kGy reduced PAH content by 53 to 75% for the moist sludge, and 26 to 63% for the dry sludge, respectively (El Motaium et al., 2002)

Sludge hygienization facility may not be a business model for smaller municipalities

An MoU has been signed between Gujarat Agro Industries Corporation(GAIC) and Ahmedabad Municipal Corporation (AMC) for marketing of the product. An attempt has been made for establishing a market linkage for the sludge. The cost involved in establishing a gamma irradiation facility of 100 tons/day capacity is about 25-30 crore rupees and requires an area of about 4500 square meter. The 100 tons/day facility will cater to a city of about 2-3 million population. Hence, establishing gamma irradiation facility in areas where small quantities of sludge is generated, will prove to be unviable due to the relatively high cost of civil construction and machinery (Varshney, 2016)

Thus, in spite all the proven benefits of radiation technology setting up a sludge hygienization facility may not prove to be a sustainable business model for smaller municipalities. However, municipalities can run it with marginal profits and the indirect benefits of protecting the environment and health should also be considered, as the threat of not treating the sludge can result in higher cost to the municipalities. It is to be noted that although the benefits are many fold, the economic value of such benefits can be difficult to estimate (Varshney, 2016).

CONCLUSIONS

The case study of Ahmedabad shows how radiation technology can be successfully designed and implemented for large municipalities, for treatment of sewage sludge. Radiation technology for hygienization of sewage sludge, followed by inoculation of useful microorganisms in the sludge, can be a practical system to economically treat sewage sludge in larger municipalities, to reuse for agricultural application. The bio-fertilizer produced through sludge hygienization can benefit farmers, decrease risk to human health and prevent environmental pollution. The technology and radiation source both are available now in India. Irradiation facility can be utilised to treat the sludge of the entire city at one place in a fully automatic process. The technology has high potential in contributing towards meeting the objectives of Clean India Mission (Swachh Bharat Mission).

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4.7 European Context, Alicante, Spain, Case study (agricultural, urban and recreational reuse)

Introduction

The Valencia region of Spain reuses 57% of all the treated wastewater. One of the three treatment facilities operating in the city of Alicante is the Rincón de León wastewater treatment plant–water reclamation plant (WWTP-WRP) (Melgarejo et al., 2016). In Spain water reclamation is a normal practice since the last decades, and an increasing trend in wastewater treatment plant construction and planning is seen. In Spain, even though agricultural irrigation is the main driver of treated domestic wastewater reuse (80%), 20% is reused for environmental purposes such as landscape irrigation, firefighting, boat and street cleaning after tertiary level treatment (Kellis et al., 2013).

Policy interventions

Spanish water reuse regulations for urban, agricultural and recreational uses

In 2007 Spanish regulations for water reuse were created based on the Californian standards (Royal Decree 1620/2007). According to this legal framework, the quality criteria for reused water distinguish 5 groups of application: (1) urban, (2) agricultural irrigation, (3) industrial, (4) recreational and (5) environmental (Melgarejo et al., 2016). Table 12 shows the description of quality criteria and applications for urban, agricultural irrigation, and recreational uses.

Table 12: Quality criteria for urban, agricultural irrigation, and recreational uses Source: (Royal Decree 1620/2007).

Quality 1.1 Residential: (a) private garden watering; (b) discharge from sanitary appliances	10	2	0	1 egg/10 L
Quality 1.2 Urban services: (a) watering of urban green areas (parks, sports grounds, etc.); (b) hosing down streets; (c) fire-fighting systems; (d) industrial car wash	20	10	200	1 egg/10 L
Agricultural uses				
Quality 2.1: (a) irrigation of fresh food crops for human consumption, through water application systems allowing for direct contact of regenerated water with edible parts	20	10	100	1 egg/10 L
Quality 2.2: (a) irrigation of crops for human consumption, through water application systems without avoiding direct contact of regenerated water with edible parts, but not for consumption as fresh food since there is subsequent industrial treatment; (b) irrigation of pastureland for milk or meat-producing animals; (c) aquiculture	35	No limit set	1,000	1 egg/10 L
Quality 2.3: (a) localized irrigation of ligneous crops impeding contact of regenerated water with food for human consumption; (b) irrigation of ornamental flowers, greenhouses and nurseries with no direct contact of regenerated water with crops; (c) irrigation of industrial crops, greenhouses, fodders stored in silos, cereals and oleaginous seeds	35	No limit set	10,000	1 egg/10 L
Recreational uses				
Quality 4.1: (a) irrigation of golf courses	20	10	200	1 egg/10 L

Maximum values permitted for urban, agricultural and recreational uses.

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WASTEWATER TREATMENT TECHNOLOGY DESIGNS

Reuse purpose and wastewater characteristics drive technology design

The plant is designed to treat 75,000 m^3/d. The wastewater treatment includes pre-treatment (screening and grit removal and flow equalization), primary treatment (settling), secondary treatment (activated sludge), sludge treatment (thickened, anaerobic digestion, centrifugation and sludge storage), and cogeneration (combustion in biogas engines to obtain electricity and heat recovery). An overview of tertiary treatment alternatives is given in the figure 10. The reverse osmosis is required for desalination.

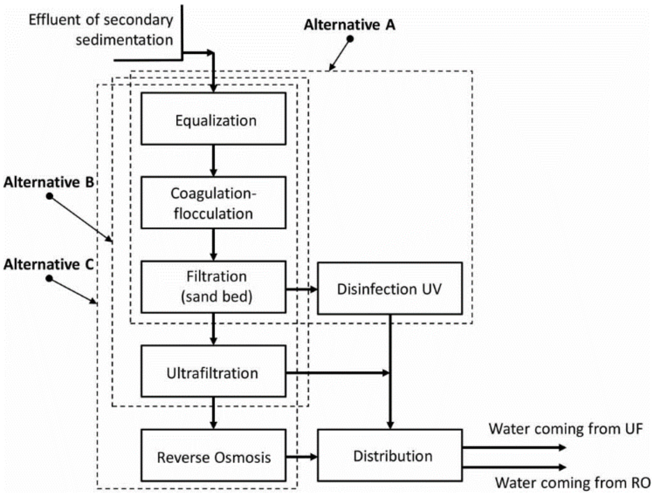

Figure 10: Overview of tertiary treatment alternatives of WWTP-WRP
Source: (Melgarejo et al., 2016)

Tertiary treatment comprises three alternatives: A: CFF + UV, B: CFF + UF and C: CFF + UF + RO. The performance of the different alternatives is given in Table 13.

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Table 13: Performance of the different treatments (% elimination efficiency) Source: (Melgarejo 2016)

Parameter	Alternative A	Alternative B	Alternative C
SS	33.5	94.6	98.1
Conductivity 20 °C (μS/cm)	–	1.16	97.6
Turbidity	33.3	91.0	95.8
COD	20.0	48.2	93.5
BOD	45.7	75.7	92.8
Total N	7.2	12.3	91.0
Total P	12.2	23.0	95.6
Chlorides	–	2.5	97.0
E. coli	99.96	99.98	100

Treated water is used for urban uses, agricultural irrigation and golf course irrigation. Water treated with alternative A is not suitable for residential and irrigation of fresh food for human consumption, water treated with alternative B is suitable for all applications except for residential, and water treated with alternative C is suitable for all uses mentioned in this study.

Irrigation associations hold concessions allowing them to reuse wastewater granted by the Watershed Authority. The associations use treated wastewater for agricultural irrigation as well as for watering golf courses. The prevailing irrigation system is drip irrigation. The main crops are almonds, citrus fruits, tomatoes and pomegranate and olive trees. The golf field requires spray irrigation, while the trees are drip irrigated.

OTHER DRIVERS AND BARRIERS

Fluctuating water demands and scarcity drive water reuse

The water demand in summer is much higher than in winter, and because there is not enough storage capacity, the tertiary treatment step stops in winter leading to an increase in maintenance costs. The various uses of treated water demand different water qualities, which are obtained by mixing treated water from the three different treatment options.

Acceptance and willingness to pay for treated wastewater is high due to unavailability of freshwater sources (water stress, economic incentive)

The cost of tertiary treatment, transportation and distribution is directly charged to the farmers. The farmers have to pay more than the average amount charged for surface water or groundwater for agricultural use in Spain. However, as water stress makes other, cheaper water resources unavailable, the costs for wastewater reuse becomes acceptable for users. The costs of wastewater treatment prior to tertiary treatment are charged to people producing the wastewater.

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Conclusions

In summary, in Alicante, the reuse of treated domestic wastewater is becoming a common practice for agricultural irrigation and other uses such as golf course irrigation due to the lack of other sources of water. Spain has more than ten years' experience with a number of regulations for water reuse, which seem to have helped promoting the development and implementation of different models for wastewater reuse technologies. These technologies have created new sources of water not only for agricultural irrigation but also for other uses such as industrial, recreational and environmental.

4.8 European Context, Barcelona, Spain, Case Study (agricultural and environmental reuse - river flow substitution and seawater intrusion barrier)

Introduction

The main water supply source in the Barcelona Metropolitan Area is the Llobregat River. The intensive exploitation of the river as a water source for urban, industrial and agricultural uses, the high population density of the Metropolitan area, and the water quality deterioration of the Llobregat River due to agricultural runoff and disposal of industrial and urban treated effluents have resulted in quantitative and qualitative water deficits in most of the areas supplied from the Llobregat River.

Policy interventions

Spanish water reuse regulations for urban, agricultural and recreational uses

The main regulations for water reuse in Spain were established since 2007 as mentioned in Section 4.7. These regulations have set specific quality criteria for different uses of reused water including urban, agricultural irrigation, and recreational (See Table 12 in Section 4.7).

Wastewater treatment technology designs

Reuse purpose and wastewater characteristics drive technology design

Based on a participatory stakeholder dialogue, the treatment of the wastewater in the Llobregat delta follows a step-wise approach to meet the particular water quality requirement of each reuse purpose, considering that any additional treatment will cost extra and should only be activated on demand.

Wastewater leaving the plant for the sea undergoes secondary treatment, while for aquifer recharge tertiary treatment including reverse osmosis can be used, while farmers demanded in addition the demineralization of the reused water as water salinity prevented them from using it. As a result, the two WWTPs (El Prat and Sant Feliu) in the district of Baix Llobregat were designed to support directly or via water exchange a range of demands (agriculture, environmental flow, wetland ecosystem services, seawater barrier through managed aquifer recharge, urban water supply, recreation and industry) by the Catalonian Water Agency (ACA) (Mujeriego et al., 2008, Drechsel et al., 2018).

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 could undergo depending on demand tertiary treatment for reuse, by coagulation-flocculation and lamella settling, filtration through a microscreen followed by UV disinfection. Oxygen supplied from a cryogenic tank is injected into the pipelines conveying reclaimed water flows for environmental uses, to ensure a saturated dissolved

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oxygen concentration. A smaller part of the flow undergoes reverse osmosis (RO). An additional desalination plant which uses membranes for electrodialysis reversal (EDR), is able to produce for farmers. So the water reused plant has been designed to produce three different qualities of reused water, with increasing physico-chemical and microbiological quality levels: (1) water for in-stream river flow substitution and restoration of wetland areas; (2) water for agricultural irrigation; and (3) water for supplying the seawater intrusion barrier.

OTHER DRIVERS AND BARRIERS

Acceptance of treated wastewater quality and quality of waste-water irrigated products

The regular use of reused water, as a partial (50%) substitution of surface water allocations from the Llobregat River, has been traditionally opposed by the Right River Bank Irrigation District. The main reasons for rejection have been the high electrical conductivity levels of reused water, particularly during the summer season, and also the widespread fear that produce markets, particularly in EU countries, may reject crops irrigated with reused water. To overcome the electrical conductivity limitation and promote the use of reused water for agricultural irrigation, the decision was taken to build an additional water reuse process able to lower the electrical conductivity of the already available reused water by a demineralisation plant. The demineralized effluent is mixed with the remaining flow of reused water to achieve irrigation the limit determined necessary for the agricultural crops commonly grown at the lower Llobregat Delta.

Economic incentives over freshwater sources

One of the drivers for success was also that the farmers are in relatively close proximity to the wastewater treatment system, limiting pumping costs of the treated water. The income of the farmers has increased to some extent and the availability of reused water for irrigation has been improved in times of low freshwater supply. Through freshwater savings and additional aquifer recharge, ACA can continue its freshwater supply for the urban population (Drechsel et al., 2018). The city gains in this situation by securing additional freshwater for domestic and industrial purposes with a higher water value than what it can offer agriculture. An interesting side-effect is that water consumption for domestic use has decreased and the water quality of the Llobregat aquifer has improved widely.

Clear allocation of roles/responsibilities and leadership between involved stakeholders

Another driver for success was that a single agency (ACA) was involved with mandate for wastewater treatment and providing drinking water to the city, thus providing greater flexibility and ease for negotiating with farmers.

CONCLUSIONS

To sum-up this case study shows that the reuse of treated water for agricultural irrigation in Barcelona is becoming widely accepted. The case study also shows that other benefits of reusing treated water can be achieved such as an increase in the income of farmers. As mentioned in the previous case study the fact that Spain has had regulations for water reuse since 2007 seems to be contributing to improve the development and implementation of different wastewater reuse technologies.

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4.9 EUROPEAN CONTEXT, WULPEN, FLANDERS, BELGIUM, CASE STUDY (MANAGED AQUIFER RECHARGE)

INTRODUCTION

This case study describes the experience of Wulpen, located in the province of West-Vlaanderen, at the western part of the Flemish coast, about 119 km west from Brussels. In that area water demand expanded from 526,000 m³ in 1950 to 5,500,000 m³ in 1990.

The dune water catchments, where fresh groundwater is pumped from the unconfined aquifer by the Intermunicipal Water Company of the Furnes Region (IWVA), could no longer produce more as this could cause saline water intrusion. Given the fact that also the ecological interest for the dunes was growing (Van Houtte and Vanlerberghe, 2002) alternative exploitation methods were studied to remediate decreasing water levels and to guarantee current and future water extraction possibilities.

This resulted in the project for artificial recharge of the unconfined dune aquifer of St-André. This infiltration water, 2,500,000 m^3/year, is then recharged in the dune water catchment 'St-André' at a mean rate of 285 m^3/h using effluent from the WWTP Wulpen. The infiltration pond has a surface area of 18,200 m^2. At a minimum distance of 40 meters from the edges of the infiltration pond, 112 extraction wells extract 400 m^3/h of groundwater. After aeration and rapid sand filtration, drinking water is produced. As the total drinking water demand in the area where IWVA distributes water is currently around 5.5 million m^3/year approximately 45% is fulfilled reusing wastewater effluent.

As a result of this project, the natural groundwater extraction in the two existing dune water catchments, St-André and Westhoek, has been reduced by 30% or 1 million m^3/year. The groundwater levels increased enhancing the natural value of the dunes (Van Houtte and Vanlerberghe, 2002).

The wastewater treatment plant of Wulpen is operated by Aquafin, which is a Flemish public entity. Aquafin is responsible for designing and building the supra-municipal infrastructure needed to purify sewage, financing the investments, operating and optimising new and existing infrastructure, and providing quality control of the municipal sewers. Aquafin functions include project design and dimensioning, process technology choice, investment costing and timing of delivery, detailed process design, procurement, project management during execution, delivery to the government, cost-effective operations. The Flemish Government allocates the annual investment programmes by means of the Flemish Environment Agency (VMM).

POLICY INTERVENTIONS

The 1991 UWWTD has played a crucial key role in moving forward the improvement of water quality in Belgium. As mentioned in Chapter 1, this directive aims to protect the environment from discharges of urban wastewater. 'Urban wastewater' means domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water. The directive also requires that all member states identify sensitive areas, where removal of nitrogen and phosphorus in agglomerations of more than 10,000 PE (population equivalents) is also required.

Another EU Directive that has played a core role in improving water quality in Belgium is the 2000 WFD. One of its core requirements is that all natural waters must be of good quality. High standards for water quality are set, demanding even greater remediation efforts. This also implies that leaking sewers needs to be upgraded, and polluting emissions from sewer overflows needs to be reduced.

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To efficiently achieve the goals of these directives the Flemish Government decided to review its water policy. The framework has been translated in 2003 into the Flemish Integral Water Policy Decree.

WASTEWATER TREATMENT PLANTS TECHNOLOGIES

The Torreele plant was built on the premises of the existing Wulpen wastewater treatment plant, operated by Aquafin. The existing Wulpen treatment process consists of a primary settlement, pre-denitrification, aerobic treatment followed by a clarifier. As the rainwater is collected in the same sewer system, the effluent water quality can vary largely. The effluent of the Wulpen WWTP is treated by the Torreele plant, owned and operated by the Intercommunale Waterleidingsmaatschappij van Veurne-Ambacht (IWVA) since 2002.

The composition and variation of the effluent that is used as feed water for the Torreele plant is given in Table 14, showing a high salt and nutrient content.

Table 14: Feed water analysis
Source: (Aquafin 2020)

Feed water analysis Parameter	Unit	Average	Minimum	Maximum
Temperature	°C	15.3	9.8	22.3
pH			7.06	7.88
Total organic carbon	mg/L	8.8	4.8	13.7
Total nitrogen	mg/L	12.1	2.6	37
Total phosphorous	mg/L	1.2	0.3	2.7
Suspended solids	mg/L	3	<1	15
Chemical oxygen demand	mg/L	33	<21	49
Biological oxygen demand	mg/L	<5	<5	9

Reuse purpose and wastewater characteristics drive technology design

From the effluent reservoir the pre-treated water flows to 5 parallel UF basins, each containing 3,120 m^2 of ZeeWeed membranes, with a maximum pore size of 0,1 µm. To remove the contaminants out of the UF basins, the membranes are periodically backwashed by a reverse permeate flow. The basins are built in concrete and open to the air. The UF compartment of the Torreele plant can treat a maximum of 450 m^3/h of effluent. The minimal recovery should be 85 %.

From the UF filtrate reservoir the water is pumped to the RO system. To prevent scaling, both anti-scalant and acid (pH adjustment) are dosed. The water first passes cartridge filters with pore sizes of 15 µm; this is an extra protection for the RO membranes. High pressure pumps then feed the 2 RO skids, each skid contains 7,872 m^2 of membrane area and can treat a maximum of 205 m^3/h of UF filtrate. The recovery of the RO system is minimum 75 % and is varied according to feed water conductivity.

Since the project started 35 to 40% of IWVA's annual drinking-water demand is fulfilled by the combination of reuse/recharge. Due to the sensitive environmental nature of the dune area to be recharged, the quality of the recharge water is subject to stringent standards (Table 15).

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As reused water is high in both salt and nutrient content, reverse osmosis (RO) was chosen as the final treatment step. Water reuse intended for drinking-water production, both direct or indirect, is not possible without intensive quality monitoring. Both UF and RO produced filtrate as was expected. The UF was capable to produce water free of bacteria and suspended solids and thus proving to be a good pre-treatment for the RO process. The infiltration water meets the standards that were set as in Table 15.

Table 15: Water quality after RO compared with standards for infiltration water
Source: (Aquafin 2020)

Overview of quality in 2010 parameter	Quality of Infiltration water after RO.	Quality standards set for the infiltration water
Conductivity (µS/cm)	45 (<10 – 89)	1000
pH	6.29 (5.28 – 6.86)	
Total Organic Carbon (mg/l)	0.4 (0.1 – 1.1)	
Total hardness (mg/l as CaCO3)	<0.5	40
Chlorides (mg /l)	3.2 (1.0 – 4.7)	250
Fluorides (mg/l)	<0.2	
Sulfates (mg/l)	<1	250
Nitrate (mg NO3/l)	2.5 (<1 - 6.3)	15
Ammonia (mg NH4/l)	0.13 (0.03 – 0.38)	1.5
Phosphate (mg PO4/l)	<0.1	0.4
Silicium (mg SiO2/l)	0.3 (0.1 – 0.4)	
Total trihalomethanes (µg/l)	3.8 (1.2 – 6.7)	
Aluminum (µg/l)	12 (2 – 59)	
Chromium µg/l)	<2.5	
Copper (µg/l)	<5	
Lead (µg/l)	<5	
Mercury (µg/l)	<0.2	
Nickel (µg/l)	<3	
Sodium (mg/l)	10.5 (4.5 – 17.7)	
Zinc (µg/l)	<20	
Total Coliform bacteria (counts/100 ml)	0	
E. coli (counts/100 ml)	0	
HPC 22°C (counts/ml)	<1 (0 – 10)	

OTHER DRIVERS AND BARRIERS

Compliance with EU directives drive improvements in wastewater treatment infrastructure

In 1991, the European Court of Justice convicted Belgium because it was not in compliance with the modernization and expansion of wastewater treatment infrastructure in urban areas as stipulated in the UWWTD 91/271.

Compliance with EU directives foster revision of Belgium's water resources management (policy and institutional arrangements)

As a result, the wastewater management in Flanders and the region of Wallonia was completely reorganized. Flanders created a PPP organized structure (Aquafin), that took complete responsibility for the wastewater sector. As such in 2006 the WWTPs in Belgium complied both with the European nitrogen concentration standards and the 75% target for the nitrogen removal imposed by Flanders itself. In 2006, 99% of the treatment plants complied with all the European standards. The Flemish standards for treated wastewater,

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that became gradually stricter from 2004 onwards, gave rise to new challenges. In 2006, 91% of the plants complied with these new standards, thanks to a constant focus on innovation and improvements to processes. In order to increase that percentage, it is not only necessary to implement further measures on the treatment plants but also on the regional and municipal sewer systems.

Increasing water demand and scarcity drive water reuse

The drivers behind this case study are: increasing water demand - more water supply connections -; comfort and tourism development; increased salinity in the local groundwater due to sea water intrusion and tidal rivers; and higher expectations for the ecological management. As mentioned before, Belgium has recently suffered from increased water scarcity in summer months, therefore, the re-use of water is becoming a viable and sustainable way to create an alternative source of water. Treated wastewater can be reused for a wide range of applications, including that of drinking.

CONCLUSIONS

The case study of Wulpen has showed that wastewater treatment, recharge of aquifers and water reuse in Belgium have achieved considerable improvements in the last two decades. It has also illustrated how drinking-water demand can be fulfilled by the combination of reuse/recharge. More broadly, this case study evidenced a number of important investments, policy interventions, and execution of projects that have happened in Belgium with the objective of creating alternative sources of water for different proposes including that of drinking.

4.10 EUROPEAN CONTEXT, SCHILDE, FLANDERS, BELGIUM, CASE STUDY (INDUSTRIAL REUSE)

INTRODUCTION

The potential role of treated wastewater reuse as an alternative source of water supply is being more and more acknowledged in Belgium. Another interesting example of this innovative trend is that of the Schilde WWTP. This WWTP, which is located in the province of Antwerp, is on the frontline of this important revolution.

In this frame the old CAS Schilde plant was retrofitted with an MBR system as to increase the biological flow. The CAS system is overloaded and in winter the nitrification is regularly lost, while the MBR performs with full nitrification all over the year.

POLICY INTERVENTIONS

As mentioned in the previous case study, the most important water policy intervention in Belgium (Flanders) is the 2003 Flemish Integral Water Policy Decree. Important policy interventions at the EU level, as also mentioned in the previous case study are: UWWTD, the Water Framework Directive and the Groundwater Directive.

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TECHNOLOGY AND TYPE OF REUSE APPLICATION

Reuse purpose and wastewater characteristics drive technology design

The WWTP of Schilde is designed for achieving tertiary treatment of wastewater for a population of 31,000 people equivalent, and a maximum peak flow of 2,020 m^3/h. The MBR lane treats a maximum peak flow of 600 m^3/h. The CAS treats the remaining flow, resulting in a variable flow pattern. The WWTP is composed of two treatment lanes: a conventional activated sludge (CAS) lane and an MBR lane that run in parallel. The CAS lane was built in 1989 and it has been renovated in 2017. The primary treatment consists of 6 mm mesh screens and a rectangular primary clarifier subdivided into 3 lanes (1,200 m^3). Secondary treatment is achieved by an activated sludge system with up-to-date technological features: a pre-denitrification tank equipped with Zeelung technology is followed by a tank operated with on-line controlled intermittent aeration (2×600 m^3) (Figure 11).

The MBR lane was built with the aim of meeting more stringent water quality norms. The MBR lane is composed of a drum-sieve to protect the downstream system, a sand trap, a pre-denitrification tank (500 m^3), an aeration basin (500 m^3) and an aerated filtration unit (240 m^3) (Figure 11). The filtration unit is composed of 4 Zenon MBR filtration trains having a total surface area of 20,000 m^2.

The main purpose of the MBR construction and besides the extremely low nutrient effluent concentrations, the MBR lane provides effluent water with a 5-log reduction of pathogens. It is thus an excellent station for enforcing water reuse policies and production of demineralised water for nearby industries. Additionally, further promotion of water reuse policies has also been fostered. An additional membrane step (nano filtration) has been applied for further polishing of a limited amount of Schilde permeate water. Actually this produced water is used as source water for breweries.

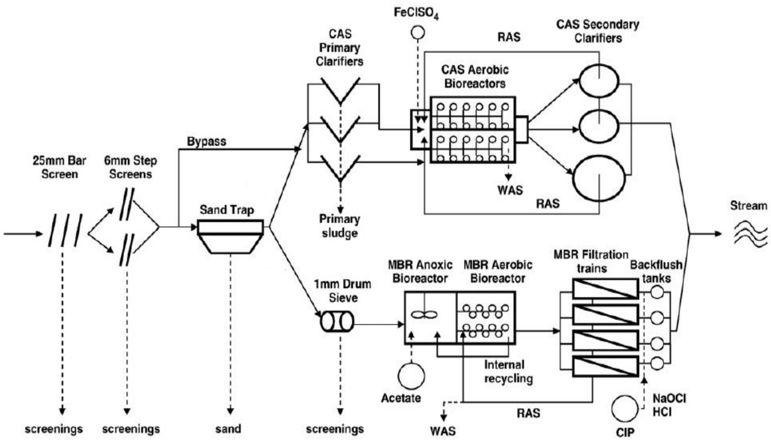

Figure 11: Schilde WWTP process scheme
Source: (Aquafin 2020)

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OTHER DRIVERS AND BARRIERS

Compliance with UWWDT drives improvements in wastewater treatment infrastructure

As mentioned in the previous case study, in 1991, the European Court of Justice convicted Belgium for its non-compliance with the UWWTD. As a consequence, in the last 29 years Belgium has done considerable improvements in this regard. This has provided a key motivation to focus resources in designing, testing and implementing adequate technology.

Increasing water demand and scarcity drive water reuse

Noteworthy is to highlight again the matter of scarcity. Belgium is ranked 23rd out of 164 countries in water scarcity (World Resources Institute 2019), which measures water shortage, drought and river flooding. On a global scale, Belgium and particularly Flanders also scored badly. This phenomenon becomes extremely visible during dry and hot summers. Therefore, in times of water scarcity, effluent water from normal STP's in Flanders are providing farmers with water for agricultural purposes.

CONCLUSIONS

The case study of the Schilde WWTP illustrates more wastewater treatment and reuse improvements in Belgium. It shows that Belgium is advancing and catching up with neighbouring countries. Policy interventions and investments in developing different technologies, have facilitated that water reuse can be an option to create alternative sources of water for different proposes.

Overall aquifer recharge, wastewater treatment and reuse in Belgium can be considered as a successful experience. In the field of reuse of treated wastewater, technology for drinking water production is being implemented. Reusing treated wastewater for many other proposes such as irrigation is also on the rise in Belgium. Currently Belgium is discussing the setting up an integrated water legal and policy framework.

4.11 EUROPEAN CONTEXT, FLANDERS, BELGIUM, CASE STUDY (RECOVERY OF ENERGY - PRODUCTION OF BIO GAS)

INTRODUCTION

Sludge production in the EU has been increasing for several years. More than 10 million tons dry matter of sewage sludge (SS) were produced in 2006 (Laturnus et al., 2007), representing about 58 kg dry matter per inhabitant-equivalent and year (Mogoarou, 2000). As society demands cleaner water, and because of the strict regulations contained in the 91/271/EEC Council Directive (EC 1991), new waste-water treatment plants are built and the existing ones optimized; this will cause a further increase in sludge production. Aquafin has done important steps to accelerate the execution of the sanitation tasks of the Flemish Government on the supra-municipal level. This measure was urgent, given the facts of the poor quality of the Flemish watercourses in the early nineties and the obligations of the European Directive on 'Urban wastewater' (91/271/EEC). By then only 45% of the wastewater in Flanders was centralized and only 30% of the collected wastewater was connected to a treatment plant. The specific tasks entrusted to Aquafin are defined in a long-term Management Agreement with the Flemish Government.

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As soon as a sewage asset (STP – Digester) has been built and commissioned, the investment will be repaid in 30 years by the Flemish Government, represented by the economic regulator. This cost and the cost for operating all assets under management is forwarded to the drinking water companies, who include it in the Water Tariff.

The expansion of the investment done in Flanders over the last 30 years resulted in a coverage ratio of 85%. The impact on sludge production has tripled over the last 20 years. The construction, operation and optimization of digesters in the region became a necessity. Not only to reduce heavy burden on disposal costs but also to reduce the volume of sludge by 40%. As such the added value of transferring biomass into biogas became a fact.

POLICY INTERVENTIONS

Sewage Sludge Directive encourages use of treated sewage sludge in agriculture

The Sewage Sludge Directive 86/278/EEC seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man. Among the main provisions of this Directive are: to prohibit the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil.

According to this Directive treated sludge is defined as: 'biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use'. The Directive also establishes protection against potential health risks from residual pathogens. In this regard it mandates that sludge must not be applied to soil in which fruit and vegetable crops are growing or grown, or less than ten months before fruit and vegetable crops are to be harvested. The Directive also requires that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired.

Moreover, the Directive specifies rules for the sampling and analysis of sludge and soils. Limit values for concentrations of heavy metals in sewage sludge intended for agricultural use and in sludge-treated soils are in Annexes I A, I B and I C of the Directive.

Although at Community level the reuse of sludge accounts for about 40% of the overall sludge production, landfilling as well as incineration in some Member States are the most widely used disposal outlets despite their environmental drawbacks.

Revision of the Sewage Sludge Directive

Directive 86/278/ EEC was adopted over 30 years ago with a view to encourage the application of sewage sludge in agriculture and to regulate its use, so as to present harmful effects on soil, vegetation, animals and humans. The European Commission is currently assessing whether this Directive should be reviewed – and if so, the extent of this review. For example, Directive 86/278/EEC sets limit values for seven heavy metals. Since its adoption, several Member States have enacted and implemented stricter limit values for heavy metals and set requirements for other contaminants. In Flanders the practice of land spreading was never adopted. During the 1990s the sewage connections rates were still low meaning that sewage production was only 20,000 TDS. The very strict limit values for heavy metals in 1999 meant that sewage sludge spreading would not have happened as sewage connections rates increased to 90% and sewage production increased to 100,000 TDS.

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Kyoto protocol and First Renewable Energy Directive (Directives 2001/77/EC)

Within the framework of the UN Climate Convention, the Contracting parties agreed on the Kyoto Protocol at a meeting (the so-called COP) in 1997 after years of negotiations in Kyoto (Japan). This protocol entered into force in 2005 and was a concrete implementation of the UN Climate Change Convention. For the first time in history, there are now concrete and binding reduction targets for six greenhouse gases for industrialized countries. Climate change was recognised as a global problem and had to be tackled internationally. The European Commission quickly announced its intention to play a pioneering role in climate change at international level.

The primary objective of climate and energy policy is to reduce greenhouse gas emissions, the European Union is committed both at international level and at European level to combat climate change caused by greenhouse gas emissions. In addition, the promotion of renewable energy production was one of the spearheads of European Energy and Climate Policy. This became quite visible by the publication of the White Paper for a Community Renewable Energy Strategy in 1997.

The EU 2010 target

The First Renewable Energy Directive (Directives 2001/77/EC) was finally approved in 2001 and set the target for the EU as a whole to achieve 12% of energy consumption and 22% of electricity consumption should be covered by renewable energy, based on national targets. However, these “first generation” targets were purely indicative and therefore non-binding in nature. Art. 3 (1) of The First Renewable Energy Directive 2001 specifically obliged Member States, with the national targets as a guideline, to "take appropriate measures to encourage the consumption of electricity from renewable energy sources"

The EU 2020 target

Due to the increasing dependence on oil and other fossil fuels, rising energy prices and energy security in the EU, the European Union set three main objectives in 2008 in a package of measures. This package is better known as the '2020 EU Climate and Energy Package' and contains the following three objectives:

i. a reduction of all greenhouse gases by at least 20% compared to 1990 by 2020;

ii. a share of 20% renewable energy in EU consumption by 2020 (with a sub-target of 10% of energy consumption in "all modes of transport");

iii consume less energy by 2020 (compared to a business as usual scenario), among other things, thanks to energy efficiency.

The definition of renewable energy sources can be found in the current Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and repealing Directives 2001/77/EC and 2003/30/EC. At the Member State level (in Belgium) a corresponding definition was formulated in the Decree containing general provisions on energy policy (hereinafter: “the Energy Decree”) and the Federal Electricity Act. The concept of "support mechanisms" / Initiation of "support mechanisms" under the first Renewable Energy Directive. Renewable energy, and more specifically green energy, has become an important topic of European renewable energy policy for the last 15 years. In this context, Member States are generally given a certain degree of freedom to develop their own national policy.

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Energy Recovery technology

Sewage sludge contains a high percentage of organic matter (60–70% of the dry matter) and nutrients such as phosphorous and nitrogen, which can be recycled for agricultural use if the sewage sludge is free of heavy metals and other pollutants. The anaerobic digestion process is a well-known technology that improves sewage sludge quality for agricultural use, while at the same time producing biogas that can supply between 40–60% of the energy required to run a WWTP (Shizas and Bagley, 2004).

Anaerobic digestion is a suitable technique for sludge treatment (Gavala et al., 2003). The first goal of anaerobic digestion of sewage sludge is the stabilization of the organic material. This also involves a reduction of the odor nuisance and a reduction of pathogenic organisms. In addition, there is a significant decrease in the amount of solid organic matter to be further treated as waste (Parkin and Owen, 1987). After all, it is the organic part from the sludge that is converted into biogas during anaerobic digestion.

At Aquafin the standard wastewater treatment technology applied at all STPs, provides no primary settlement tanks. As such the whole BOD fraction is brought straight into the biological part of the STP. From this biological part of the STP, the sludge produced during this phase, the secondary sludge (excess sludge, secondary sludge or waste activated sludge, WAS), is fermented in a sludge fermentation tank. This usually happens in a one-step process.

In the Flanders region (6.6 Million inhabitants) all wastewater treatment activities result today in a yearly production of approximately 100,000 TDS. Flanders built its first digester in 1988, with a massive volume of 13,000 m^3. In the period of 1988 till 1998, not much interest was given to these assets. Mainly because all installations were inefficient and caused many operational problems. Since that period thanks to the policy drive to tackle Climate Change and promote renewable energy, the “support mechanisms” have enabled Member States to put more emphasis on energy recovery from sewage sludge. With the new policy in mind a complete digester renovation programme was elaborated and executed within a period of 10 years. In 2007 the last digester in Ghent was extended and commissioned. By 2007, 17 digesters of different sizes, age and efficiencies were in place and are fed with approximately 60% of the total volume of sludge per year. This volume is converted into “green” electricity (Figure 12). Some fermenters became subject of complete review of sludge strategy, and even in some cases measures were taken already in the waterline, to optimise sludge quality. This resulted in major improvements in efficiencies, including advanced heat recuperation techniques, to improve in biogas to energy conversions.

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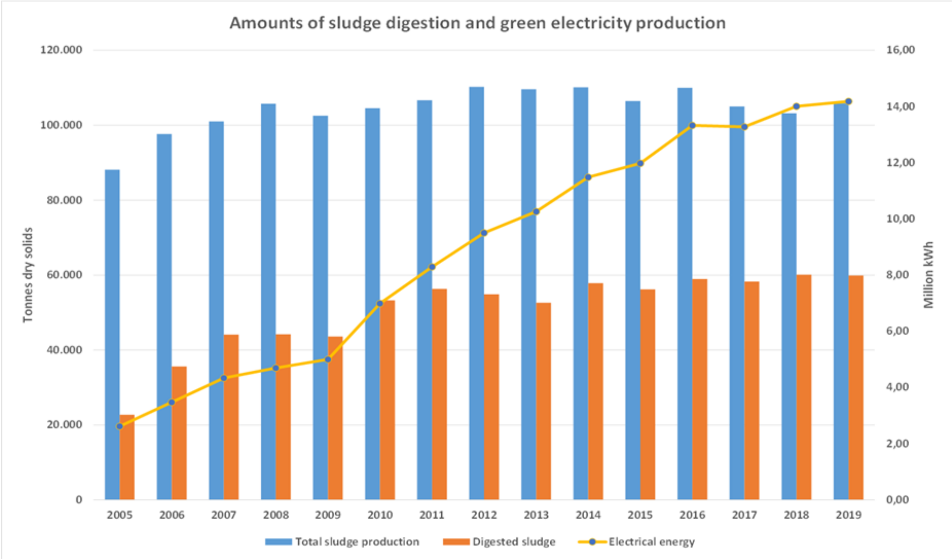

Figure 12: Sewage sludge 'green' electricity production at Aquafin installations in Flanders, Belgium

DRIVERS AND BARRIERS

Valorisation of biogas for multiple applications/ On-site electricity production cuts operational costs and reduces carbon footprint

The real driver of this technology is the added value of the production of biogas. This product has multiple applications, as energy source for production of electricity or as green biogas as energy source for cars. Considering that the operational company is challenged by its statutes to work as a public entity with private rules, and as it has to source its own green financing on the market, the production of biogas is a real benefit in the cost schemes of the company. Additionally it is the driver to motivate investment funds to invest in green and environmental assets. Implementation of this energy recovery strategy also entails the reduction of residual sludge volumes. This in turn reduces the costs incurred of disposing of residual sludge by incineration, as disposal in landfills or on agricultural land has been banned since 1997 and 1999, respectively. The disposal of sewage sludge on agricultural land does not occur because of the stringent heavy metal norms. The region is also classified as a Nitrates Vulnerable Zone, so there is already an excess of N in the soils.

Biogas recovery more cost-efficient in densely populated areas

A barrier to the the implementation of energy recovery by digesters is that the process only becomes efficient if there is at least 85,000 p.e. connected to the STP. This is not a real problem in heavily populated areas,but in more rural areas, where the population is fragmented, another strategy is collect sludge and transport it to central sludge treatment / biogas plant. The above mentioned limit value is based on the percentage of biomass found in EU countries. It is logic that if the percentage of biomass is lower the efficiency limit shall also decrease. Thenormal Return on Investment for Digesters in Flanders region is set at 15 years. Digesters working under normal conditions remove approximately 28% of the TDS fraction. The sludge used for digesting purposes in Flanders contains approximately 60% of Organic matter. Although

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digester technology is dating from the nineties, it is still a technology where the needed vigilance and skilled operational input is required to gain enough efficiency.

CONCLUSIONS

In the Flanders region, when the Sewage Sludge Directive became law the sewage sludge volumes were only 20,000 TDS per year, as the sewage connection rate was only 25%. With the increase of compliance to the UWWTD and the subsequent increase of sewage sludge to 100,000 TDS per year, it was necessary to invest in biogas and incineration facilities. Climate change and successive renewable energy policies have helped to drive improvements, using support mechanisms, in energy recovery efficiencies from sewage sludge. Energy recovery using digester technology can be efficient and recovers a large part of the energy contained in wastewater. It entails a large reduction of residual sludge volumes and as such reduces disposal costs. Although investment costs are relatively high, the financial gains of producing "green" energy can provide a rapid return on investment. The main negative issue is the necessity to deal with the very high N loaded streams. As these waste streams are not allowed to be put for use on agricultural land an appropriate post-treatment, such as anamox, is required. A high level of vigilance and operation skills are needed to manage the technologies efficiently.

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4.12 European Context, Lombardy, Italy Case study (sewage sludge treatment and reuse in agriculture)

Introduction

The application of treated sewage sludge (or 'biosolids') on agricultural land can improve crops productivity, soil physical properties and reduce the effect of organic matter loss in the soil which is a common problem in southern European countries, like Italy (Colivignarelly et al., 2020; Rusco et al., 2001).

The European Directives 91/271/EC and 68/278/EEC (chapter 1.3.3) were introduced to safely manage wastewater and sewage sludge treatment in European member countries and promote its safe reuse for agricultural lands. Based on these directives, many EU member states have introduced national regulations regarding sewage sludge treatment and reuse.

Policy Interventions

In Italy, the European Directive has been implemented with the Legislative Decree 99/1992 (Italian Parliament, 1992). It mandates the Italian regions to establish own limits and conditions for the reuse of sewage sludge in agriculture, taking into account different types and compositions of sewage sludge, characteristics of the soils, the types of crops produced, and treatment methods. In 2018, further requirements for treated sewage sludge in terms of heavy metals, hydrocarbons and organic pollutants were introduced under law n.130, article 41, 'urgent provisions on biosolids management' (Italian Parliament, 2018).

In Italy, around 970,000 tons of sewage sludge (dry matter) is produced, out of which around 30% is reused for agricultural applications (Mininni and Sagnotti, 2014). Agricultural reuse is mainly done in regions of northern Italy, i.e., Lombardy, Veneto and Emilia Romagna. These regions have drafted regional level legislation with respect to Legislative Decree 99/1992 (Collivignarelli et al., 2019).

The Lombardy legislation was the D.G.R X/2031/2014 (Lombardy Region, 2014), which was effective until September 2017. It introduces i) requirements for the acceptability of sludge sent to sludge treatment plants; ii) provides two different biosolid quality classes: 'high-quality biosolids' and 'biosolids suitable for spreading' with different heavy metal limits values; and iii) defines the characteristics of agricultural soils to receive the treated sewage sludge as well as the spreading methods (Collivignarelli et al., 2020).

The requirements for treated sewage sludge for agricultural land application relate to microbiological and agronomic characteristics, heavy metals and organic pollutant contents and the degree of stabilisation (Table 16). Different types of soil react differently to the contribution of the same load of contaminants. This aspect is not considered in detail in the EU legislation. However, Italy's national and regional legislation in Lombardy differentiates the maximum amounts of treated sewage sludge to be applied according to the pH and the cation exchange capacity of soils.

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Table 16: Limit values for treated sewage sludge for land application in Italy and Lombardy (Collivignarelli et al., 2019)

Parameter		Unit of Measure (u.m.)	Italy: Legislative Decree n.99/1992 and n. 130/2018	Lombardy: DGR n. X/2031/2014 and d.d.u.o. 6665/2019 – Suitable	Lombardy: DGR n. X/2031/2014 and d.d.u.o. 6665/2019 – High Quality
Heavy metals	As	$mg\ kg_{DM}^{-1}$	<20	≤10	≤20
	Be	$mg\ kg_{DM}^{-1}$	≤2	≤2	
	Cd	$mg\ kg_{DM}^{-1}$	<20	≤20	≤5
	Cr	$mg\ kg_{DM}^{-1}$	<200	≤200	≤150
	Cr (VI)	$mg\ kg_{DM}^{-1}$	<2	<2	
	Cu	$mg\ kg_{DM}^{-1}$	<1000	≤1000	≤400
	Hg	$mg\ kg_{DM}^{-1}$	<10	≤10	≤5
	Ni	$mg\ kg_{DM}^{-1}$	<300	≤300	≤50
	Pb	$mg\ kg_{DM}^{-1}$	<750	≤750	≤250
	Se	$mg\ kg_{DM}^{-1}$	≤10	≤10	
	Zn	$mg\ kg_{DM}^{-1}$	<2500	≤2500	≤600
Chemical/physical parameters	VSS TSS^{-1}	%	-	<65	<60
	pH	-	-	5.5 < pH ≤ 11	
Agronomic parameters	Organic carbon	% DM	>20	>20	
	Total nitrogen	% DM	>1.5	>1.5	
	Total phosphorus	% DM	>0.4	>0.4	
Organic micropollutants	PAH	$mg\ kg_{DM}^{-1}$	≤6	<6	
	PCB	$mg\ kg_{DM}^{-1}$	≤0.8	<0.8	
	AOX	$mg\ kg_{DM}^{-1}$	-	<500	
	LAS	$mg\ kg_{DM}^{-1}$	-	-	
	Toluene	$mg\ kg_{DM}^{-1}$	≤100	≤100	
	DEHP	$mg\ kg_{DM}^{-1}$	-	<100	
	NPE	$mg\ kg_{DM}^{-1}$	-	<50	
	PCDD/F	$ng_{TE}\ kg_{DM}^{-1}$	≤25	≤25	
	Hydrocarbon (C10-C40)	$mg\ kg_{DM}^{-1}$	-	<10,000	
	Hydrocarbon (C10-C40)	$mg\ kg_{WW}^{-1}$	<1000	<1000	
Microbiological parameters	Salmonella	$MPN\ g_{DM}^{-1}$	<1000	<100	
	Faecal Coliforms	$MPN\ g_{DM}^{-1}$	-	<10,000	

Sewage sludge from WWTPs is characterized before it is sent to sludge treatment plants to verify its suitability for agricultural reuse (Figure 13). The characterization further includes parameters such as phytotoxicity tests, polychlorinated dioxins and polychlorinated dibenzofurans, polycyclic aromatic hydrocarbons, and chlorinated diphenyls. These analyses evaluate the quality of the sludge to be treated and its compatibility with the proposed treatment processes in the sludge treatment plants (Collivignarelli et al., 2019).

In 2017, the D.G.R X/7076/2017 was approved in Lombardy (Lombardy Region, 2017). It introduces additional limit values for AOX (adsorbable organ halides), DEHP (bis(2-ethylhexyl)phthalate), NPE (nonylphenol ethoxylates) and hydrocarbons (C10-C40) (Collivignarelli et al., 2020).

SLUDGE TREATMENT TECHNOLOGY

Pavia Province in Lombardy has 10 sludge treatment plants (from a total of 18 authorized sludge treatment plants in Lombardy), which receive around 700000 tons of raw sewage sludge (ca.140000 tons dry matter) from WWTPs in Lombardy. Sludge treatment plants in Pavia generally use chemical treatments (lime dosage) and biological treatment (anaerobic stabilisation) for hygienization and putrefaction reduction (Collivignarelli et al., 2020). Subsequently, the biosolids are spread on agricultural soil (Figure 13).

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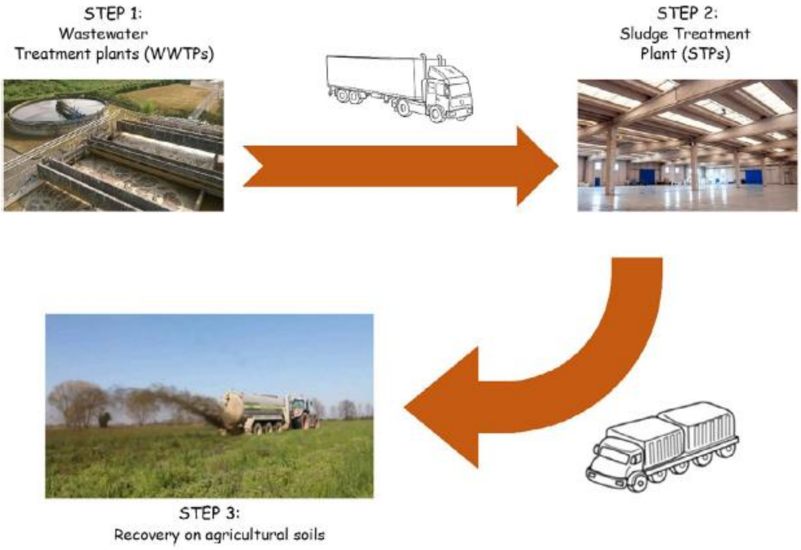

Figure 13: Sewage sludge management in Lombardy, Italy (Collivignarelli et al., 2020)

According to a study by Collivignarelli et al., (2020), the sewage sludge management and treatment in Pavia bear the following technological challenges:

Degree of stabilisation of sewage sludge from wastewater treatment plants should be legally enforced

In some cases, the sludge arriving at sludge treatment plants has a too low stabilization degree (high VSS/TSS ratio). This can cause significant problems concerning odour emissions and putrefaction. There is no regulatory limit provided (not in the national nor in the regional regulations) for the degree of sludge stabilization before being transported to sludge treatment plants.

Existing sludge treatment processes are designed for pathogen reduction before land application but cannot remove heavy metals

The most commonly used treatment process in Pavia's sludge treatment plants is conditioning with hydrated lime (or with calcium oxide or ammonia solution). Chemical treatment aims at pathogen inactivation before application on agricultural soils. However, this chemical stabilization presents the risks of uncontrolled degradation after spreading lime-treated sludge and can cause malodours. It thus works rather as hygienization but not as stabilization process. Few plants use anaerobic stabilisation processes to reduce the putrefaction of the sewage sludge and thus prevent odour emission while also reducing the pathogen load.

However, both stabilization processes applied in sludge treatment plants in Pavia region were not designed to remove heavy metals. Therefore, the regional regulation legislation D.G.R. X/2031/2014 introduced limits of heavy metals contents for the sludge being transported to sludge treatment plants thereby allowing a more careful selection of the sludge for land application.

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Other Drivers and Barriers

Land spreading of treated sewage sludge enhances the fertility of soils

The use of treated sewage sludge has clear ecologic advantages as it improves soil organic matter and nutrients. Decreasing soil organic matter is a significant problem in Italy and other Mediterranean states (Rusco, Jones, and Bidoglio, 2001). Studies have shown that the accumulation of heavy metals in the soils is lower than the national limits but that copper and zinc should be carefully monitored in cases of repeated spreading (Collivignarelli et al., 2020).

The adoption of good agricultural practices is key to support environmental benefits and gain acceptance

The treated sewage sludge application must be carried out in compliance with good agricultural spreading practices. For example, after the deposition on the ground, it must be completely buried by appropriate ploughing and result in absolute absence of biosolids on the surface to limit emission of malodours and ammonia (Collivignarelli et al., 2020). Regulations concerning biosolids spreading processes, which to date are lacking, would introduce better control of environmental benefits (Collivignarelli et al., 2019).

Incentives for the use of 'high-quality' biosolids should be introduced

Treated sewage sludge used for agricultural purposes has to be of better quality than for other land but non-agriculture applications. Legislation should be put in place to incentivize the use of high-quality biosolids for agricultural purposes.

Conclusions

Land application of treated sewage sludge enhances soil fertility in Lombardy, Italy. To mitigate any adverse effects on the environment, the regional legislation in Lombardy has sets stringent limit values for different contaminants of concern. As most existing sludge treatment plants are not designed for heavy metal removal, the regional legislation further mandates sludge treatment plants to treat only sludge with heavy metal contents below defined thresholds. Sewage sludge with very low heavy metal contents are further classified as high-quality biosolids. Incentives (legislative, financial) for the use of these high-quality biosolids for agricultural reuse are currently missing but could improve the cost-effectiveness of current sludge management in Lombardy.

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4.13 European Context, Flanders, Belgium case study (Resource Recovery – Production of Phosphorus (Struvite))

Introduction

Phosphate is an essential part of life. It is a basic element in the energy management and building stone of human DNA. Animals and humans absorb phosphate through the consumption of plants, meat and dairy products. Population growth, the shift to more protein-rich diets and the use of biomass for energy and bio-based production will further increase the demand for fertilizers. Phosphate is a mineral with a finite resource of which 85% of the world reserves are in the hands of a few countries (amongst Morocco and China). It is a chemical element that cannot be artificially made, so there is no alternative available.

The only way to meet the continuous and increasing need for phosphate is recovery. Logically, this is best done in places where large amounts of phosphate are (relatively) concentrated, such as WWTPs and animal manure processing. A possible technique that can be used is the precipitation of phosphate in the form of struvite (MgNH4PO4.6H20).

Policy Interventions

Authorisation required to use recovered struvite from sewage sludge as fertilizer

In Belgium, (inorganic) fertilisers are required to comply with the Belgian legal requirements as mentioned in the Royal Decree of 28 January 2013 on the marketing and the use of fertilizers, soil improvers and growing media. Annex I to this Decree provides an overview of products which may be marketed, in the same way as in EU Regulation 2003/2003 (designation, description, requirements and markings). Struvite is an end product and is not included in the Annex.

Therefore, the Federal Public Service (FPS) Health, Food Chain Safety and Environment can grant exemptions for the trade of struvite products as fertilizers when the producer applies for mutual recognition (or derogation). In this case, not only the purity of the product, but also the agronomic properties are evaluated.

In Belgium, there is a legislative framework to valorise waste materials into new raw materials. The Flanders Waste Agency (OVAM) assesses the environmental hygiene aspects. The Flanders Environmental Law (VLAREMA - Appendix 2.3.1 conditions regarding composition and use as fertilizer or soil improver), describes the conditions for converting the status from waste to raw material. It concerns contamination of metals and organic substances. If the prescribed requirements are met, the Flanders Waste Agency (OVAM) issues a Resource Declaration. In order to place the relevant raw material (such as struvite) on the market as fertilizer, it is also necessary to apply for an exemption from the Federal Public Service (FPS) for Public Health, Food Chain Safety and the Environment.

Phosphorus recovery technology

In 2010 Aquafin studied the P- recuperation from sludge water using the NuReSys-P system (P-recuperatie uit slibwater met NURESYS Projectnr. KB100047 – P. Clauwaert), and concluded that there are two operating

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STPs (Antwerpen Zuid and Leuven), which could be used to install a full scale pilot. The study concluded that is possible to recover phosphorus under the form of struvite from sludge water after dewatering at the Aquafin STPs. This seems to be the case for sludge dewatering with sludge that (mainly) originates from a waterline where phosphorus is removed biologically, and where (preferably) no iron is dosed in the sludge line. Based on 2 tests, a P-removal of 85% was achieved for the centrate of WWTP Antwerpen-Zuid. If these results can be extrapolated, this would result in a yearly production of 7.5 ton P (= 59 ton struvite/year) from approximately 2,250 TDS.

NuReSys-P is a struvite precipitation technique, installed in 2014 and tested on digested sludge from the Aquafin WWTP in Leuven. Due to the relatively low cost of phosphate ores, the advantage is not simply to look for the production of struvite as a potential fertilizer. The removal of phosphate from the digestate also offers the advantage that less struvite is formed spontaneously in the digestate processing path.

A full scale test reactor was placed on the digestate of the secondary sludge digester of the Aquafin WWTP in Leuven (Figure 14). Measurement campaigns were conducted for one year to study the effectiveness and efficiency of the reactor, in different seasons so that the influence of temperature, composition of wastewater, etc. was also taken into account.

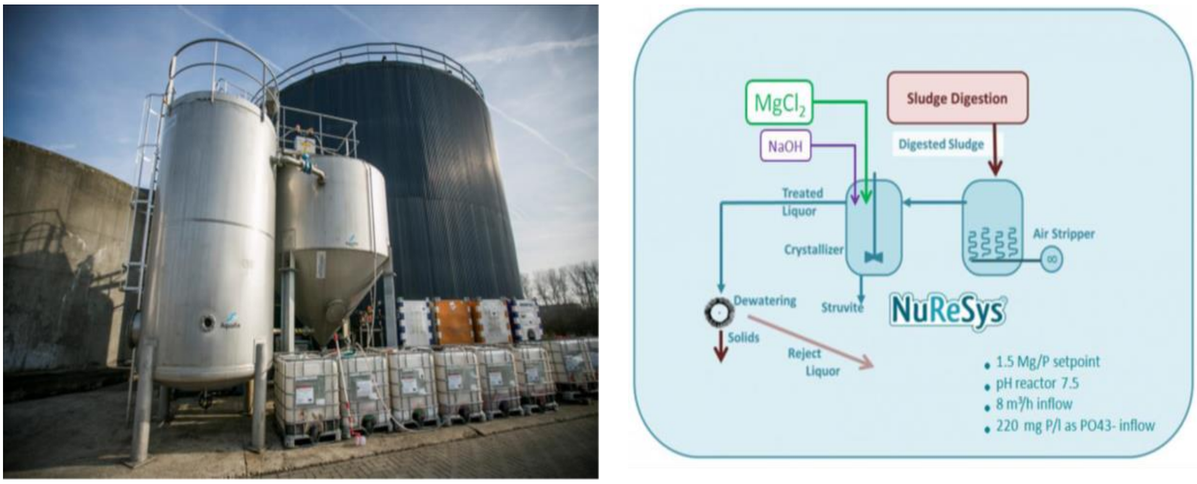

Figure 14: Struvite and digester facility LEUVEN / PID scheme of Struvite facility

The removal rate, or the maximum removal potential of phosphorus, is around 30kgP/d, which represents 15% of the incoming phosphorus on the entire water treatment plant. This is consistent with the figures of 10-20% removal rates in the literature on struvite precipitation from concentrate of urban WWTPs. The calculation of the removal percentage takes into account only the internally produced sludge on a WWTP, so external delivered sludge is excluded.

The introduction of the struvite process resulted in a 50% reduction in the phosphorus load in the centrifuge effluent, typically 30 kg P/d to 15 kg P/d.

OTHER BARRIERS AND DRIVERS

P recovery has clear ecological and economic benefits

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The main driver to produce phosphorus from digestate is the reduction of final disposal of phosphorus in the sludge with 15% to 20%. While at the same time producing a product that can be re used as a fertiliser in agriculture. It decreases the pressure on the phosphorus reserve as a mineral, and it reduces the phosphorus concentrations in the rest sludge taken away in the disposal route.

Complex certification process of recovery P-products

The main barrier is the difficulty to receive a certification according to the actual regulation. The producer of the struvite has to prove to the Flanders Waste Agency (OVAM) that the struvite meets the composition requirements regarding the maximum content of pollutants as described in annex 2.3.1 of VLAREMA. These requirements are quite strict and difficult to achieve with phosphate produced from sewage. The same controls are not enforced on mineral phosphate, which can also contain heavy metals as well (Kratz S. et al, 2011).

Complex and high-tech technologies

The technology of production of phosphate is quite complex and very sensitive to the quality of sewage water used. Operators of installations need to be very highly trained in comparison to wastewater treatment operators.

CONCLUSIONS

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. The same controls are not imposed on mineral phosphates which are also liable to be “contaminated” with heavy metals. Currently this is an unequal playing field for struvite.

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4.14 European Context, Switzerland case study, (mandatory Phosphorous recycling from municipal Wastewater)

Introduction

Phosphorous is an essential nutrient in fertilizer and livestock feed products. Mineral P fertilizer and feed production rely on phosphate rock that is classified as critical raw material by the EC (EC, 2014; Egle et al., 2016). Countries without natural P deposits, such as Switzerland, are entirely dependent on P imports and are thus vulnerable to market fluctuations in fertilizer and mineral P prices (BAFU, 2017b). Switzerland imports 5,900 tons of P in fertilizer products yearly (Binder et al., 2009). The imported fertilizer products often do not comply with quality standards for heavy metals, like Cadmium and Uranium, which poses risks to human and environmental health (BAFU, 2017b).

To reduce dependency on natural P sources and mitigate adverse effects of imported P fertilizers, recovery and recycling of phosphorous from highly concentrated and unexploited waste streams, such as municipal wastewater or meat and bone meal, has been intensively discussed by science and policy lately (Egle et al., 2016; Hukari et al., 2016). In Switzerland, 5,700 ton of P could be recovered yearly from 783 municipal WWTPs and additional 3,700 ton from meat and bone meal (BAFU, 2017b). Thus, Switzerland would be able to cover its total P demand in agriculture through recycling P from WWTPs and slaughterhouses.

Policy interventions

For many years, Swiss farmers have used sewage sludge from municipal WWTPs to fertilize their farmlands. In 2003 these practices were prohibited by law due to the presence of heavy metals, organic pollutants and pathogens endangering long-term soil fertility in sewage sludge. Since 2006, digested sludge (200,000 tons dry matter yearly) has been exclusively incinerated in specific sludge incinerators (64%), municipal solid waste incineration (MSWI) plants (14%) or in cement kilns (22%) (BAFU, 2019). While cement plants embed the incinerated sewage sludge into the final cement product, the ash residues from sludge and MSWI are commonly landfilled accumulating a highly concentrated, unused P deposit.

Mandatory P recycling from WWTPs by 2026

In 2016 the Swiss Waste Avoidance and Disposal Act (VVEA) was passed that requires the operators of WWTPs in Switzerland to recover P from their sewage sludge before its disposal (VVEA, 2015; Spörri et al., 2017). After a 10-year transition period, P recovery at Swiss WWTPs is legally required from 2026. The recovered P shall be further used in recycling fertilizers.

In 2019 the Swiss Federal Office for the Environment (BAFU) drafted guidelines for quantitative and qualitative P recovery rates. The minimal recovery rates are 45% from municipal wastewater and sewage sludge, 80% from ash residues of incinerated sludge (sewage sludge ash) and 100% from meat and bone meal. If recovered P is used for recycling fertilizer, the pollution standards, especially related to heavy metals, set in the Chemical Risk Reduction Ordinance (ChemRRV 814.81) have to be met (BAFU, 2019a).

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TECHNOLOGY AND TYPE OF REUSE APPLICATION

Different P-recovery techniques are available or in an advanced stage of development. They differ regarding their extraction point (e.g., sewage sludge, sewage sludge ash) and the processing principles (e.g., wet chemical or thermochemical) (Spörri et al., 2017; Nättorp et al., 2017, Hukari et al., 2015, Egle et al., 2016) (Figure 15).

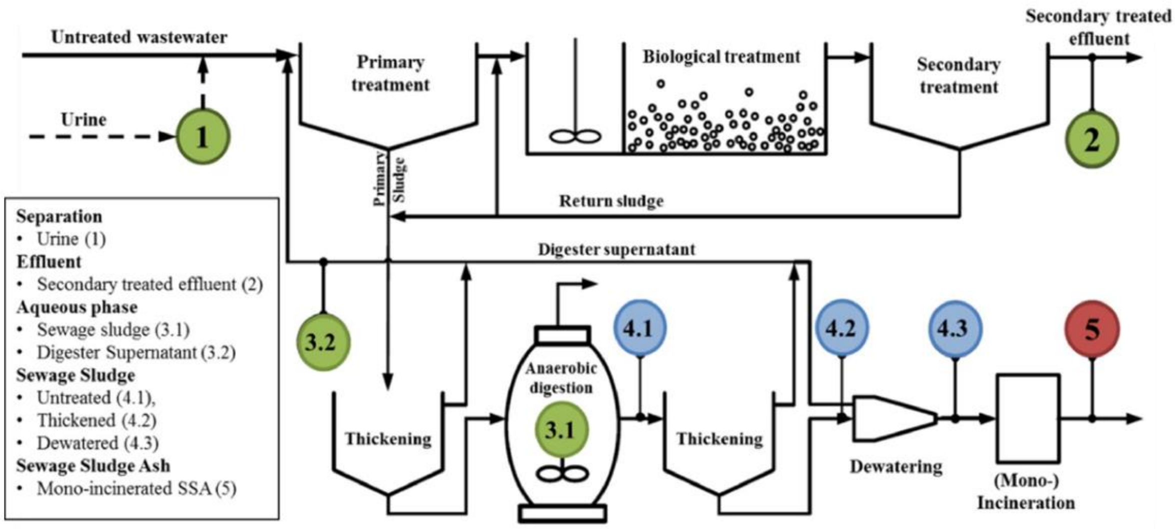

Figure15: Various possible extraction points for P-recovery approaches during wastewater and sewage sludge treatment
Source: (Egle et al., 2016)

Technologies that are considered for implementation in Switzerland within the 10-year transition period base on the following five processes (Spörri et al., 2017) (Table 17):

Crystallization from sewage sludge (before and after dewatering)

These processes are commonly applied to sewage sludge before dewatering (4.2, Figure 15)or for sludge liquor after sludge dewatering (4.3). An existing enhanced biological elimination of P is required for the process. P and nitrogen (N) dissolved in the aqueous phase are removed by the addition of magnesium (or calcium) and pH increase in stirred or fluidized bed reactors. The product is crystallized struvite (magnesium ammonium phosphate). After P recovery, the remaining sludge can be disposed of with conventional methods.

Acid treatment of sewage sludge followed by crystallization

These processes base on acid leaching of P from sewage sludge (4.2 Figure 15). Carbonic acid is used under high pressures for sewage sludge before dewatering. Since heavy metals are not

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dissolved with carbonic acid, they do not end up in the product. Carbonic acid is mostly recovered in the process. Sulphuric or hydrochloric acids are also used. The acid also dissolves heavy metals that need to be removed by complex formation and sequential precipitation. Sulphuric or hydrochloric acids are largely consumed in the process. Subsequently, the dissolved P is crystallized to struvite or calcium phosphate by adding magnesium or calcium and raising the pH. After P recovery, the remaining sludge can be disposed of with conventional methods.

Thermochemical digestion of sewage sludge

Dewatered sewage sludge (4.3 Figure 15) is dried, followed by thermal treatment in furnaces with temperatures between 650 – 1,400 °C depending on the technology. Due to the high temperatures, heavy metals can be separated (volatile metals evaporate while non-volatile metals melt if > 1,000 °C). The product is a P containing ash or slag.

Acid digestion of sewage sludge ash

Mono-incinerated sewage sludge ash (or meat and bone meal) are used in these processes (5 Figure 15). The processes differ regarding P-separation (acid and precipitants), the recycling product, and the heavy metal separation. Phos4Green does not apply any heavy metal removal and provides a calcium mixed phosphate. The other processes differ regarding the heavy metal separation processes (ion exchanger, solvent extraction or fractionated precipitation) and deliver di-calcium phosphates, Ca-Al mixed phosphates or phosphoric acid.

Thermochemical digestion of sludge ash

The processes base on the thermochemical utilization of P-rich ash from the mono-incineration (or gasification) of sewage sludge, meat and bone meal, or other biomass (5 Figure 15). ASH-DEC uses temperatures of around 950 °C and an alkali salt to digest P and deplete volatile heavy metals (As, Cd, Hg and Zn). RecoPhos P4, on the other hand, brings P and volatile heavy metals into the gas phase; what remains is a slag which is suitable as a cement aggregate. The heavy metals are separated from the gas and elemental P is extracted, which can be hydrolyzed to phosphoric acid.

In Switzerland, currently no full-scale plant is in operation, but several different P recovery processes are tested in pilot and demonstration plants. WWTP Altenrhein SG and WWTP Oftringen AG test thermochemical digestion of sewage sludge, which shows economic advantages over other processes. At the WWTPs Zuchwil and Werdhölzli (ZH), acid digestion of sludge ash is tested with Phos4Life technology (BAFU, 2019b; Phosphornetzwerk Schweiz, 2020) with promising results regarding P-recovery >95%, contained in phosphoric acid (AWEL, 2018).

Given the significant differences in performance of P recovery processes as well as in existing WWTP infrastructures in Switzerland, a well-founded decision on the optimal P-recovery processes to be implemented cannot be given at this point-in-time.

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Table 17: Overview on P-recovery processes, technologies, products, recovery rates and advantages/disadvantages (adapted from Spörri et al., 2017; Phosphornetzwerk Schweiz, 2020)

Process	Technology	Product	Location/demonstration or full scale implementation	Recovery rate of P
Crystallisation from sewage sludge (before and after dewatering)/ wastewater	Airprex, Ekobalans, NuReSys, Crystallactor, Ostara Pearl, Struvia	Struvite (magnesium ammonioum phosphate)	40-60 full-scale implementations in Europe, Northern America and Asia	15%
Acid digestion of sewage sludge followed by crystallization	Carbonic Acid process Gifhorner Verfahren, Stuttgarter Verfahren, Budenheimer Verfahren	Struvite / calcium hydrogen phosphate	Demonstration plants in Mainz Mombach (DE), Gifhorn (DE), Offenburg (DE), Bern (CH)	40%
Thermochemical digestion of sewage sludge	Kubota, Mephrec, Pyreg, Susteen, Pyrophos	P-containing slag/ ash	6 full-scale plants in Japan (Kubota), Demonstration plants for other technologies in Nürnberg (DE), Linz-Unkel (DE) and Altenrhein (CH)	90%
Acid digestion of sewage sludge ash	EcoPhos, LeachPhos, Phos4Green, TetraPhos, Phos4Life	Calcium mixed phosphate, phosphoric acid	EcoPhos Full scale plant in Dunkerque (F), demonstration plants in Bern (CH, Extraphos), Hamburg (DE, TetraPhos) and Emmenspitz (CH, Phos4Life),	50-90%
Thermochemical digestions of sludge ash	ASH DEC, RecoPhos (P4)	Calcium hydrogen phosphate, white phosphorous P4, phosphoric acid	Demonstration plants in Leoben (A)	90%

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OTHER DRIVERS AND BARRIERS

Ecologic and socio-economic advantages of recycling P fertilizers over mineral P fertilizers

The advantages of recycling P fertilizers from domestic effluent are the social and environmental benefits over manufacturing them from phosphate minerals. The mining of phosphate rock is often done under precarious ecological and social conditions. P-recycling i) conserves phosphate rock reserves; ii) prevents importing fertilizers that contain harmful heavy metals such as uranium and cadmium; and iii) prevents Swiss farmers of being exposed to uncertain price trends for mineral P fertilizers and makes Switzerland independent from imports of a scarce resource (Hukari et al., 2016; Egle et al., 2016; BAFU, 2019b).

Even though a detailed economic analysis of P recycling in Switzerland is not yet available, it provides an opportunity for the local economy that benefits from technological developments. Costs of P-recovery have been estimated at 5 CHF (4.60 EUR) per inhabitant per year or less than 5% of wastewater treatment costs (Hukari et al., 2015; BAFU, 2017b).

Revision of recycling P fertilizer standards/ monitoring capacities have to be established

Recycled P fertilizers contain clearly lower cadmium concentrations compared to imported mineral P fertilizers. However, recycled P materials still contain copper, whose concentration exceeds current fertilizer quality standards (ChemRRV). In order to use recycled P material in fertilizers, the Swiss Federal Council revised its Fertiliser Ordinance (DüV) and the Chemicals Risk Reduction Ordinance (ChemRRV). Limit values for various heavy metals and harmful organic compounds in recycling P fertilizers have been introduced to prevent adverse impacts on soil fertility and organisms (BAFU, 2017b; 2019b).

The Swiss cantons will play an important role to transparently monitor and report P-recycling quantities and qualities from WWTPs on their territories. Compliance monitoring capacities need to be established in the individual cantons (BAFU, 2019b).

Market demands for recycled P products vary largely; for recycling P fertilizers acceptance among farmers is key

While struvite can be used as a substitute for raw phosphate in the fertilizer industry and phosphoric acid can be sold at good market prices to various sectors in the EU, the subsequent use of P-containing slag/ ash is more difficult (Spörri et al., 2017).

In Switzerland, the market for P fertilizers recovered from effluent is yet to be established. This requires similar or better plant availability of recycled P fertilizers, competitive prices and a minimal demand. In principle, phosphate is only directly available to plants in dissolved form. For this reason, the P fertilizer recovered must be converted into a soluble mineral, which can add significantly to process costs and could compromise recycling efforts (Hukari et al., 2016). To ensure market success, the acceptance of recovered P fertilizer among farmers is key. Farmers must be able to use the recovered fertilizer in all areas of production (intensive, extensive and organic farming) and thus need to be informed about the product quality and advantages, the targeted applications and the importance of recycling efforts (Hukari et al., 2015).

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CONCLUSIONS

P recovery from waste has clear ecological and socio-economic benefits. Switzerland has made P recovery from municipal sewage sludge mandatory from the year 2026, marking a significant step towards sustainable use of raw materials and closing local nutrient cycles. Further investigations to identify optimal technologies and processes are needed before full-scale P recycling is implemented on existing sewage sludge disposal infrastructures. Consultation and close collaboration with cantons and farmers will be crucial to increase acceptance of waste-derived products and to establish a market for P fertilizers recovered from sewage sludge.

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CHAPTER 5 LESSONS LEARNT FROM THE CASE STUDIES ABOUT SUCCESSFUL AND UNSUCCESSFUL WATER GOVERNANCE MODELS ACROSS INDIA AND THE EU

5.1 INTRODUCTION

This section aims to discuss core lessons learnt from the wastewater treatment and RRR policies (Chapter 1 and 2), the stakeholder workshops (Chapter 3) and current wastewater treatment and RRR practices in India and the EU (Chapter 4). It highlights the policy and regulatory factors that trigger the development and implementation of wastewater treatment technology and RRR systems and summarizes technical-operational, socio-economic, environmental and institutional enabling factors and barriers of current wastewater treatment and RRR practices (Table 18 for wastewater treatment and water reuse and Table 19 for energy and nutrient recovery from sewage sludge). This chapter sets the basis for formulating recommendations towards enhancing wastewater treatment and RRR governance arrangements in India and the EU (Chapter 6).

Table 18: Enabling factors (+) and barriers (-) affecting current wastewater treatment and water reuse practices in Europe and India

Factor (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
	(+) EU Member States with individual water reuse norms legislations (e.g., Spain, Portugal), 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)

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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 design matching resource contexts	(-) Technology designs not matching resource context and not taking long term development plans of the area into account (-) Prescribed standard technologies in tender processes
Operation and maintenance	(+) High degree of automation (+) Skilled operators	(-) Unreliable power supply (-) Financial constraints (+/-) Some plant operators have developed skills and capacities (-) Outdated O&M on installations
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 irrigated agricultural, 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	(+) Government support/initiatives (e.g. Swacch 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
	(+/-) Charges for wastewater services influenced by socio-cultural norms and political interests	
	(-) High investments needed for wastewater treatment and reuse (+) Fit-for-purpose treatment at the design stage reduces capital expenditure compared to retrofitting	(+) Creation of Viability Gap Funds (VGF) to support infrastructure projects
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 waste-water irrigated products (+) On-site treatment and reuse (industrial reuse)	

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Table 19: Enabling factors (+) and barriers (-) affecting current energy and nutrient recovery practices from sewage sludge in Europe and India

Factor (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	(+/-) New Waste Management Rules 2016 obliges municipalities to postprocess sewage sludge and promotes reuse in agriculture. But there is weak enforcement. (+/-) 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)
New legislative initiatives/under revisions	(+) 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	(+) 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
Environmental and socio-economic aspects	(+/-) Land spreading of treated sewage sludge can enhance the fertility of soils. Heavy metal accumulation is of concern and 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	(-) 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)
Financing/Cost recovery	(+) Land application of sewage sludge (where permissible) is a cheaper alternative to incineration or landfill disposal	(-) Feed-in tariffs for biogas production are too low to encourage investment and increase production

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	(+) Digestion of sludge reduces volumes of residual sludge for incineration / landfill disposal	(+) PPP for waste-to-energy projects (investors)
	(-) 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 (-) Incentives (legal, financial) for the use of high-quality biosolids in agriculture are needed	
Acceptance	(-) Market for recovered P products still needs to be established (+/-) Acceptance of treated sludge among farmers is key	

5.2 Lessons learnt from current wastewater treatment and RRR practices in Europe

The history and population growth dynamics of the EU and India are different and this has impacted their development of water management and governance practices. EU countries, especially those in Western Europe, have been investing in sewerage systems for many decades. The development of sewer systems to transport the domestic effluent out of the cities came with the introduction of the flushed toilet in the 19th and early 20th century in Europe, which replaced the latrines and use of excreta in agriculture. However, this system resulted in point source pollution elsewhere. Slowly, centralized WWTPs were introduced.

In Europe, after World War II, the environment and surface water quality did not receive adequate attention and was not a priority. For instance, the quality of the water in the Rhine river was at its worst between 1960-1970. However, in the 1970s EU countries started to develop policies and laws to protect water quality and the environment. The first law was introduced in the Netherlands in 1970 ('Wet Verontreiniging Oppervlaktewateren') with the aim to protect the quality of surface water. At the EU scale, the first step to tackle surface water pollution was in taken in 1991, by the development and implementation of the UWWTD, which is discussed in many of the EU case studies (Chapter 4) and has played a key role in improving EU water quality. The UWWDT also regulates the treatment and disposal of sewage sludge and in combination with other EU Directives (chapter 1.3.3.) promotes land application of treated sewage sludge (nutrient recovery) and energy recovery through e.g. anaerobic digestion or incineration.

On the basis of these Directives the EU Member States were mandated to draft national guidelines for their wastewater and sewage sludge management to comply with EU legislation. Compliance with the EU Directives is regularly monitored and non-compliance is penalized. The EU legal framework is thus a strong driver for investments for wastewater and sewage sludge treatment technologies.

Bulk removal of organics and nutrients was taken care of by the treatment plants that used primary, secondary and tertiary (advanced nutrient removal) treatment processes. In the early 21st Century, the focus had shifted to tertiary and quaternary treatment in order to make a circular economy possible i.e. the reuse of water, the removal of trace organics and the recovery of nutrients such as

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P and the production of energy from waste sludge as illustrated by the EU case studies in Chapter 4. The up-coming regulation on 'minimum quality requirements for water reuse' will further stimulate the uptake of water reuse by EU member states as it promotes public confidence in agricultural products coming from fields irrigated with reclaimed water and remove potential barriers to the free movement of agricultural goods.

The case studies of the EU show that there has been increased utilization of wastewater treatment and RRR in recent years, for many different purposes including agriculture, industrial use and energy production. They also illustrate the recent development of clearer governance arrangements by EU Member States, more dedicated economic instruments and the setting-up of water reuse guidelines. The water sector in the EU is changing quickly to tackle the problems of water scarcity (though experienced on a limited scale in some EU member countries) and sustainable development. The EU has unique opportunities for wastewater treatment and RRR to be implemented on a larger scale as a sustainable practice as part of the water governance approach. Success of this approach depends as much on individuals, local communities and companies as on government and/or EU policy and regulations.

The four case studies of Belgium illustrate that the development of legislation and enforcement are fundamental triggers for improved wastewater treatment and RRR. Efforts to reduce and recover materials (e.g. P from sludge), water (water reuse for different purposes) and energy (e.g. anaerobic digestion or incineration of sewage sludge) are on-going in Belgium and several other EU countries. Policy interventions and economic investments in developing different technologies have facilitated the improvement and wide use of wastewater treatment and RRR along the country. As well as policy drivers there is also the issue that water scarcity and the increasing non-availability of conventional water sources (due to groundwater permits being rescinded) mean that treated wastewater has become a viable alternative water source. Belgium is also taking important steps to make water reuse a common activity and to make this 'new' water an alternative source for different purposes such as irrigated agriculture, demineralized water for industry and drinking. The case study of Wulpen demonstrates how drinking-water demand can be fulfilled by the combination of reuse and recharge. The case study of the Schilde WWTP illustrates further successes of water reuse due to improvements in technology and strict legal enforcements in Belgium to deliver demineralized water for industry. The case study of anaerobic digestion and biogas generation showcase how EU member countries adopt energy-efficient or on-site electricity production technologies to achieve an optimisation of operational energy consumption. Lowering energy consumption and thus carbon dioxide emissions from wastewater treatment are regulated by the European Energy and Climate Policies, including Renewable Energy Directives which have enabled support mechanisms (e.g. attractive energy pricing systems) for biogas and electricity production from sewage sludge in some EU countries (e.g. Belgium, Germany and UK). Finally, the case study of P recovery evidenced the clear ecological and economic benefits of resource recovery to be used as a fertilizer in agriculture. This while decreasing the pressure on the P reserve as a mineral. There remains a discrepancy between the controls on recovered P fertilizers and mineral P fertilizers, which can also be contaminated with heavy metals.

The Spanish case demonstrates the importance of having wastewater treatment and water reuse policies and legislation in place. Policy and legislation have helped promoting the development and implementation of different models for wastewater treatment and reuse practices over the last decade. These technologies have created new sources of water not only for irrigation but also for other uses such as industry recreation and environmental management. The case study of Barcelona shows the benefits of having quality criteria for different classes of wastewater reuse, and the treatment process for each type of reuse. Additional benefits of reusing treated wastewater are: increase in the income of farmers, and freshwater availability for domestic use. The case study of Alicante illustrates how the reuse of treated domestic wastewater is becoming a common

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practice, especially for irrigation due to water stress and concessions made available to irrigation associations. However, it is important to remember that the situation in Spain is not representative of Europe, as in Europe as a whole only 2.4% of wastewater is being reused.

The Switzerland case study on mandatory P recovery from municipal WWTPs illustrates how countries without natural P deposits, can produce alternative P products. This would change their dependency on other countries to export P and eventually it would allow Switzerland to be able to cover its total P demand in agriculture through recycling P from WWTPs. The case study also highlighted the many ecological and socio-economic benefits of P recovery. Switzerland will make P recycling from municipal sewage sludge mandatory in 2026, which will represent a milestone towards sustainable use and circular economy.

Finally, the case study of Lombardy, Italy shows that the success of applying treated sewage sludge on agricultural land. This study provides evidence to the effect that treated sewage sludge can improve crops productivity and enhance soil fertility. It also illustrates how, through legislation, it is possible to mitigate adverse effects on the environment, when establishing stringent limits for different contaminants of concern.

5.3 LESSONS LEARNT FROM CURRENT WASTEWATER TREATMENT, WATER REUSE AND RESOURCE RECOVERY PRACTICES IN INDIA

In India the largest cities have centralized sewage systems and treatment plants. However, only 37% of the wastewater generated receive full treatment. Sewage sludge generated from these plants is a further concern, as no or poorly maintained treatment infrastructure is available. Untreated or partly treated sludge is discharged into water streams, dumped on landfills or reused by farmers implying considerable human and environmental health risks.

Urban India is growing rapidly and this poses significant challenges for urban infrastructure and services like water supply, sanitation, wastewater collection and treatment. Untreated and partially treated sewage and industrial effluents are still the major polluter of water sources in India, causing diseases among humans and animals, crop contamination and environmental degradation. The urban poor often live alongside dirty drains and canals in which mosquitoes breed and germs spread. Furthermore, water supply in most cities and towns is often insufficient to meet the growing demand for water by all economic sectors, so recycled wastewater could be a valuable alternative water source, besides recovering nutrients and energy from wastewater.

The case studies of India illustrate that the state governments have been taking important steps to tackle - to some extent - the problems of water pollution and water scarcity. However, the case studies also show a lack of an overarching and clearly-defined guideline from the Central or State governments, along with the lack of an established framework for safe and sustainable reuse of treated wastewater with clear incentive/disincentive mechanisms. 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).

The case study of Kanpur has shown that the Ganga Action Plan, which specifically calls for 'new technology of sewage treatment', led to the introduction of wastewater treatment technologies. However, the technical design and implementation did not adequately take into account the long-term and rapid growth of the area, the specific contaminant issues of the tannery industry and the

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problem of mixing of industrial effluent and municipal wastewater. Hence, the capacity and the performance of the existing treatment system is lower than expected. A new CETP (20MLD) in Jajmau contracted by WABAG is under construction. As the treated wastewater is of poor quality, it is not reusable if not desalted and polished. Prior to arriving at the stage of reuse, the wastewater treatment technologies need to be made effective to ensure that water of requisite quality is produced. The communities that live downstream of the STP have been significantly impacted by the poor quality of water. The communities have been accustomed to using it and the poor quality water has high acceptability among the farmers who depend on this free resource for irrigation. However, certain crops are no longer viable in the area. Further the domestic water sources of the local communities have been polluted, threatening their health and livelihood. Optimization of treatment technology backed by effective monitoring system and well-defined reuse standards/norms along with a clear framework for wastewater reuse is required for Kanpur.

The case study of Nagpur illustrates how policy interventions have facilitated the development and implementation of WWTPs and water reuse systems. In Nagpur, the first driver that facilitated the development of infrastructure projects associated with water supply, sewerage, and treatment was the Jawaharlal Nehru National Urban Renewal Mission, which was launched in 2005. In order to complement the efforts achieved with the Mission, the state of Maharashtra adopted the wastewater reuse policy in 2017. This last policy intervention has been instrumental in encouraging reuse of wastewater in the production of electricity in the TPPs and in industrial estates in the region. The Nagpur experience also shows the importance of a strong contractual agreement backed by government policies to create successful models for wastewater treatment and reuse systems.

The case study of treated wastewater in Kodungaiyur, Tamil Nadu illustrates how sludge collected from primary and secondary treatment processes has been used to generate biogas, which has been then used as fuel to generate electricity. This case can be considered as a good experience of wastewater treatment and reuse. It also shows how while using resource recovery techniques it is possible to reduce economic costs. Furthermore, the case study evidences that policy and regulatory intervention can create successful models for wastewater treatment and RRR.

The case study of Rithala, New Delhi on resource recovery illustrates valuable options of water reuse and resource recovery. It shows how treated wastewater can be used for gardening and horticulture. It also exemplifies how methane rich sludge can produced during treatment of wastewater and how methane –after thermal hydrolysis and anaerobic digestion – can be used as on-site energy source to produce electricity. The case study also indicates the importance of policy and regulation have encouraged the reuse of treated wastewater in horticulture and industrial processes. Overall the case study shows a successful experience in treating sewage to superior quality standards.

The case study of Ahmedabad Municipal Corporation in Gujarat highlights first attempts to treat sewage sludge in a centralized sludge treatment plant and reuse. The plant set up at Pirana converts 100 ton of dry sludge into bio-fertilizer by radiation technology and NPK treatment. The case study underpins that sewage sludge treatment can be a promising business model for large municipalities, which helps increase the cost-recovery of sewage sludge treatment. As the plant was installed recently, great emphasis has now to be placed on promoting bio-fertilizer and increase its acceptance among farmers to make it a viable business model.

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CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This document highlights that i) the Indian Government has been taking important steps to create an enabling environment for tackling the issues of water pollution, and water scarcity; ii) there is a great deal to learn from practices – from the India and EU experiences (case studies) – about the benefits but also the challenges that exist in order to advance in wastewater treatment, water re-use and resources recovery; and (iii) key drivers to increase water reuse and resource recovery uptake are the decreasing availability of conventional water and energy sources, deteriorating soil health and a strong policy and legal framework.

On the basis of the lessons learnt from the policy and legal analysis, the consultation workshops with key stakeholders and the analysis of 13 case studies - from India and the EU - we can conclude that the following factors are important for successful wastewater treatment and RRR schemes:

Policy and Law

- When legislation is followed by effective monitoring, enforcement and follow-up at all levels, so that it can be key driver for improved wastewater treatment and RRR technology investments
- Simplicity and clarity of the law facilitates its effectiveness;
- An integrated approach with policy and legislative framework allows a holistic planning and governance of wastewater and RRR developments, and;
- Circular economy initiatives to increase wastewater and RRR require robust business models to ensure cost recovery;
- Financial incentives for the use of recovered resources (water, nutrients and energy) and their promotion among potential customers are crucial to facilitate market-uptake.

Technical and Operational

- Openness to new technologies and configurations allow for different degrees of treatment for different water uses as well as for different resource recovery possibilities (nutrient, energy) from sewage sludge;
- The increased willingness to pay for treated water is clearly linked to the increased non-availability of conventional water sources i.e. surface and or groundwater for economic activities and social uses;
- 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 on conventional mains electricity supply;
- Technologies need to be adequately monitored and maintained when delivering water for all kinds of reuses (promoting a water fit-for-use approach);
- Quality monitoring is needed for treated sewage sludge used for land application to ensure farmer acceptance;
- Resource recovery technologies are complex and proper training programmes for engineers and operators are needed to ensure that potential recovery efficiencies are attained and that sewage sludge is of acceptable quality for land application;

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- In areas where cost recovery is low, there is a need to provide public budget transfers as evidenced in the EU by the need to use Cohesion Funds in Eastern Europe to implement the UWWTD.

6.2 Recommendations for water governance arrangements in India

On the basis of the 13 analysed cases from India and the EU and two stakeholder workshops in India, we deduct the following recommendations to improve the governance of water, with particular reference to enhance wastewater treatment and RRR in India.

Legislation/regulations for wastewater treatment and RRR

The Indian government has been taking important practical steps for tackling the issues of water pollution, water scarcity and sustainable development. Yet, there is a lack of an overarching and clearly-defined guideline from the central and/or state governments. Added to this is the lack of an established framework for safe and sustainable reuse of treated wastewater and RRR with a clear market and incentive/disincentive mechanisms. These are some of the key limiting factors to enhancing wastewater and RRR activities in India. These gaps are evident from the fact that most State Governments do not have laws and policies concerning wastewater treatment and RRR. Wastewater treatment and RRR is still in its nascent stage in India, nevertheless, several states (Gujarat, Jharkhand, Karnataka, Haryana and Punjab) have formulated policies (with varying approaches and priorities as per location and socio-economy of the states) to improve wastewater treatment and encourage the reuse of water and resource recovery. These policies consider treated wastewater and resource recovered from sludge as economic commodities. Yet, there is limited capacity to enforce regulations that are already in place.

Recommendations

- Clear target-based regulations, defined national standards of reuse water quality, resource recovery as well as water safety planning and risk mitigation measures, are imperative interventions for stepping up wastewater and 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 this needs to be supported by an effective administrative mechanism for enforcement of regulations;
- Policy and guiding frameworks in India need to establish detailed guidance on wastewater and sewage sludge 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 and sewage sludge; and,
- Decentralized systems are required to be promoted in larger number to facilitate and enhance wastewater and RRR in peri-urban and rural areas.

Institutional arrangements for pollution control

Improvements are needed in the institutional framework for water supply, distribution, sewage, wastewater treatment and RRR at the national and state levels. The state pollution control boards (SPCBs) have very limited human resources to monitor water quality (with a reasonable frequency and geographical spread of collection, testing, and interpretation) in all the water bodies that either constitute the source for water supply schemes or serve the ecosystem, and to disseminate the results to the concerned parties. The inadequate number of monitoring stations and the fact that many of them are not located in cities or immediately downstream of the points of pollution are

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also some of the reasons for the lack of a realistic picture of the extent of water pollution in the country. Second, while the SPCBs themselves do not have the legal power to penalise polluters, they are required to pursue legal action against them. But they have limited organizational capabilities to pursue legal action against violators of pollution control norms or those who do not comply with effluent disposal standards, with delays in judicial processes (Kumar and Tortajada, 2020).

In the same sense, the discussions during the two workshops conducted in Delhi at TERI on 27 February 2020 and at IIT Kanpur on 6 March 2020 echoed the problems with poor or non-existent wastewater and sewage sludge treatment systems, which are resulting in pollution of fresh water bodies, seriously affecting humans, animals and ecosystems health. Furthermore, awareness regarding the necessity of wastewater treatment is often lacking. Another recurrent topic was the need to improve control and enforcement mechanisms for polluters.

Recommendations

- Enforcement mechanisms for polluters need to be established in order to reduce the pressure on end of pipe treatment systems;
- Substantial investments in monitoring stations and monitoring capacity are needed to better assess the pollutants and identify sources of pollutions into water bodies;
- Reliable and regular monitoring of treated wastewater and sewage sludge is crucial to ensure total confidence and protect human health of the end users such as farmers using treated wastewater or sewage sludge;
- Developing a robust implementation framework involving last mile connectivity of solutions for better upscaling;
- Regular and planned engagement of key stakeholders in policy formulations and implementation;
- Community mobilization, awareness and capacity building are important and collaborative action 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.

Financing strategies for wastewater treatment, water reuse and resource recovery

Although public funds are available for treatment infrastructure, most utilities are unable to recover costs of treatment. Low cost reuse options such as reuse of treated wastewater and treated sewage sludge in agriculture will not increase cost-recovery significantly, as revenues from the recovered products are expected to be minimal. In-house electricity generation from sewage sludge through anaerobic digestion technology can improve cost recovery as expenditures for operational activities (electricity consumption) can be decreased. To boost industrial reuse of treated wastewater, several industries and bulk water users will need to look towards treated wastewater as economically viable option to meet their water requirements.

Recommendations

- Policies are needed to support more effective water- and wastewater-pricing systems, electricity feed-in tariffs and use of recycled products from STPs that permit sufficient cost recovery, ensure adequate investments and support long-term operation and maintenance;

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- 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 reclaimed water;
- Increase government support and investments into research and development for innovative technologies for wastewater reuse and resource recovery, its upscaling and viable business models; and;
- Effective and specific incentive and disincentive mechanisms for wastewater reuse and resource recovery with financial benefits to entities (e.g. exemptions/rebate in from GST charges, incentives to recycle/reuse by-products, tax incentives for 'green' energy and favorable loan facilities for green investments).

As a way forward, it is fundamental to rethink wastewater treatment and RRR in India and continue designing, implementing and enforcing robust policy and regulatory frameworks - taking lessons from EU countries that have focussed on this for a longer time - that stress the importance of water quality protection and sustainable use, as well as to provide clear functions, responsibilities, risks and sanctions in water governance. Research and the development of 'new', cost effective, and sustainable technologies that work in different environmental settings have an important role to play in achieving this gigantic task. It is the aim of PAVITRA GANGA to make a contribution towards achieving this.

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ANNEXES

1. Agenda workshop in New Delhi

Time	Programme
9:30-10:00 hrs	*Registration*
Session I: Plenary Session	
10:00-10:30 hrs	*Setting the Theme* Mr. Anshuman Associate Director – Water Resources Division, TERI
10:30-1130 hrs	*Plenary Round Robin Session* Introductions and feedback
11:30-11:45 hrs	*Tea Break*
Session II: Breakaway Groups	
11:45-13:15 hrs	Part I: Introduction Part II: Work in Thematic Groups Part III: Synthesis
13:15-14:15 hrs	*Lunch*
Session III: Breakaway Groups	
14:15-15:15 hrs	Part I: Group Discussion Part II: Synthesis
15:15-15:30 hrs	*Tea Break*
15:30-16:30 hrs	*Key Takeaway and Wrap-Up*

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2. Agenda Workshop in Kanpur

Time	Programme
9:30-10:00 hrs	***Registration***
Session I: Plenary Session	
10:00-11:00 hrs	***Setting the Theme*** Presentation- Mr. Anshuman Associate Director – Water Resources Division, TERI Presentation: Nathaniel Water Resources Division, TERI Introduction Round
11:00-11:15 hrs	***Tea Break***
11:15-11:30 hrs	Instructions-Dr. Lisa Scholten and Dr. Tara Saharan, TU Delft
Session II: Plenary Session	
11:30-12:30 hrs	Part I: Group Discussion Part II: Synthesis
12:30-13:30 hrs	***Lunch***
Session III: Plenary Session	
13:30-14:10 hrs	Part I: Group Discussion Part II: Synthesis
14:10-14:20 hrs	***Key Takeaway and Wrap-Up***

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3. Workshop participants in Delhi

S.No.	Name	Designation	Organisation
1	Sh D P Mathuria	Executive Director (Technical)	National Mission for Clean Ganga (NMCG)
2	Dr Anil Mishra	Bacteriologist	Delhi Jal Board
3	Mr Arun Sharma	Chemist	Delhi Jal Board
4	Ms Sushmita	Bacteriologist	Delhi Jal Board
5	Ms Hemlata	Asst. Chemist	Delhi Jal Board
6	Ms Rupali	Asst. Chemist	Delhi Jal Board
7	Mr Jay Krishna	Lab. Tech	Delhi Jal Board
8	Sh. P.K. Tyagi	SE(Dr)Pr-III	Delhi Jal Board
9	Sh. Girraj Goyal	Director (IEC)	DoWR, RD & GR, Ministry of Jal Shakti
10	Ms Veena Khanduri	Executive Secretary-cum-Country Coordinator,	India Water Partnership
11	Sh Suneel Kumar Arora	Adviser	National Water Mission
12	Dr Vijaya Lakshmi	Vice President	Development Aleternatives
13	Mr Tatheer Raza Zaidi	Senior Program Manager - Leather and Dairy	Solidaridad, New Delhi
14	Ms Sakshi Chawla	Program Officer	Solidaridad, New Delhi
15	Prof. Ranjana Chaudhuri	Professor	TERI-SAS
16	Mr Rahul Chhabra	CEO	Transchem Agritech Pvt Ltd
17	Mr Sushant Kumar	Marketing Manager	Transchem Agritech Pvt Ltd
18	Ms Neha Agarwal	Manager, Research and Analysis	Development Aleternatives
19	Dr Prabhat Ranjan	Scientist B	Central Pollution Control Board
20	Dr Swati Singh	Research Associate	Central Pollution Control Board
21	Ms Sulagna Roy	Business Development Executive	VA Tech WABAG Limited
22	Sh. S K Juneja	Scientist D	Central Ground Water Baord
23	Sh. M K Hans	Chief Engineer Water Works	Delhi Jal Board
24	Ms Sherly M A	Asst. Professor	TERI SAS
25	Mr Sravan Kumar	Research Officer	National Mission for Clean Ganga (NMCG)
26	Mr Sundeep Gupta	YAP III	National Mission for Clean Ganga (NMCG)
27	Mr Suresh Sharma	CEO	SEPL
28	Mr P Yadav		Central Ground Water Board

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4. Workshop participants in Kanpur

S.No	Name	Designation	Organization
1	Sh. Anil Kumar Gupta	Chief Engineer Kanpur Zone	UP Jal Nigam
2	Mr Ajay Patel	Process Chemist	UP Jal Nigam
3	Mr Venkaiah Naidu	Program Manager - Leather Kanpur	Solidaridad
4	Mr Mohd. Zeeshan	Water Professional	Solidaridad
5	Dr N. Manickam	Sr. Principal Scientist	CSIR-IITR
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.