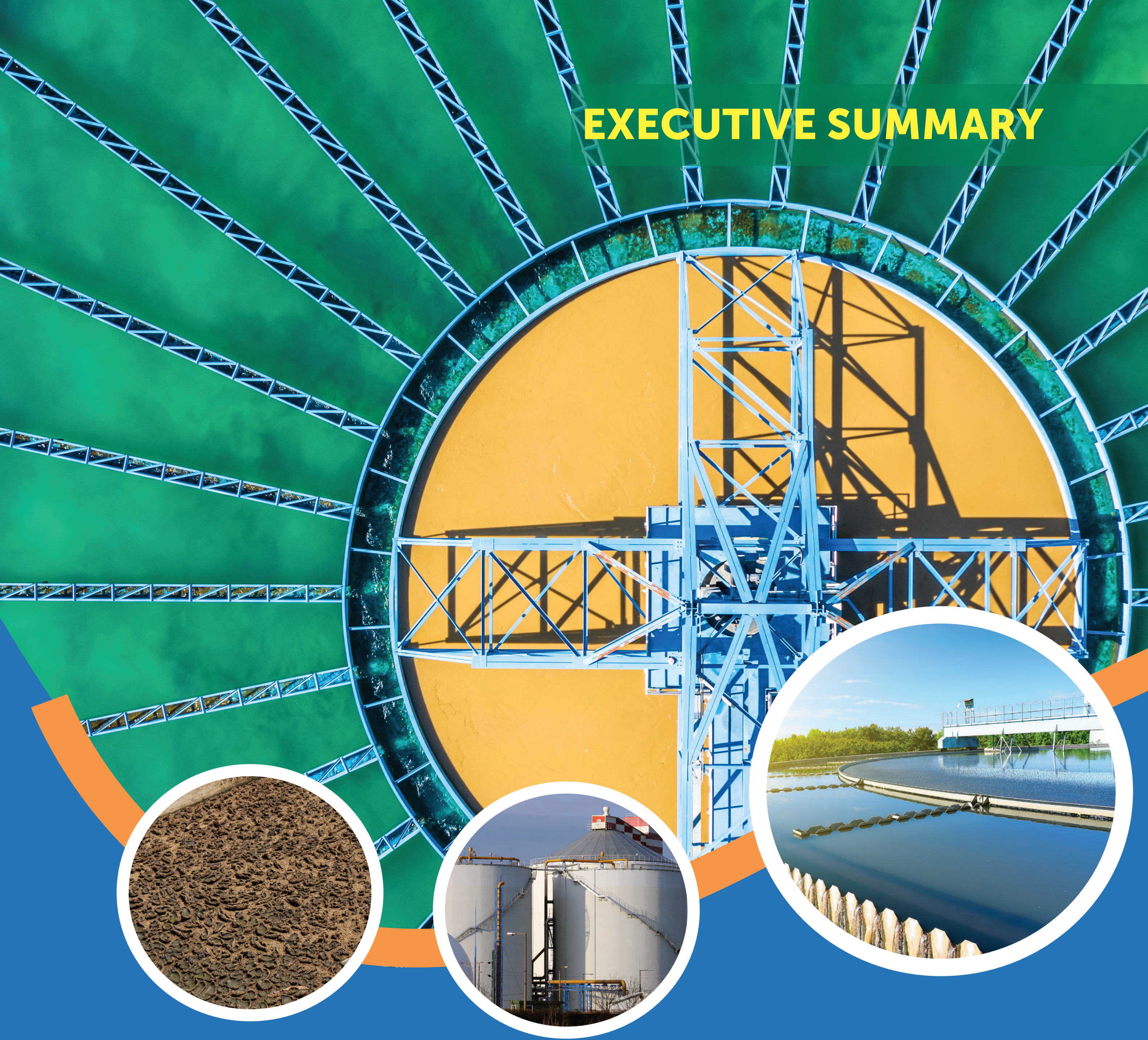

Options for Advanced Treatment and Resource Recovery for Decarbonization of Wastewater Utilities in the Bengaluru Metropolitan Area

WORLD BANK GROUP Water

Bangalore Water Supply and Sewerage Board
ಬೆಂಗಳೂರು ನೀರು ಸರಬರಾಜು ಮತ್ತು ಒಳಚರಂಡಿ ಮಂಡಳಿ

THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future

NMCG-TERI Centre of Excellence on Water Reuse

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OVERVIEW

As one of India's rapidly developing modern urban centres, Bengaluru City is experiencing unprecedented growth in its industrial, commercial, and institutional sectors. As a result, the population of the city has grown significantly in a very short period of time. This sudden growth in population is posing tremendous pressures on urban infrastructure especially on the water supply and sewerage system. Peripheral regions of central Bengaluru are particularly concerning, lacking adequate infrastructure to support the growing populace.

To provide better infrastructure in the surrounding urban areas bordering core Bengaluru area, the Government of Karnataka (GoK) in 2007 extended the jurisdiction of Bruhat Bengaluru Mahanagar Palika (BBMP) to cover additional 110 villages along with existing core area and 8 ULBs. The 110 villages which have been mainly dependent on ground water, and the sanitation facilities in the area have been primarily provided by household septic tanks and soak pits.

The global practice team of the World Bank Group and the Bengaluru Water Supply and Sewerage Board (BWSSB) came together and identified The Energy and Research Institute (TERI) to undertake a project to assess the existing wastewater generation and treatment facilities in Bengaluru, recognize available advanced treatment technologies of wastewater & sludge management and to maximize the recovery of resources and its utilization, such as biosolids, biogas and reusable treated water. Thus, this project aims to determine the need of infrastructural expansion to support the additional 110 Villages by focusing on innovation, fiscal discipline, resource recovery and sustainable growth consistent with the vision and goals of the BWSSB and transform BWSSB into Utility of The Future (UOTF).

Wastewater Treatment and Discharge Standards

In view of the severity of depletion of aquatic resources in the country, the Nation Green Tribunal (NGT) revised the effluent discharge norms for STPs in 2019 as listed in Table 1.

TABLE 1: Effluent discharge norms from STP

Sr. No	Parameters	Draft Norms (NGT) placed in 2019[1]
1	pH	6.5-9.0
2	BOD (mg/l)	<10
3	COD (mg/l)	50
4	TSS (mg/l)	<20
5	Total Nitrogen (mg/l)	<10
6	Ammonical Nitrogen (mg/l)	<5
7	Total Phosphorus (mg/l)	<1
8	Faecal Coliform (FC)	Desirable-: <100 Permissible: <230

These standards shall apply to all new STPs for which construction was initiated from year 2020 and all the existing/under construction STPs shall achieve these standards within 07 years (until 2026) from the date of notification.

Sludge Treatment and Utilization Standards

Central Public Health and Environmental Engineering Organisation (CPHEEO), Ministry of Housing and Urban Affairs, Government of India refers to USEPA classification of biosolids, as a standard parameter[2] (listed in Table 2) to ensure safe disposal of treated STP sludge.

1 https://scbp.niua.org/sites/default/files/NGT_Order_30.04.2019_Sewage_Disposal_Norms.pdf

2 https://cpheeo.gov.in/upload/uploadfiles/files/engineering_chapter6.pdf

TABLE 2: Biosolids disposal standards for land applications

Sr No.	Parameters	Unit	USEPA Ceiling Concentration for Agricultural Use[3]
1	Arsenic as As	mg/kg	75
2	Cadmium as Cd	mg/kg	85
3	Copper as Cu	mg/kg	4300
4	Lead as Pb	mg/kg	840
5	Mercury as Hg	mg/kg	57
6	Molybdenum as Mo	mg/kg	75
7	Nickel as Ni	mg/kg	420
8	Selenium as Se	mg/kg	100
9	Total chromium as Cr	mg/kg	500
10	Zinc as Zn	mg/kg	7500
11	PCBs (sum)	mg/kg	49
	Faecal Coli	MPN/gram	<1000 MPN/gram of dry Solids for Class A Biosolids <2,00,000 MPN/gram of dry solid for Class B Biosolids

Based on the treatment standards, the existing infrastructure has been assessed and future needs have been mapped.

[3] https://www.govinfo.gov/content/pkg/CFR-2018-title40-vol32/xml/CFR-2018-title40-vol32-part503.xml

EXISTING INFRASTRUCTURE CHARACTERISTICS

Status of Wastewater Collection and Treatment

Bengaluru is located on the watershed of two principal river basins, Arkavathi to the West and South Pennar to the East. The three principal valleys here are Vrishabhavathy, Koramangala and Chellaghatta which lies to the south of the ridge and divide the greater part of the metropolitan area into three separate and distinct drainage zones. A fourth valley system referred to as the Hebbal, forms a drainage zone to the north of the ridge and runs in a north-easterly direction. The administrative area of BBMP is divided into eight zones (Figure 1), i.e., three B.M.P zones, Bytarayanpura zone, Mahadevpura zone, Bommanahalli zone, R. R. Nagar zone and Dasarahalli zone. The configuration of valleys is well-graded by side slopes of their tributary areas, which has provided Bengaluru with a natural system of drainage without recourse to pumping allowing both sewerage and storm water to flow by gravity.

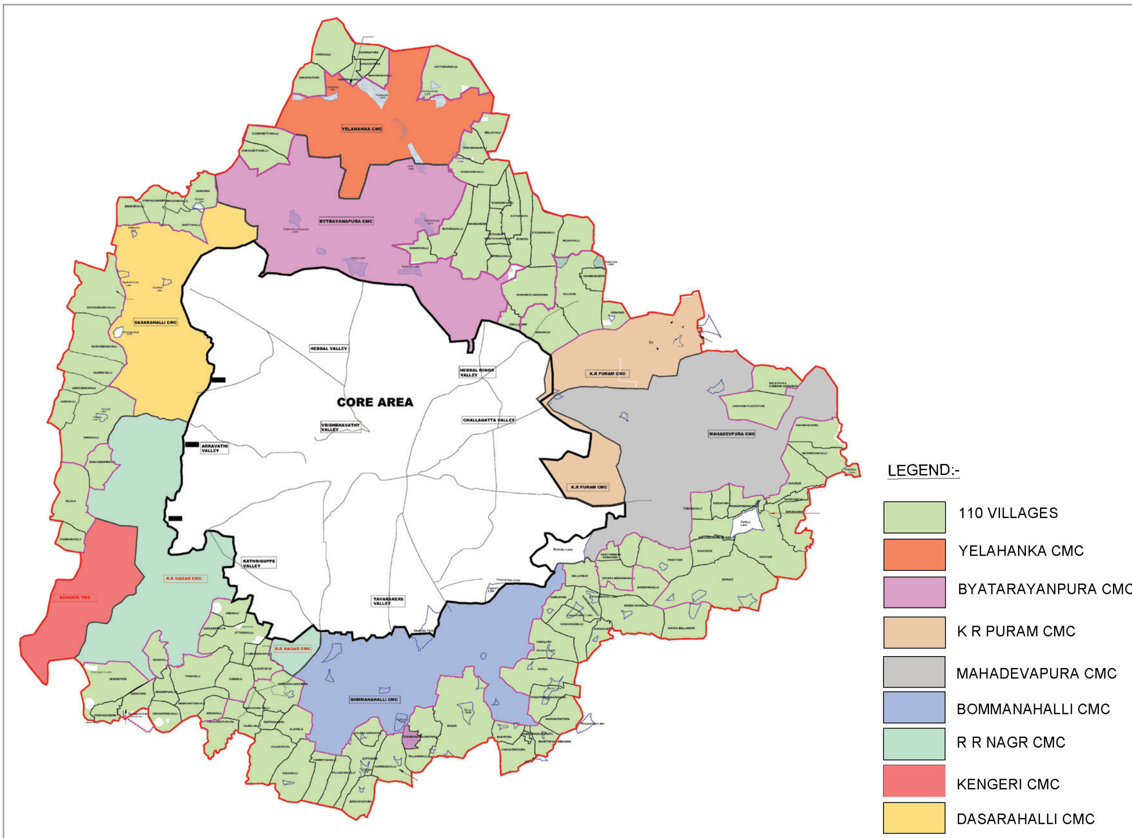


FIGURE 1: Bengaluru Map with Core Area and 110 Villages

To facilitate the collection of 1440 MLD wastewater generated in the city, underground drainage network is provided in the core Bengaluru. Currently, 36 Sewage Treatment Plants (STPs), with a total installed treatment capacity of 1527.5 MLD are distributed in four drainage zones. Although core Bengaluru area has the required infrastructure for wastewater collection and treatment, planned water distribution network, underground drainage facilities, and adequate treatment and management of wastewater is missing in the extended 110 villages and are being planned under various future projects.

Status of Reuse and Recycle of Treated Water

Bengaluru has made significant strides in wastewater reuse. Out of 1440 MLD total sewage generated; currently the city treats around 1189 MLD of wastewater. Approximately, 907 MLD of treated water directly discharged into Rivers and Valleys or discharged to nearby lakes for rejuvenation and ground water recharge and 123 MLD treated water directly taken for agricultural activities in the nearby areas. BWSSB is also generating INR 16 Crores of annual revenue by supplying 18 MLD of treated water for industrial & commercial use.

Status of Sludge Treatment, Management and Resource Recovery

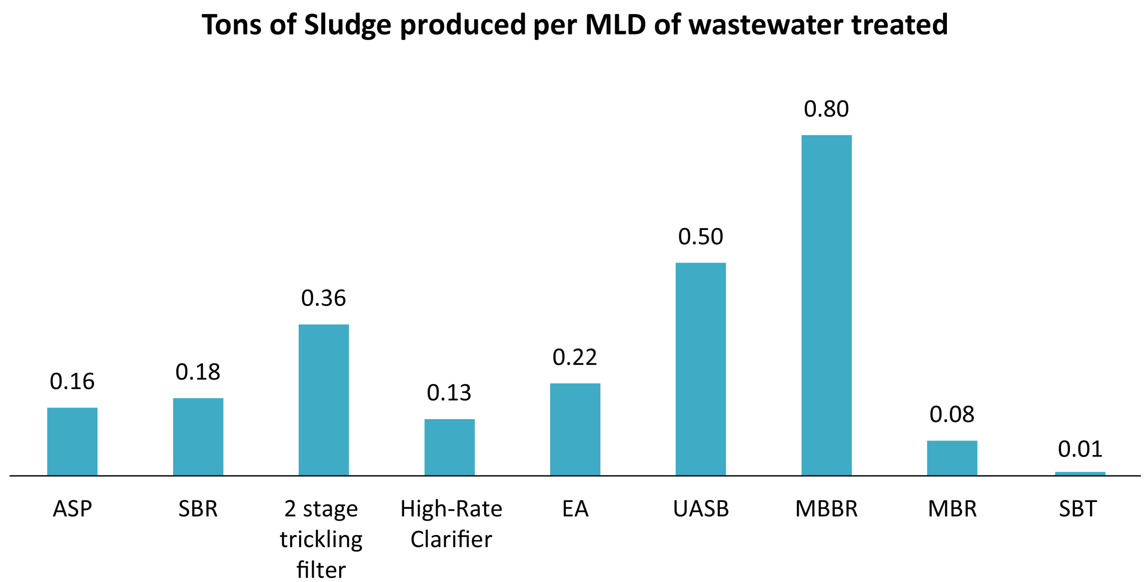
Sludge Treatment and Biosolid Production

The 36 STPs installed in Bengaluru area are collectively producing approximately 250 tons of sludge per day which is dewatered and dried and at present is given to local farmers for free to use as manure in agriculture. Average sludge generation from different wastewater treatment technologies deployed in BWSSB and the valley-wise percentage production of sludge has been depicted in Figure 2. The treated sludge conforms to USEPA Class B biosolid standards and is distributed to the local farmers free of cost for agricultural use.

Biogas Production and Utilization

Currently three STPs in Bengaluru viz. K.C Valley 60 MLD, Hebbal 100 MLD and Bellandur 90 MLD have installed anaerobic digesters to stabilize the sludge produced from primary and secondary clarifier and hence produce Biogas. The 3000 m^3 Biogas produced at K.C Valley and 2500 m^3 biogas produced at Hebbal is utilized for power generation. Bellandur STP produces 6400 m^3 per day of biogas which is currently being flared. The V. Valley STP is being upgraded to produce electricity and will be operational by 2024, while anaerobic digester for production of biogas at 60 MLD Kengeri STP has been proposed.

Based on the above data, the existing infrastructure in Bengaluru has been summarized in Table 3.



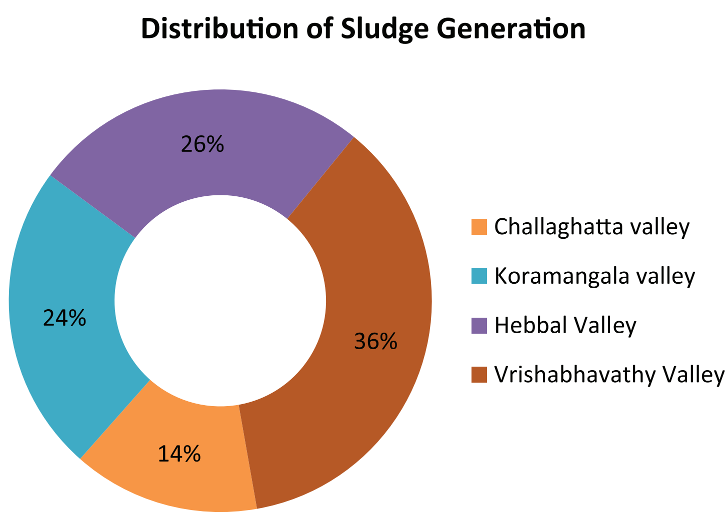


FIGURE 2. Technology and Valley-wise percentage production of sludge

Current Status of Procurement Policy

The STPs are constructed through the tendering process and as part of the contract; for first 2-5 years after commissioning, the plants are operated and maintained by the same contactor. Thereafter, STPs are operated and managed by contractor selected through a competitive bidding process. Based on the treatment technology, quantity of chemicals, manpower requirement etc., and the bidding cost varies for each STP.

TABLE 3: Summary of existing wastewater treatment infrastructure in Bengaluru Metropolitan Area

Sr. No	Existing Data	
1	Current Population	13.19 Million (approx.)
2	Projected Population (2050)	20.96 Million (approx.)
3	Per capita water use	135 lpcd
4	No of Sewage Treatment Plants (STPs)	36
5	Existing Wastewater treatment infrastructure capacity	1527.5 MLD
6	Wastewater generated	1440 MLD
7	Wastewater Treated	1189 MLD
8	Annual Energy consumption by STPs	87 million kWh
9	Annual Electricity Expenditure by BWSSB	INR 67 crores/Annum
10	Treated water directly discharged into rivers and Valleys	488 MLD
11	Treated water directly discharged to nearby lakes for rejuvenation and ground water recharge	419 MLD
12	Treated water directly taken for agricultural activities	123 MLD
13	Quantity of treated water sold for industrial & commercial use	18 MLD
14	Revenue generated from sale of treated water (@INR 25/kl)	INR 16.42 Crore/Annum
15	Quantity of Biosolids generated	250 tons/day (approx.)
16	Quality of Biosolids	USEPA Class B
17	Existing Biogas generation infrastructure	75000 m^3
18	Biogas currently generated	11900 m^3
19	Biogas currently utilized	7500 m^3
20	Existing Electricity generation infrastructure from Biogas	2 MW/ day (2 STPS)
21	Actual Electricity generated	<1 MW/day

Current Status of Financing Options

Currently, the most prevalent practice by BWSSB is to undertake STP projects under an Engineering Procurement and Construction (EPC) or Design Built Operate (DBO) basis for a period of 2 to 5 years.

Current Status of Regulatory Compliance

Besides adhering to the compliances set by Government of India for safe treatment and disposal of wastewater and sludge (listed in Table 1 and 2), the state of Karnataka also has a State Level Legislative Framework for Reuse of Treated Waste Water and relating to bio-solid, bio-gas etc.

a) **Karnataka State Policy on Urban Wastewater Reuse, 2017:** establish an enabling environment for the reuse of municipal wastewater to maximize efficient use of resource, protect the environment, address water scarcity, and enhance economic output.

b) **Karnataka Renewable Energy (RE) Policy, 2022-27:** The key objectives of the policy includes promoting the generation of energy through biomass, waste-to-energy projects and promote initiatives and emerging energy technologies in the State.

PROJECT OBJECTIVES

Thus with the given background, following are the objectives of the study:

1. To assess existing wastewater generation and treatment infrastructure and estimate future needs for expansion in order to meet the regulatory norms and provide adequate sanitation facilities in the expanded BBMP area including 110 villages and also take measures as to how BWSSB becomes Utility of the Future.
2. To identify and summarize the characteristics of advanced treatment technologies for adequate wastewater treatment, enhanced treated water reuse, sludge and to document environmental benefits, and conduct a cost assessment of the various technologies.
3. To review and assess the potential of integrating advanced treatment technologies for production and better utilization of biosolids, biogas, its utilization for electricity production and better reuse of treated wastewater for various application such that STPs becomes Resource Centres and not liabilities.
4. To provide a Compendium of best case studies from India and abroad in the proposed areas of interventions.
5. To define any regulatory and legislative barriers that may hinder the implementation of the advanced technology interventions, assess options for financing and propose a regional strategy for efficient and sustainable wastewater treatment and reuse.

ESTIMATION OF FUTURE NEEDS

Based on current status and immediate future requirement with the addition of 110 villages in BBMP area, all 36 STPs have been systematically analyzed in terms of valley wise location, capacity, treatment technology, level of wastewater treatment, sludge treatment, biosolids and biogas generation together with the STPs' upgradation potential.

Entire data together with status of compliance or non-compliance with NGT's treated water discharge standards has been tabulated in Table 4. The reported data presented in Table 4 has been obtained between January to June 2023. This table forms the basis for analysing the available technologies for the treatment of wastewater and sludge, identify gaps in current infrastructure and explore the possibilities of integrating advanced technologies to ensure safe disposal of treated water and sludge along with options to maximize the reuse of treated water and recovery of resources like biosolids, biogas through technological, regulatory and legislative interventions.

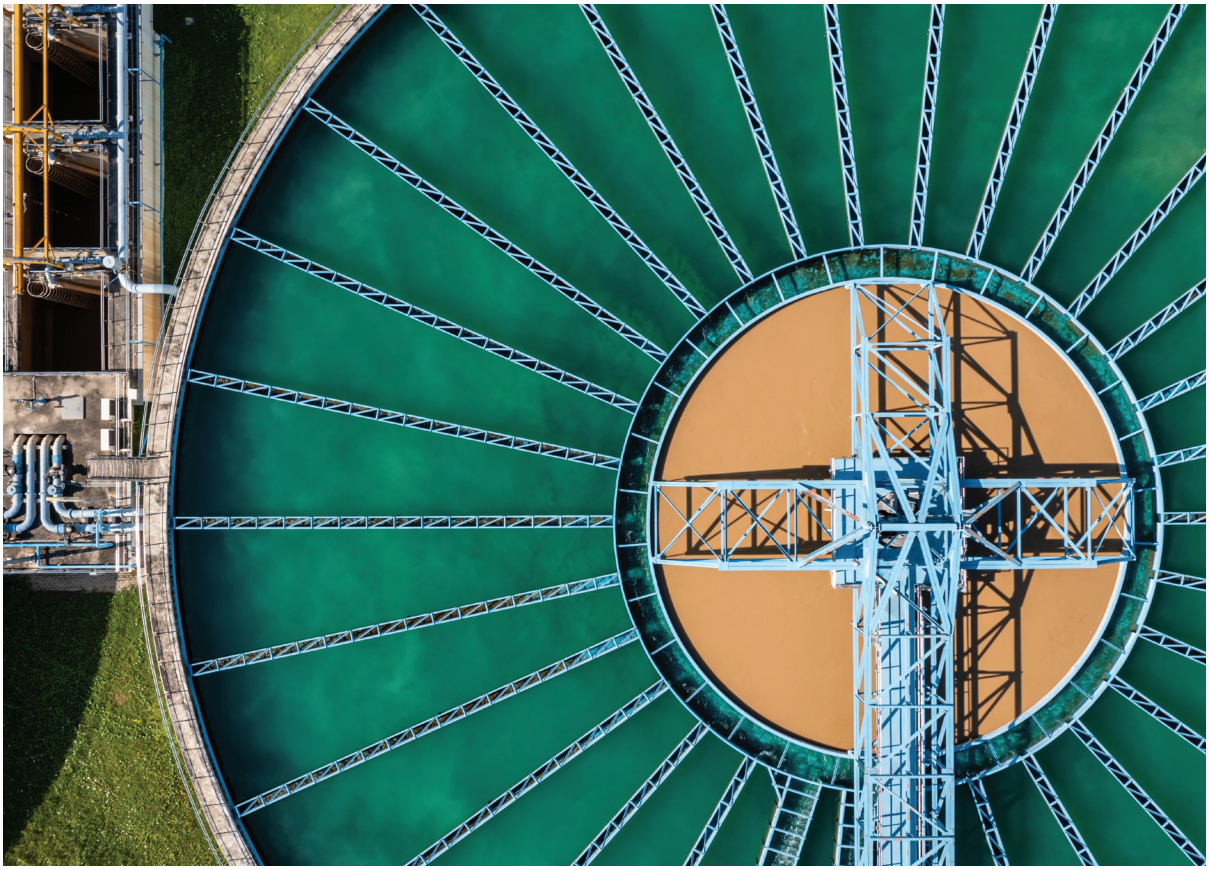


TABLE 4: Detailed list of existing STPs in BWSSB based on Valley wise distribution [Reported data acquired during January-June 2023]

S.No	Drainage Zone	Name	Capacity (MLD)	Type of Process	Sludge Generation (Tons/Day)	Meeting NGT(2019) Discharge Norms	Upgradation Potential
1	**Challaghatta Valley**	K&C valley	218	ASP	NA	NO	Need Rehabilitation
	(Total treatment	K&C Valley	150	ASP+ BNR	18	YES	Good Working Condition
3	**capacity = 518 MLD**	K&C Valley*	60	ASP +BNR		YES	Good Working Condition
4	**Total Sludge**	K&C valley	30	EA	NA	NO	Good Working Condition
5	**Generation =**	K.R.Puram	20	SBR	4	YES	Under Refurbishment
6	**33.33 Ton/Day)**	K.R.Puram Ph-I	20	UASB + EA	4	NO	Under Refurbishment
7		Yelemallappa Chetti kere	15	SBR	3	NO	Good Working Condition
8		Cubbon Park	4	MBR	0.8	YES	Good Working Condition
9		Lalbagh#	1.5	ASP + UV	0.33	YES	Good Working Condition
10	**Koramangala Valley**	Bellandur Amani kere	90	ASP+BNR	17	NO	Good Working Condition
11	**(Total treatment capacity = 207 MLD**	Kadabeesanahalli Ph-I	50	EA	17	NO	Under Refurbishment
12	**Total Sludge**	Agaram	35	SBR + BNR	12	YES	Good Working Condition
13	**Generation =**	Hulimavu	10	SBR + BNR	0.83	YES	Good Working Condition
14	**54.93 Ton/Day)**	Kadugodi	6	SBR	0.3	NO	Under Refurbishment
15		Sarakki	5	SBR + BNR	1.5	YES	Good Working Condition
16		Chikkabegur	5	SBR + BNR	1.5	YES	Good Working Condition
17		Madivala	4	SBR	1	NO	Under Refurbishment
18		Halasuru	2	SBR	0.3	NO	Under Refurbishment

19	**Hebbal Valley**	Hebbal*	100	ASP	10	YES	Under Refurbishment
20	**(Total treatment capacity = 276 MLD**	Rajacanal - Ph-I	40	ASP	6	NO	Under Refurbishment
21		Rajacanal (old)	40	ASP	8	NO	Under Refurbishment
22	**Total Sludge Generation = 60 Ton/Day)**	Horamavu Agara	20	SBR	6	NO	Under Refurbishment
23		Nagasandra Ph-I	20	SBR	10	NO	Under Refurbishment
24		Nagasandra	20	SBR	6	NO	Under Refurbishment
25		Jakkur#	15	MBBR+UF	12	YES	Good Working Condition
26		Yelahanka Ph-I#	10	ASP +UF	1.5	YES	Good Working Condition
27		Mallathahalli	5	SBR	NA	NA	Under Refurbishment
28		Hennur	1	SBT	NA	YES	Good Working Condition
29	**Vrishabhavathy Valley**	V.Valley	180	TF	64	NO	Need Rehabilitation
30	**(Total treatment capacity = 586 MLD**	V.Valley*	150	ASP +BNR		YES	Good Working Condition
31		V.Valley	60	TF + DENSADEG		NO	Good Working Condition
32	**Total Sludge Generation = 84.6 Ton/Day)**	Mailasandra Ph-I	75	ASP	NA	NO	Under Refurbishment
33		Kengeri	60	ASP+BNR	12	YES	Good Working Condition
		Doddabele	40	SBR	6	YES	Under Refurbishment
34		Doddabele	20	SBR	2.6	NO	Under Refurbishment
35		Chikkabanavara	5	SBR	NA	NO	Under Refurbishment
36		Kempambudhi	1	ASP	NA	YES	Good Working Condition
Total capacity			**1527.5**		**250 (approx.)**		

* STPs with In-house Power Generation

STPs with UV or UF are equipped with tertiary treatment

NA: Sludge Data Not Available

ASP: Activated Sludge Process, SBR: Sequential Batch Reactor, BNR: Biological Nutrient Removal, MBBR: Moving Bed Bioreactor, MBR: Membrane Bio Reactor, UASB: Up flow anaerobic sludge blanket, TF: Trickling Filters, DENSADEG: High Rate Clarifier, EA: Extended Aeration, SBT: Camus Soil Biotechnology, UF: Ultra filtration

ASSESSMENT OF WASTEWATER TREATMENT TECHNOLOGIES AND TREATED WATER REUSE POTENTIAL

Referring to Table 4, the key observations on the existing wastewater treatment infrastructure and potential for treated water reuse are:

Key Observations

1. There are 4 major STPs in each of the 4 Valleys that caters to maximum capacities and act as the centralized wastewater treatment facility: K&C Valley STP cluster with combined capacity of 458 MLD, 90 MLD Bellandur Plant in Koramangala Valley, 100 MLD Hebbal STP in Hebbal Valley and STP cluster with combined capacity of 390 MLD in V. Valley.
2. 13 out of 36 STPs totaling 585.5 MLD capacities are compliant with the NGT norms for treated water discharge, rendering it suitable for reuse in irrigation, industrial applications, as well as the construction and housing sectors.
3. STPs operating with standalone ASP and SBR are unable to meet the revised NGT norms and require integration of advanced technologies like BNR, UV or UF.
4. Two STPs of K.C Valley 218 MLD and V. Valley 180 MLD are utilizing only 66% and 21% respectively of their existing capacities and are unable to meet the current discharge standards and hence needs complete rehabilitation.
5. 41% of the treated water is discharged to nearby lakes for rejuvenation and ground water recharge, 33% is directly discharged into Rivers and Valleys, 10% is directly taken for agricultural activities, and merely 1.5% of treated water is sold for industrial and commercial use, leaving 14.5% for enhancing treated water reuse which has a capacity to generate revenue of INR 142 Crore (USD 17 Million) per annum.

Based on the observations, it is evident that the Wastewater Treatment Technologies (WWTT) plays a critical role in enhancing water quality and facilitating its safe reuse across multiple sectors. The detailed assessment of the available WWTT has been given below:

Technology Assessment

1. Treatment technologies such as ASP+BNR, SBR+BNR, ASP+UV, MBBR, and MBR are able to produce high-quality treated water suitable for non-portable reuse, offering revenue opportunities to offset the associated considerable high costs involved in CAPEX and OPEX.
2. Technologies such as MBBR and MBR have lower land footprint compared to other technologies but higher CAPEX and OPEX, hence are more suitable for handling lower capacities from 10 to 50 MLD.

3. Nature based technologies like SBT having lowest energy demand, but highest land footprint could be suitable alternative to MBBR and MBR in the capacity bracket of 10 -50 MLD, where land availability is not a constraint.
4. ASP, SBR integrated with advanced technologies like BNR, UV, UF, advanced oxidation process (AOP) etc. can be prioritized while designing large STPs with capacity more than 50 MLD.

Based on the comprehensive assessment of the conventional and advanced wastewater technologies installed in the 36 STPs of BWSSW, following are key recommendations.

KEY RECOMMENDATIONS

Recommendation 1: Selection of technologies for Newer STPs:

Recommended technologies for STPs based on capacities:

i. Capacity less than 10 MLD should prefer integration of Tertiary Treatment Technologies like UV disinfection, Tertiary Filtration (UF), Advanced Oxi-dation Process etc. to ensure superior treatment for high end reuse.

ii. Capacity ranging between 10-50 MLD should prefer advanced treatment technologies like Moving Bed Bioreactor (MBBR), Membrane Bio Reactor (MBR) or Camus Soil Biotechnology (SBT).

iii. Capacity ranging between 50-100 MLD should prefer Sequential Batch Re-actor (SBR) with integration of Biological Nutrient Removal (BNR).

iv. Capacity greater than 100 MLD should prefer Activated Sludge Process (ASP) with integration of Biological Nutrient Removal (BNR).

Recommendation 2: Upgradation of STPs with Advanced Technologies

STPs that are unable to meet revised NGT discharge norms should be integrated with Advanced or Tertiary treatment technologies to ensure safe discharge as well as enhance water reuse potential. The sale of treated water from 13 STPs meeting NGT norms, totaling 585.5 MLD capacity can generate revenue up to INR 463 Crore/Annum (USD 58 Million) with sale @ INR 25/KL and upgrading non-compliant STPs will further increase the revenue generation potential by INR 583 Crore/Annum (USD 70 Million)

Recommendation 3: Treated Water Reuse

i. Based on reuse demand for treated water, customize the selection of wastewater treatment technologies.

ii. If the objective is to meet compliance and rejuvenation of lakes and water bodies then conventional technologies like Activated Sludge Process (ASP) and Sequential Batch Reactor (SBR) along with integration of Biological Nutrient Removal (BNR) should be preferred, whereas if industrial reuse and revenue generation is the objective, then advanced treatment technologies like Moving Bed Bioreactor (MBBR), Membrane Bio Reactor (MBR) combined with tertiary treatment technologies like UV, Tertiary Filters, etc. should be adopted.

iii. Rehabilitation of K.C Valley 218 MLD and V. Valley 180 MLD Plants will ensure additional 33% treated water available for reuse together with a revenue potential of INR 390 Crore (USD 46 Million) per annum.

ASSESSMENT OF SLUDGE TREATMENT, PRODUCTION AND UTILIZATION OF BIOSOLID & BIOGAS

Referring to Table 4, approximately 250 tons per day (TPD) of centrifuged and dried sludge is produced from 36 STPs of BWSSB, and is given to the local farmers for free. Further three STPs currently have anaerobic digesters which are producing Biogas from treatment of sludge, where only two of these STPs partially utilize the Biogas to generate power which is utilized to meet the energy demand of these STPs to some extent.

Key Observations

1. The current sludge treatment scheme in 33 STPs includes thickening and dewatering only, which fails to eliminate pathogens, makes it unsuitable for human contact and land application.
2. Only 3 STPs, have installed Anaerobic Digester (AD) for sludge stabilization, but fail to fully utilize the digester capacity due to low on-site sludge production.
3. 26 out of 36 STPs operating with capacities under 50 MLD, produces less than 10 tons of dewatered sludge per day which makes installation of Advanced Anaerobic Digester (ADD) at individual level underutilized and hence less financially viable.
4. BWSSB is yet to tap on the potential of production and utilization of Biogas from the sludge produced from 36 STPs.
5. Production and sale of biogas generated from the treatment of sludge has huge potential to cover a large part of the capital and operational expenditure of STPs.

Strategies for enhancing Biosolids Production

A. Centralized Sludge Treatment Facility (CSTF)

One of the strategies to enhance biosolid production is to enhance the sludge treatment by bringing sludge to a common bigger STP from nearby smaller STPs, and establishing Centralized Sludge Treatment Facility, as described in Figure 3. The strategic placement of STPs in four valleys includes one large capacity STP surrounded by smaller 5 to 6 STPs, each with a capacity below 50 MLD. Concentrating sludge from nearby smaller facilities to these larger facilities and converting them to Centralized Sludge Treatment Facilities (CSTF) will reap better benefits from sludge treatment due to economies of scale.

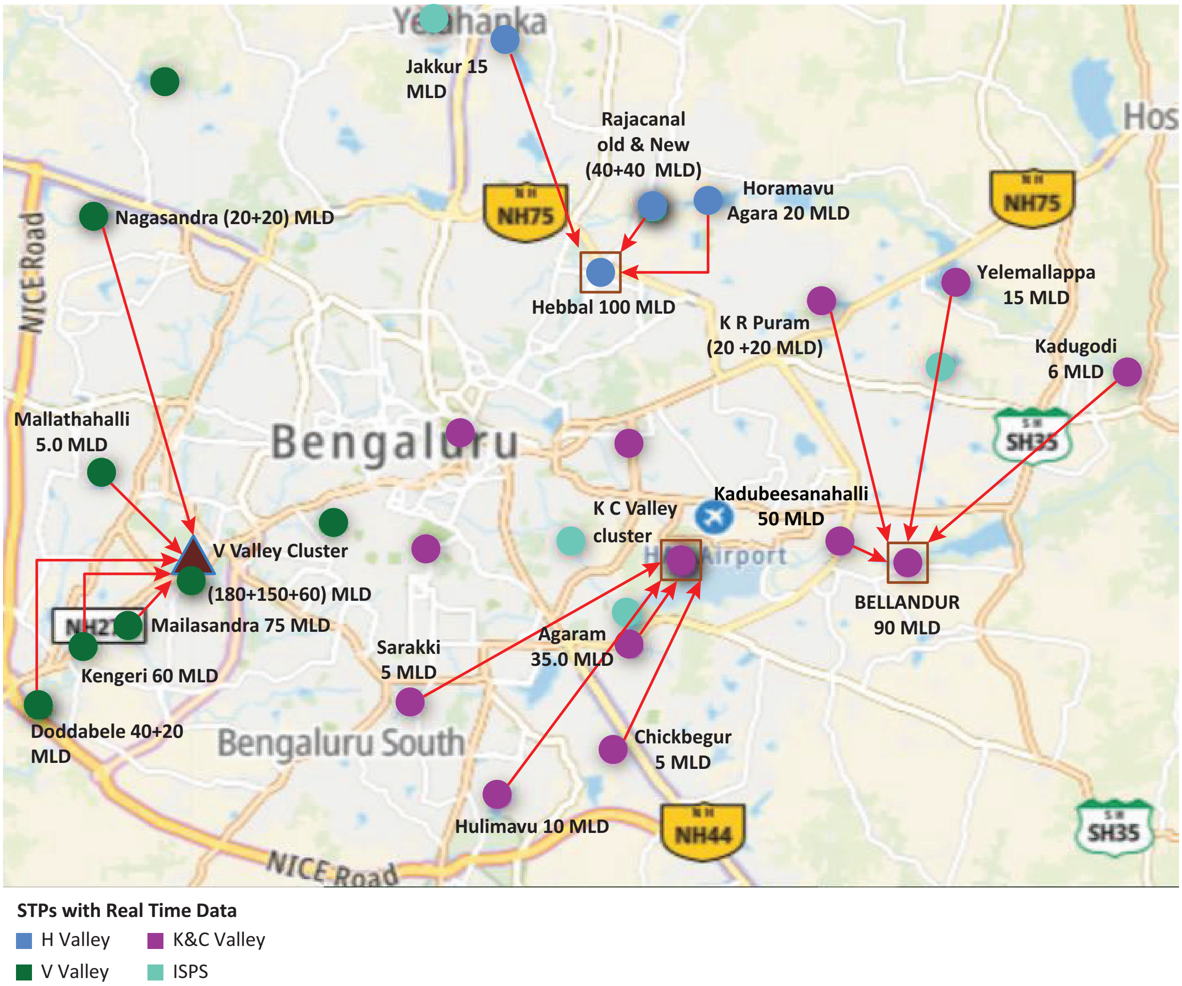


FIGURE 3: Biogas Production and Utilization with THP integration

B. Integrating Advanced Technology in the existing Sludge Treatment Scheme

Sludge thickening and dewatering technologies are integral steps for sludge treatment but do not play any significant role in the quality of biosolids produced. However sludge stabilization in AD significantly influence the quality of biosolids produced, ensuring reduced pathogen content, enhanced safety and improved suitability for disposal methods or various reuse including safe land applications.

The currently employed technologies in BWSSB for sludge stabilization include conventional Mesophilic Anaerobic Digestion (MAD) and Thermophilic Anaerobic Digestion (TAD). However, the final centrifuged and dried sludge after stabilization with MAD or TAD is complying to Class-B biosolid standards of USEPA but fail to achieve USEPA Class–A standards and hence there is scope of improvement with advanced technological interventions like Thermal Hydrolysis Process (THP) in order to enhance biosolid quality, resource recovery, reuse potential and economic benefits.

Thermal Hydrolysis Process (THP) involves high temperatures (160 – 180 °C) pre-treatment of sludge which enables better sludge dewatering and pathogen removal resulting in Class A biosolids together with lesser requirement of digester volume, leading to smaller footprint and resulting in superior resource recovery. Class-A biosolids could be directly used in parks, gardens, green spaces and nurseries for soil amelioration and could act as a replacement for organic fertilizers to maintain and increase the green spaces in urban centres of Bengaluru. Also Production of high quality Biosolids meeting USEPA Class-A standards from sludge which can serve as a substitute to currently used inorganic fertilizers, resulting in a minimum saving of INR 20 Crores (USD 2.4 Million) per annum. THP also augments the existing capacity of digesters by 2 to 3 times, increasing sludge treatment within current infrastructure, hence boosting Biogas production.

Potential for Biogas Production & Utilization

The production of Biogas is directly dependent on the treatment of sludge. Hence, by integrating high temperature pre-treatment technology like Thermal Hydrolysis Process (THP) with conventional Anaerobic Digester (AD) can reduce the solid retention time of sludge in the digester leading to 130 to 150% enhanced biogas yield. This is elaborated in Figure 4, where the produced biogas can be utilized either for:

a. Power generation in Combined Heat and Power (CHP) Plant, to meet the energy needs of the STP, which is currently done at 2 STPs of BWSSB.

b. Compressed Biogas (CBG) for use in vehicles, canteens etc. Initiatives like Sustainable Alternative Towards Affordable Transportation (SATAT),[4] launched by Ministry of Petroleum and Natural Gas, Government of India, promoting the sale of biogas as automotive and industrial fuels, indicates promising opportunities for BWSSB in leveraging Biogas within this area.

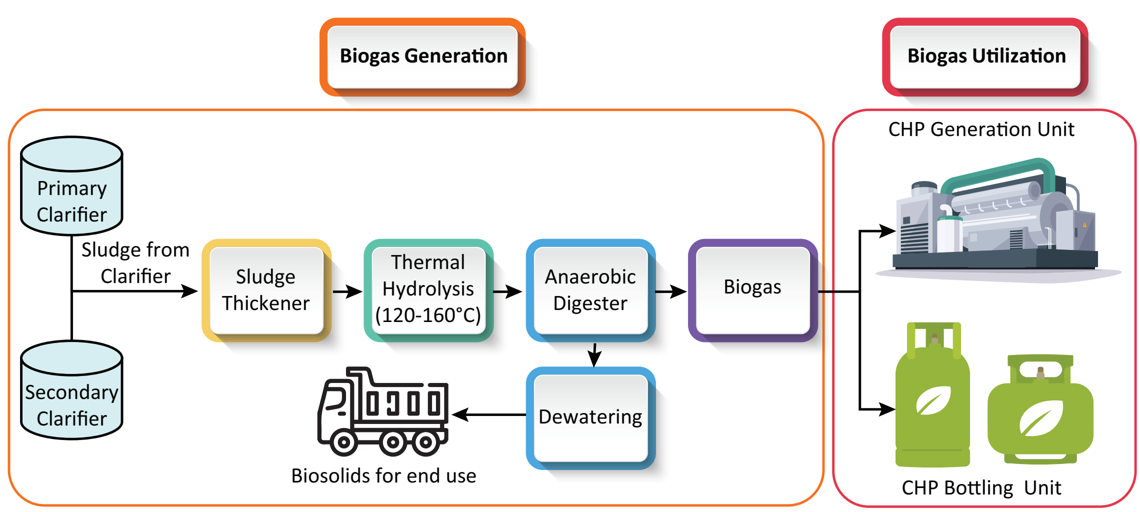


FIGURE 3: Proposed Plan to create Centralized Sludge Treatment Facilities

[4] https://satat.co.in/satat/

KEY RECOMMENDATIONS

Recommendation 4: Transition from USEPA Class-B to Class-A Biosolid

BWSSB should ensure that the current sludge produced at all STPs is treated to meet USEPA Class B Standards and should eventually upgrade to produce sludge that meets Class A Standards in next 5 to 7 years.

Recommendation 5: Centralized Sludge Treatment Facility

Convert larger STPs (treating more than 90 MLD) like Bellandur, K C Valley, Heb-bal and V Valley, into Centralized Sludge Treatment Facilities (CSTF). This will ensure efficient utilization of existing sludge treatment facilities, allow treatment of sludge from nearby smaller STPs without extensive investments in new infra-structure and maximize energy recovery though biogas production, capitalizing on all advantages of economies of scale.

Recommendation 6: Technology Intervention

Integrate high temperature pre-treatment technology such as Thermal Hydrolysis Process (THP) with existing Anaerobic Digester leading to:

i. Capacity augmentation of Anaerobic Digester (AD), resulting in treatment of 2 to 3 times more sludge in the existing infrastructure leading to en-hanced biogas production.

ii. Production of high quality Biosolids meeting USEPA Class-A standards from sludge which can serve as a substitute to currently used inorganic fer-tilizers, resulting in a minimum saving of INR 20 Crores (USD 2.4 Million) per annum.

CASE STUDY OF BELLANDUR STP

The analysis of existing infrastructure indicates that BWSSB is a forward Utility which is focused on adequate treatment of wastewater and even reusing approximately 70% of the treated water including rejuvenation of surface water bodies. However, key resources like biosolids and biogas are still underutilized. Based on the above observations and looking at the future needs adequate sludge treatment and biogas production and utilization, and to explore the potential for maximizing resource recovery from the 36 STPs, Bellandur has been selected as a model STP and 4 cases have been developed to assess the financial viability of advanced technology interventions and its potential benefits.

Existing Infrastructure at Bellandur STP

The Bellandur 90 MLD Sewage Treatment Plant (STP) stands as a landmark in the field of urban wastewater management in Bengaluru, India. This state-of-the-art facility is designed to treat 90 million litres per day (MLD) of sewage, and can handle peak flow of 171 MLD, addressing the pressing need for wastewater treatment and environmental sustainability in the rapidly growing metropolitan area.

Advanced Treatment Process: The STP employs Activated Sludge Process (ASP), which is supported by Biological Nutrient Removal (BNR) using Anaerobic Anoxic Oxic (A_2O) process, to ensure the removal of contaminants and pollutants from the wastewater. The treated water parameters are meeting NGT discharge norms for surface water (Refer Table 1) as given in Table 5, which indicates that the current treatment scheme is fine.

TABLE 5: Treated water characteristics for Bellandur STP

Parameters	Unit	Bellandur (Monthly Average)
pH	-	7.6
TSS	mg/L	13
BOD	mg/L	7
COD	mg/L	25 - 47
Total Nitrogen	mg/L	5-7
Total Phosphorus	mg/L	<1
Faecal Coliform	Counts	77.7 MPN/100 mL

Treated Water Reuse: The treated water from the STP is sent to Bellandur Lake for rejuvenation and to promote groundwater recharge.

Sludge Treatment and Biosolid Production: Currently 16-18 tons per day of sludge is produced in Bellandur. The treatment scheme for sludge includes thickening, stabilization in anaerobic digester and dewatering. TERI team collected and tested two samples of sludge (1st sample is thickened sludge and 2nd sample is digested sludge, which is given to farmers for free to use as manure in agricultural fields) from Bellandur STP and found that the concentration of Faecal coliform to be 2400 MPN/gram of dry solids, which is exceeding the USEPA Class A Biosolids standards; however, it was meeting the standards of USEPA Class B biosolids. Although Class B biosolids are safe for agricultural land application, it is restricted for direct human contact and can cause pathogen overload.

Biogas Production and Utilization: The two digesters at Bellandur have a combined capacity of 15095 cubic meters and biogas production capacity of 14982 cubic meters. However currently, only 6400 cubic meters of Biogas is being produced and flared at the facility.

However, there are following areas of concern:

1. **Biosolid Production:** The sludge produced from the wastewater treatment process is anaerobically digested, but fail to meet USEPA Class A biosolids, and hence not safe for human contact.
2. **Biogas Production:** The existing biogas production capacity of 14982 cubic meters remains underutilized and only 6400 cubic meters of biogas is being produced and flared at the facility.
3. **Environmental Impact**: The carbon equivalent emissions from burning the 6400 m^3 of biogas, is approximately 7040 kg of CO_2-equivalents per day, which is approximately 2,323.2 metric tons of eCO_2 per annual emissions.
4. No revenue generation from resource recovery:

   Cost Incurred in Operation and Maintenance: INR 25 lakhs/ month
   Power Expenditure: INR 40 lakhs/ month
   Total OPEX: 7.8 Cr/ Annum
   Revenue Generated from sale of treated water, biosolids/ bio manure and biogas: None

Figure 5, shows the existing sludge treatment facility in Bellandur and the available area for expansion. To address the above mentioned concerns, two scenarios were visualized for Bellandur:

Scenario 1: Upgradation of Bellandur within Existing Infrastructure:

This scenario aims to fully utilize the digester's designed capacity of 15,095 cubic meters which currently remains underutilized. To achieve this, Bellandur STP should establish a Centralized Sludge Treatment Facility (CSTF) to facilitate processing of sludge from nearby STPs. As described in Figure 3 this will enhance the biogas production from 6400 cubic meters to 14,982 cubic meters and shall result in substantial revenue generation.

FIGURE 5: Google Earth view of Bellandur STP

Scenario 2: Upgradation of Bellandur STP with Advanced Technology Interventions for sludge treatment:

This scenario aims to augment the existing digester capacity by 3 times. Integrating advanced pre-treatment technology such as Thermal Hydrolysis Process (THP) with existing anaerobic digester at Bellandur will allow approximately 80 tons of excess sludge which could be treated in the existing infrastructure leading to enhanced biogas production as described in Figure 4.

FINANCIAL ANALYSIS

The financial viability and revenue potential has been assessed for both scenarios 1 and 2, through the utilization of the produced biogas by the following two ways:

1. **Combined Heat and Power (CHP) Plant**: Where biogas will be fed into gas engines to generate power.
2. **CBG Bottling Plant**: Where the biogas produced will be bottled and sold as fuel for vehicles as compressed biogas and/or as cooking gas.

Hence additional cost to bring this infrastructure has been added in Capital and Operational expenditure calculation as currently there is no infrastructure present for biogas utilization at Bellandur. The outcome of the financial feasibility analysis (for two cases each in scenarios 1 and 2) has been given in Table 6.

TABLE 6: Outcome of the Financial Feasibility Analysis for Upgradation of Bellandur STP

	Scenario 1: Within Existing Infrastructure				Scenario 2: With Advanced Technology Interventions			
Biogas Utilization	**CBG Bottling Plant**		**Bio-Gas Power Plant**		**CBG Bottling Plant**		**Bio-Gas Power Plant**	
CAPEX (INR Cr)	41.5		24.21		212		180.43	
OPEX (INR Cr)	2.08		1.21		8.8		7.22	
Revenues (INR Cr)	14.85		10.55		51.3		36.43	
Tenure	IRR	NPV	IRR	NPV	IRR	NPV	IRR	NPV
5 years	**20.46%**	**-12.75**	**32.45%**	**-3.33**	**1.81%**	**-114.33**	**-5.99%**	**-112.41**
10 years	39.76%	33.09	49.57%	30.19	24.84%	37.98	18.70%	-7.84
15 years	42.19%	69.40	51.31%	56.74	28.79%	158.65	23.46%	75.00
20 years	42.64%	98.18	51.56%	77.78	29.81%	254.25	24.85%	140.63
25 years	42.73%	120.97	51.60%	94.45	30.12%	329.99	25.34%	192.62
30 years	42.75%	139.03	51.61%	107.66	30.22%	389.98	25.52%	233.81

* IIR: Internal Rate of Return, NPV: Net Present Value

Key Considerations to Ascertain Actual Viability

1. The Financial Assessment does not include the following:
   a. The cost of transportation of sludge/ solids from nearby plants, which is estimated to be approximately INR 250-500/ MT of sludge

   b. The disposal cost of residual solids/ any revenue accruing from the sale of residual solids. With stringent standards being implemented, the cost of disposal of residual solids may cost as much as INR 500-1000/ MT comparable with that of Municipal Solid Waste.

   c. The additional revenues that may accrue from sale of secondary or tertiary treated water.

   d. The incremental environmental benefits of extracting and utilizing the energy available in sewage sludge.

   e. The carbon revenues that may accrue to BWSSB on procurement and sale of Certified emission reductions (CERs)

2. The assessment assumes that the residual solids are utilized by farmers, free of cost for land applications. However, this practice of utilizing residual solids for land application has the following drawbacks:
   a. Statutory / regulatory environment for sludge management in India is not at par with the Global/ International standards, such as that of US EPA, leading to poor quality, pathogen containing bio-solids being utilized for land applications today.[5]

   b. Uncontrolled application of poor quality solids leads to infectious diseases due to microbial pollution/ pathogen load[6]

   c. Long-term health impact due to consumption of food crops grown utilizing poor quality bio-solids.[7]

   d. The potential cost of health & environmental impacts due disposal of stabilized/ poor quality solids is not included in the assessment.

3. The following are the benefits that may accrue to BWSSB by adopting thermal hydrolysis as pre-treatment

   a. Lower land footprint compared to the conventional digestion process, with 60-70% less digester volume required.

      i. Anaerobic digester costs around Rs 1.50 Cr/ MT solids and by augmenting the capacity of Bellandur Digester utilizing thermal hydrolysis BWSSB can save around INR 125 Crores in the form of capital cost that may otherwise be required to create additional digesters.

      ii. Land is a precious resource in Urban India today and Bengaluru being a cosmopolitan city, cost of land saved cannot be ignored.

   b. Increased biogas production leading to better utilization resulting in more revenue generation.

   c. Enhanced volatile solids destruction by 20-50% leading better quality biosolids that

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5 https://www.sciencedirect.com/topics/earth-and-planetary-sciences/biosolid

6 https://www.mdpi.com/2073-4441/6/12/3701#:~:text=Pathogens%20contained%20in%20biosolids%20include,illnesses%20%5B24%2C32%5D.

7 https://ehjournal.biomedcentral.com/articles/10.1186/s12940-023-01008-4

are pathogen-free, little with no odour which has increased potential to be used for soil amelioration. There's also potential for earning revenue by selling biosolids as bio-fertiliser or soil conditioner, that may be priced on par with bio-manure @ Rs 1000-5000/ MT.

d. Lower biosolids volume for transport, leading to lower cost of handling, transportation & disposal.

4. It is important to note that there is a growing demand around the world to produce Class A biosolids and it is expected that India will adopt global sludge management standards in the near future

Outcomes of the Financial Analysis

1. All cases seem to be financially viable for BWSSB.
2. The Return on Investment (RoI) for all cases could be achieved within 5 to 10 years.
3. Utilizing the biogas produced as Compressed Biogas (CBG) for vehicular use as compared to be used for power generation, seems more financially lucrative for BWSSB.
4. While the upfront cost of upgrading Bellandur STP with Advanced Technology Interventions (scenario 2) is higher, the potential for revenue generation is threefold compared to scenario 1, making it more profitable in the long run.
5. Also, considering the additional benefits like enhanced Biosolid quality (Class A), increased Biogas production and utilization, revenue from sale of carbon credits, lower cost of transportation and disposal of final solid cake etc. Scenario 2 outweigh Scenario 1 completely

KEY RECOMMENDATIONS

Recommendation 7: Centralized Sludge Treatment Facility at Bellandur

Create at Bellandur STP, a Centralized Sludge Treatment Facility (CSTF) where additional 80 tons of dry sludge from nearby STPs could be treated to allow complete utilization of existing sludge treatment facility. Further, integrating advanced pre-treatment technology like Thermal Hydrolysis Process (THP) will allow adequate treatment of the existing anaerobic digester, enhancing the biogas production as well as ensuring the production of Class A biosolids.

Recommendation 8: Biogas utilization

Integration of advanced technology like THP will increase CAPEX from 7.8 Cr to 16.6 Cr, which could be recovered from the sale of biogas as Compressed Biogas (CBG) for Vehicular use, which is expected to generate revenue up to INR 51.3 Crore (USD 6 Million) per annum with a Return on Investment (RoI) within a period of 5 years.

Recommendation 9: Reduction in Budget Dependency

BWSSB should reduce its dependency on State budgets focusing on Circular Economy and Resource Recovery approaches. BWSSB should consider a board level policy focusing on recovery and reuse from wastewater considering the following:

i. Sale of secondary and tertiary treated water.

ii. Recovery and utilization of energy in the form of Biogas.

iii. Selling bio-solids as a commodity, which is produced 17 tons/day. If composted and turned to bio manure can have a value of INR 1000- 5000/ MT, which could have addition-al value of minimum INR 56 lakhs to maximum of 2.8 Cr/ annum.

iv. Indirect revenue from recovering Nutrients from treated Wastewater: Assum-ing minimum 0.054 tons of nutrients are present in 1MLD wastewater with estimat-ed Nutrient Value of 4.86 tons/day nutrients can be extracted when land is irrigated with of 90 MLD wastewater. Given value of per ton load of nutrient is INR 8000, which could potentially replace or have indirect nutrient value of 1.28 Cr (330 year days)

Recommendation 10: Development of STPs/ Sludge Handling Facilities as PPP project

Given the economic/ revenue potential of wastewater, BWSSB should consider procuring such facilities on PPP basis.

FINANCING OPTIONS

Establishing and upholding sewage treatment systems is crucial for the well-being of society and the environment. However, newer STPs demand a substantial amount of financial resources and energy. This places a significant fiscal strain on municipal bodies like BWSSB. To reduce the fiscal burden, numerous financial strategies have been explored as a part of this project.

The primary objective was to evaluate different methods of implementation available to the BWSSB, with a particular focus on the potential for a public-private partnership arrangement in the project. Consequently, a comprehensive examination was conducted, considering various models like Build-Operate-Transfer (BOT), Build-Own-Operate (BOO), Build-Own-Operate-Transfer (BOOT), Design-Build-Finance-Operate-Transfer (DBFOT) and Hybrid Annuity Model (HAM). Additionally, real-world examples from water-related projects that have successfully employed these models were reviewed for better insights. It was observed that cities like Nagpur, Maharashtra, India has developed Tertiary Treatment Plants on Public Private Partnership (PPP) basis which provide treated water to the nearest power generation plant, where the treated water is used as coolant for different parts of the power plant. Likewise, city of Surat in Gujrat State of India has also set a benchmark with the sale of treated wastewater and earned gross revenue of INR 140 Crore (USD 16.88 Million) in the year 2019-2020.A comparative statement of potential models for involvement of private sector (selected National & International best practices) is provided in Table 7.

TABLE 7: Comparison of various Financing Models

	EPC	DBO	HAM	BOT/ DBFOT	BOOT/ Captive Use Plants
Design	Public	Private	Private	Private	Private
Financing	Public	Public	Public & Private	Private	Private
Construction	Public/ Private	Private	Private	Private	Private
O&M	Public/ Private	Private	Private	Private	Private
Sources of revenue to Private	Construction payments from utility	Construction & Operation payments from utility	• Construction payments from utility • Performance incentives • Interest income on deferred/ structured payments	Tariff/ end user payments	Tariff/ end user payments
Term	<3 years	2-10 years in India 10-20 years internationally	15-20 years	20+ years	20+ years
Key Advantages	Simple and well known	Integrated procurement leads to cost & operational advantages	• Better designed, constructed & operated asset given the involvement of private sector equity and longer contract tenure • Well balanced in terms of risk & rewards to the Private Sector • Performance ensured for longer term • Payment based on performance ensures operation & maintenance and compliance throughout the tenure of project execution.	Greater level of risk sharing with private sector Complete conversion CAPEX/ OPEX in to contingent liabilities	Entire risk of design, financing, development & operating the assets is with Private Sector including the risk of ownership

	EPC	DBO	HAM	BOT/ DBFOT	BOOT/ Captive Use Plants
Key Disadvantages	Utility has to identify and procure different entities for different functions such as design, construction, O&M, etc.	Not performance/ KPIs driven, the overall quality tend to be lower due to lack of private sector diligence- given there's no financing/ equity risk and skin in the game	Increased procurement timelines & cost	Increased procurement timelines & cost	Increased dependency on private sector

CARBON FINANCING

Wastewater treatment facilities are essential for ensuring clean water for communities, however, these are sources of generating significant amount of Greenhouse Gas (GHG) emissions. However, through the implementation of certain strategies, these facilities can reduce their emissions and even earn carbon credits.

The VCS methodology VM0033, "Methane capture and destruction at municipal wastewater treatment facilities," is designed to quantify GHG emission reductions from the capture and destruction of methane, a potent GHG produced during wastewater treatment. Under this methodology, facilities can earn carbon credits by capturing and destroying methane through installation of methane recovery system. A short list of such projects has been summarized in Table 8.

TABLE 8: Examples of STPs from different Indian Cities earning Carbon Credits

S.No.	Project Name	City / State	Carbon Credits Generated
1	Pimpri Chinchwad Municipal Corporation STP	Maharashtra	15,547
2	Bhiwandi Municipal Corporation STP	Maharashtra	27,436
3	Koyambedu market TTRO	Tamil Nadu	56,987
4	Tirupur dyeing industrial CETP	Tamil Nadu	63,208
5	Delhi Jal Board STP	Delhi	80,865

Indian projects have already demonstrated the effectiveness of this approach and serve as models for future projects. Potential for GHG Emission Reduction is captured in Table 9.

TABLE 9: Potential for GHG Emission Reduction is captured in the following table:

Parameter	Potential	
Total Solids Produced in Bangalore Metropolitan Area	MT	250
Biogas production	m^3	1,20,000
Methane content of biogas	%	60-65%
Electricity production capacity	kWh/m^3	2
Total electricity production in a year	MWh	84,000
GHG reduction from avoided fossil fuel-based electricity[8]	Metric tons CO_2e	55,887
Current carbon pricing[9]	USD/tCO_2e	2.2
Future pricing post establishment of carbon market in India[10]	USD/tCO_2e	80

8 https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results

9 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/031723-india-may-announce-details-of-national-carbon-market-scheme-in-june-official

10 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/031723-india-may-announce-details-of-national-carbon-market-scheme-in-june-official

REGULATORY CONSIDERATION

A. The "**Karnataka State Policy on Urban Wastewater Reuse, 2017**" recognizes the fact that demand for water in the State is increasing due to increase in population, urbanization and industrialization and highlights the following:

1. Demands all the industrial estates/ zones situated within 30 km of a STP shall mandatorily consider, as a first option, availability of treated water from the STP, with regard to reliability of supply, quality and pricing. Only if off-take of such treated water is shown to be non-viable, alternate sources of water should be considered for use by the industry.
2. Allocation of treated water and the associated tariff should be adjusted to recover the operational cost of the supply network.
3. Targets to reuse 20% of treated water by 2025 & 50% by 2030.

Gaps Identified:

1. The reuse targets at State level policy does not align with the "**National Framework on the Safe Reuse of Treated Water, 2023**" which aims to achieve 100% safe reuse of treated water by 2030.
2. The selection criterion of wastewater treatment technology has not been detailed in the State Policy.
3. The quality for treated water as per the intended purpose of reuse provided in the existing policy needs to be elaborated and updated.
4. There are no incentives provided under the policy to encourage treatment of waste water and its usage.

Hence, the Karnataka State Policy on Urban Wastewater Reuse, 2017 should be revised with a clear action plan supported by required institution for operationalizing the policy.

B. The **Karnataka Renewable Energy (RE) Policy, 2022-27** promotes the generation of energy through biomass, and waste-to-energy projects. However, the policy lacks clear directions for utilization of sewage sludge as an energy source.

KEY RECOMMENDATIONS

Recommendation 10: Revise State Policy on Urban Wastewater Reuse

The target in the State Policy to achieve milestones relating to treated water reuse needs to be revisited taking into account the infrastructure availability and the region-specific requirements. The State Reuse Policy should be incentivized and have treatment capacity based technology preference and stated water quality parameters fit for reuse for various applications.

Recommendation 11: Pricing of Treated Water

The pricing of treated water should include components like the quality and purpose of reuse, lifecycle cost of STP, capital, O&M cost of the network laid for distribution of treated water.

Recommendation 12: Development of PPP Projects

i. Development of STPs and Sludge Treatment facilities should be developed on Hy-brid Annuity Basis/ DBFOT basis.

ii. Development of Biogas power plants on BOOT/ Captive Use basis

iii. Development of Bio- CNG plants on DBFOT basis utilizing offtake arrangements available under Sustainable Alternative Towards Affordable Transportation (SA-TAT) Schemes

Recommendation 13: Designing the Procurement Strategy

i. BWSSB need to adopt output based design specifications focusing performance measurements (through KPIs)
ii. Minimum 50% of remuneration should be provided to the private sector through performance measurements.
iii. Allow private sector to bring superior technology subject to confirmation of lifecycle cost to operational benefit assessment.
iv. Adopt long term (20+ years) contracts integrating the entire value chain on treatment & disposal and reuse.
v. Focus on balancing risk allocation considering value for money on offer.

Recommendation 14: Policy regarding utilization of Biogas

Policy measures to increase the usage of biogas produced from STP sludge treatment, in the energy and transportation sectors of the State in line with Bio-Fuel Policy 2018 should be adopted.

Recommendation 15: Carbon Neutrality

BWSSB to focus on carbon neutrality & carbon sequestration through the following means and adopt carbon based financing:

i. Recovering Methane from biogas, and utilization as compressed biogas or for power generation.
ii. Reuse of recycled water
iii. Commoditization of biosolids
iv. Using the VM0033 methodology and working with carbon offset registries, BWSSB can turn their waste reduction efforts into a valuable asset while contributing to a more sustainable future

CONCLUSION

As urban areas such as the Bruhat Bengaluru Mahanagara Palike (BBMP) continue to grow and the need for improved wastewater treatment increases, it becomes imperative to ensure that infrastructure design and related investment strategies must avoid inefficient and unsustainable solutions and utilize available technology options for recovering energy, biosolids, reusable water, and other resources from wastewater using circular economy principles, thereby making wastewater treat-ment facilities financially and environmentally more sustainable.

By adopting new wastewater treatment technologies and approaches, BWSSB can increase water reuse while meeting the stringent 2030 standards, convert sludge to biosolids and utilize biogas for energy production. This sizeable investment has a return on investment but not within the standard 5-year operation period. For a PPP to finance this, a 15-20-year operation contract is necessary, which is also in line with international practice. This means that BWSSB can achieve a positive return on such a massive investment while preparing for future wastewater treatment needs. Estab-lishing and upholding sewage treatment systems is crucial for the well-being of society and the environment. However, newer STPs demand a substantial number of financial resources and energy. This places a significant fiscal strain on municipal bodies like BWSSB. To reduce the fiscal burden, numerous financial strategies have been explored as a part of this project. Also wastewater treatment facilities are essential for ensuring clean water for communities, however, these are sources of generating significant amount of Greenhouse Gas (GHG) emissions. However, through the implementation of certain strategies, these facilities can reduce their emissions and even earn carbon credits.

This report provides deep insights and recommendations, which may help BWSSB to transform into Utility Of The Future (UOTF) by focusing on innovation, fiscal dis-cipline, resource recovery and sustainable growth consistent with the vision and goals of the Bangalore Water Supply and Sewerage Board (BWSSB).