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Investigating Study on Used Water Management Under SBM- U 2.0

Nakul Shenode[1], Dilip L. Budhlani[2], Mayuri Kanzode[3]

[1]*Assistant Professor, Civil Engineering Department, Swaminarayan Siddhanta Institute of Technology, Nagpur.*
[2]*Head of Department, Civil Engineering Department, Swaminarayan Siddhanta Institute of Technology, Nagpur.*
[3]*Research Scholar, Civil Engineering Department, Swaminarayan Siddhanta Institute of Technology, Nagpur.*

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ABSTRACT

The effective management of used water is a critical component of sustainable urban development, particularly under the Swachh Bharat Mission - Urban 2.0 (SBM-U 2.0) initiative. This project investigates the current practices, challenges, and opportunities in used water management across urban areas, aligning with the goals of SBM-U 2.0 to achieve an Open Defecation Free (ODF++) status and ensure scientific wastewater treatment and reuse. The study focuses on evaluating the implementation of modern sewage treatment technologies, including SBR (Sequential Batch Reactor), MBBR (Moving Bed Biofilm Reactor), along with decentralized solutions like FSSM (Faecal Sludge and Septage Management). Through a combination of data analysis, field observations, and stakeholder engagement, the project identifies gaps in existing systems and recommends sustainable strategies to improve the efficiency of sewage treatment plants (STPs), reduce the environmental impact of untreated discharges, and promote the reuse of treated wastewater for non-potable applications. The findings of this study aim to contribute towards the realization of SBM-U 2.0 objectives, ensuring cleaner and more resilient urban water management systems in India.

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Water is an essential and finite resource that plays a critical role in sustaining life, maintaining public health, supporting economic growth, and preserving the environment. Yet, the increasing demands of a growing population, rapid urbanization, and industrialization have placed immense pressure on available water resources. The global water crisis is exacerbated by the lack of proper wastewater treatment and management systems, leading to severe environmental degradation, contamination of natural water bodies, and the spread of waterborne diseases. In India, this challenge is particularly pronounced in urban areas where the generation of used water, or wastewater, far exceeds the capacity of existing treatment infrastructure. With over 60% of urban wastewater being discharged into rivers, lakes, and open drains without adequate treatment, the need for a comprehensive and scientific approach to wastewater management has become an urgent priority for ensuring public health, environmental sustainability, and the conservation of precious water resources. Recognizing the critical importance of addressing sanitation and wastewater management issues, the Government of India launched the Swachh Bharat Mission – Urban (SBM-U) in 2014, with the primary goal of eliminating open defecation and promoting safe sanitation practices. Building upon the achievements of the first phase, the Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0) was launched in October 2021, with a broader and more ambitious vision. SBM-U 2.0 aims to make all cities "Garbage Free" and "Water Secure" by ensuring 100% scientific management of wastewater and faecal sludge, achieving ODF++ compliance, and promoting the reuse of treated water for non-potable purposes such as irrigation, industrial processes, and landscaping. The mission also emphasizes the need for technological innovations, capacity building, financial sustainability, and the active participation of all stakeholders, including urban local bodies (ULBs), private sector players, and communities.

Used water management, within the scope of SBM-U 2.0, encompasses the collection, conveyance, treatment, and safe disposal or reuse of wastewater generated from households, commercial establishments, and industries. However, the challenges in achieving effective used water management are multifaceted. Many Indian cities continue to face issues such as inadequate sewerage networks, poor operational efficiency of sewage treatment plants (STPs), lack of proper faecal sludge and septage management (FSSM) facilities, limited reuse of treated wastewater, and the discharge of untreated or partially treated effluents into the environment. According to recent estimates by the Central Pollution Control Board (CPCB), the total sewage generation in urban India exceeds 72,368 million litres per day (MLD), while the operational treatment capacity is only around 31,841 MLD, indicating a significant gap in the infrastructure and its utilization. Furthermore, the performance of existing STPs is often suboptimal, with many plants operating at less than 60% of their installed capacity due to factors such as poor maintenance, lack of skilled manpower, unreliable power supply, and inadequate monitoring systems. Another critical aspect of used water management under SBM-U 2.0 is the integration of decentralized solutions such as faecal sludge and septage management (FSSM), which is particularly important in smaller cities and towns without conventional sewerage networks. While FSSM provides a cost-effective and scalable alternative to centralized systems, its implementation faces challenges such as insufficient infrastructure, limited awareness, regulatory gaps, and weak enforcement mechanisms. Moreover, the potential for resource recovery and circular economy approaches—such as the reuse of treated water, energy generation through biogas, and nutrient recovery from sludge—remains largely untapped in India's wastewater sector, despite its proven benefits in enhancing sustainability and reducing operational costs. The environmental impacts of untreated or poorly treated wastewater discharge are severe. They include the contamination of rivers and lakes, depletion of dissolved oxygen levels, eutrophication, and the spread of waterborne diseases such as cholera, dysentery, and hepatitis. This has far-reaching consequences on public health, biodiversity, and the overall quality of life in urban areas. In the context of climate change, the risks are further compounded by increasing water scarcity, rising temperatures, and the vulnerability of water infrastructure to extreme weather events. Therefore, addressing the challenges of used water management is not only essential for achieving the objectives of SBM-U 2.0 but also for contributing to broader national and global goals such as the Sustainable Development Goals (SDGs), particularly Goal 6: Clean Water and Sanitation, and Goal 11: Sustainable Cities and Communities. This study, titled "Investigating Study on Used Water Management under SBM-U 2.0", aims to provide a comprehensive assessment of the current status, challenges, and opportunities in the management of used water in urban India. It seeks to evaluate the effectiveness of existing wastewater treatment technologies such as the Sequential Batch Reactor (SBR), Moving Bed Biofilm Reactor (MBBR), and Activated Sludge Process (ASP), as well as the performance of decentralized systems like FSSM units. The study also aims to identify gaps in the implementation of SBM-U 2.0 guidelines, examine the role of regulatory frameworks and policy instruments in ensuring compliance, and explore strategies for enhancing the reuse of treated wastewater in sectors such as agriculture, industry, and urban landscaping. By analyzing case studies, field data, and best practices from various urban local bodies, this study will offer practical recommendations for improving the efficiency, sustainability, and resilience of used water management systems in India.

1.2 USED WATER MANAGEMENT

Used water management, also known as wastewater management, is the process of collecting, treating, and potentially reusing wastewater to protect public health and the environment. It's a crucial aspect of overall water management, ensuring that water returned to the environment is clean and safe. Used water management is an essential aspect of sustainable urban development, public health protection, and environmental conservation, particularly in rapidly urbanizing regions like India where the generation of wastewater is increasing at an alarming rate due to population growth, urban expansion, industrialization, and lifestyle changes. Used water, often referred to as wastewater, includes all types of water that have been adversely affected by human activities, primarily from domestic, commercial, and industrial sources, and typically contains a mix of organic matter, nutrients, pathogens, suspended solids, toxic substances, and other pollutants. Proper management of this used water is crucial to prevent environmental degradation, safeguard water bodies, ensure public health, and support the circular economy by enabling the reuse and recycling of treated water and recovery of valuable resources such as energy and nutrients. The scope of used water management is comprehensive and includes various processes such as collection, conveyance, treatment, safe disposal, and beneficial reuse. In urban areas, used water is primarily generated from household activities such as bathing, cooking, cleaning, washing, and toilet use, along with wastewater from commercial establishments, institutions, and industries. The management of this used water involves establishing an efficient sewerage network or adopting decentralized systems like septic tanks, bio-digesters, or faecal sludge and septage management (FSSM) units in areas where conventional sewer systems are not feasible. Central to used water management is the treatment of wastewater to remove harmful contaminants and reduce pollutant loads to acceptable levels before it is either safely discharged into water bodies or reused for non-potable purposes such as irrigation, horticulture, industrial cooling, and construction activities. Treatment technologies vary from conventional methods such as Activated Sludge Process (ASP), Extended Aeration, Sequential Batch Reactors (SBR), and Trickling Filters, to advanced technologies like Membrane Bioreactors (MBR), Moving Bed Biofilm Reactors (MBBR), Constructed Wetlands, and Anaerobic Digesters, depending on the scale of the system, the quality of effluent required, and the intended reuse application. Effective used water management also involves the safe handling and disposal of sewage sludge, a byproduct of treatment processes, which can be further processed for resource recovery through anaerobic digestion to produce biogas, composting for organic manure, or incineration where appropriate. Furthermore, the concept of water reuse and recycling is a critical dimension of used water management, aiming to reduce the burden on freshwater sources by treating and reusing wastewater for secondary purposes, thus contributing to water security, climate resilience, and sustainable water resource management. In India, the need for improved used water management is underscored by the alarming data that a significant portion of generated sewage remains untreated or partially treated, leading to the contamination of rivers, lakes, and groundwater, with severe implications for public health, aquatic life, and environmental integrity. Therefore, effective management practices must address not only technical solutions but also institutional strengthening, capacity building of urban local bodies (ULBs), financial planning for O&M costs, policy frameworks, public awareness campaigns, and monitoring systems to ensure that the entire value chain of used water – from generation to final disposal or reuse – is managed in a safe, efficient, and environmentally sustainable manner.

Used water management under initiatives like the Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0) focuses on achieving ODF++ and Water+ city status by ensuring that no untreated wastewater is discharged into the environment, all faecal sludge is safely collected and treated, and treated water is maximally reused. It also promotes public-private partnerships, adoption of innovative technologies, and digital monitoring systems for real-time performance tracking of treatment plants and sanitation facilities. Moreover, used water management is intricately linked to the broader objectives of the Sustainable Development Goals (SDGs), particularly SDG 6: Clean Water and Sanitation, SDG 11: Sustainable Cities and Communities, and SDG 12: Responsible Consumption and Production, thereby highlighting its critical role in building resilient, inclusive, and environmentally responsible urban spaces. Ultimately, the goal of used water management is to transform the current linear model of wastewater disposal into a circular, resource-efficient system where water, energy, and nutrients are recovered, reused, and reintegrated into the economy, thereby contributing to the long-term sustainability of urban ecosystems and the well-being of communities.

1.3 SWACHH BHARAT MISSION – URBAN 2.0

The Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0) is a flagship initiative of the Government of India that builds upon the success of the original Swachh Bharat Mission launched in 2014, with a renewed vision, expanded objectives, and a stronger commitment towards achieving sustainable urban sanitation and solid-liquid waste management across Indian cities and towns. Officially launched on 1st October 2021, SBM-U 2.0 seeks to transform urban India into a clean, garbage-free, and water-secure nation by promoting comprehensive sanitation solutions that go beyond the initial focus on eliminating open defecation. The mission aims to consolidate the gains of the first phase and scale up efforts to address emerging challenges, such as effective management of used water, proper treatment and safe disposal of faecal sludge and septage, 100% scientific processing of municipal solid waste, and maximum reuse of treated wastewater for non-potable applications, including irrigation, industrial use, and urban landscaping. The guiding vision of SBM-U 2.0 is aligned with the broader goals of environmental sustainability, public health improvement, and circular economy principles, wherein waste is viewed as a resource, and innovative technologies are leveraged for resource recovery, energy generation, and nutrient reuse. The mission targets achieving Open Defecation Free (ODF)++ status across all statutory towns, ensuring not just access to toilets but also the safe management of faecal waste, proper functioning of community and public toilets, and complete elimination of unsafe disposal practices like open discharge of wastewater and sludge.

In addition, SBM-U 2.0 places significant emphasis on greywater and used water management, recognizing the critical need to address the growing volumes of untreated or partially treated sewage being discharged into rivers, lakes, and the environment, which poses severe threats to public health, aquatic ecosystems, and the overall water security of the country. The mission envisions the integration of Faecal Sludge and Septage Management (FSSM) solutions, especially in smaller towns and peri-urban areas where conventional sewerage systems are not feasible, by promoting the construction of decentralized treatment units, co-treatment facilities in existing STPs, and ensuring safe desludging services in collaboration with private sector partners and urban local bodies (ULBs). SBM-U 2.0 also encourages the use of modern technologies such as digital monitoring systems, IoT-enabled sensors, and geo-tagging for real-time tracking of sanitation assets, desludging operations, and treatment plant performance, thereby improving transparency, accountability, and data-driven decision-making. The mission strongly advocates for the reuse of treated wastewater in non-potable applications, aligning with national policies such as the National Water Policy and the Jal Shakti Abhiyan, by mandating that cities explore options to use treated water in agriculture, industry, construction, and urban greening projects, thus reducing the dependency on fresh water sources and contributing to climate resilience.

Financial sustainability is another critical pillar of SBM-U 2.0, which aims to ensure that urban local bodies are empowered to mobilize funds for capital investments and operation and maintenance costs through mechanisms such as user charges, Public-Private Partnerships (PPP), and convergence with other schemes like AMRUT 2.0 and Jal Jeevan Mission (Urban). Capacity building, stakeholder engagement, and community participation are integral to the success of SBM-U 2.0, as the mission recognizes that sanitation is not merely a technical issue but also a socio-cultural and behavioral challenge that requires widespread awareness, citizen ownership, and collective action. Special attention is given to the inclusion of marginalized communities, gender equity, and the empowerment of sanitation workers through the provision of safety gear, mechanized equipment, and health benefits under initiatives like the NAMASTE scheme. SBM-U 2.0 also integrates the goals of the United Nations Sustainable Development Goals (SDGs), particularly SDG 6: Clean Water and Sanitation, SDG 11: Sustainable Cities and Communities, and SDG 12: Responsible Consumption and Production, thereby aligning India's national objectives with global commitments for a cleaner, healthier, and more resilient urban future. In essence, SBM-U 2.0 is not merely an infrastructure development program but a holistic mission that envisions transforming the sanitation landscape of urban India through a combination of robust policies, technological innovations, financial mechanisms, and community-driven approaches, ensuring that every citizen has access to safe sanitation services, treated water is effectively reused, and the environment is protected for future generations.

2. LITERATURE REVIEW

The field of wastewater treatment has witnessed significant advancements in recent years, with researchers and engineers developing a range of technologies aimed at improving treatment efficiency, reducing energy consumption, and enabling resource recovery. Conventional treatment processes such as the Activated Sludge Process (ASP), Trickling Filters, and Oxidation Ponds have been extensively studied and remain widely used in many parts of the world due to their reliability and scalability. However, these systems often face challenges related to high operational costs, large land requirements, and limited nutrient recovery. To address these issues, emerging technologies such as Membrane Bioreactors (MBR), Moving Bed Biofilm Reactors (MBBR), Sequential Batch Reactors (SBR), and Anaerobic Digesters have been developed and studied extensively. Furthermore, research by the Indian Institute of Technology (IITs) and Central Pollution Control Board (CPCB) has focused on the reuse potential of treated wastewater in agriculture and industry, the co-treatment of septage in existing STPs, and the integration of sludge management practices with biogas production for energy recovery. Studies on Zero Liquid Discharge (ZLD) systems, particularly in industrial settings, have also gained momentum, promoted complete water reuse and minimized pollution loads. However, challenges such as high capital costs, complex maintenance requirements, and the need for skilled operators remain key barriers to the widespread adoption of advanced treatment technologies. Overall, while the literature on wastewater treatment is rich and diverse, it underscores the need for context-specific solutions that are affordable, scalable, and environmentally sustainable.

[1] A study presented at the International Work Session on Water Statistics (IWG-Env) in Vienna, June 20-22, 2005, by R.M. Bhardwaj from the Central Pollution Control Board of India, highlighted the critical status of wastewater generation and treatment in India. The study found that urban centers in India lack adequate sanitation infrastructure, leading to the deterioration of water quality in aquatic resources. The increasing population and resultant wastewater generation threaten to render water bodies unsuitable for their intended uses unless comprehensive wastewater treatment measures are adopted. According to the study, Class I cities (population >100,000) and Class II towns (population between 50,000 and 100,000) generate approximately 26,254 million liters per day (MLD) of wastewater, while the developed treatment capacity is only about 7,044 MLD—covering just 27% of the wastewater produced. These findings underscore the urgent need for improved wastewater treatment strategies and policies that balance water supply augmentation with the development of treatment facilities. Future urban water supply sustainability will largely depend on efficient wastewater treatment systems, as downstream cities increasingly rely on treated wastewater from upstream urban centers.

[2] Domestic Wastewater Treatment using Phytorid Technology by R. Kaalipushpa, S. Karthika, S. Revathi (2018) In the developing technologies and growing environment, the usage of the water source plays a vital role and it's been needed and used in large amount. Insufficient management of municipal and wastewater in immense environmental problems and increasing hygienic risks for the growing urban population thereby hampering poverty alleviation and a sustainable development of Indian society. But now days, the waste water is converted into a source for various purposes in different aspects by the use of phytorid technology. phytorid technology is a patented technology and being very effective in water pollution treatment it leads one step forward to sustainable treatment of wastewater in safe manner using Iris Pseudacorus (Yellow Iris) plants and natural source for the treatment without affecting the ecosystem. The Chrysopogonzizanioides is to increase the pH value and to reduce the nitrogen, phosphorous content. The coagulation and flocculation process is done by alum to have a turbidity and to remove the suspended solids. This method is more advantageous of cost effective, negligible operation and maintenance with minimum electricity, smaller footprint. The main focus of the project is to avoid the scarcity of the irrigation water and to avoid the odor in the treated water and to enhance the quality of the water to prevent ground water pollution by analyzing the nominal water parameters that need to be satisfied for reusing the treated water with the references of IS 3025 code books.

[3] Phytorid System for Urban Wastewater Treatment by Suryapratap Galande, Gopi Kuwar, Satish Jadhal, Pankaj Akhade, Prof. Hameed Rafai, Prof. Keerthi BGurani (2022) The treatment of urban wastewater has become a significant challenge, especially in rural and urban areas where the demand for effective sewage treatment exceeds the capacity of existing infrastructure. As urban populations grow, so does the volume of wastewater generated, leading to untreated sewage being released into rivers, lakes, and other water bodies, causing severe environmental degradation. With increasing awareness of the harmful effects of untreated sewage, there is a growing need for alternative treatment solutions. Traditional methods like activated sludge systems, trickling filters, and lagoons, though effective, have limitations such as high operational costs and space requirements. This has led to the exploration of more sustainable, cost-effective methods, such as constructed wetlands and phytoremediation techniques. Phytoremediation, particularly the use of plant-based systems, has gained popularity as a natural method of treating wastewater. The Phytorid system is a form of constructed wetland that uses plants to filter and degrade pollutants in wastewater. By harnessing the power of plant roots and microorganisms, this system has proven to be highly effective in reducing organic matter, nutrients, and pathogens from urban wastewater. Studies, including the work by Galande et al. (2022), highlight the Phytorid system's potential to serve as an alternative or complementary treatment method in urban areas where centralized treatment plants are not feasible.

[4] Phytorid Technology by Tanmay Saka, Damini Ghule, Imran Patel, Safwan Sayyed, Assistant Prof. P.A. Manatkar (2021) The management and treatment of wastewater, particularly in rapidly growing urban and rural areas, is a critical concern in many countries, including India. Traditionally, wastewater was collected through primitive systems that relied on gravity to transport sewage to a disposal point. This method often involved open channels or direct disposal into water bodies, which contributed to environmental contamination. Over time, more sophisticated systems were developed, incorporating modern water carriage sewerage techniques, where sewage is mixed with water and transported through closed conduits under gravity flow. These modern systems ensure that sewage is safely carried and disposed of, often after undergoing treatment processes to remove harmful pollutants. In India, the situation is complex, with major metropolitan cities and larger towns typically equipped with modern sewage treatment facilities. However, smaller towns and villages continue to use outdated systems that struggle with efficient waste management. As urbanization intensifies, there is a pressing need for affordable, efficient, and sustainable wastewater treatment solutions, especially in areas that cannot accommodate expensive, large-scale infrastructure. One such promising solution is Phytorid Technology, a natural treatment process that utilizes plants to treat wastewater. Phytorid technology is a type of constructed wetland system where the root zone of plants and the surrounding soil matrix act as natural filters, removing contaminants from wastewater.

[5] Implementation of Sewage Treatment Plant by using Phytorid Technology by Anuradha Manikrao Patil, Sagar Gawande (2016) With rapid population growth, urbanization, and industrial development, the pressure on water resources is mounting not just in terms of quantity but also in terms of quality. In many urban areas, domestic sewage, industrial effluents, and runoff from agricultural and mining activities are major contributors to water pollution. This pollution is a significant environmental and health concern, particularly in cities where water contamination is widespread. The competition for limited water resources, coupled with inadequate sanitation systems and insufficient wastewater treatment infrastructure, aggravates the problem. In India, approximately 95% of sewage treatment plants (STPs) in major cities are reported to be inefficient or not fully functional. Common issues include interrupted operations due to frequent power failures, hydraulic or organic overloading, inadequate oxygenation caused by mechanical breakdowns of aerators, uneven sewage distribution, difficulties in sludge handling, and financial constraints. These challenges make it increasingly difficult for traditional treatment plants to effectively manage urban wastewater and meet environmental standards. Phytorid technology offers a promising solution to address these issues. This system utilizes constructed wetlands with specific plant species to treat sewage through natural filtration processes. Plants play a crucial role in absorbing and filtering out pollutants, including organic matter, nutrients, and pathogens, while promoting microbial activity in the root zone. As a cost-effective, low-energy alternative to traditional STPs,

[6] Performance Assessment of Domestic Wastewater Treatment Plants Operating on Different Technologies by Sudhir Kumar, Mahendra Pratap Choudhary (2020) The city of Delhi, with its rapidly growing population, faces significant challenges in managing wastewater, which contributes to the severe pollution of the Yamuna River. As one of the most polluted rivers in India, the Yamuna suffers from untreated wastewater being directly discharged into it, exacerbating environmental and public health risks. The sewerage system in Delhi has been affected by improper drainage management and insufficient sewer installations, particularly in undeveloped and slum areas. This results in poor water quality in surface water bodies, especially the Yamuna, which poses serious hygiene and health concerns for its increasing population. To address these concerns, the Delhi Jal Board has implemented sewage treatment plants (STPs) using various treatment technologies to efficiently treat wastewater before discharging it into rivers or using it for non-domestic purposes such as irrigation and cleaning. This study focuses on assessing the performance of three STPs located in Delhi: Najafgarh, Delhi Gate, and Shahdara, each employing different treatment technologies – Extended Aeration (EA), Biological Filtration and Oxygenated Reactor (BIOFOR), and Phytorid, respectively. The study found that the STPs using BIOFOR and Phytorid technologies were more efficient in treating municipal wastewater compared to the EA technology employed at the Najafgarh STP. Specifically, the effluent quality from the BIOFOR and Phytorid-based systems met the required standards for discharge into surface water bodies and could be safely utilized for irrigation, agricultural activities, and cleaning purposes.

[7] Constructed Wetlands - Natural Treatment of Wastewater by Mrs. Snehal Bhaskar Thamke, Dr. Arif Khan (2021) Constructed wetlands are engineered and managed wetland systems that are increasingly receiving worldwide attention for wastewater treatment and reclamation. Compared to conventional treatment plants, constructed wetlands are cost-effective and easily operated and maintained, and they have a strong potential for application in a small community. Constructed wetlands for wastewater treatment have substantially developed in the last decades. As an eco-friendly treatment process, constructed wetlands may enable the effective, economical, and ecological treatment of agricultural, industrial, and municipal wastewater. Constructed wetlands are very effective in removing organics and suspended solids, whereas the removal of nitrogen is relatively low, but could be improved by using a combination of various types of constructed wetlands meeting the irrigation reuse standards. The removal of phosphorus is usually low, unless special media with high sorption capacity are used. Pathogen removal from wetland effluent to meet irrigation reuse standards is a challenge unless supplementary lagoons or hybrid wetland systems are used. In this paper studies various case study related to Wetlands in Indian Cities and also described include systems involving both constructed and natural wetlands, habitat creation and restoration.

[8] The research paper titled "Design of MBBR Based Sewage Treatment Plant" was published in the year 2022 by authors Priyanka R. Kamble, Nalini Thakre, and Hiradas Lihare. The study explores the effectiveness of Moving Bed Biofilm Reactor (MBBR) technology in treating sewage, particularly within educational institutions where water demand is high. MBBR technology is an advanced and efficient method for biological wastewater treatment. It combines the advantages of activated sludge and biofilm processes, making it an ideal solution for sewage treatment plants (STPs). The system utilizes suspended plastic carriers with a high surface area to support biofilm growth, enhancing microbial activity and wastewater treatment efficiency. Numerous studies have highlighted the effectiveness of MBBR technology in municipal and industrial wastewater treatment. Research indicates that MBBR systems achieve high removal efficiencies for organic matter, nitrogen, and phosphorus. Unlike conventional treatment methods, MBBR is resistant to shock loads and variations in influent characteristics. Studies also show that MBBR requires a smaller footprint compared to conventional activated sludge systems, making it suitable for space-constrained areas such as educational campuses. A critical aspect of wastewater treatment is its cost-effectiveness. Literature suggests that MBBR technology has moderate operational costs due to reduced sludge production and minimal maintenance. The estimated treatment cost of 1 KLD of sewage in India ranges between INR 18 to 20, with treated water valued at INR 40-60 per KLD.

[9] Akshay Kshetre et al. (2018), "Comparative Study on Activated Sludge Process and Stabilization Pond to Reduce BOD", emphasized the need for wastewater treatment and explored various available techniques. These included Activated Sludge Process (ASP), Trickling Filter, Extended Aeration Sludge Process, Aerated Lagoon, Oxidation Ditch, Waste Stabilization Pond (WSP), Up-flow Anaerobic Sludge Blanket (UASB), Membrane Bio-Reactor (MBR), Moving Bed Bio-Film Reactor (MBBR), Sequential Batch Reactor (SBR), and Rotating Biological Contactors (RBCs). Among these, the study particularly focused on a comparative analysis of the Activated Sludge Process and the Stabilization Pond in their effectiveness at reducing Biochemical Oxygen Demand (BOD). According to Kshetre et al. (2018), ASP is a widely used aerobic treatment process that offers a higher removal efficiency in a relatively compact space and within a shorter retention time. However, it requires skilled operation and higher energy input. On the other hand, Stabilization Ponds, while requiring a larger area and longer retention time, offer a more natural and cost-effective method for treating wastewater with minimal energy use and simpler operation. Their findings revealed that both methods are effective in BOD removal, but the choice between them largely depends on site-specific conditions, availability of land, and operational capabilities. The study serves as a valuable reference for selecting an appropriate biological treatment method based on environmental and economic considerations.

[10] Rishabh Shukla et. al. (2022), "Performance evaluation and microbial community structure of a modified trickling filter and conventional activated sludge process in treating urban sewage", The performance and microbial community structure of a Modified Trickling Filter (MTF) and a conventional Activated Sludge Process (ASP) were analyzed in the context of urban sewage treatment. The MTF system, operated with a hydraulic retention time (HRT) of 2 hours and effluent recycling, was found to outperform the ASP system, which had an HRT of 8 hours, particularly in terms of nitrogen removal. Both systems achieved over 60% removal efficiency for chemical oxygen demand (COD), ammonia-nitrogen (NH_3-N), and phosphate (PO_4^{3-}-P); however, MTF demonstrated superior denitrification capability, with less than 5 mg/L of nitrate-nitrogen (NO_3^--N) detected in its effluent. A key highlight of the study was the higher abundance of nitrogen-removal functional genes such as amoA, nirK, nirS, napA, narG, and nosZ in the MTF system, indicating the dominance of simultaneous nitrification and denitrification (SND) processes. Using Miseq sequencing, the microbial communities in both systems were characterized, revealing a dominance of Proteobacteria, Planctomycetes, Chloroflexi, and Actinobacteriota. Notably, the co-occurrence of nitrifiers, denitrifiers, aerobic denitrifiers, and anaerobic ammonium oxidation (ANAMMOX) bacteria in the MTF suggested a more diverse and functionally active microbial ecosystem contributing to its enhanced nitrogen removal. The findings of Shukla and Ahammad (2022) underscore the potential of MTF as an efficient alternative to conventional ASP systems, especially in scenarios requiring compact design and effective nutrient removal.

3. RESEARCH METHODOLOGY

The project components related to sewerage system are to be funded from the Central and State Government / ULB funds. The eligibility of project components for funding under the two streams of funds is shown below in Figure 3.1.

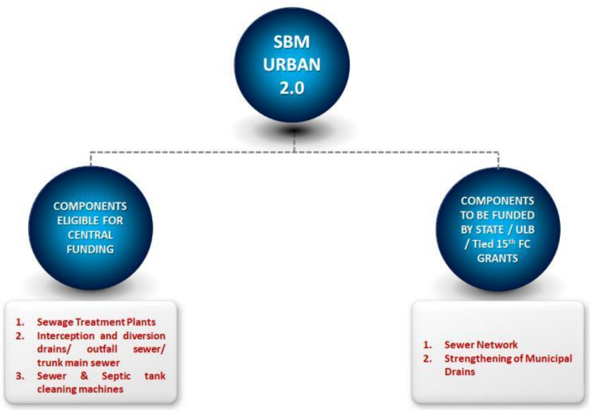


Fig.3.1: Components of Sewerage System eligible for funding under SBM-U 2.0

Approach for Used Water management & FSM:

To amicably address used-water management challenges under SBM 2.0, an integrated plan for a city is to be prepared involving sewered and non-sewered solutions including faecal sludge management and the implementation maybe taken up as per the availability of resources and priority in an incremental approach. However, in some states and cities where already a significant improvement is done in used-water management, the same maybe taken up to saturation level. The detailed approach are as follows:

1. **Sewer Network in Core Sanitation Zone:** ULBs have to identify its "Core Sanitation Zone (CSZ)", defined as a zone which has at least 50% of the town's current population settled over an area comprising about 20-30% of the town's spread (please refer to the diagram given below). The CSZ will be provided with a sewer network to connect it directly to the STP. The cost of the CSZ sewer network will be borne entirely by the State/ ULB from 15thFC Grants/ SFC Grants/ their own funds etc. States/ UTs are expected to encourage the ULBs to identify any suitable area in the city to provide a sewer network. City can expand network coverage based on necessity and availability of resources over time. For upcoming new green field developments in and around towns, the provision of sewerage network along with decentralized sewage treatment facilities should be factored into planning.
2. **Intercepting Used Water from open drains to Sewer network:** State is also required to strengthen existing open drains carrying sullage/sewage and connect the same to the sewer network, wherever feasible, after providing suitable I&D structures like coarse screen, grit chamber, fine screen and settling basin etc. before intercepting into sewer network.
3. **Approach for Fringe Areas:** For remaining inhabitants residing in fringe areas outside the CSZ, the town authorities may work out economically judicious solutions, opting between continuing with onsite disposal systems (septic tanks with soak pits) and providing localized community level sewage treatment plants for grey/ black water where feasible or conveying it to STP depending on economics. The septage from these households will continue to be safely hauled to a designated STP under professional arrangements. It is advised that the fringe areas may try to strengthen their onsite disposal arrangements by providing for soak pits where they are missing and forcing the septic tank effluent into the ground, adhering to IS 2470. However, due to practical difficulties in providing sewerage systems to the entire population, onsite sanitation systems are encouraged in the fringe areas of the towns where it is uneconomical to provide sewers and in areas where it is difficult to provide sewer network. In such cases, STPs along with co-treatment of faecal sludge have been proven to be advantageous and sustainable.

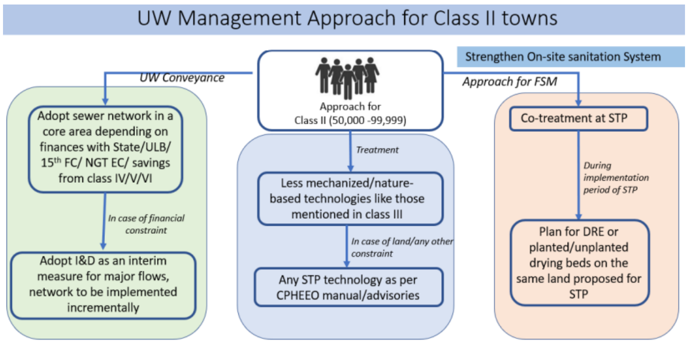


Fig.3.2: UW Management Approach for Class II towns

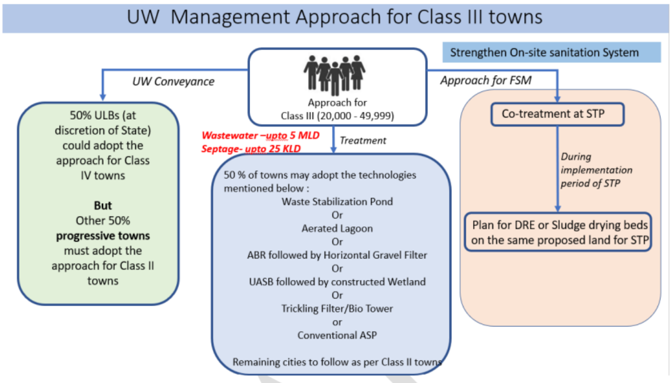


Fig.3.3: UW Management Approach for Class III towns

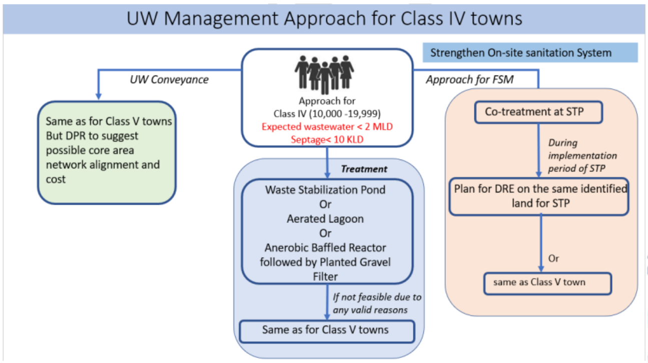


Fig.3.4: UW Management Approach for Class IV towns

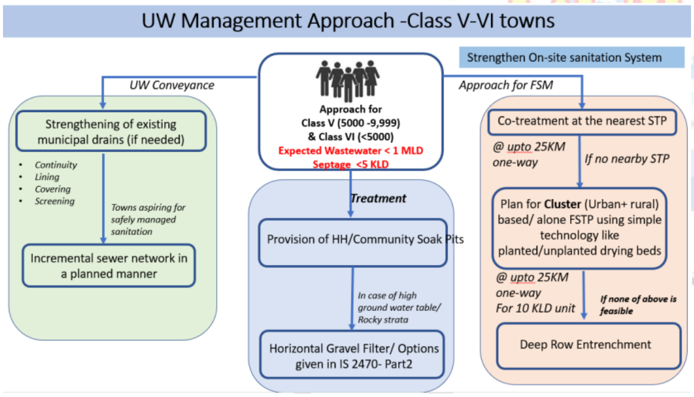


Fig.3.5: UW Management Approach for Class V-VI towns

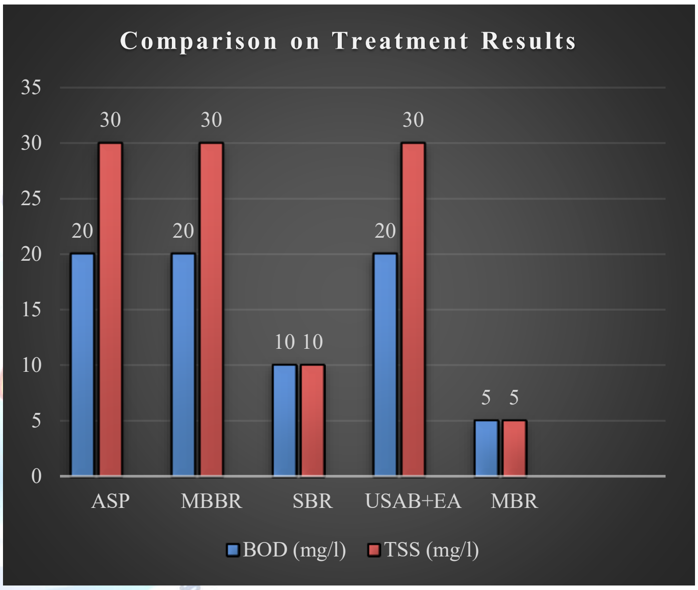
4. RESULTS AND DISCUSSION

4.1 COMPARISON OF DIFFERENT STP TECHNOLGIES UNDER SBM- U 2.0

A Comparative study of different major technologies for sewage treatment has been made considering key parameters such as performance, efficiency, treatment costs, O&M costs, energy cost and land requirement.

Table 4.1: Comparison on the basis of treatment results

SN	Parameter	ASP	MBBR	SBR	UASB+EA	MBR
1.	BOD (mg/l)	<20	<20	<10	<20	<5
2.	TSS (mg/l)	<30	<30	<10	<30	<5
3.	Faecal Coliform, log unit	Upto 2<3	Upto 2<3	Upto 3<4	Upto 2<3	Upto 5<6
4.	T-N Removal efficiency, %	10-20	10-20	70-80	10-20	70-80

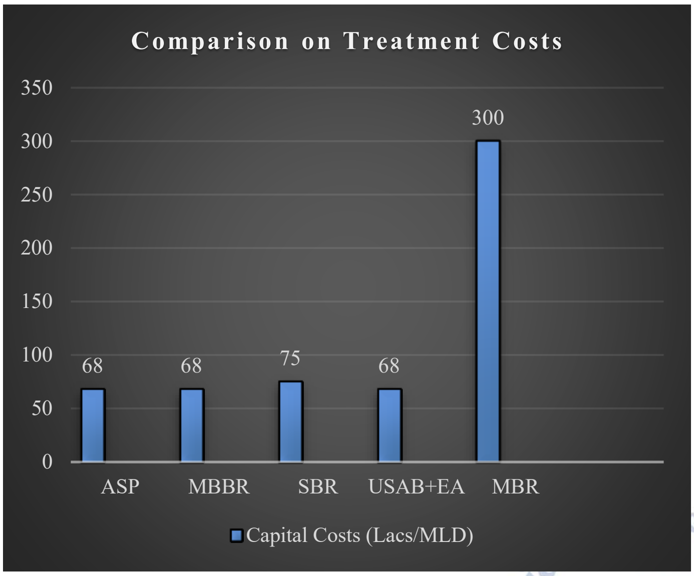


Graph 4.1: Comparison on Treatment Results

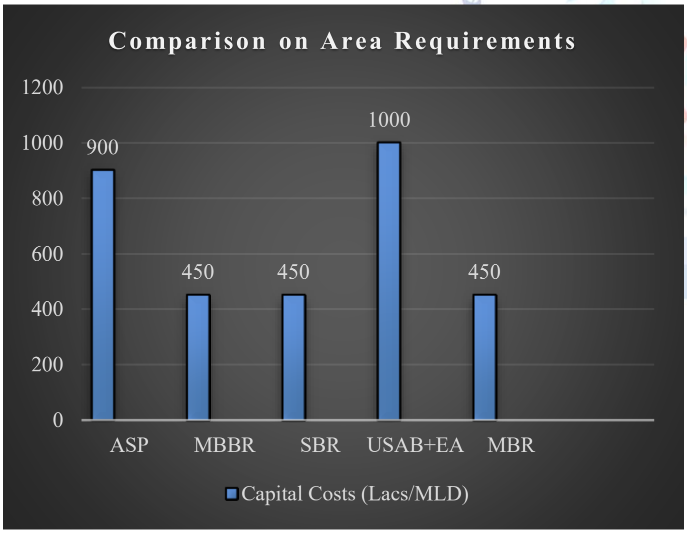
Table 4.2: Comparison on the basis of area requirement & treatment costs

SN	Parameter	ASP	MBBR	SBR	UASB+EA	MBR
1.	Average Area, m² per MLD	900	450	450	1000	450
2.	Average Capital Cost, lacs/MLD	68	68	75	68	300
3.	Civil Works, % of total capital costs	60	60	30	65	20

4.	E&M Works, % of total capital costs	40	40	70	35	80



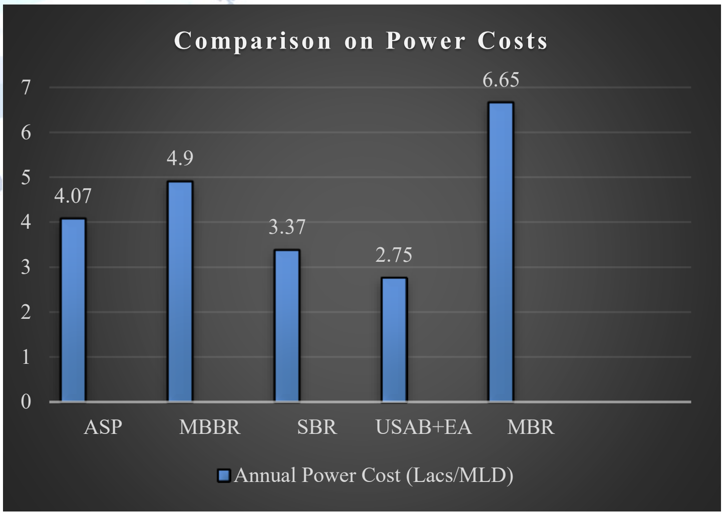
Graph 4.2: Comparison on Treatment Costs



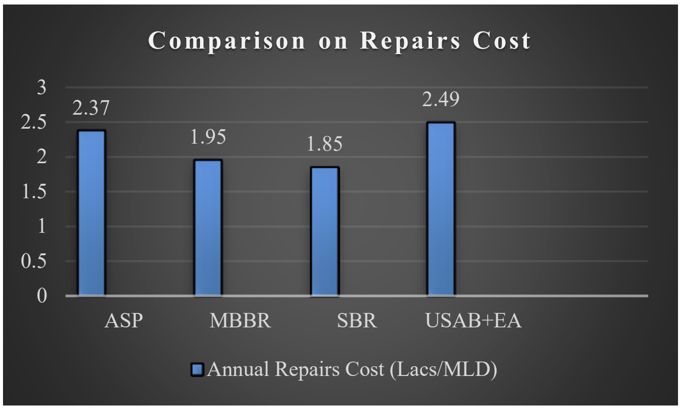
Graph 4.3: Comparison on Area Requirements

Table 4.3: Comparison on the basis of Operation & Maintenance costs

SN	Parameter	ASP	MBBR	SBR	UASB+EA	MBR
	Energy cost (Per MLD)					
1.	Avg. Technology Power requirement, kWh/d/MLD	180	220	150	120	300
2.	Avg. Technology Power requirement, kWh/d/MLD	4.5	2.50	2.50	4.50	2.50
3.	Total Daily Power Requirement (avg) kWh/d/MLD	184.50	222.50	152.50	124.50	301.50
4.	Daily Power Cost (@6.0 per kWh)/MLD/h (including, standby power cost)	46.43	55.93	38.43	31.43	75.93
5.	Yearly Power cost, lacs pa/MLD	4.07	4.90	3.37	2.75	665
	Repairs Cost (Per MLD)					
1.	Civil works Maintenance, lacs pa/MLD	1.94	1.30	1.04	2.11	-
2.	E&M Works Maintenance, lacs pa/MLD	0.43	0.65	0.81	0.38	-
3.	Annual repair Costs, lacs pa/MLD	2.37	1.95	1.85	2.49	-



Graph 4.4: Comparison on Power Costs



Graph 4.5: Comparison on Repairs Cost

Table 4.4: Criteria for selection Appropriate Treatment Technology

SN	Parameter	ASP	MBBR	SBR	UASB+EA	MBR
1.	Removal of BOD, COD, TSS	High	Very High	Very High	High	Very High
2.	Faecal Coliform Removal	High	Very High	Very High	High	Very High
3.	Nitrogen Removal	Low	Medium	Very High	Low	Medium
4.	Phosphorous Removal	Low	Medium	Very High	Low	Medium
5.	Area Requirement	High	Medium	Medium	High	Low
6.	Energy Requirement	High	High	Medium	Medium	Very High
7.	Capital Cost	Medium	Medium	Medium	Medium	Very High
8.	Repair Cost	High	Medium	Medium	High	Medium
9.	Skill Requirement	High	Medium	High	Medium	Very High

5. CONCLUSION

5.1 CONCLUSION

In conclusion, the investigation into used water management under the Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0) framework has highlighted the critical importance of adopting sustainable, integrated, and context-specific approaches to wastewater treatment and reuse in urban India. The study reveals that despite significant progress in sanitation coverage and infrastructure development, challenges related to inadequate treatment capacity, inefficient operation and maintenance, limited awareness, and institutional constraints continue to undermine the effective management of used water. It is evident that the current linear model of wastewater disposal is unsustainable, resulting in severe environmental degradation, public health risks, and wastage of valuable water and nutrient resources. The shift towards a circular economy model, where treated wastewater is viewed as a resource rather than waste, is both necessary and feasible with the adoption of advanced treatment technologies, decentralized systems, and robust policy support. Furthermore, the successful implementation of SBM-U 2.0 depends not only on technological interventions but also on strengthening institutional mechanisms, enhancing capacity building among urban local bodies, fostering community participation, and ensuring financial sustainability through innovative funding models. The findings also underscore the potential of treated wastewater reuse in various non-potable applications, which can significantly alleviate the pressure on freshwater resources, especially in water-stressed urban centers. Overall, the study confirms that comprehensive used water management is integral to achieving the goals of urban sanitation, water security, environmental protection, and public health, thereby contributing meaningfully towards the realization of national and global sustainable development targets.

5.2 Recommendations

Based on the findings and insights gained through this study, several recommendations are proposed to strengthen the management of used water under SBM-U 2.0 and beyond. Firstly, it is imperative to expand and upgrade wastewater treatment infrastructure to ensure that all generated wastewater receives adequate treatment before discharge or reuse. This includes investing in both centralized and decentralized treatment systems tailored to the needs of different urban contexts, especially for smaller towns and peri-urban areas. Secondly, operation and maintenance practices must be standardized and institutionalized, with a focus on capacity building for technical staff and urban local bodies to ensure sustainable performance of treatment plants. Thirdly, real-time monitoring and data management systems should be adopted to enable effective performance tracking, regulatory compliance, and adaptive management. Fourthly, policies and programs must prioritize the safe reuse of treated wastewater by creating awareness among stakeholders and incentivizing its use in agriculture, industry, and urban landscaping to promote water conservation. Fifthly, faecal sludge and septage management (FSSM) should be integrated comprehensively into urban sanitation planning, ensuring safe collection, transport, treatment, and disposal or reuse of sludge. Additionally, innovative financing mechanisms including public-private partnerships, user fees, and performance-based incentives should be explored to mobilize resources for infrastructure development and service delivery. Lastly, community engagement and behavioral change communication are critical to fostering acceptance of wastewater reuse and encouraging responsible sanitation practices. Future research should focus on exploring low-cost technologies, the socio-economic impacts of wastewater reuse, and the development of resilient systems that can adapt to climate variability and urban growth. These recommendations collectively aim to support the establishment of a sustainable, efficient, and inclusive used water management system that aligns with the vision of SBM-U 2.0 and contributes to a cleaner, healthier urban environment.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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