

A review on Planning & Designing of water supply & STP of Govt. Projects

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Abstract—This study evaluates the integrated water supply and sewage treatment systems proposed for Government Medical College (GMC), Hinganghat, aiming to create a self-reliant and sustainable campus infrastructure. It covers technical design, capacity adequacy, treatment efficiency, and financial-operational viability, offering a replicable model for similar institutions.

The 1.50 MLD water supply system is designed using hydraulic modeling and demand projections, with DI K-9 rising mains, ESRs, and energy-efficient pumping stations. The Wena River, secured through formal reservation, serves as a reliable perennial source. The system meets current and future campus needs, including fire-fighting and contingency requirements.

The 1.20 MLD SBR-based STP ensures high treatment efficiency and compliance with CPCB/NGT norms. Treated water is reused for non-potable applications, and sludge is managed via anaerobic digestion with biogas recovery. The STP layout supports safe operations and automated monitoring.

Financially, the project requires ₹20.81 Cr in CAPEX, with major investments in the rising main and STP. Annual OPEX is ₹65.28 Lakhs, driven by staffing and electricity. Lifecycle analysis confirms long-term viability and cost-effectiveness.

Sustainability is reinforced through modular design, reuse strategies, and SCADA-based automation. The project aligns with national missions like Jal Jeevan and Swachh Bharat, contributing to public health and environmental goals.

Index Terms—Integrated Water Supply, Sewage Treatment Plant (STP), Operational Efficiency, Lifecycle Cost Analysis (LCCA), SCADA Automation.

I. INTRODUCTION

Water is one of the most critical natural resources required for sustaining life and development. Its availability in adequate quantity and of acceptable quality is central to human well-being, economic growth, and environmental protection. With rapid

urbanization, industrialization, and population growth, the demand for water in India has been increasing steadily. At the same time, the quality of natural water bodies is under severe stress due to untreated wastewater discharges. It is estimated that more than 60% of wastewater generated in Indian towns and cities is discharged untreated into rivers and lakes, leading to pollution, public health hazards, and ecosystem degradation.

Water supply has been a primary logistical challenge since the dawn of civilization. Water resources are insufficient for the population; people survive against disease, dehydration, or in cases like death. The growth of population directly affected the water distribution system. And if a surface water source was not available, there are other sources like shallow wells to supply water to community residents]. Water demand is increasing day by day whether it is domestic, industrial and agricultural etc., but the source of water is limited. So, authorities around the world are faced with the problem to provide sufficient water from the limited water source. Due to human consumption, water distribution system directly influences the development of the area as well as the nation. Water distribution network plays important role in providing desirable life quality to the public, which the main component is the reliability of supply. To solve this problem, it is necessary to upgrade distribution system [2]. Water distribution network problems deal with design and analysis. Engineering design is the synthesis of theory and precedent. The design problem is to determine the sizes of system components. Conventional procedures for design and analysis are iterative trial and error. The effectiveness of conventional procedures is dependent upon an engineer's intuition, experience, skill and knowledge of the system. The traditional method for designing pipe network is by trial and error guided by experience. Therefore, conventional procedures are

highly related to the human element, which could lead to inefficient design. The analysis is concerned with determining the behavior of an existing system or a new system being designed. In many cases, the study of the system behavior is to determine the operation of the system or the response of the system under specified inputs. In other words, a design is formulated and followed by an analysis to see if it performs according to specifications, hydraulic conditions, demands, costs of components, laying the system pipe links and operating the same are to be considered in developing models for water distribution network. The unit's prices of pipes are not only a function of diameter, but also a function of such parameter as the location in the system.

Government infrastructure projects such as medical colleges, hospitals, and universities are large water consumers and significant wastewater generators. They require continuous water supply for drinking, sanitation, laboratory use, patient care, and campus facilities. Simultaneously, they generate sewage that, if untreated, can be a major source of environmental contamination. Therefore, planning and designing efficient water supply systems and Sewage Treatment Plants (STPs) for such institutions is not only an engineering challenge but also a public health and environmental priority.

The Government Medical College, Hinganghat, is one such flagship project of the Government of Maharashtra. Located in Wardha district, this institution is being developed to provide high-quality medical education and advanced healthcare facilities to the people of the Vidarbha region. The project is spread over a large campus near Jamb, around 12 km from Hinganghat town. Since the municipal water supply is inadequate to meet the high and continuous demand of the college and hospital, a dedicated water supply scheme has been proposed from the Wena River, a perennial surface water source.

II. LITERATURE RIVIEW

Chandapillai et al. (2012) proposed a genetic algorithm-based framework for designing water distribution networks that ensure equitable supply in shortage contexts. Though oriented toward urban networks, the methodology highlights the importance of hydraulic fairness—a principle also relevant to

institutional campuses with mixed-use demand patterns. [1]

Wescoat, J. L. Jr., Murty, J. V. R., Singh, R., & Verma, P. (2022), A study conducted in Satara district, Maharashtra developed a sustainability planning framework for rural drinking water services. It assessed aspects like source sustainability, O&M finance, capacity, and asset management, scoring each village using mobile app data and GIS. Though rural in focus, its integrated approach can inform institutional-scale infrastructure assessments regarding sustainability readiness. [2]

2.2 Water Demand Forecasting for Indian Urban Agglomerations

Kumar, M., Singh, R., & Wescoat, J. L. Jr. (2020), Accurate forecasting is critical but challenging in rapidly urbanizing Indian cities. Traditional methods using a simplistic per capita demand (e.g., 135-150 LPCD) often lead to miscalculations. Kumar et al. (2020), in a study of Tier-2 Indian cities, highlighted the vast disparity between official per capita figures and actual metered consumption, exacerbated by intermittent supply. They advocated for zonal forecasting that accounts for socio-economic stratification. [3]

Chandramouli and General (2011), using Census data, emphasized the impact of migration patterns on urban population projections, a key input for demand forecasting. The literature suggests that adaptive methods, incorporating local municipal data and climate variables, are essential for realistic demand estimates in the Indian scenario. [4]

Ram et al. (2018) present the hydraulic design of an STP for a university campus in Gujarat. Designed to handle ~ 725.8 m³/day, the proposal includes skimming, screening, grit chamber, aeration basin, secondary clarifier, and sludge drying beds. Treated effluent is reused for irrigation, demonstrating a closed-loop model. [5]

2.3 Planning and Sourcing: Challenges Specific to India

The selection of sustainable water sources is a pressing issue for Indian projects. Sharma and Kansal (2013) extensively documented the over-dependence on distant surface water and depleting groundwater for major cities like Delhi, advocating for integrated water resource management (IWRM). Biswas and Tortajada (2020) analyzed the challenges of inter-state water disputes and their impact on the feasibility

of large government water supply schemes. The work of Central Public Health and Environmental Engineering Organisation (CPHEEO, 2013) provides the standard national manual for water supply but often struggles with enforcement of its sourcing guidelines at the state level, leading to source unsustainability.[6][7][8]

The design of WDNs in India is uniquely affected by intermittent supply, which leads to negative pressures and contamination ingress. Swamee and Sharma (2008) have contributed significantly to hydraulic design and optimization algorithms tailored for Indian conditions, focusing on cost-effective solutions. Vairavamoorthy et al. (2007) specifically addressed design methodologies for intermittent systems, proposing technical solutions to mitigate water quality risks. However, as noted by Khanna and Mohan (2016), there is a significant implementation gap where advanced design principles often fail to be adopted in standard government tender documents, leading to persistent operational problems.[9][10][11]

Tare and Nema (2012) evaluated the performance of various Sequencing Batch Reactors (SBRs) in India, highlighting their operational flexibility. While Membrane Bioreactors (MBRs) are known for high quality effluent, Singh et al. (2018) discussed their challenges, including membrane fouling and high operational costs, making them less suitable for many public sector projects without stringent reuse mandates.[12][13]

A critical yet often overlooked aspect in Indian STPs is the management of generated sludge. CPHEEO (2013) manuals provide guidelines, but practice is lagging. Kumar et al. (2016) studied the characteristics and energy potential of sewage sludge in India, promoting anaerobic digestion for biogas recovery. [8]

However, Kalamdhad and Kazmi (2019) noted that most government STPs treat sludge management as an afterthought, with inadequate facilities for stabilization and dewatering, leading to improper disposal and missed opportunities for energy recovery and resource reuse, violating the principles of a circular economy. [14]

The success of infrastructure projects is heavily influenced by the chosen project delivery model and contract management. Iyer and Jha (2005) identified critical factors affecting cost performance of public

construction projects in India, including bureaucratic delays, poor contractor selection, and adversarial relationships. The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) highlighted both the scale of investment and the challenges in execution. Singh and Tiong (2005) discussed the evolution of contract models, suggesting that models like Design-Build-Operate (DBO), while promising, face adoption barriers due to a lack of familiarity and regulatory hurdles within Indian government procurement systems.[15][16]

Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2014). *Wastewater Engineering: Treatment and Resource Recovery*, The definitive global reference covering fundamental principles, design standards, advanced treatment technologies (including nutrient removal and membrane systems), and modern emphasis on resource recovery (water, energy, nutrients) from wastewater.[17]

Metcalf & Eddy, Inc. (2014). *Wastewater Engineering: Treatment and Resource Recovery*, The industry-standard textbook providing comprehensive guidelines for the design of sewage treatment plants, from preliminary treatment to advanced tertiary processes and sludge handling.[18]

CPHEEO. (2013). *Manual on Water Supply and Treatment*. Govt. of India, The official Indian government manual dictating standards for water supply projects; covers demand forecasting, source selection, water treatment processes, and design parameters tailored to Indian conditions and public health requirements. *Manual on Sewerage and Sewage Treatment Systems*. Govt. of India, The companion manual to the water supply guide; provides mandatory national standards for sewerage system design, sewage flow estimation, and the selection and design of appropriate sewage treatment technologies for Indian cities. [8]

Arceivala, S. J., & Asolekar, S. R. (2006). *Wastewater Treatment for Pollution Control and Reuse*, A practical guide emphasizing low-energy, cost-effective treatment technologies suitable for developing economies, including waste stabilization ponds, aerated lagoons, and anaerobic systems, with a focus on reuse applications.[19]

Vairavamoorthy, K., et al. (2007), *Intermittent Water Supply under Water Scarcity Situations*, This paper addresses the design challenges specific to intermittent water supply systems common in

government projects, focusing on strategies to maintain water quality and reliability under low-pressure conditions.[20]

Sharma, S. K., & Amy, G. (2010). *Water Supply and Drainage for Buildings and Public Places*, Focuses on the internal plumbing, drainage, and water supply design for large buildings and public infrastructure projects, a key component of overall urban water management.[21]

Walski, T. M., et al. (2003). *Advanced Water Distribution Modeling and Management*, A comprehensive guide on using hydraulic simulation software for modeling, analyzing, optimizing, and managing complex water distribution networks to ensure efficiency and reliability. While discussing the issues related to water distribution system focused on some of the most compelling problems facing optimization viz. (i) Designer must strike a balance between cost minimization and net benefits (benefit minus costs) (ii) Reliability of the water distribution networks should not be reduced for the sake of cost reduction.[22]

Savic, D. A., & Walters, G. A. (1997). *Genetic Algorithms for Least-Cost Design of Water Distribution Networks*, A seminal paper introducing the application of evolutionary optimization algorithms to automatically design least-cost water network layouts that meet pressure and flow requirements.[23]

Iyer, K. C., & Jha, K. N. (2005). *Factors affecting cost performance in Indian construction projects*, Identifies critical factors leading to cost overruns in Indian projects, including owner- and contractor-related issues, providing crucial insights for improving project management in government water infrastructure.[24]

Molenaar, K. R., et al. (2010). *Framework for Evaluating Project Delivery System Selection*, Provides a structured framework for choosing the best project delivery method (Design-Bid-Build, Design-Build, etc.), crucial for government agencies to improve project outcomes.[25]

Singh, R., & Tiong, R. L. K. (2005). *A fuzzy decision framework for contractor selection*, Proposes a mathematical model using fuzzy logic to select the most suitable contractor, moving beyond the lowest-bidder approach to improve quality and performance in public works.[26]

Bhave, P. R., & Gupta, R. (2006). *Analysis of Water Distribution Networks*, A standard Indian textbook covering the hydraulic analysis and design of water supply networks, including methods for solving flow equations and network calibration.[27]

Swamee, P. K., & Sharma, A. K. (2008). *Design of Water Supply Pipe Networks*, Focuses on the optimization of pipe networks for water supply, presenting explicit design equations and algorithms for achieving cost-effective and efficient system designs.[28]

Todini, E. (2000). *Looped water distribution networks design using a resilience index*, introduces the "resilience index" as a measure of a network's reliability and ability to handle failures, advocating for its use as a criterion for robust system design.[29]

Judd, S. (2011). *The MBR Book: Principles and Applications of Membrane Bioreactors*, The authoritative text on Membrane Bioreactor (MBR) technology, covering fundamentals, design principles, operational challenges, and case studies for high-quality effluent reuse.[30]

Jacob (1991), proposed a technique for simulation of water distribution system in developing countries, where supply is less than demand i.e., intermittent supply. This work remains highly relevant for modeling urban water systems in Tier-2 and Tier-3 Indian cities, where intermittent supply is the norm and consumer demand patterns are pressure-sensitive. Developed a simulation technique tailored for low-supply conditions, common in developing countries like India. Introduced a head-flow relationship constraint at each node, allowing the model to reflect actual consumer behavior under intermittent supply. Critiqued conventional steady-state models for assuming fixed demand, which leads to unrealistic outputs when supply is less than demand. Proposed a method where node consumption dynamically adjusts based on available pressure and system configuration—ideal for cities with 2–3 hour daily supply windows.[31]

Chunping Yang, Zhiqiang Shen, Hong Chen, Guangming-Zeng, YuanyuanZhong (2006) A lot of technological problems including advanced treatment processes, pH regulation, sterilization, and pipe selection have been solved cost-effectively. Addressed advanced treatment processes including adsorption, membrane filtration, and chemical dosing. Developed pH regulation techniques using

low-cost buffering agents. Proposed sterilization methods suitable for decentralized systems. Evaluated pipe materials for durability, cost, and compatibility with treated water. [32]

Vicki L. Van Blaricum and Vincent F. Hock (2007) This paper describes the demonstration and validation of multi-parameter water quality sensors and corrosion rate sensors that were permanently installed at a U. S. Army installation to detect corrosion problems and fine-tune the chemical treatment program. The use of water quality and corrosion rate sensors has been demonstrated and validated in the field. [33]

Andrea Bolognesi, Cristiana Bragalli, Angela Marchi, Sandro Artina DISTART, (2009) This paper proposes a new model named Genetic Heritage Evolution by Stochastic Transmission GHEST, a multipopulation evolutionary strategy like algorithm applied to the design of water distribution networks. Sustainable Treatment and Reuse of Municipal Wastewater. Advocates for a paradigm shift in wastewater management towards resource recovery and reuse, presenting technologies and strategies for designing sustainable, circular economy-aligned STPs. [34]

Henze, M., et al. (2008). Biological Wastewater Treatment: Principles, Modeling and Design. Focuses on the core science of biological treatment processes (activated sludge, nitrification, de-nitrification) and provides models for simulating and designing these complex systems. [35]

Rosenberger, S., et al. (2002). Performance of a bioreactor with submerged membranes. A research paper providing performance data and operational insights into submerged MBR systems, contributing to the understanding of designing and running these advanced plants. [36]

Dhake, P., et al. (2015). Life Cycle Cost Analysis of Sewage Treatment Plants. An Indian study demonstrating that technologies with low capital cost (e.g., ASP) can have higher long-term costs than advanced technologies (e.g., SBR) when energy and maintenance are factored in. [37]

Kumar, M. S., et al. (2016). Assessment of the energy potential of sewage sludge in India. Quantifies the biogas generation potential from anaerobic digestion of sewage sludge in India, making an economic case for incorporating energy recovery into STP design. [38]

Biswas, A. K., & Tortajada, C. (2020). Water Security Under Climate Change. Provides a high-level strategic framework for planning water infrastructure that is resilient to climate change impacts, such as variable rainfall and drought, essential for long-term project viability. Procurement in Infrastructure Public-Private Partnerships. A practical guide on structuring contracts and procurement processes for PPPs in infrastructure, offering models for engaging private sector efficiency in public water projects. [39]

Gujba, H., et al. (2012). The carbon footprint of water treatment and reuse. Introduces methodologies for calculating the carbon emissions associated with water and wastewater treatment, adding a critical environmental dimension to technology selection and planning. [40]

Rathore, M. M., et al. (2016). Urban planning and building smart cities based on IoT. Explores the integration of IoT sensors, SCADA systems, and data analytics into urban infrastructure for real-time monitoring and efficient management of water supply and drainage networks. [41]

Bhave, P. R. (1991). Analysis of Flow in Water Distribution Networks. Technomic Publishing. A foundational text that provides systematic methods for the analysis and calibration of water distribution networks, essential for diagnosing problems and planning upgrades in existing government systems. [27]

Ostfeld, A., et al. (2008). The Battle of the Water Sensor Networks (BWSN): A design challenge for engineers and algorithms. Journal of Water Resources Planning and Management, 134(6). This paper presents a benchmark study comparing algorithms for optimally placing water quality sensors in a distribution network, a critical consideration for designing smart and secure municipal water systems. [42]

Crittenden, J. C., et al. (2012). MWH's Water Treatment: Principles and Design (3rd ed.). John Wiley & Sons. A comprehensive reference on the principles, theory, and design of water treatment processes, from coagulation and filtration to advanced oxidation, crucial for engineers designing surface water treatment plants. [43]

Parkinson, J., & Tayler, K. (2003). Decentralized wastewater management in peri-urban areas in low-income countries. Environment and Urbanization,

15(1). Argues for the planning of decentralized or satellite wastewater treatment systems in rapidly urbanizing fringes, a relevant strategy for large government township projects to reduce sewerage network costs. [44]

Brocklehurst, C. (2002). *New Designs for Water and Sanitation Transactions: Making Private Sector Participation Work for the Poor*. World Bank. Examines contract structures and regulatory frameworks for involving the private sector in public water utilities, highlighting pro-poor policies essential for equitable service delivery in government projects. [45]

III. RESEARCH GAP

This literature review has highlighted the need for holistic approaches in designing water supply and sewage treatment systems for institutional campuses. The Hinganghat Medical College DPR provides an opportunity to evaluate such an integrated system. The next chapter will describe the project profile and contextualize its infrastructure requirements.

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