

“A CASE STUDY OF SEWAGE TREATMENT PLANT”

Prof. C. A. Chitkeshwar¹, Mallika P. Raut², Harsh T. Nandavanshi³, Sanket P. Ugale⁴,

Pradip R. Nitnaware⁵

¹²³⁴⁵Department of Civil Engineering,

Dr. Rajendra Gode Institute of Technology and Research, Amravati
(Polytechnic)

Abstract - Sewage Treatment Plants (STPs) are crucial for safeguarding environmental quality and public health by treating wastewater prior to its release into natural water bodies. This study analyzes a specific STP, emphasizing its design, operational protocols, treatment efficiency, and associated obstacles. The research scrutinizes the primary, secondary, and tertiary treatment phases to clarify their roles in contaminant removal. Essential water quality indicators such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and pH are evaluated to assess plant performance. The results reveal substantial pollutant reductions, confirming the system's effectiveness in meeting discharge standards. The study identifies operational challenges, including elevated energy demands, complexities in sludge management, and the necessity for routine maintenance. Rigorous monitoring and optimized management strategies are vital for consistent operation. The findings highlight that efficiently run STPs not only curtail water pollution but also promote sustainable water stewardship through secure disposal and potential reuse of treated effluent.

Key Words: Sewage Treatment Plant (STP), Wastewater Treatment, BOD, COD, Total Suspended Solids (TSS), Water Quality, Primary Treatment, Secondary Treatment, Tertiary Treatment, Sludge Management, Environmental Sustainability, Wastewater Reuse, Treatment Efficiency

1. INTRODUCTION

1.1 Background of the Topic

The rapid pace of urbanization and industrial expansion across the globe has significantly increased the volume of wastewater generated daily. Sewage treatment plants (STPs) are critical for modern urban infrastructure. They serve as the primary way communities manage wastewater from residential, commercial, and municipal sources. In the past, human settlements discharged waste directly into nearby water bodies and relied on their natural self-purification. As population density grew and industrial activities increased, the environment could no longer neutralize such large volumes of contamination.

Engineered treatment solutions became not just preferable, but absolutely essential.

A sewage treatment plant is a facility specifically engineered to receive raw sewage, subject it to a series of physical, biological, and chemical processes, and discharge the treated effluent in a manner that is safe for the surrounding environment. The fundamental principle underlying sewage treatment is to reduce the concentration of harmful constituents, including suspended solids, organic compounds, pathogens, nitrogen, and phosphorus, to levels that comply with environmental regulatory standards before the treated water is released into natural water bodies or reused for secondary purposes such as agricultural irrigation or industrial cooling.

1.2 Importance of the Problem

The improper management and disposal of sewage constitute one of the most pressing environmental and public health challenges of the contemporary world. Wastewater generated from domestic and municipal activities contains a complex mixture of contaminants that, if left untreated, pose serious risks to ecosystems, human health, and long-term water security. Understanding the importance of this problem requires examining the nature of sewage composition and the cascading consequences of inadequate treatment.

Raw sewage contains biodegradable organic matter, suspended and dissolved solids, colloidal particles, heavy metals, synthetic chemicals, nitrogen compounds, phosphorus, and a wide range of biological pathogens, including bacteria, viruses, protozoa, and helminths. When such effluent is released into natural water bodies without adequate treatment, it initiates a process known as eutrophication, wherein excessive nutrient loading, particularly nitrogen and phosphorus, stimulates the uncontrolled growth of algae. This algal bloom depletes dissolved oxygen in the water, suffocating aquatic life and disrupting the ecological balance of rivers, lakes, and estuaries in a process called hypoxia.

From a public health perspective, the consequences are equally severe. Contaminated water sources become vectors for waterborne diseases such as cholera, typhoid fever, dysentery, hepatitis A, and various gastrointestinal infections. Communities that depend on surface water or shallow groundwater for drinking purposes are especially vulnerable when sewage infiltrates these sources. The World Health Organization estimates that millions of deaths occur annually across low- and middle-income countries due to diseases directly attributable to poor water and sanitation management. Children under the age of five are disproportionately affected, suffering from diarrheal diseases that are largely preventable through proper wastewater treatment infrastructure.

1.3 Objectives of the Study

Every scientific investigation is guided by clearly defined objectives that shape the scope of inquiry and determine the nature of findings. The present study, which examines the functioning and performance of a sewage treatment plant through a detailed case study approach, is guided by several interconnected objectives that collectively aim to deepen understanding of wastewater treatment processes and their real-world applications.

The primary objective of this study is to develop a comprehensive understanding of the operational workflow of a municipal sewage treatment plant. This involves examining how raw sewage is received at the plant inlet, how it passes through successive treatment stages, and how the quality of water changes at each step from preliminary screening to final disinfection. By tracing the process flow in detail, the study aims to provide a clear, technically accurate picture of what occurs at each unit operation within the STP.

1.4 Scope of Research

The scope of this research is defined by both the breadth of topics it covers and the boundaries within which the investigation is conducted. This study is focused on the operational and technical aspects of a conventional municipal sewage treatment plant, and the analysis is grounded in field-based observations, process data, and a review of established engineering literature pertaining to wastewater management.

In terms of coverage, the research encompasses the complete treatment process from raw sewage intake to final effluent discharge, including preliminary, primary, secondary, and basic tertiary treatment stages. The study also extends to sludge handling and management

operations within the plant boundary. Particular attention is given to the process flow diagram of the facility, the function of individual treatment units, inlet and outlet water quality parameters, and the potential applications of treated effluent in non-potable uses. The research additionally considers the environmental and regulatory framework within which the plant operates, including applicable discharge standards set by national environmental bodies.

However, the scope of this study is deliberately limited in certain respects to maintain depth and feasibility. The research does not engage in an extensive analysis of advanced treatment technologies such as membrane bioreactors, reverse osmosis systems, or fully automated SCADA-based control systems, as these represent specialized topics that warrant separate investigations.

2. LITERATURE REVIEW

The treatment of municipal sewage has been a subject of sustained academic and engineering inquiry for well over a century, and the body of literature surrounding it continues to grow as urbanization accelerates and environmental standards become more stringent. Researchers across the world have examined sewage treatment from multiple angles: process efficiency, effluent quality, sludge management, energy consumption, and resource recovery collectively building a knowledge base that informs both the design and operation of modern treatment facilities.

Metcalf and Eddy, in their widely referenced work on wastewater engineering, established the foundational framework for understanding conventional treatment processes. Their analysis of unit operations such as sedimentation, biological aeration, and secondary clarification demonstrated that the removal of biochemical oxygen demand (BOD), total suspended solids (TSS), and coliform organisms could be achieved effectively through a properly sequenced multi-stage process. Their work remains a cornerstone reference for civil and environmental engineers engaged in STP design and evaluation.

Studies conducted in the Indian context have highlighted the gap between installed treatment capacity and actual operational performance. Research published through the Central Pollution Control Board (CPCB) has repeatedly pointed out that a significant number of STPs across Indian cities operate below their designed efficiency

levels due to inadequate maintenance, irregular power supply, hydraulic overloading, and poor sludge management practices. These findings underline the importance of not only building treatment infrastructure but ensuring that it functions as intended on a day-to-day basis.

Nemerov and Dasgupta examined the relationship between influent sewage characteristics and treatment plant performance, noting that seasonal and diurnal variations in sewage flow significantly affect the stability of biological treatment processes. Their observations are particularly relevant in municipal settings where population density, rainfall patterns, and industrial discharge contribute to fluctuating inlet loads that challenge the consistency of treatment outcomes.

Several researchers have explored the potential of treated wastewater as a reusable resource. Studies by Lazarov and Bahri on water reuse in agriculture demonstrated that secondary-treated effluent, when subjected to basic disinfection, meets the quality thresholds recommended by the World Health Organization for restricted irrigation purposes. This finding carries considerable relevance for water-scarce regions where agricultural demand places heavy pressure on freshwater supplies.

On the subject of sludge management, Spinosa and Vesilind contributed extensively to the understanding of sludge thickening, anaerobic digestion, and dewatering processes. Their research showed that well-managed sludge digestion not only reduces the volume of solid waste requiring disposal but also generates biogas that can be captured and used as an energy source within the plant itself, improving overall sustainability.

More recent literature has also examined the role of constructed wetlands and natural treatment systems as low-cost alternatives or supplements to conventional STPs, particularly for small municipalities and peri-urban areas. However, the consensus in mainstream research continues to support conventional activated sludge processes as the most reliable and scalable approach for large municipal applications.

Collectively, this body of literature establishes a strong scientific foundation for the present case study, confirming that understanding process flow, unit performance, and effluent quality in an operational STP

provides valuable insight into the practical realities of municipal wastewater management.

3. METHODOLOGY

3.1 Research Design

The present study is based on a descriptive and observational research design, wherein the functioning of a municipal sewage treatment plant is examined through direct field visits, process observation, and systematic data collection. A case study approach has been adopted because it allows for an in-depth, context-specific investigation of a single operational facility, making it possible to understand not only the theoretical framework of sewage treatment but also the practical realities of day-to-day plant operation. This approach is widely accepted in civil and environmental engineering research, where real-world process analysis is essential to generating meaningful and applicable findings.

3.2 Study Area and Plant Selection

The sewage treatment plant selected for this study is a conventional municipal facility serving an urban area with a defined catchment population. The plant was selected on the basis of accessibility, operational status, availability of process data, and the presence of complete treatment stages from preliminary screening to final disinfection. Permission was obtained from the plant authorities prior to data collection, and all observations were carried out in accordance with the operational schedule of the facility. The plant processes domestic sewage collected through an underground drainage network and treats it before discharging the final effluent into a designated water body or reuse distribution system.

3.3 Data Collection Methods

Data for this study were collected through two primary methods: field observation and secondary data review.

Field Observation involved multiple visits to the treatment plant during which each treatment unit was physically inspected and documented. Observations were made regarding the condition and functioning of bar screens, grit chambers, primary settling tanks, aeration tanks, secondary clarifiers, sludge handling units, and chlorination facilities. During these visits, operational parameters such as flow rates, aeration conditions, sludge return practices, and disinfection procedures were noted and recorded systematically.

Secondary Data Collection involved gathering process records maintained by the plant operating staff, including daily influent and effluent quality reports, flow measurement logs, sludge production records, and maintenance registers. Parameters recorded from these sources included BOD, COD, TSS, pH, dissolved oxygen, total coliform count, and turbidity values at various stages of treatment. This data allowed for a quantitative assessment of treatment efficiency across individual process units.

3.4 Water Quality Analysis Parameters

The following parameters were identified as primary indicators of treatment performance and were studied at both the inlet and outlet of the plant:

- **Biochemical Oxygen Demand (BOD)** — to assess the organic load in sewage and the effectiveness of biological treatment
- **Chemical Oxygen Demand (COD)** to measure total oxygen demand from both biodegradable and non-biodegradable compounds
- **Total Suspended Solids (TSS)** to evaluate the removal of particulate matter across settling and filtration stages
- **pH** to monitor chemical balance and suitability of effluent for discharge or reuse
- **Dissolved Oxygen (DO)** to assess the health of biological aeration processes
- **Total Coliform Count** to measure pathogen removal efficiency and evaluate disinfection effectiveness
- **Turbidity** to assess the clarity of treated effluent as an indicator of overall treatment quality

These parameters were compared against the standards prescribed by the Central Pollution Control Board (CPCB) and the Bureau of Indian Standards (BIS) to determine whether the plant's effluent met regulatory discharge norms.

3.5 Process Flow Documentation

The complete treatment process of the selected STP was mapped and documented in the form of a process flow diagram. Each unit operation was described in terms of its design purpose, working principle, key operational parameters, and contribution to overall pollutant removal. This documentation allowed for a stage-by-stage evaluation of how raw sewage is progressively transformed into treated effluent suitable for discharge or reuse.

3.6 Sludge Management Assessment

In addition to liquid stream analysis, the methodology included an assessment of sludge generation, treatment, and disposal practices within the plant. The types of sludge produced — primary sludge, waste activated sludge, and digested sludge — were identified and their handling processes were documented. Information regarding sludge thickening, anaerobic digestion, dewatering through filter press or drying beds, and final disposal methods was gathered during plant visits and reviewed against standard engineering practices.

3.7 Limitations of Methodology

While every effort was made to collect accurate and comprehensive data, certain limitations are acknowledged. The study is restricted to a single plant and therefore the findings cannot be generalized broadly across all municipal STPs. Some operational data was collected from existing plant records rather than independent laboratory testing, which means the accuracy of that data depends on the record-keeping standards of the facility. Additionally, advanced treatment processes such as tertiary filtration or membrane separation were not part of the selected plant's operations and therefore fall outside the scope of this methodology.

4. ARCHITECTURE

4.1 Overview of Plant Layout and Physical Structure

When you walk into a sewage treatment plant for the first time, one thing becomes immediately clear nothing about its layout is accidental. Every tank, every channel, and every building has been placed with a specific purpose in mind. The entire facility is arranged so that wastewater moves naturally from one treatment stage to the next, following a logical path that mirrors the sequence of the treatment process itself. Wherever the site gradient allows, gravity does the work of moving sewage forward, reducing the dependence on pumps and cutting down on energy costs.

The plant occupies a clearly defined land area that is fully enclosed and secured along its perimeter. Internal access roads run alongside the major units, wide enough to accommodate heavy maintenance vehicles and equipment. The raw sewage inlet is positioned at one end of the site, and the treated effluent outlet sits at the opposite end, creating a clean directional flow across the plant that physically separates the untreated and treated streams at all times. Administrative buildings, staff facilities, and the laboratory are usually grouped together away from the treatment units, keeping operational areas distinct from support areas.

4.2 Preliminary Treatment Units

Before sewage can enter any of the main treatment processes, it must first be cleared of the coarser materials that could damage equipment or block pipelines. This is the job of the preliminary treatment units, which form the first line of defense at the plant entrance.

The bar screen is the very first structure the incoming sewage encounters. It consists of a series of parallel metal bars or a mesh frame, fixed either vertically or at a slight angle across the flow channel. The spacing between bars varies depending on the type of screen coarse screens have wider gaps while fine screens have narrower ones. As sewage flows through, anything larger than the screen opening gets caught on the bars, including plastic bags, cloth pieces, paper, sticks, and other floating debris. In large plants, mechanical rakes automatically clean the screen surface at regular intervals, pushing the collected material onto a conveyor for compaction and disposal as solid waste.

Immediately after screening, the sewage enters the grit chamber. This is a carefully dimensioned channel where the flow velocity is deliberately slowed down just enough to allow heavy, dense particles like sand, gravel, and small stones to drop to the bottom while keeping the lighter organic particles moving forward. The settled grit

is collected periodically and removed from the chamber. This step is particularly important because grit is highly abrasive if it were allowed to travel further into the plant, it would cause rapid wear on pump impellers, pipe bends, and aeration equipment, leading to costly repairs and downtime.

4.3 Primary Treatment Units

Once preliminary treatment is complete, the sewage still carries a substantial load of suspended organic solids that need to be separated before biological treatment can begin. This is where the primary settling tanks come in.

These tanks also called primary clarifiers are large, quiet pools of concrete, either circular or rectangular in shape, where sewage is allowed to slow down and rest for roughly one to two hours. During this calm period, the heavier organic solids gradually sink to the floor and accumulate as a soft layer of primary sludge. At the same time, lighter materials like grease and oils rise to the surface and collect as a floating scum layer. Mechanical scrapers move slowly along the tank floor, pushing the settled sludge toward a central pit from which it is pumped away to the sludge handling section. Surface skimming arms simultaneously sweep the floating scum toward collection troughs. By the time sewage leaves the primary clarifier, roughly half to two-thirds of its suspended solids have been removed, along with a meaningful portion of its organic load.

4.4 Secondary Treatment Units

The secondary treatment stage is where the real biological work happens, and it is typically the most space-intensive part of the entire plant.

The aeration tank is a large open basin constructed from reinforced concrete where the pre-settled sewage is introduced and mixed with a dense population of carefully cultivated microorganisms. These microorganisms, collectively referred to as activated sludge, feed on the dissolved and suspended organic matter present in the sewage, breaking it down into simpler, harmless end products. To keep these organisms alive and active, air is pumped continuously into the tank through fine bubble diffusers fixed to the tank floor, or through mechanical aerators that churn the surface. The oxygen levels inside the tank are maintained at carefully monitored concentrations to ensure that the biological process proceeds efficiently. The sewage and microbial mixture, known as mixed liquor, typically spends between four and eight hours in the aeration tank before moving forward.

From the aeration tank, the mixed liquor flows into the secondary clarifier, which functions on the same settling principle as the primary tank but handles biological solids rather than raw organic matter. The microbial floc — dense clumps of microorganisms carrying trapped organic material — settles to the bottom while the clarified water above overflows gently into the outlet channel. A controlled portion of this settled biological sludge is pumped back into the aeration tank to maintain the microbial population at the level required for effective treatment. The remaining excess sludge is drawn off separately for further processing in the sludge treatment zone.

4.5 Tertiary Treatment and Disinfection Units

Even after secondary treatment, the effluent still contains microorganisms at concentrations that would be unsafe for direct discharge into water bodies. The disinfection unit addresses this final concern.

The treated effluent enters a disinfection contact chamber where a measured dose of chlorine applied as liquid chlorine, sodium hypochlorite solution, or chlorine gas is introduced and mixed thoroughly with the flow. The chamber is designed to hold the effluent for sufficient contact time to ensure that harmful bacteria, viruses, and other pathogens are inactivated before the water leaves the plant. The chlorine dose is carefully controlled to achieve effective disinfection without leaving excessive residual concentrations that could themselves harm aquatic life in the receiving water body.

4.6 Sludge Treatment Architecture

The sludge treatment zone occupies its own dedicated section of the plant and handles all the solid residuals generated throughout the treatment process. Primary sludge and waste activated sludge are first directed to thickening tanks where their water content is partially reduced through gravity settling or mechanical means.

Thickened sludge then enters the anaerobic digesters large covered tanks made of concrete or steel where sludge is held under warm, oxygen-free conditions for several weeks. Inside these digesters, anaerobic bacteria slowly break down the organic content of the sludge, reducing its volume, stabilizing it chemically, destroying a large proportion of pathogens, and releasing biogas as a natural byproduct. This biogas, consisting primarily of methane, is captured and can be used to generate electricity or heat within the plant, contributing to its energy self-sufficiency.

After digestion, the sludge still holds a high moisture content and must be dewatered before final disposal. Mechanical dewatering equipment such as belt filter presses or centrifuges removes additional water efficiently, while sludge drying beds shallow sand-based enclosures open to the sun and air are used in plants where land is available and climate conditions support natural drying. The resulting dried sludge cake can be safely disposed of in landfills or, where quality permits, applied to agricultural land as a soil conditioner.

4.7 Ancillary Structures

A sewage treatment plant cannot function on its treatment units alone. A range of supporting structures work quietly in the background to keep the entire facility operational. The pump house contains the main lift pumps that raise incoming sewage to the level required for gravity flow through the plant. The blower house accommodates the air compressors that supply oxygen to the aeration tanks. An electrical substation manages the plant's power supply and distribution. A chemical storage and dosing room houses the disinfectants and other reagents used in the treatment process. The on-site laboratory enables routine water quality testing so that plant operators can monitor performance and respond quickly to any deviation from expected parameters. Together, these ancillary facilities form the operational backbone of the plant, ensuring that treatment never stops and quality is always maintained.

5. RESULTS AND DISCUSSION

5.1 Result

5.1.1 Overview of Results

The results of this study were obtained through systematic observation of the treatment process, review of operational records maintained at the plant, and analysis of water quality data collected at various stages of treatment. The findings are presented in a stage-wise manner to reflect the progressive improvement in sewage quality as it passes through each treatment unit. The results demonstrate that the selected municipal sewage treatment plant is largely effective in reducing key pollutant parameters to levels that meet prescribed regulatory discharge standards, though certain observations also point toward areas where operational improvements could further enhance performance.

5.1.2 Inlet Sewage Characteristics

The raw sewage arriving at the plant inlet was found to carry a high concentration of organic matter, suspended solids, and biological contaminants, which is consistent with the characteristics of typical domestic municipal wastewater. The influent BOD was recorded in the range of 220 to 260 mg/L, indicating a moderately high organic load. TSS values at the inlet ranged between 250 and 300 mg/L, reflecting the presence of significant quantities of settleable and suspended particulate matter. The pH of incoming sewage was measured between 6.8 and 7.4, falling within the mildly acidic to neutral range commonly observed in domestic wastewater. Total coliform counts at the inlet were recorded at levels exceeding 10^7 MPN per 100 mL, confirming the presence of substantial fecal contamination requiring effective disinfection before discharge.

5.1.3 Performance of Preliminary Treatment

The bar screens and grit chambers at the preliminary stage performed their intended function effectively. Screenings collected at the bar screen included plastic materials, rags, and coarse debris, which were removed prior to entering the main treatment sequence. The grit chamber successfully separated sand and inorganic grit from the sewage flow, and the collected grit was observed to be relatively free of organic matter, indicating proper velocity control within the chamber. No significant measurable change in BOD or COD was recorded at this stage, as preliminary treatment is not designed for dissolved pollutant removal but rather for physical protection of downstream units.

5.1.4 Performance of Primary Treatment

The primary settling tanks demonstrated satisfactory removal of settleable solids. Observations of the tank surface showed minimal turbulence and consistent skimming of floating scum by surface scrapers. Analysis of settled primary sludge indicated a moisture content of approximately 95 to 97 percent, which is typical for freshly settled primary sludge. After primary treatment, TSS concentration in the partially treated sewage was reduced by approximately 58 percent, and BOD reduction at this stage was recorded at around 32 percent. These values fall within the expected performance range for primary clarification under normal operating conditions.

5.1.5 Performance of Secondary Biological Treatment

The aeration tanks and secondary clarifiers together constituted the most significant treatment stage in terms of pollutant removal efficiency. Dissolved oxygen levels within the aeration tank were maintained between 2.0 and 3.5 mg/L throughout the observation period, which is

within the range recommended for stable aerobic biological activity. The mixed liquor suspended solids concentration was recorded at approximately 2500 to 3500 mg/L, indicating a healthy and active microbial population within the tank.

Following secondary clarification, effluent BOD was reduced to values between 18 and 28 mg/L, representing an overall BOD removal efficiency of approximately 88 to 92 percent across the combined primary and secondary stages. TSS in the secondary effluent was recorded between 20 and 35 mg/L. These results indicate that the biological treatment process is functioning effectively and producing effluent of acceptable quality for further disinfection and discharge.

5.1.6 Disinfection Results

After chlorination, the total coliform count in the final treated effluent was reduced to levels below 230 MPN per 100 mL, representing a reduction of more than 99.99 percent from the inlet coliform concentration. The residual chlorine in the disinfected effluent was measured at 0.5 to 1.0 mg/L, which is consistent with standard disinfection practice for municipal wastewater. The final effluent pH was recorded between 6.9 and 7.5, suitable for safe discharge into inland surface waters as per CPCB norms.

5.1.7 Summary of Water Quality Results Comparative Table

The following table presents a comparison of key water quality parameters measured at the inlet and outlet of the sewage treatment plant, along with the applicable CPCB discharge standards for inland surface waters:

Parameter	Unit	Inlet (Raw Sewage)	After Primary Treatment	After Secondary Treatment	Final Effluent (After Disinfection)	CPCB Discharge Standard
BOD	mg/L	240	165	28	22	≤ 30
COD	mg/L	480	340	90	75	≤ 250
TSS	mg/L	275	115	32	24	≤ 100
pH	—	7.1	7.2	7.3	7.2	6.5 – 8.5

Dissolved Oxygen	mg/L	0.8	1.2	3.2	4.1	≥ 4.0
Total Coliform	MPN/100mL	10 ⁷	10 ⁶	10 ⁴	180	≤ 230
Turbidity	NTU	85	48	12	6	≤ 10
Total Nitrogen	mg/L	38	32	18	14	≤ 100

Table 5.1: Comparison of Influent and Effluent Water Quality Parameters

5.2 Discussion

The data presented in Table 1 clearly demonstrates that the treatment plant achieves progressive and measurable improvement in effluent quality across each stage of the treatment process. The most substantial pollutant removal occurs during the secondary biological treatment stage, which accounts for the majority of BOD and TSS reduction. This finding is consistent with the established understanding in wastewater engineering literature that the activated sludge process is the most effective stage for organic matter removal in conventional municipal STPs.

The final effluent values for BOD, TSS, pH, turbidity, and total coliform all meet the CPCB standards for discharge into inland surface waters, confirming that the plant is fulfilling its primary regulatory obligation. The dissolved oxygen level in the final effluent reaching 4.1 mg/L is particularly encouraging as it indicates that the treated water will not exert significant oxygen demand on the receiving water body.

6. CONCLUSION

This case study of a municipal sewage treatment plant has successfully achieved its intended objectives by providing a detailed examination of the plant's physical architecture, operational process flow, treatment performance, and sludge management practices. The investigation confirmed that conventional sewage treatment, when properly designed and consistently operated, is capable of transforming heavily contaminated raw sewage into treated effluent that meets established environmental discharge standards. The results obtained during this study demonstrated that the plant achieves an overall BOD removal efficiency of approximately 90 percent, TSS removal exceeding 91 percent, and coliform reduction of more than 99.99 percent across the complete treatment sequence. These

figures establish that the activated sludge based secondary treatment process remains the most reliable and effective approach for municipal wastewater management at scale.

The study also highlighted that treated effluent from the plant holds genuine potential for reuse in agricultural irrigation and landscape maintenance, which carries significant value in the context of increasing freshwater scarcity across urban and peri-urban regions. Proper sludge management, including anaerobic digestion and mechanical dewatering, further contributes to the overall sustainability of the facility by reducing disposal volumes and enabling biogas recovery.

However, the study also identified that hydraulic overloading during peak flow periods and routine maintenance gaps can temporarily reduce treatment efficiency, pointing toward the need for operational improvements. Overall, this research reinforces that investment in functional, well-maintained sewage treatment infrastructure is one of the most impactful contributions a municipality can make toward environmental protection and public health security.

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