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Design of Sewage Treatment Plant: A Case Study of Okhla District, New Delhi

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Abstract - The main objective of the wastewater treatment plan implemented in Okhla district, Delhi, and to evaluate its effectiveness in mitigating the negative impacts associated with untreated wastewater.Okhla is a densely populated area in south Delhi that has seen significant real estate development in recent years. Sewage produces an unpleasant odour that causes illness in humans and animals. The problem is that sewage needs to be properly treated before it is disposed of on the land by not throwing it directly into natural resources and reusing the treated water, which ultimately reduces the overall demand for fresh water. Our primary objective is to generate liquid and solid waste that conforms to eco-friendly standards and can be safely disposed of or repurposed. Delhi generates about 744 million litres of wastewater per day, 80 percent of the 930 MGD that will serve Delhi's estimated population over the next 30 years. The focus of this paper lies in the analysis of wastewater generation in the Delhi area, and subsequently, the design of a treatment plant that aligns with population requirements. The proposed design aims to adhere to established standards and acceptable thresholds for treated effluent by developing various components of the wastewater treatment plant. The various components of the wastewater treatment plant are screening, grit chamber, disinfection tanks, biological reactor, sludge treatment and effluent discharge.

***Key Words*:** wastewater, sewage disposal, sewage system, sustainable design

1. INTRODUCTION

Water is an indispensable resource that is vital for the sustenance and development of various activities worldwide. However, with the growth of population, water consumption has risen, leading to water scarcity and an increasing demand for water. To manage and conserve this precious resource, sewage treatment has become a crucial process that removes pollutants from wastewater, ensuring its safe discharge into the environment. In the Okhla District of Delhi, with its growing population and consequent increase in sewage generation, wastewater treatment is essential to prevent environmental degradation.

Before the late 1800s, most people disposed of human waste through methods such as outdoor privies and open defecation, but with the discovery of the link between sewage and infectious diseases, sewage treatment systems were introduced in cities. However, early attempts at sewage treatment, such as spreading sewage on land or discharging it into water bodies, proved ineffective and actually caused further deterioration of the environment. It became clear that nature could not serve as an infinite sink for sewage and wastewater. The discharge of industrial wastewater is also a major concern, as it can contain various pollutants such as heavy metals, chemicals, and oils that require specialized treatment processes to remove them before the water can be safely released back into the environment.

The sewage treatment process is divided into three levels of treatment, namely primary, secondary, and tertiary. The primary treatment phase removes floating and suspended solids from raw sewage using screening and sedimentation. Gravity is the primary method of removing suspended solids, although chemicals may be used. This level of treatment, also known as the "Mechanical" level treatment, typically reduces the Biological Oxygen Demand (BOD) by 20-30% and the total suspended solids by 50-60%. The secondary treatment phase involves removing dissolved organic matter that escaped primary treatment. Indigenous microorganisms usually perform the secondary treatment in a controlled environment. The treated water must undergo a separation process to remove micro-organisms before discharge or proceed to tertiary treatment. Tertiary treatment is considered anything beyond primary and secondary treatment necessary for discharge into a highly sensitive ecosystem. It removes up to 99% of impurities from the effluent, resulting in nearly pure water that meets drinking water quality standards. However, treated water may require chemical or physical disinfection before discharge into a stream, river, or wetland.

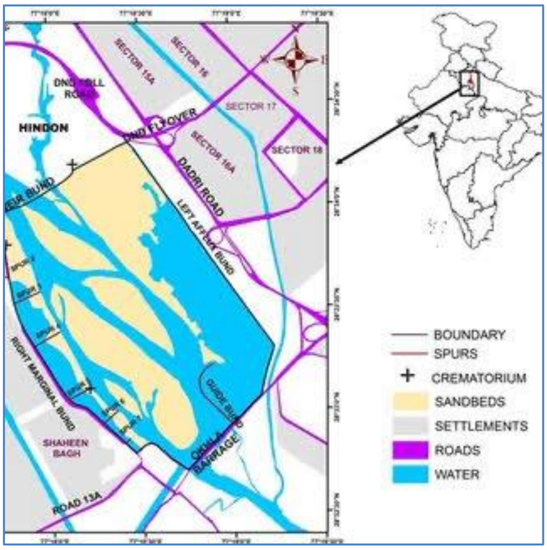

Fig -1: Area of Okhla District, New Delhi under study

The sewage treatment plant in Okhla District, Delhi, follows a similar process to remove pollutants effectively from wastewater. The plant is designed to ensure that the treated effluent meets the established standards and permissible limits for safe discharge into the environment. This has significantly contributed to mitigating the negative environmental impacts associated with untreated sewage, making Okhla District a cleaner and safer place to live in. Nevertheless, there is always room for improvement, and plant operators must continuously monitor and maintain the plant to ensure optimal performance and minimize any adverse effects on the environment.

2. LITERATURE SURVEY

Wastewater treatment plants are an important part of the infrastructure for urban areas. The Okhla wastewater treatment plant is located in the Okhla Industrial Area in Delhi, India. The main function of this plant is to treat wastewater and reduce pollution in the Yamuna River. The objective of this study is to collect literature on wastewater treatment plants to improve the operation and maintenance of Okhla wastewater treatment plant.

Yadav et. al. evaluated the performance of a sewage treatment plant using oxidation pond technology. The study found that with proper maintenance and timely sludge removal, the technology is effective in reducing pollutants in wastewater. Recommendations for improving the treatment technology include increasing dissolved oxygen levels, optimizing sludge retention time, and reducing organics in the influent wastewater.

Qureshi et. al. showed the importance of considering various criteria for the design of wastewater treatment plants. The study identifies wastewater characteristics, performance objectives, environmental regulations, and available technologies as important factors. The study recommends that the design of wastewater treatment plants must be tailored to the specific characteristics of the wastewater to be treated.

Nigam et. al. reviewed the literature on advanced oxidation processes to improve the performance of wastewater treatment plants. The advanced oxidation processes are shown to be effective complements to conventional treatment technologies. The study recommends that advanced oxidation processes be integrated with existing treatment technologies to optimize performance.

Jiao et. al. proposed an approach to design optimization of wastewater treatment plants using artificial neural networks. The approach is based on using historical data to train the neural networks to predict the optimal process parameters. The study suggests that the optimization approach can be used to improve the overall performance of wastewater treatment plants.

Lin et. al. studied the application of chemical coagulation and sequential batch reactor (SBR) methods in treating municipal sewage wastewater to meet the water quality standards required for agricultural irrigation. Both conventional and modified SBR methods were evaluated. With chemical coagulation alone, the wastewater's COD and color were significantly reduced by up to 75 and 80%, respectively (with COD and NTU levels below 20 and 2mg/l). As a result, the water quality consistently met the required standards and was deemed appropriate for agricultural irrigation purposes.

Arrojo et. al. also investigated the use of SBR process in treating wastewater, which was further enhanced by the incorporation of a membrane filtration system. This combination completely removed coliform bacteria and suspended solids, leading to a higher quality effluent compared to conventional processes. The membrane filtration system achieved 100% removal efficiency for both bacteria and suspended solids, indicating the potential of the compact system (SBR + membrane filtration) to produce high-quality effluent suitable for agricultural reuse, particularly for rural communities.

3. Objectives of Study

In this paper, the following objectives are fulfilled:

a) Background on the history and demographics of Okhla district.
b) Overview of the current sewage treatment infrastructure in Okhla district.
c) Analysis of the effectiveness of the current sewage treatment system in Okhla district.
d) Exploration of the potential for sustainable and innovative solutions to sewage treatment in Okhla district.
e) Assessment of the role of civil society and citizens' groups in influencing sewage treatment policies and practices in Okhla district.
f) Recommendations for policy and practice changes to improve sewage treatment in Okhla district.

4. Methodology

4.1 Research Design

The research design used in this study is a mixed-methods approach that combines both qualitative and quantitative methods. This approach was chosen to gain a better understanding of the Okhla WWTP from multiple perspectives, including the functionality of the facility, resident satisfaction levels, operational challenges, and environmental impacts.

4.2 Data Collection

Primary data for this study were collected using three methods: Surveys, interviews, and on-site observations. Surveys were distributed to residents of the WWTP to determine their satisfaction and perceptions of the operation of the facility. Interviews were conducted with WWTP staff and experts in the field of wastewater treatment to gain a comprehensive understanding of WWTP operations and management. Field observations were conducted to gather information on the physical infrastructure of the plant and the quality of the effluent discharged.

Secondary data were gathered from published reports, government documents, and research papers that provided information on the historical background of the plant, government policies and regulations governing wastewater treatment, and recent developments in the field of wastewater treatment.

4.3 Data Analysis

The data obtained from the surveys and interviews were analyzed using statistical methods such as descriptive statistics, frequency distribution, and chi-square test. The qualitative data from the interviews and field observations were analyzed using content analysis to identify recurring themes and patterns in the responses. The results of the study were presented using tables, graphs, and charts to illustrate key findings and trends. The research findings were then discussed in the context of the existing literature on wastewater treatment, highlighting the strengths and weaknesses of plant operations and management. The paper concludes with a series of recommendations and potential areas for future research.

5. Sewage Disposal Process

5.1 Treatment of Sewage & Effluent Irrigation

Okhla, one of the most densely populated areas in Delhi, is faced with the daunting challenge of managing the large volume of wastewater generated by its population of over two million. To tackle this issue, the Okhla wastewater treatment plant has been designed to handle 60 million liters of wastewater daily using the activated sludge process. The process of wastewater disposal at the Okhla WWTP involves three primary stages, namely wastewater quality monitoring and disinfection, sewage sludge disposal, and disposal of the treated wastewater.

After the wastewater is treated, it undergoes quality monitoring to ensure that it meets the prescribed parameters for pH, dissolved oxygen, BOD, COD, TSS, and fecal coliform.

Table -1: Salient Details of Sewage

Sl.no	Characteristic	Effluent from plant	Tolerances limit IS3307 - 1986
1	PH	5.5 - 9	5-9
2	BOD	<=30mg/l	90mg/l
3	Suspended solid	<=40mg/l	200 mg/l
4	Oil and grease	<=10mg/l	1000 mg/l
5	chlorides	<=980mg/l	600 mg/l
6	Sulphate	<=270 mg/l	1000 mg/l

The Land Effluent Irrigation process involves ploughing the disposal land up to 45 cm and creating embankments and furrows in each subplot to grow crops on the dams, while runoff flows into the furrows. The effluent is applied to the land at intervals of 8-10 days, depending on the plant requirements and soil characteristics.

Subsequently, chlorine is used to disinfect the wastewater and make it safe for disposal into the environment. One of the by-products of the wastewater treatment process is sewage sludge, which is generated in significant quantities. To dispose of the sludge, it undergoes a two-stage treatment process involving thickening and dewatering.

The thickening stage involves mixing the sludge with polymers to increase its concentration, while the dewatering stage employs a belt press to extract excess water. The resulting sludge cake can then be disposed of in landfills or utilized for agricultural purposes.

Finally, the treated wastewater is disposed-off into the Yamuna River, after its flow has been measured to ensure it does not exceed allowable limits. The discharged water is regularly monitored for pH, temperature, and other parameters to ensure that it does not harm the river's water quality or negatively impact public health.

In conclusion, the Okhla WWTP's wastewater disposal process is crucial for the safe discharge of treated wastewater into the environment. Proper maintenance of effluent quality parameters and strict adherence to discharge standards are necessary to avoid any adverse impacts on the environment and the health of residents.

5.2 Population Forecasting of Okhla District

In estimating the population, it is necessary to take into account all factors that are critical to the future industrial, commercial, educational, social, and administrative growth and development of the project area. Special factors causing sudden immigration or influx of residents should also be anticipated as much as possible. The population will have to be estimated with due regard to all the factors governing the future growth and development of the project area in the industrial, commercial, educational, social, and administrative spheres. Special factors causing sudden immigration or influx of population should also be foreseen to the extent possible. Population is calculated by geometrical increase method.

Population as calculated by geometrical increase method formula used: $P_n = P\,(1 + (G/100))$

Where, P- Population at present

G- Average percentage of growth of ‘n’ decades

Table -2: Salient Details of Sewage

Year	Population	Increase in population	% increase in population
1961	69,875		
1971	113,101	43226	38.21
1981	191,308	78207	40.88
1991	308,583	117275	38.004
2001	444,365	135782	30.05
2011	650,000	205635	31.63
TOTAL	883,649	580125	178.81

Average % increase in population = (38.21 + 40.88 + 38.004+30.05+31.63 + 178.81)/6 = 59.60

Table -2: Expected Population Data over 3 decades

Year	Expected population
2021	6,50,000 + 6,50,000 *(59.60/100)= 10,33,500
2031	10,33,500 + 10,33,500 *(59.60/100) = 16,49,466
2041	16,49,466 + 16,49,466 *(59.60/100) = 26,32,547

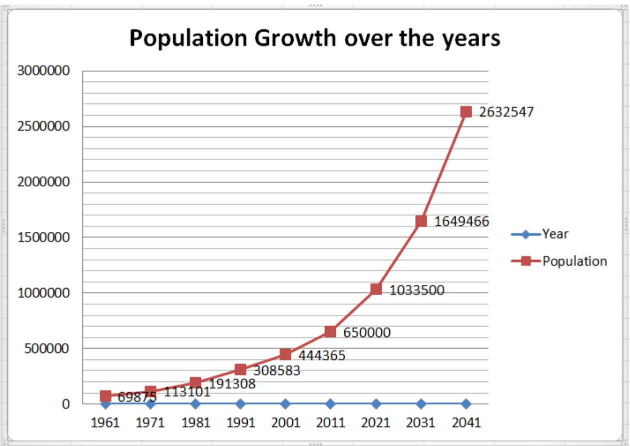

Fig -2: Increase in Population in Okhla District

6. Design of Treatment Units

This paper deals with design of sewage treatment plant for the population of Okhla district, New Delhi.

Expected Population in 2041: 26,32,547

Per capita demand =135 lpcd

Since, Sewage generation 80% of per capita demand

Sewage generation per capita=108 lpcd

Total sewage generation = 26,32,547*108 = 2843.15076 MLD

6.1 Design of Screen Chamber

Average flow = 2843 MLD (as calculated above)

Peak factor = 2.25

Peak flow = 0.13 m^3/s

Screen bar size = 10 mm (As per NIT)

Screen opening = 25 mm (As per CPHEEO)

Area provided = 0.16 m^2

Provided depth of flow = 0.45m

Width of the screen channel = 0.35m

No. of openings = 523 Nos.

No. of bars = 500 Nos.

Width of the screen channel = 480 mm

Provided width of the Screen Channel = 600 mm

Approach velocity in the channel for average ultimate flow = 0.30 m/s

Net area of flow of screen=0.25 m^2

Velocity through screen at average present flow = 0.08/0.25 = 0.32 m/s

HENCE OK.

6.2 Design of Grit Chamber

Peak flow sewage = 0.13 m^3/s

Assume average detention period = 180 Seconds

Aerated volume = 0.13*180 =23.4 m^3

In order to drain the channel periodically for routine cleaning and maintenance, one chamber is used. Therefore volume of one aerated chamber = 23.4m^3

Assume depth of 2m &width to depth ratio 2:1

Width of the channel = 2m*2m

Breadth = 4m

Length of the channel = V/(B*D) = 24/(4*2) = 3m

Increase the length by about 20% to account for inlet & outlet.

Provide length = 3*1.2 = 3.6 m.

Hence the size provided is 3.6m * 4m * 2m

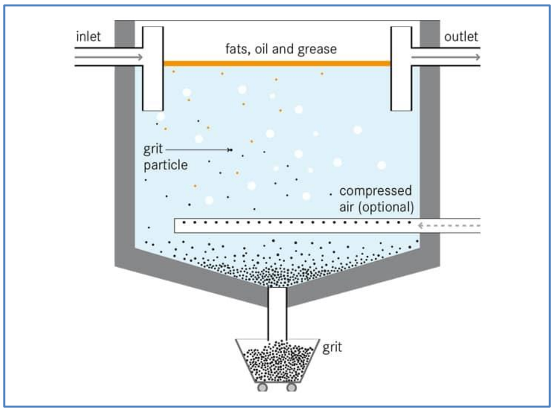

Fig -3: Grit chamber *(source: theconstructor.org)*

6.3 Design of Primary Sedimentation Basin

Design flow = 2843 MLD

According to CPHEEO, Design overflow of primary sedimentation is between 35 and 50 $m^3/m^2/day$.

Let Design overflow = 43 $m^3/m^2/day$

Consider clarification depth = 4.40 m

Required area = 5000/43 = 116.27 m^2

Volume of clarifier = 117*4.40 = 515 m^3

Hydraulic retention time (HRT) = 2.5 hrs

Diameter = 12.5 m

Design tank size = 12.5 m Diameter * 4.40 m

6.4 Design of Aeration Tank

The aeration tank is the mixing and diffusion structure in the activated sludge plant. They have a rectangular shape with dimensions of 3 to 4.5 m depth, 4 to 6 m width and 20 to 200 m length. Air is continuously introduced into the basin.

Number of aeration basins = 1

Design flow rate = 2843 MLD

Average flow of tank = 2843 m^3

BOD inlet (Y_O) = 240 mg/l

BOD outlet (Y_E) = 30 mg/l

BOD removed in activated plant = (Y_O-Y_E) = (240-30) = 210mg/l

Percent of BOD removed in activate Plant = (210/240) × 100 = 87.5%

The extended aeration process can remove 85-92% of BOD. Hence it is ok.

Fig -4: Aeration Tank at current WWTP at Okhla District

MLSS (Xt) = 2400mg/l

F/M ratio = 0.4

Volume of the tank = (Q/F/M) × (Y_O/X_t) = 1000 m^3 (approx.)

The liquid depth of the tank is 3m and width to depth ratio is 2m.

Width of the tank (B) = 3*2 = 6m

Length of the tank = V/(B*D)= 1000/(6*3) = 55.55 m (Approximately 60 m)

Volume provided = 60*6*3 = 1080 m^3

7. Results and Conclusion

One of the challenges that the Okhla wastewater treatment plant faces is the increasing population in the surrounding areas. As the population grows, the demand for wastewater treatment will also increase, and the plant may need to be expanded to accommodate the additional demand. This will require additional investment in infrastructure and technology to ensure that the plant can continue to operate effectively and efficiently.

Another challenge for the plant is the need for regular maintenance and upgrades. The treatment process involves several stages, each of which requires regular monitoring and maintenance to ensure optimal performance.

In addition, technology is constantly evolving, and the plant will need to keep up with these changes to remain effective. Operational and financial constraints are also a challenge for the plant. The plant requires a skilled workforce to operate and maintain the treatment process, and this can be a challenge in terms of staffing and training.

Furthermore, the plant requires a significant investment in capital and operating expenses, and securing funding for these expenses can be a challenge. Despite these challenges, the Okhla wastewater treatment plant has been successful in treating wastewater and improving water quality.

The plant's success is due in part to the efforts of the plant's operators and staff, who are committed to maintaining high standards of performance. In addition, the plant has benefited from partnerships with government agencies and private sector organizations that have provided funding and technical expertise. Looking to the future, it will be important to address these challenges to ensure that the plant can continue to operate effectively and meet the growing demand for wastewater treatment.

This will require continued investment in infrastructure, technology, and human resources, as well as partnerships with government agencies and private sector organizations. By working together, it should be possible to continue improving water quality in the Yamuna River and protecting the health and well-being of the communities that depend on it.

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