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# Design and Hydraulic Modelling of UGD System with Comparative Study on STP Technologies: Akot City

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***Abstract*— The research provides a detailed design and hydraulic model of an underground drainage network of an area of Akot City, Maharashtra, which lacks an official sewage system that currently results in a direct wastewater disposal in open drains and natural waters. Sewerage collection system was designed to serve a population of 44,030 by 2058 (4.585 MLD sewage generation) with SewerGEMS software in strict accordance with CPHEEO design specifications. The suggested network will include 48.845 km of sewers (150-600 mm diameter), one pumping station, and 2,086 manholes. The comparative study has been carried out to assess following treatment technologies: Sequential Batch Reactor (SBR), Membrane Bioreactor (MBR), Moving Bed Biofilm Reactor (MBBR), Activated Sludge Process (ASP), Anaerobic Digestion, and Oxidation Pond/Lagoon assessing technical feasibility, the work's efficiency, cost-effectiveness, and environmental sustainability. SBR technology was chosen to be implemented in Zone 3 because of high reliability in operation, low footprint, and removal of nitrogen and phosphorous was more than 80%. This integrated system guarantees 100% treatment of wastewater which will be disposed in the natural watercourses and meet CPCB norms to allow utilisation of treated effluents. This engineer solution will overcome the most significant public health risks and environmental pollution, as well as it will provide sustainable sanitation infrastructure in Akot City.***

***Keywords*— SewerGEMS, Sewerage Network, Underground Drainage System, Sewage Treatment Technologies and Akot City.**

## I. INTRODUCTION

The efficient management of the wastewater is very important to the sustainability of a city as unplanned urbanization and inadequate infrastructure development has increased waterlogging, sewer overflow, and environmental degradation of Indian cities [1]. Sewerage networks are an important urban infrastructure which gathers, treats, and disposes sewage to protect the environment and health of the people [2]. Underground Sewerage Systems- These are sewer pipes and fittings that run under the ground so that foul drainage that is to be channelled to the treatment facilities is carried. SewerGEMS software has come up as a vital system in the creation of cost effective and efficient networks of sewer systems by allowing it to select an optimal pipe diameter based on the velocity of flow. Similar to system design, efficient sewage treatment systems, such as Activated Sludge Process (ASP), Sequential Batch Reactor (SBR), and Moving Bed Biofilm Reactor (MBBR), are essential towards environmental safety and water rehabilitation. There is a need to make comparative analysis in these treatment methods to establish the most appropriate technology in specific regions in terms of values (cost) efficiency and feasibility of operations.

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*A. Project Location*

Akot is a municipal council located in Akola district, Maharashtra and with a lat 21.0973° N ,Long 77.0538° E, the average elevation of the area is 345 metres as shown in fig.1 below. Its population was estimated at 92,637 in census of 2011. Akot Railway Station feeds the city through the National Highway 161 to Bidar and Hyderabad and Maharashtra State Highways 204 and 194 and 124 to Harisal, Jamod and Anjangaon respectively each two platforms which are poorly covered with no basic drinking and sanitation amenities.

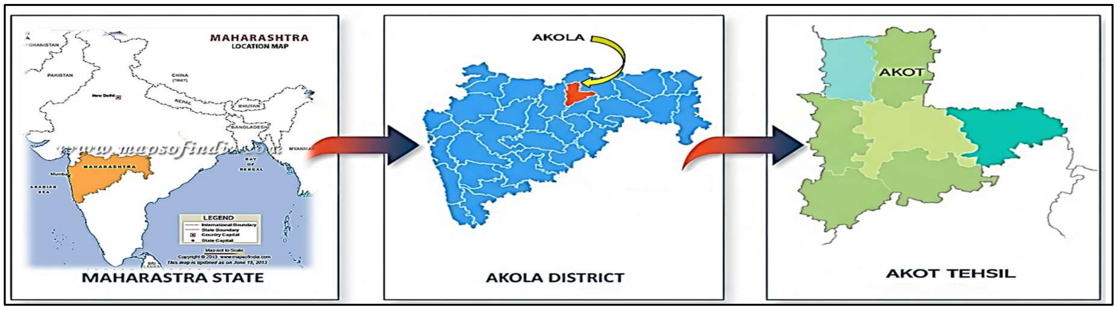


Figure1. Geographical Location of Project Area

*B. Need for Proposed Work*

Akot city does not have an established sewage collection and treatment facility at the moment. Household wastewater is released in open drains which cause foul smells and unhealthy environments. Septic tanks are only available in the new localities with a large plot size, and their effluent is also drained into open drains. The sewage infiltrates sewage nallahs, polluting down water streams at Mohadi Nala, Khayi River. The contamination of groundwater takes place thus leading to outbreak of diseases such as diarrhoea, dengue and malaria. It is important to install an underground drain, which will be associated with sewage treatment to avoid diseases.

*C. SewerGEMS*

SewerGEMS is a complete hydraulic simulator of the sewer system developed by Bentley Systems to analyse and design the sewer systems [3]. The software is compatible with AutoCAD and GIS, allowing the simulation of the flow, optimization of the pipes, and the definition of the bottlenecks. The important capabilities are water quality analysis, sediment modelling, pump sizing and energy costs as well as scenario simulation of emergency response.

*D. Literature Review*

Authors, A. Kulkarni, S. Wankhede, S. Takale, R. Chaudhary and P. Thakar designed an GIS-based sanitary drainage in Holkarwadi village [4]. Authors Harpreet Kaur and Dr. Sanjay Sharma have conducted a comparative study of sewage treatment technologies where the researchers have compared the six sewage treatment technologies that fulfil NGT standards as the female researcher has selected SBR type of technology as the most suitable which removes BOD/COD/TSS, nutrient removals, and low capital requirements [5]. Prof. Aparna Dutta and Sudipta Sarkar reviewed SBR technology, how it works, five stages of cleaning up with 90-99 per cent COD, BOD, and nitrogen, phosphorus removal, biofloc technology, performing better than conventional systems [6].

## II. Materials and Methods

A breakdown of the numerous steps that will be considered while implementing the project as shown in the fig.2.

*A. Topographical Survey*

The design of the gravity-driven sewage collection system depends on the precise topographic survey. Topographic & field survey of Akot City has been done as shown in fig.3 and a contour map of the total AMC (Akot Municipal Council) area was prepared in consideration of newly surveyed and existing street levels. The map comprises of newly done roads and explores ground levels, slope, marketplaces, STP location, discharge locations.

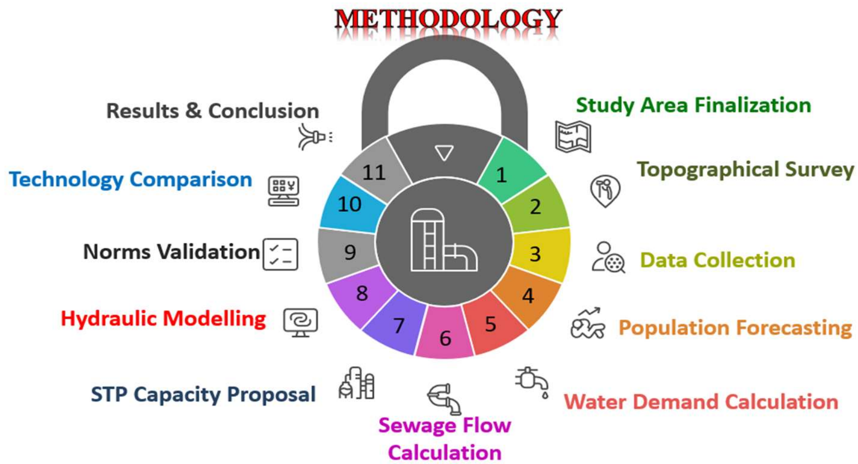


Figure 2. Various stages of project


Figure 3. Site investigation of various locations of the project area

### *B. Sample Testing*

Sewage sample has been taken at the various places of the project area and preserved accordingly to ensure that the sample is not deteriorated until the laboratory analysis. The proper procedure on the handling of the samples based on the standard protocol of sewage analysis will permit the proper quantification of the chemical characteristics of the sample to be utilized in the compliance and the treatment performance assessment. The laboratory testing results are shown in table I below.

TABLE I. LABORATORY TESTING RESULTS OF THE COLLECTED SEWAGE SAMPLE

| Parameter | Unit | MPCB Standard (NMT) | Measured Value | Compliance Status | Test Method |
|---|---|---|---|---|---|
| Chemical O2 Demand | mg/l | 250 | 330.56 | FAILS | IS 3025 Part 58 |
| Biochemical O2 Demand | mg/l | 30 | 126.9 | FAILS | IS 3025 Part 44 |
| pH | - | 5.5-9.0 | 6.62 | PASSES | IS 3025 Part 11 |
| Ammonia (as NH3) | mg/l | 50 | 2.73 | PASSES | IS 3025 Part 34 |
| Chloride (as Cl) | mg/l | 600 | 127 | PASSES | IS 3025 Part 32 |
| Dissolved Oxygen | mg/l | 1.5 (NLT) | 1.5 | FAILS | IS 3025 Part 38 |
| Oil & Grease | mg/l | 10 | Nil | PASSES | IS 3025 Part 39 |
| Total Alkalinity | mg/l | - | 477.4 | - | IS 3025 Part 23 |
| Sulphate (SO4) | mg/l | 1000 | 20.21 | PASSES | IS 3025 Part 24 |
| Total suspended solids (TSS) | mg/l | 100 | 16 | PASSES | IS 3025 Part 17 |
| Total dissolved solids (TDS) | mg/l | 2100 | 748 | PASSES | IS 3025 Part 16 |

### *C. Data Collection*

Sufficient data gathering is essential to proper design of sewage systems. The data that is necessary includes area plans of the project, topographic sheets, historical census populations, 2011 census ward-wise populations, ward boundary plans, and land availability of pumping stations and sewage treatment plants.

TABLE II. POPULATION DATA COLLECTED FROM MUNICIPAL COUNCIL

| YEAR | POPULATION |
|---|---|
| 1971 | 41534 |
| 1981 | 51936 |
| 1991 | 65681 |
| 2001 | 80726 |
| 2011 | 92637 |

TABLE III

| Zone No. | Ward No. | Contribution | Contributing Pop. (2011) |
|---|---|---|---|
| 3 | 3 | 25% | 10298 |
| | 4 | 95% | 11124 |
| | 5 | 5% | 8867 |
| | 12 | 65% | 8348 |
| | 13 | 50% | 8700 |
| | 14 | 100% | 9996 |
| | 15 | 90% | 10631 |
| | 17 | 10% | 11042 |

The number of persons contributing to the population in terms of decadal population to the zone in the Akot Municipal Council has been presented in table II above.

### *D. Population Forecasting, Sewage Generation and Sewage Flow Calculation*

The CPHEEO (Central Public Health and Environmental Engineering Organisation) manual states that 135 litres per capita per day (LPCD) is the water supply rate taken for the population 20,000 to 1,00,000 [4-5]. The population forecasting for the base, intermediate, and ultimate year has been done. According to the CPHEEO manual, 80% of total water supply (135 LPCD) is considered as sewage i.e. 108 LPCD, and 5-10% of infiltration rate is included in the total sewage. Peak factor of 2.5 has been taken according to CPHEEO norms. The calculation of water demand, sewage generation, and sewage flow is as follows in table III below.

TABLE III. CALCULATED CONTRIBUTION OF POPULATION, DEMAND, SEWAGE GENERATION AND SEWAGE FLOW

| Zone No. | Ward No | Contribution | Contributing Pop. | Base Year 2028 | Intermediate Year 2043 | Ultimate Year 2058 |
|---|---|---|---|---|---|---|
| 3 | 3 | 25% | 10298 | 1923 | 2244 | 2575 |
| | 4 | 95% | 11124 | 8147 | 9660 | 10568 |
| | 5 | 5% | 8867 | 315 | 358 | 443 |
| | 12 | 65% | 8348 | 3851 | 4376 | 5426 |
| | 13 | 50% | 8700 | 3087 | 3508 | 4350 |
| | 14 | 100% | 9996 | 7706 | 9136 | 9996 |
| | 15 | 90% | 10631 | 7376 | 8744 | 9568 |
| | 17 | 10% | 11042 | 851 | 1009 | 1104 |
| Population | | | | 33256 | 39035 | 44030 |
| Water Demand (MLD) | | | | 1.223 | 1.283 | 1.348 |
| Sewage Generation (MLD) | | | | 3.424 | 3.995 | 4.585 |
| Sewage Flow (MLD) | | | | 3.77 | 4.43 | 4.99 |

### *E. Network Layout Marking*

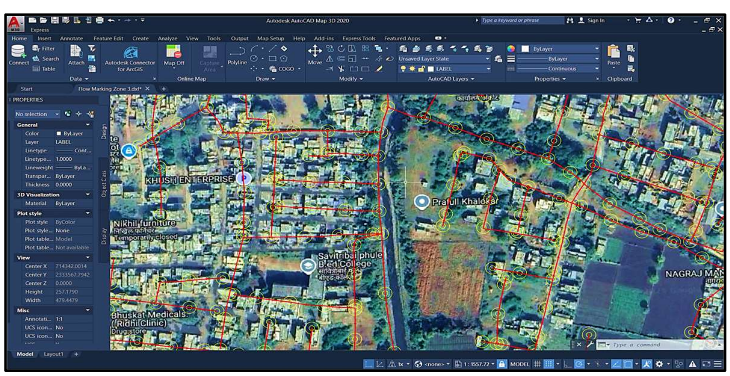


Figure 4. Network Marking of project area

The underground drainage sewer networks marking entails the planning of outfall points, trunk mains along the natural nallas and main sewers, laterals and manhole marking at the crossing or change of direction that should be spaced at 30 meters along the straight routing. Nallas should be traced to provide an efficient way of transporting wastewater, and the branched network is to be done in accordance with gravity, minimizing pumping [6]. The minimum depth covers are based on the ground water levels and precautions, in this case at least 1 meter of cover and up to 5 meters of depth limit. The crossings of the highways, roads, railways, and waterways should be kept to the minimum in order to minimize disruptions and expenses. The network marking is given in fig. 4 above.

### *F. Hydraulic Modelling on SewerGEMS Software*

SewerGEMS hydraulic modelling begins with preparation of a base map, network layout definition, manholes and conduit creation and size, material, and elevation with correct pipe sizes, loads, or flow estimation, hydraulic parameter setting, and simulation, steady flow or dynamic flow [7-8]. It also involves testing and refining the network design, and in many cases, the scenario analysis can be employed to make sure that the system is well-performing at varying demands and sustainable. The hydraulic modelling is shown in fig. 5 below.

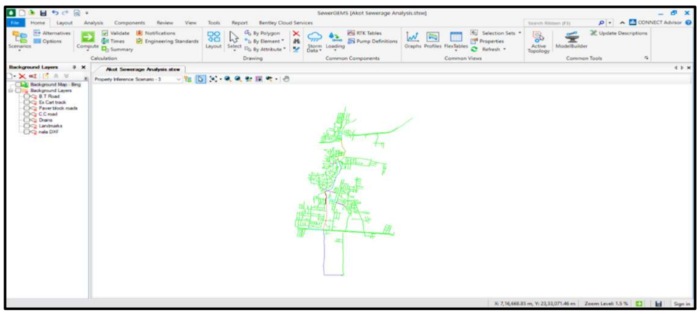

Figure 5. Hydraulic Modelling of Underground Sewer Network

### *G. STP Technologies*

The choice of the treatment technology is based on the nature of the raw sewage and the quality of the effluent required [9]. Different sewage treatment methods are examined and contrasted to treat the sewage produced in MLD.

*Activated Sludge Process*
It is a waste treatment process that treats wastewater using the aerobic method, it is the process in which microorganisms in an aerated tank decompose organic pollutants. The biomass and treated effluent are then separated in a settling tank in which part of the effluent is recycled to maintain the continuous treatment efficiency.

*Sequencing Batch Reactor*
It is essentially a fill-and-draw activated sludge system that performs all the wastewater treatment within a single reactor so there is no need to construct separate clarifiers or tanks [10]. It runs through five different phases, first it fills up with raw wastewater, second, the microbes breakdown the organic matter and nutrients in an aerated or anoxic conditions, third, solids settle out but everything is still and then the treated effluent is drawn off, and finally there's the idle phase where excess sludge goes to waste. This time-based approach in one tank has the potential to reduce BOD removal by 85-95% as well as dealing with nitrogen and phosphorus removal.

*Moving Bed Biofilm Reactor*
It involves the utilization of biofilm carrier elements that are suspended in mixed liquor through the use of air or mixers that are kept in place by sieves or plates within complementary receptor. It improves activated sludge process providing excessive biomass concentration and possible decrease in basin size requirements.

*Membrane Bioreactor*
It is a variant of bioreactor which is composed of both activated sludge treatment and membrane filtration [9-10]. The membrane barrier provides high quality effluents besides being capable of treating comparatively higher biomass levels that result in reduced volume of the reactor and enhanced the treatment efficacy of the reactor compared to the conventional systems.

*Anaerobic Digestion*

It is a biochemical digestion which occurs when organic material is degraded by microorganism under anaerobic conditions during biomass production (methane and carbon dioxide) into biogas. In it, there is reduction of sludge volume, generation of renewable energy and it has been particularly effective in treatment of high-strength organic waste and sewage sludge.

*Oxidation Pond/Lagoon:*

These are superficial designed basins whereby wastewater undergoes treatment using natural processes whereby degradation of bacteria, algal photosynthesis, and sunlight are mixed to treat wastewater. They are relatively inexpensive systems which require minimal input of operation and can be utilized on small communities but require additional land and additional retention time than the mechanical treatment plants.

## III. RESULT AND DISCUSSION

### *A. SewerGEMS Result*

The hydraulic modelling has been done, and results are computed using SewerGEMS as shown in fig.6 below. The design parameters are compared to the results and acceptable to use in the field. The Infiltration Rate per Loading Unit (MLD) is taken as 0.025. The network achieved 80% d/D ratio as CPHEEO suggested and was within the parameters required. Zero velocities result in deposition of sediments in sewers resulting in blockages and subsequently inefficiency in the systems. This will discourage self-cleaning, undermining the wastewater delivery system and causing difficulty in maintenance in drainage pipelines. Velocities within all sewer segments are maintained at 0.25-0.36 m/s, which is greater than the 0.3 m/s self-cleansing minimum, although CO-1 and CO-14 have lower velocities, and provide proper clearance of sediments within the Zone 3 drainage system. An increased population generates more sewage, resulting in an increase in velocities and hydraulic loads. Future growth can be accommodated effectively (in pipes e.g. CO-14 and CO-15 with diameter of 250 mm) but smaller pipes (150 mm) could be in proximity to capacity and need frequent monitoring and upgrading. The output of the hydraulic modelling is presented in the fig.7 below. Also, the hydraulic model has been validated, and no validation issues are found as shown in fig. 8.

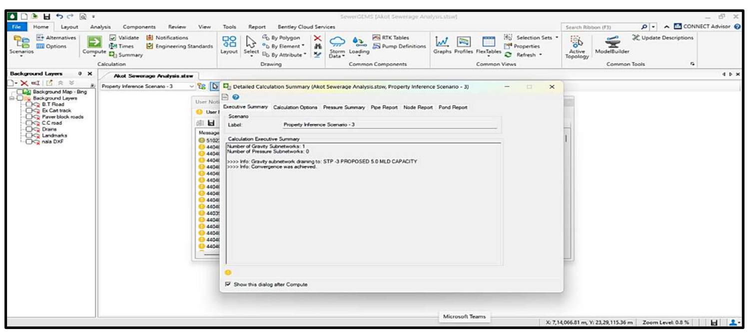

Figure 6. Hydraulic Model Computation using SewerGEMS

| Label | Start Node | Stop Node | Length (Scaled) (m) | Dia. (mm) | Invert (Start) (m) | Invert (Stop) (m) | Elevation Ground (Start) (m) | Elevation Ground (Stop) (m) | Slope (Calculated) (1/S) | Velocity (m/s) | Depth (Maximum) / Rise (%) | Flow (MLD) | Cover (Average) (m) | Material |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO-1 | MH-1 | MH-2 | 17 | 150 | 316.95 | 316.86 | 318.19 | 318.03 | 170.00 | 0.25 | 7.5 | 0.010 | 1.03 | HDPE-DWC |
| CO-2 | MH-2 | MH-3 | 30 | 150 | 316.86 | 316.68 | 318.03 | 317.87 | 170.00 | 0.31 | 9.8 | 0.020 | 1.01 | HDPE-DWC |
| CO-3 | MH-3 | MH-4 | 30 | 150 | 316.68 | 316.50 | 317.87 | 317.68 | 170.00 | 0.35 | 10.8 | 0.029 | 1.01 | HDPE-DWC |
| CO-4 | MH-4 | MH-5 | 30 | 150 | 316.50 | 316.33 | 317.68 | 317.51 | 170.00 | 0.35 | 10.9 | 0.030 | 1.01 | HDPE-DWC |
| CO-5 | MH-5 | MH-6 | 30 | 150 | 316.33 | 316.15 | 317.51 | 317.36 | 170.00 | 0.35 | 10.9 | 0.030 | 1.02 | HDPE-DWC |
| CO-6 | MH-6 | MH-7 | 30 | 150 | 316.15 | 315.97 | 317.36 | 317.21 | 170.00 | 0.35 | 10.9 | 0.030 | 1.05 | HDPE-DWC |
| CO-7 | MH-7 | MH-8 | 30 | 150 | 315.97 | 315.80 | 317.21 | 317.05 | 170.00 | 0.35 | 10.9 | 0.030 | 1.07 | HDPE-DWC |
| CO-8 | MH-8 | MH-9 | 30 | 150 | 315.80 | 315.62 | 317.05 | 316.90 | 170.00 | 0.35 | 10.9 | 0.030 | 1.09 | HDPE-DWC |
| CO-9 | MH-9 | MH-10 | 30 | 150 | 315.62 | 315.44 | 316.90 | 316.78 | 170.00 | 0.35 | 11.0 | 0.030 | 1.13 | HDPE-DWC |
| CO-10 | MH-10 | MH-12 | 30 | 150 | 315.44 | 315.27 | 316.78 | 316.64 | 170.00 | 0.35 | 11.0 | 0.030 | 1.18 | HDPE-DWC |
| CO-11 | MH-11 | MH-13 | 30 | 150 | 315.33 | 315.15 | 316.50 | 316.33 | 170.00 | 0.3 | 8.1 | 0.016 | 1.00 | HDPE-DWC |
| CO-12 | MH-12 | MH-14 | 30 | 150 | 315.27 | 315.09 | 316.64 | 316.51 | 170.00 | 0.36 | 11.3 | 0.030 | 1.22 | HDPE-DWC |
| CO-13 | MH-13 | MH-16 | 30 | 150 | 315.15 | 314.97 | 316.33 | 316.16 | 170.00 | 0.3 | 8.1 | 0.016 | 1.01 | HDPE-DWC |
| CO-14 | MH-14 | MH-15 | 30 | 150 | 315.09 | 314.97 | 316.51 | 316.40 | 250.00 | 0.31 | 11.5 | 0.031 | 1.27 | HDPE-DWC |
| CO-15 | MH-15 | MH-17 | 30 | 150 | 314.97 | 314.85 | 316.40 | 316.29 | 250.00 | 0.31 | 11.6 | 0.031 | 1.28 | HDPE-DWC |
| CO-16 | MH-16 | MH-18 | 30 | 150 | 314.97 | 314.79 | 316.16 | 315.99 | 170.00 | 0.3 | 8.2 | 0.017 | 1.02 | HDPE-DWC |
| CO-17 | MH-17 | MH-19 | 30 | 150 | 314.85 | 314.73 | 316.29 | 316.13 | 250.00 | 0.31 | 11.6 | 0.031 | 1.27 | HDPE-DWC |

Figure 7. Hydraulic Model Output

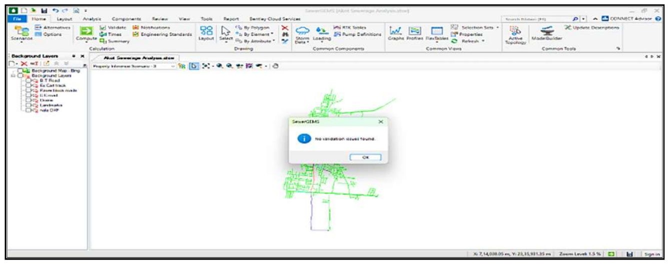

Figure 8. Validation of Hydraulic Model

*B. Finalization of STP technology*

Comparative analysis of the STP technologies has been done as shown in table IV & V below and it helps in identifying efficiency of performance, cost of capital and operating, energy requirements and utilisation of space which helps an individual to choose the necessary technology as much as sites constraints and the quality of effluent is laid out.

TABLE IV. TECHNICAL OVERVIEW OF THE STP TECHNOLOGIES

| Technology | Activated sludge process (ASP) | Sequencing batch reactor (SBR) | Moving bed biofilm reactor (MBBR) | Membrane bioreactor (MBR) | Anaerobic digestion | Oxidation pond/lagoon |
|---|---|---|---|---|---|---|
| Type | Suspended Growth | Suspended Growth | Hybrid (Attached & Suspended) | Suspended Growth + Membrane | Anaerobic Process | Natural Process |
| Treatment Stage | Secondary | Secondary | Secondary | Secondary-tertiary | Primary-secondary | Secondary |
| Key Principle | Aerobic biological oxidation using suspended microorganisms | Time-based activated sludge in single reactor | Biofilm on plastic carriers + suspended growth | Activated sludge + membrane filtration | Biological degradation without oxygen | Natural aerobic treatment in large ponds |
| Space Requirement | Large | Medium | Small-Medium | Small | Medium | Very Large |
| Operational Complexity | High | Medium-high | Low-medium | High | Medium | Very low |
| BOD Removal (%) | 85-95 | 90-95 | 85-95 | 95-99 | 60-80 | 70-90 |
| COD Removal (%) | 80-90 | 85-92 | 80-90 | 90-98 | 65-85 | 70-85 |
| TSS Removal (%) | 85-95 | 90-95 | 85-92 | 98-99.9 | 50-70 | 60-80 |
| $N_2$ Removal (%) | 20-30 | 70-85 | 60-80 | 80-95 | 10-20 | 30-50 |
| Phosphorus Removal (%) | 10-20 | 60-80 | 20-40 | 70-90 | 5-15 | 20-40 |
| Effluent Quality | Good | Very Good | Good-Very Good | Excellent | Moderate | Moderate |
| Capital Cost | Medium-High | Medium | Medium | High | Medium-High | Very low |
| Operating Cost | Medium-High | Medium | Low- Medium | Very high | Low | Very low |
| Energy Consumption (kWh/m³) | 0.6-1.2 | 0.5-0.9 | 0.4-0.8 | 1.0-2.5 | 0.05-0.2 | 0-0.05 |
| Sludge Production | High | Medium-high | Low-medium | Low | Very low | Low |
| Maintenance Requirement | High | Medium-high | Low-medium | Very high | Medium | Very low |

TABLE V. RATING OF STP TECHNOLOGIES

| Selection Criteria | ASP | SBR | MBBR | MBR | Trickling Filter | Anaerobic | Oxidation Lagoon |
|---|---|---|---|---|---|---|---|
| Available Land Area | 3 | 5 | 4 | 5 | 2 | 3 | 1 |
| Capital Budget | 3 | 4 | 4 | 2 | 4 | 3 | 5 |
| Operating Budget | 3 | 4 | 3 | 2 | 5 | 5 | 5 |
| Technical Expertise | 3 | 4 | 3 | 2 | 5 | 3 | 5 |
| Effluent Quality Req. | 4 | 4 | 5 | 5 | 3 | 2 | 2 |
| Energy Availability | 3 | 4 | 3 | 2 | 5 | 5 | 5 |
| Maintenance Capacity | 3 | 4 | 3 | 2 | 5 | 3 | 5 |
| Nutrient Removal Need | 2 | 4 | 5 | 5 | 2 | 2 | 3 |
| Shock Load Handling | 3 | 5 | 4 | 3 | 4 | 2 | 4 |
| Sludge Disposal Capacity | 2 | 4 | 3 | 4 | 4 | 5 | 4 |
| Total Score (out of 50) | 29 | 42 | 37 | 32 | 39 | 33 | 39 |

Rating scale: 5=excellent, 4=good, 3=moderate, 2=poor, 1=very poor
The analysis carried out above has led to the proposed 4.5 MLD STP at Akot and the selection of the technology to utilise was the SBR Technology. The highest score (42/50) of SBR technology is on general application.

## IV. Conclusion

The proposed underground drainage system in Akot City Zone 3 is aimed at providing the sewage efficient collection and conveyance as an increase in population (a projected population growth of 33,256 in 2028 to 44,030 in 2058) is anticipated to raise the amount of flowing sewage, which will be 3.4 MLD to 4.5 MLD. It contains 48.845 km of sewer lines (150-600 mm in diameter), 150 mm makes use of HDPE-DWC sewer lines, and larger sewer lines make use of RCC sewer lines, and 2,086 manholes to reach and maintain the lines. Optimization of sewer hydraulics, done with by SewerGEMS software, has kept the depth of sewers 6 meters to minimize pumping. The system divides stormwater, holds property connections, and avoids discharge of untreated sewage thus protecting the health and environment. The plan is technically sound, up to the year 2058 and is sustainable to current engineering standards. The sample of Akot exhibits high COD (330.56 mg/L), BOD (126.9 mg/L), which denote severe organic pollution. SBR should be used in treatment with a maximum of 98 and 99 percent COD and BOD removal; low dissolved oxygen (1.5 mg/L) indicates it required more aeration.

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