Performance Evaluation/Adequacy Assessment of SusBio EcoTreat 2 KLD Sewage Treatment System

Sponsor

M/s Vaari Nirvana Private Limited, Hyderabad

CSIR-NIIST

Environmental Technology Division (ETD), CSIR-National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram, Kerala 695 019

JUNE 2026

Cover page image credits :M/s Vaari Nirvana Private Limited, Hyderabad

Foreword

M/s Vaari Nirvana Private Limited, Hyderabad, approached CSIR–National Institute for Interdisciplinary Science and Technology (CSIR-NIIST), Thiruvananthapuram, to undertake a performance evaluation and adequacy assessment of its 2 KLD SusBio EcoTreat Sewage Treatment System. The present report outlines the methodology adopted for the evaluation and presents the findings of the study based on key wastewater quality parameters, including Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphates (TP), and Faecal Coliforms (FC), monitored over a period of three months.

The cooperation and support extended by M/s Vaari Nirvana Private Limited during the course of the study are gratefully acknowledged. The confidence reposed in CSIR-NIIST by entrusting the Institute with this evaluation assignment is sincerely appreciated.

June 2026

Thiruvananthapuram

Akshay D. Shende

Scientist-D/Project Leader

Dr. Akshay Dilip Shende
Senior Scientist & Assistant Professor (AcSIR)
Environmental Technology Division
CSIR - National Institute for Interdisciplinary Science and Technology
Ministry of Science and Technology, Govt. of India
Thiruvananthapuram 695 019

Disclaimer

The results presented in this report are based on the site specific operating conditions, influent characteristics, and monitoring period considered during the study. This report should not be construed as a certification, guarantee, endorsement, or permanent validation of treatment performance under all operating conditions. Any presentation of the report should be made in full context without selective extraction of data, figures, or conclusions that may alter the technical interpretation of the study. The observations and data may be used for technical reference and assessment purposes. The data, observations, figures, and conclusions presented in this report should not be reproduced or used for publication in scientific journals.

Project Personnel

Team Members

Dr. Krishnakumar B, Scientist-G, ETD (Co-PI)

Dr. Saurabh Sakhre, Scientist-D, ETD (Co-PI)

Students/Research Scholars

Mr. Dipin Nath
Miss. Navomi Srinivasan
Mrs. Athira A
Mr. Sreejith
Mr. Rohit
Mr. Anand Yogesh

Project Leader

Dr. Akshay Shende, Scientist-D, ETD

Table of Contents

List of Figures

List of Tables

1. Introduction

Rapid urbanization, population growth, and increasing water consumption have led to a significant rise in wastewater generation, particularly from residential, commercial, and institutional establishments. In India, decentralized wastewater treatment systems are becoming increasingly important to ensure compliance with regulatory standards and to promote sustainable water reuse practices. Conventional sewage treatment plants (STPs), although effective, often require large footprints, high energy consumption, skilled operation, and long installation times, making them less suitable for small to medium-scale applications.

In this context, prefabricated and modular sewage treatment technologies have emerged as efficient alternatives. The SusBio EcoTreat system is one such solution designed to address the limitations of traditional STPs. As claimed by the manufacturer, it is a compact, plug-and-play, fiber-reinforced plastic (FRP)-based unit that integrates multiple treatment stages within a single module. The system is capable of treating sewage through a combination of primary sedimentation, anoxic treatment, aerobic biological processes, recirculation, disinfection, and tertiary treatment in the form of pressure sand filter (PSF) and activated carbon filter (ACF) thereby ensuring the effective removal of organic matter, nutrients, and pathogens. Additionally, its modular design allows rapid installation (typically within 1–2 days), scalability, and adaptability to space-constrained environments such as apartment complexes. The units are available in varying capacities ranging from 2 KLD to 50 KLD.

Vaari Nirvana Private Limited, Hyderabad, has approached the Environmental Technology Division of CSIR–National Institute for Interdisciplinary Science and Technology (CSIR-NIIST) to carry out a Performance Evaluation/Adequacy Assessment of its SusBio EcoTreat 2 KLD Sewage Treatment System. The assessment is intended to evaluate the technical adequacy, process design, and operational performance of the system. Therefore, the major objective of the study is

- To evaluate the performance of the "SusBio EcoTreat 2 KLD sewage treatment unit" under realistic operating conditions and to verify compliance with effluent discharge norms

2. Description of the unit

The EcoTreat system employs a dual-stage biological treatment process, integrating both anoxic and aerobic treatment mechanisms within a single compact unit. The treatment begins with primary sedimentation, wherein suspended solids (SS) present in the incoming sewage settle under gravity. This step significantly reduces the organic load and prevents overloading of subsequent biological treatment stages. The partially clarified wastewater then enters the anoxic chamber, where denitrification of nitrified effluent occurs. To facilitate this process, a recirculation line from the aerobic chamber to the anoxic chamber is provided, enabling the return of nitrate-rich mixed liquor. Under anoxic conditions, heterotrophic microorganisms utilize organic carbon to convert nitrates into nitrogen gas, thereby achieving nitrogen removal.

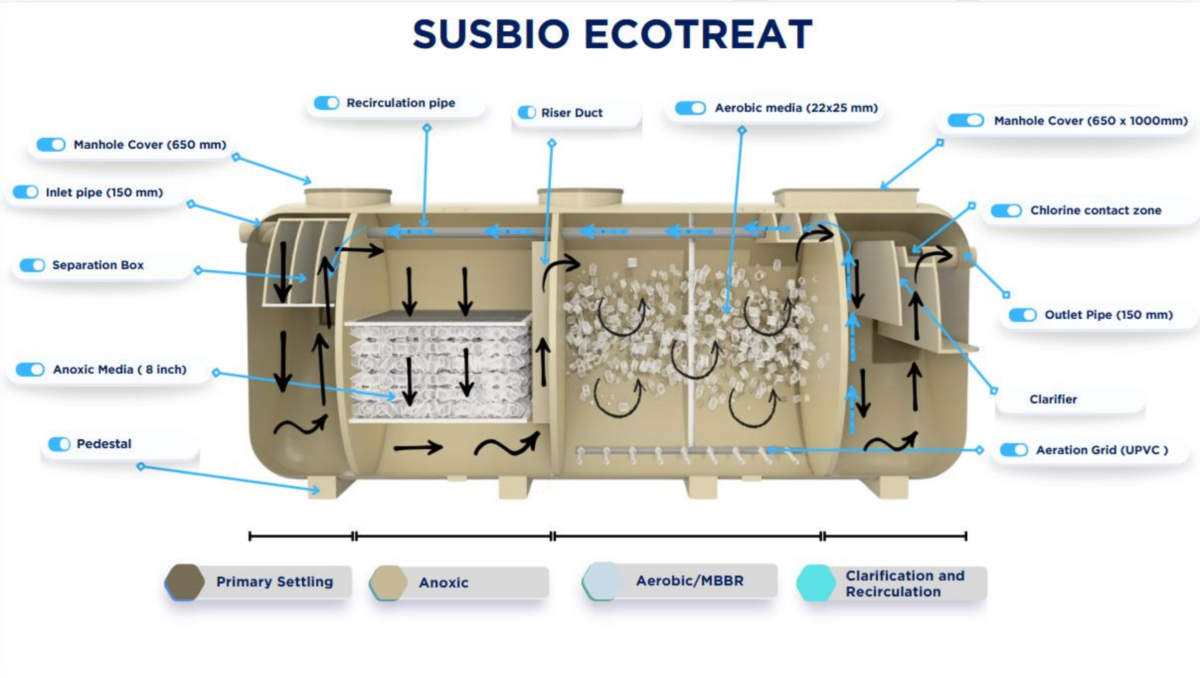

Figure 1: SusBio EcoTreat Sewage Treatment System (Photo Courtesy- M/s Vaari Nirvana Private Limited)

Subsequently, the wastewater flows into the aerobic treatment chamber, where air is supplied through energy-efficient blowers. In this stage, aerobic microorganisms degrade dissolved and colloidal organic matter, leading to significant reduction in chemical oxygen demand (COD) and biochemical oxygen demand (BOD). The aerobic unit is packed with plastic carrier media, which provide a large surface area for biofilm formation. These media remain in suspension due to continuous aeration, enhancing microbial activity and treatment efficiency. The hydraulic retention time (HRTs) in each of the individual units are presented in Table 1 based on the data provided by the client.

Table 1. Hydraulic Retention Time (HRT) of Individual Units in the Wastewater Treatment System

Treatment Unit	Hydraulic Retention Time (HRT in Hrs)
Primary Settling	3.75
Anoxic Tank	5
MBBR (Aerobic)	7.5
Secondary Clarifier	3.75
Overall Unit	20

Following biological treatment, the effluent undergoes disinfection using chlorine to eliminate pathogenic microorganisms. In the final stage, the clarified effluent is passed through sand filtration and activated carbon filtration using pressure pumps. This tertiary treatment ensures further removal of residual suspended solids, color, and odor, and produces treated water that is safe for discharge or reuse applications.

3. Methodology

The study was conducted at the residential staff quarters of CSIR-NIIST, Thiruvananthapuram, from February to April 2026. The study area, due to its proximity to the equator and the Arabian Sea, experiences a moderate tropical climate with temperatures ranging from 23 to 31 °C and moderate to high humidity, which is favorable for biological treatment processes. Domestic sewage generated from the staff quarters was collected in an initial collection tank equipped with a mixer to ensure homogenization. The installation and commissioning of the wastewater treatment unit were carried out by the client. The collected sewage was then fed into a SusBio EcoTreat unit with an installed capacity of 2 KLD. The system was operated under intermittent flow conditions using a timer and float switch, such that the influent pump operated for approximately five minutes per cycle, delivering about 80–90 L of sewage per cycle. The unit was allowed to stabilize for one month during February 2026. During this period, the recirculation flow rate from the aerobic to the anoxic chamber was maintained at approximately 4000 L/day, which is nearly twice the influent flow rate. The treated effluent was subsequently passed through a pressure sand filter (PSF) followed by an activated carbon filter (ACF), and a fin-type manual flow meter was installed at the outlet to measure the daily treated flow. Flow meter readings were recorded daily, except on Sundays and holidays. For these non-recorded days, the cumulative flow was evenly apportioned across the missing days. The pH and dissolved oxygen (DO) were monitored daily between 10:00 and 11:30 AM in the anoxic and aerobic chambers except for holidays. Influent and effluent samples were collected weekly from the initial and final collection tanks for performance evaluation, resulting in a total of eight sampling events during March–April 2026. The collected samples were analyzed for physicochemical parameters including pH, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total nitrogen (TN), and total phosphates (TP). All analyses, except for total nitrogen (TN), were carried out as per APHA (2017) standard methods, while total nitrogen was determined using a TOC analyzer (Analytik Jena multi N/C). The faecal coliforms were analyzed as per the USFDA-Bacteriological Analytical Manual (BAM) using three dilutions (viz. 10, 1, 0.1) and incubation at 44.5°C for 24 to 48 Hrs using lactose broth and transfer of loopful of suspension to tube of Escherichia coli Broth (EC broth).

4. Performance Evaluation

4.1 Inflow

The variation in influent flow rate to the SusBio EcoTreat system during the monitoring period (March–April 2026) is presented in Figure 2. The flow rate was determined from cumulative flow meter readings, and for days where measurements were not recorded (Sundays and holidays), the cumulative values were proportionally distributed. The influent flow rate showed moderate daily fluctuations, ranging approximately from 1620 to 2095 L/day, with most values lying between 1800 and 2000 L/day. The observed average flow rate was close to the design capacity of the unit (2 KLD), indicating that the system was operated under near-design loading conditions throughout the study period.

The variation in flow rate can be attributed to changes in daily water usage patterns within the residential quarters, including differences in occupancy, water consumption habits, and intermittent inflow conditions governed by the pumping cycle. Occasional lower flow values (e.g., around 1620–1700 L/day) and higher peaks (above 2000 L/day) reflect typical domestic wastewater generation variability. Despite these fluctuations, the overall flow pattern remained relatively stable, with no extreme hydraulic shocks or overloading conditions observed.

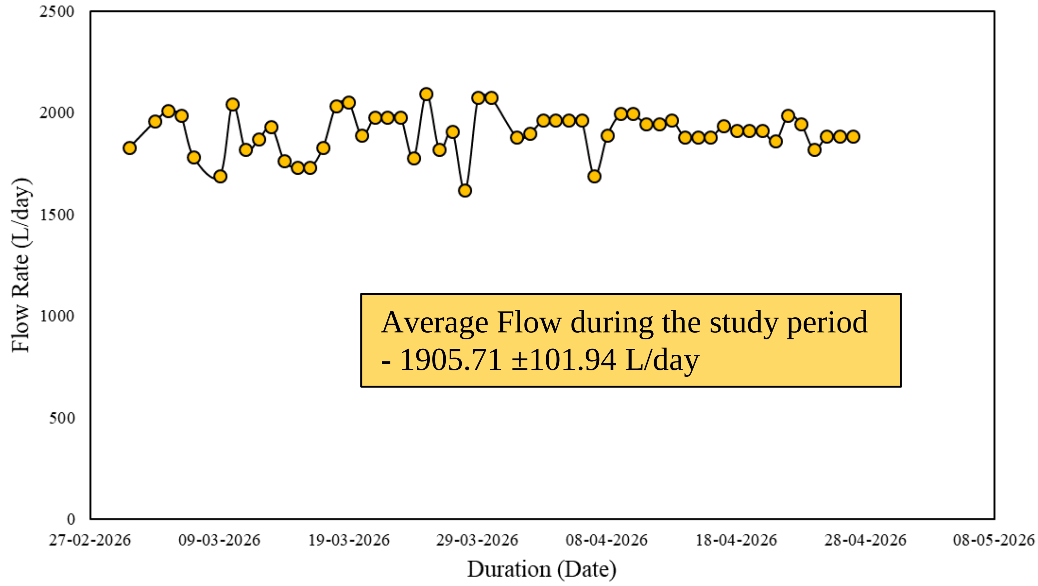

Figure 2: The variation of daily flow rate to the SusBio EcoTreat unit during March–April 2026

This consistent inflow regime contributed to stable reactor performance, as reflected in the low variability of effluent quality parameters. Furthermore, the intermittent feeding mechanism and controlled recirculation likely aided in dampening short-term variations in hydraulic loading. Overall, the influent flow characteristics indicate that the system was subjected to realistic and representative operating conditions, and the consistent flow regime supports the reliability of the performance evaluation results.

4.2 pH and DO variation

The variation of pH and dissolved oxygen (DO) in the aerobic and anoxic chambers of the SusBio EcoTreat system was monitored throughout the study period (March–April 2026) to evaluate the suitability of operational conditions for biological treatment processes and the same is presented in Figures 3 and 4, respectively. The pH values in both chambers showed moderate fluctuations within a narrow range, indicating stable system operation. The pH in the anoxic chamber varied approximately between 6.2 and

7.6, while in the aerobic chamber it ranged from about 6.0 to 7.6. The observed values remained within the optimal range for microbial activity (6.5–8.5), suggesting favorable conditions for both organic matter degradation and nutrient removal. Slight variations in pH between the two chambers can be attributed to ongoing biochemical reactions, including nitrification in the aerobic zone and denitrification in the anoxic zone.

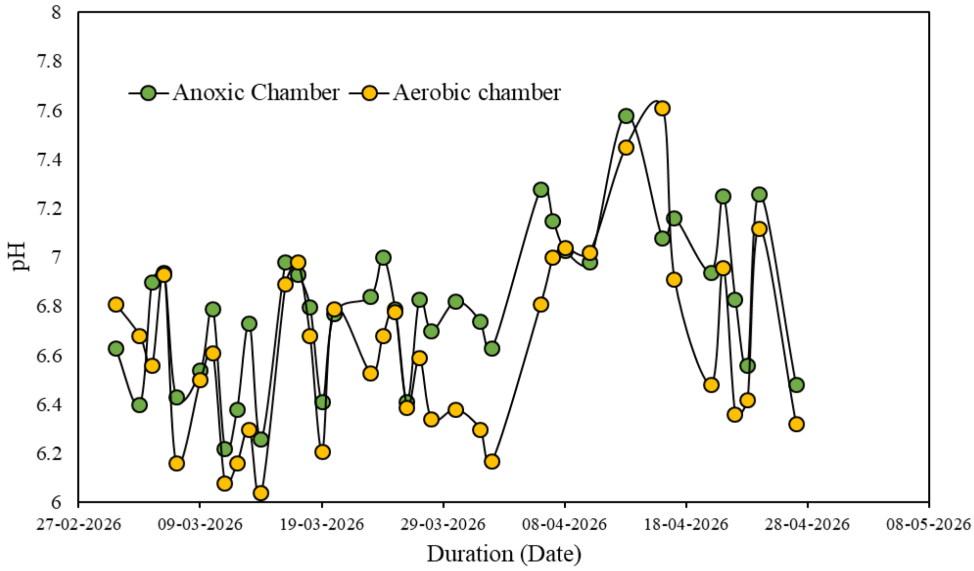

Figure 3: The variation of pH in aerobic and anoxic chambers during March–April 2026

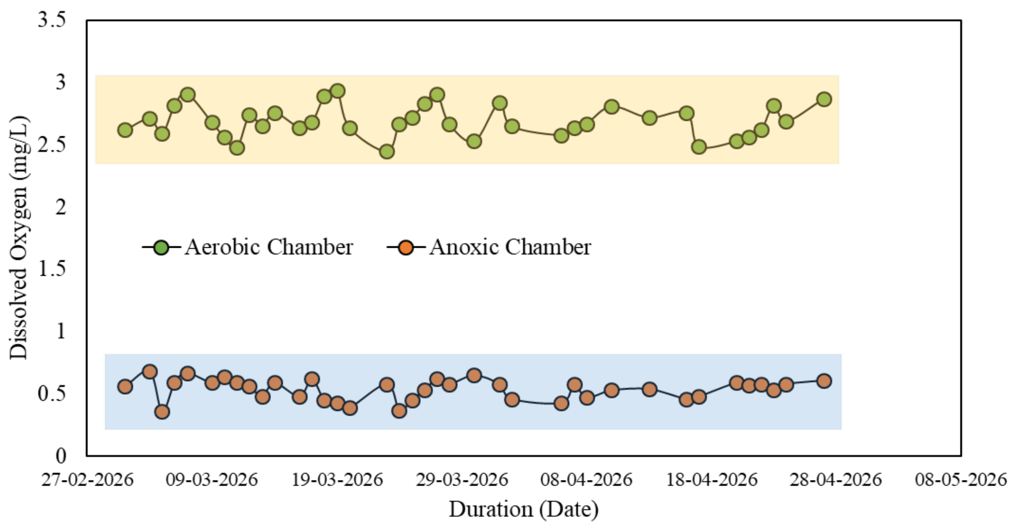

Figure 4: The variation of dissolved oxygen (DO) in aerobic and anoxic chambers during March–April 2026

Dissolved oxygen profiles clearly distinguished the functional roles of the two treatment zones. In the aerobic chamber, DO concentrations were consistently maintained in the range of approximately 2.5 to 2.9 mg/L (Avg – 2.69 ± 0.12 mg/L), indicating adequate aeration for effective oxidation of organic matter and supporting nitrification. The relatively stable DO trend reflects proper aeration control and efficient mixing conditions within the reactor. In contrast, the anoxic chamber exhibited significantly lower DO levels, generally ranging from about 0.4 to 0.65 mg/L (Avg – 0.53 ± 0.08 mg/L). These values are within the acceptable limit for anoxic conditions (<1 mg/L) and are close to the optimal range required for denitrification (<0.5 mg/L). The slightly higher DO values compared to ideal anoxic conditions may be due to oxygen carryover through internal recirculation from the aerobic chamber.

Overall, the DO distribution between the aerobic and anoxic chambers demonstrates effective segregation of aerobic and anoxic environments within the treatment system. The maintained DO levels in the aerobic zone facilitated efficient biodegradation and nitrification, while the controlled low DO conditions in the anoxic zone supported denitrification. The observed pH and DO trends collectively indicate stable reactor performance and suitable environmental conditions for simultaneous carbon and nutrient removal.

4.3 Removal Efficiency

The performance of SusBio EcoTreat Sewage Treatment System during the monitoring period (March–April 2026) is presented in Table 2, demonstrating removal of organic matter, suspended solids, and nutrient. The influent pH ranged from 6.72 to 8.02 (average 7.31), while the effluent pH stabilized between 6.61 and 7.17 (average 6.92), indicating effective buffering and favorable conditions for biological treatment. Significant reductions in organic load were observed, with biochemical oxygen demand (BOD) decreasing from an average of 232.50 mg/L to 8.25 mg/L (~96–97% removal) and chemical oxygen demand (COD) reducing from 395.98 mg/L to 35.51 mg/L (~91% removal), reflecting efficient microbial degradation of biodegradable matter. Total suspended solids (TSS) also showed high removal efficiency (~93%), declining from an average of 206 mg/L to 15 mg/L, indicating effective solid-liquid separation and performance of tertiary filters such as PSF and ACF. Nutrient removal was moderate, with total nitrogen (TN) decreasing from 23.81 mg/L to 6.37 mg/L (~73% removal), suggesting partial nitrification–denitrification, while total phosphates (TP) reduced from 2.02 mg/L to 0.69 mg/L (~66% removal), likely due to a combination of biological uptake, sedimentation, and tertiary polishing through activated carbon filtration. Although the influent characteristics exhibited noticeable variability, as reflected by higher standard deviation values, the treated effluent remained stable with low variability, indicating robust and reliable plant operation. The influent faecal coliform (FC) concentration remained consistently higher than the detectable limit (>1100 MPN/100 mL) throughout the monitoring period, indicating a high microbial load in the incoming sewage. However, the treatment system achieved substantial FC removal, with outlet concentrations decreasing to 9.2–35 MPN/100 mL after treatment and chlorination. This corresponds to an overall removal efficiency greater than 96–99%, demonstrating the effective performance of the biological treatment and disinfection units. Although slight variations in outlet FC values were observed during April, the final effluent consistently remained well below the commonly prescribed discharge standard of 100 MPN/100 mL, confirming adequate pathogen reduction and effective chlorination. Overall, the STP demonstrated satisfactory removal efficiency in organics (COD/BOD), TSS, nutrients (TN, TP), and FC producing an effluent that meets sewage discharge standards (NGT, 2019).

Table 2. Influent and Effluent Characteristics of the Treatment System During March–April 2026

	Mar-26								Apr-26							
Parameters	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Sampling Date →	02-03-2026		09-03-2026		16-03-2026		27-03-2026		06-04-2026		13-04-2026		20-04-2026		27-04-2026	
pH	6.72	7.12	6.96	6.72	7	6.72	8.02	7.14	7.56	6.84	7.44	6.61	7.56	7.17	7.23	7.06
TSS	200	16	256	16	220	20	152	16	172	16	240	12	172	12	236	12
COD	386	40.6	413.3	40.3	315	30.48	375.92	20.32	430	40.96	481.28	30.72	406.4	40.64	360	40
BOD	203.3	8	280	10	196.7	8	246.67	10	226.7	6	246.67	10	250	8	210	6
TN	20.4	4.2	24.2	9.6	18.8	5.8	26.4	8.6	23.2	5.8	22.1	6.4	26.8	5.8	28.6	4.78
TP	2.1	0.8	3.2	0.7	1.5	0.8	1.8	0.6	2.6	0.7	2.3	0.7	1.5	0.6	1.12	0.6
FC	>1100	9.2	>1100	11	>1100	11	>1100	16	>1100	20	>1100	27	>1100	28	>1100	35

Table 3. Average Influent and Effluent Characteristics, Standard Deviation, and Removal Efficiency of the Treatment System

Parameters	Average of 8 events (Average ± Standard Deviation)		NGT Standards, 2019	Average Percentage Removal (%)
	In	Out		
pH	7.31 ± 0.39	6.92 ± 0.21	5.5 to 9.0	-
TSS	206 ± 35.38	15 ± 2.65	20	92.72
COD	395.98 ± 46.37	35.51 ± 7.11	50	91.03
BOD	232.5 ± 26.55	8.25 ± 1.56	10	96.45
TN	23.81 ± 3.14	6.37 ± 1.72	10	73.24
TP	2.02 ± 0.63	0.69 ± 0.08	1	65.88

pH, TSS- Total suspended solids, COD-Chemical oxygen demand, BOD- Biochemical oxygen demand, TN-Total nitrogen, TP-Total phosphate, FC-Faecal Coliform;
All values except pH and FC are expressed in mg/L, FC is expressed in MPN/100 mL

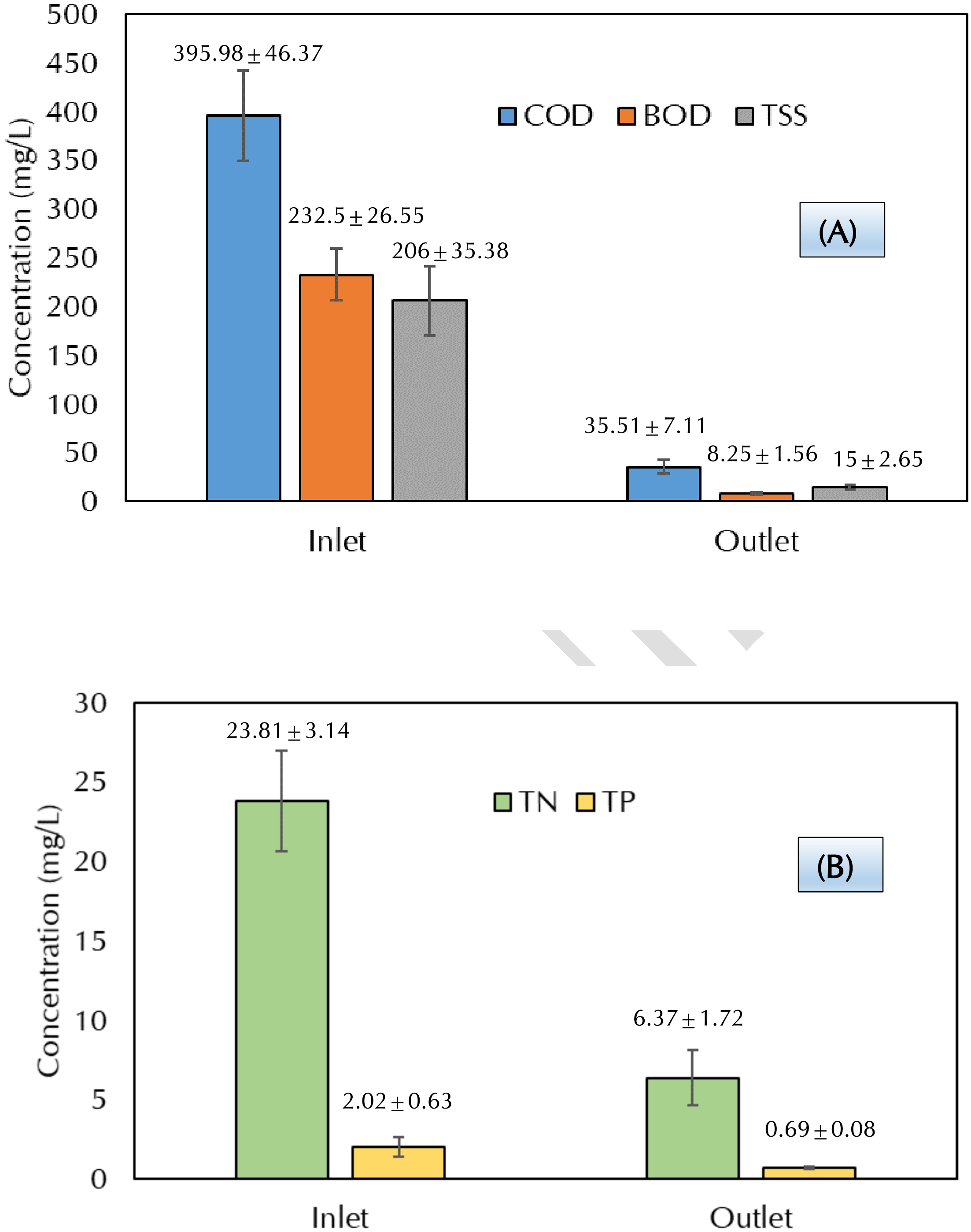

Figure 5: Average Removal efficiencies in terms of (A) COD, BOD, and TSS and (B) TN and TP (Average of Eight Sampling Events along with standard deviation)

5. Operational Cost

The operational cost of the decentralized wastewater treatment unit was estimated primarily based on the electricity consumption of the electro-mechanical components used during treatment. The major energy-consuming units in the system include the inlet sewage transfer pump, air blower used for biological aeration, and the filter feed pump used for tertiary filtration.

The power consumption of each unit was calculated using the rated motor capacity and the average operational hours per day. The treatment system was designed to treat approximately 2 KL of wastewater per day, and therefore the pumping duration was estimated based on the hydraulic flow requirement. The operational details and estimated energy/chlorine consumption of the individual units are presented in Table 4.

Table 4. Energy/Chemical Consumption and Operational Cost (2 KLD SusBio EcoTreat Unit)

Energy Cost			
Electro-mechanical unit along with specifications	**Power in kW**	**Operational Hours per day**	**Total Power Consumed**
Submersible Sewage Pump (Three phase) Flow Rate: 10 m^3/Hr Make: CRI	0.75 kW	0.4 Hrs (24 minutes)	0.30 kWh
Air Blower Air flow 60 L/min Pressure 15 kPa Make: FujiMAC	0.035 kW	24 Hrs	0.84 kWh
Filter Feed Pump Flow rate: 7 m^3/Hr Head: 29.80 m Make: Kirloskar Brothers	Feeding 1.10 kW	0.3 Hrs (17-18 minutes)	0.33 kWh
	Rinsing & backwashing	0.33 Hrs (20 minutes)	0.36 kWh
Daily Power Consumption			1.83 kWh/day
Power cost in Rs. /kWh			Rs. 5/kWh (Assumed)

(Based on https://kseb.in/uploads/Downloadtemsuppy/Annexure-I%20Comparison%20of%20rates-174021070633101455.pdf)	
Total Power cost per day	Rs. 9.15
Total Power cost per KL/day	Rs. 4.6/KL/day
Chemicals/Consumables	
Chlorine consumption for disinfection	5 gm/KL
Chlorine Cost	Rs. 350 per kg
Daily Chlorine cost	Rs. 1.75/KL/day
Total Operational Cost (Energy + Chemicals)	Rs. 6.325/KL/day
Daily Operational Cost for 2 KLD SusBio Unit	Rs. 12.65
Annual Operational Cost for 2 KLD unit	Rs. 4617.25/Annum

The results indicate that the developed treatment system operates with relatively low energy requirements (1.83 kWh/day) and minimal operational expenditure (Rs. 6.325/KL/day). The low operational cost further enhances the feasibility of wastewater reuse and sustainable water management practices. It may be borne in mind that the manpower cost is not considered while calculating the operational cost, since, manpower intervention is required only for half an hour a day for backwashing operation of the PSF and ACF.

6. General Observations

- No choking or clogging of the inlet sewage feed pump was observed during the monitoring period. The cutter-type submersible pump was able to handle suspended and fibrous materials present in the sewage.
- No significant odour issue was observed from the treatment unit during the operational period.
- The air blower operated without noticeable sound disturbance during the study period. The blower noise level was approximately 35 dB.
- The recirculation system for returning nitrified effluent from the aerobic chamber to the anoxic chamber functioned continuously during the monitoring period.

- Dissolved oxygen levels in the aerobic and anoxic chambers remained within the operational range throughout the study period.
- The pressure sand filter (PSF) and activated carbon filter (ACF) units remained operational during the monitoring period without any operational issues.
- The filter feed pump supplying treated water to the PSF and ACF units required manual operation for backwashing. Therefore, manpower involvement may be required during this period (approximately half an hour per day).
- Since the system does not presently include a dedicated sludge wasting arrangement, gradual accumulation of settled solids and biological sludge within the unit is likely during prolonged operation. Periodic sludge wasting, preferably on a weekly basis, is therefore recommended to maintain effective reactor volume and treatment efficiency.
- Low-cost sludge handling options such as dewatering bags and sludge drying reed beds may be explored for sludge management. For facilitating sludge withdrawal, the existing recirculation line from the clarifier to the anoxic chamber may be modified by providing a T-junction and sludge wasting valve arrangement for controlled removal of excess sludge.

7. Conclusions

- The SusBio EcoTreat 2 KLD sewage treatment unit was operated under near-design hydraulic loading conditions during March–April 2026 with an average influent flow of approximately 1905.71 ± 101.94 L/day.
- The treatment system achieved substantial reductions in all major wastewater quality parameters. The influent COD concentration was 395.98 ± 46.37 mg/L, which decreased to 35.51 ± 7.11 mg/L in the treated effluent (removal efficiency: 91.03%). Similarly, the influent BOD concentration of 232.50 ± 26.55 mg/L was reduced to 8.25 ± 1.56 mg/L (removal efficiency: 96.45%). The TSS concentration decreased from 206.00 ± 35.38 mg/L to 15.00 ± 2.65 mg/L (removal efficiency: 92.72%). Total nitrogen (TN) was reduced from 23.81 ± 3.14 mg/L to 6.37 ± 1.72 mg/L (removal efficiency: 73.24%), while total phosphate (TP) decreased from 2.02 ± 0.63 mg/L to 0.69 ± 0.08 mg/L (removal efficiency: 65.88%).

- The treated effluent quality remained relatively stable during the monitoring period despite moderate variations in influent characteristics.
- The faecal coliform concentration in the treated effluent remained below 100 MPN/100 mL following chlorination during the monitoring period.
- Dissolved oxygen conditions in the aerobic and anoxic chambers remained within the operational range required for biological treatment and denitrification processes.
- The recirculation of nitrified effluent from the aerobic chamber to the anoxic chamber functioned during the study period and supported nutrient removal.
- No choking of the inlet sewage feed pump was observed during the monitoring period. No significant odour issue was observed from the treatment unit during operation.
- The blower operated continuously during the study period with a reported noise level of approximately 35 dB.
- The estimated operational energy consumption of the treatment system was approximately 1.83 kWh/day, corresponding to an estimated operational energy cost of approximately Rs. 4.6 per KL/day of treated wastewater. Including chlorine consumption, the total estimated operational cost was approximately Rs. 6.325 per KL/day.
- Backwashing of the filter feed pump for operating the pressure sand filter (PSF) and activated carbon filter (ACF) required manual operation, and therefore manpower involvement may be required during backwashing/rinsing (approximately half an hour per day).
- Based on the monitoring results obtained during the study period, the treatment unit was able to produce treated effluent meeting the prescribed discharge standards (NGT, 2019) for the analyzed parameters under the observed operating conditions as mentioned in the report.

------------------------------XOX---------End of Report---------XOX------------------------------