Project Report

Performance Assessment of Biopipe's Decentralised containerized WWT Plant located at Pimpari Chinchwad

Report Submitted by:

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This study was conducted as consultancy project titled "Guidance about the testing protocol for the validation of new wastewater treatment technology claims" and funded by Biopipe.

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2. The WWT is tested by Biopipe by using third party NABL accredited laboratories under the protocol guidance of IIT Mandi.
3. The results mentioned in this report are obtained on a particular sample/unit and under the laboratory conditions as defined in this report. Any change in plant design and dimensions may lead to changes in the results and the reported results may not be applicable /valid.
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Table of Contents

Information from Biopipe

1.Brief of WWT Challenges in India
2. Biopipe plant technology overview
3. Details of plants tested
4. Details of Influent and Effluent Testing labs and testing methods
5. Table of measured water quality parameters at influent and effluent
6. Comparison of Effluent Parameter with CPCB Standards
7.Benchmarking comparison of Biopipe technology operating parameters (installation footprint, electricity consumption, GHG emissions, cost etc.) with other technologies with cited source of used data

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1. Introduction

Expeditious advancement in masses, urbanization, industrial development, and exuberance of essentials in developing countries has drawn attention responsiveness of various scholars towards the suitable wastewater treatment system. Ecological experts are furthermore highlighting now on suitable wastewater treatment systems to preserve the water environment and fresh water resources for certification the ingenuousness of imbibing water in little and prevalent manner.

In the most recent two decades, decentralized wastewater treatment frameworks (DEWATS) have been accounted for more proper answer for sanitation in developing nations. Also a paramount part of the environmental engineers accept that DEWATS can be a perpetual answer for the wastewater administration in provincial and urban territories of developing countries.

Urbanization and industrialization draw people from rural areas to migrate to cities in search of a better standard of living. In fast-developing countries like India, the large flow of migrants to major cities put much pressure on city infrastructure, especially on the water supply and sanitation system and particularly on sanitation infrastructure such as the wastewater collection network, treatment through sewage treatment plants (STPs), sewage disposal system, and the reuse distribution system.
As a consequence, around 80% of the total drinking water supply ends up as wastewater. In several instances, the facilities provided have become either insufficient or improperly maintained. Kulkarni, Wanjule, and Shinde (2018) report that out of the total sewage produced in India only 10% is treated and the rest is discharged into water bodies or on the ground. In most cities, wastewater is often untreated, thus contaminating the surface as well as groundwater resources. Therefore, proper sewage treatment is essential; and sometimes-treated sewage can be used for other purposes as well.

There are emerging treatment technologies that have come into practice in recent times in other parts of the world, but they have not come into practice in India at large scale, one of them is Biopipe technology. It is the world's first biological wastewater treatment system where the process

takes place entirely in the pipe, which is patented, in more than 55 countries. It's the result of years of research that has now developed into one of the most sustainable, eco-friendly and cost-effective wastewater treatment solutions in the world.

2. Domestic wastewater treatment technologies

There are 2 main biological wastewater treatment methodologies in literature. Activated Sludge (suspended growth) and Attached Growth.

The first and common one is activated sludge processes such as traditional STP, extending aeration systems and so on. The main idea for this process is to create sludge by aerating wastewater. Bacteria in sludge treats the wastewater. Sludge is circulated in the process and at the end of the treatment process, sludge must be removed from the system.

Activated sludge processes are globally well-known processes and we will not get into the details of treatment in this report.

The second and less common methodology is attached growth (biofilm) systems such as Rotating discs, trickling filters and so on. In attached growth systems, the biomass grows attached to a support medium to create a biofilm. Attachment to the support medium is influenced by composition of the media used, cell-cell interactions and the presence of polymer molecules on the surface. The support medium can be immersed in the liquid medium or receive continuous or intermittent discharges. The support medium can be of any nature, such as solid natural (rocks, stones, gravels, sand and soil), artificial (rubber, plastic) or agglomerates of the biomass itself (granules). These biofilms grow on support media by feeding off the organic matter and nutrients in the wastewater that flows over them. In attached growth systems, there is a difference in the density gradient of the support medium together with biomass and the density of the liquid inside the reactor that allows the velocity gradient between the liquid and the external layer of biofilm. Therefore, bacterial cells being continually exposed to new substrates tend to increase their activity.

Biopipe is an attached growth biofilm system that gets the maximum efficiency from it's biofilm by utilizing the process in horizontal pipes.
An assemblage of microbial cells enclosed in a matrix of bacterial self-generated extracellular polymeric substances (EPSs) irreversibly associated with a surface is termed a biofilm. Generally, the development of biofilms is composed of five main stages as shown in Figure 1

1. initial attachment of planktonic microorganisms with the exposure of a surface to an aqueous medium;
2. irreversible adhesion upon the production of microorganism-mediated EPSs as polyhydroxyl groups in EPSs colonize bacteria to the surface via hydrogen bonding ;
3. formation of monolayer microcolonies on the fixed surface due to replication of early colonizers;
4. maturation of biofilm into a three-dimensional arrangement by attaching debris from the adjacent environment and by employing new planktonic bacteria and
5. dispersion or expansion by active and passive processes in which sessile, matrix-encased biofilm cells convert to freely swimming planktonic bacteria through quorum sensing (QS) or a cell-to-cell signaling mechanism.

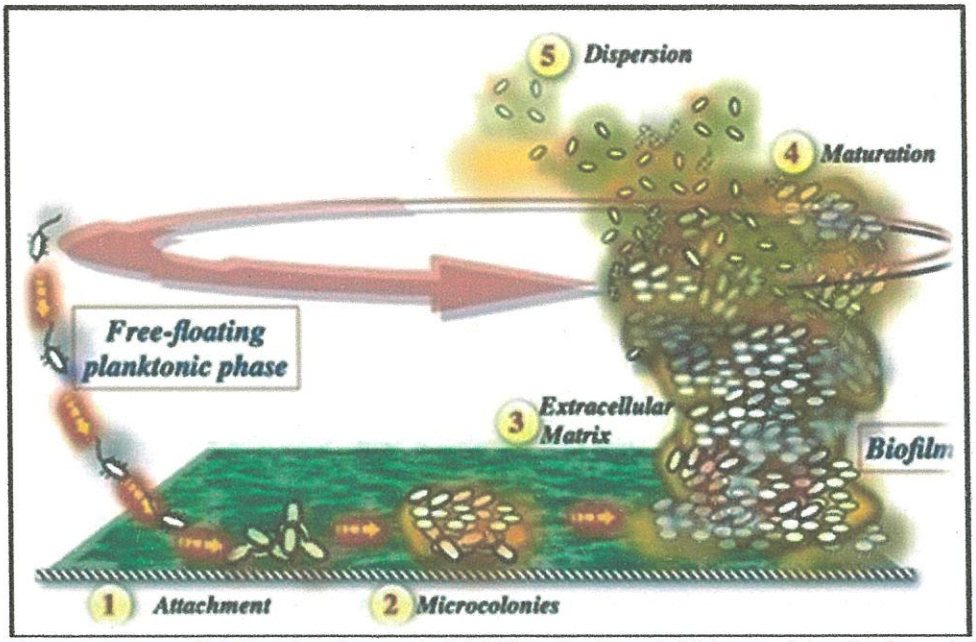

Figure 1: Stages of biofilm development : (1) initial attachment; (2) irreversible attachment; (3) replication; (4) maturation and (5) dispersion.

3. Biopipe plant technology overview and status as reported by Biopipe

Biopipe Global Corp. "Biopipe" is a wholly owned subsidy of Lifequest World Corp. with headquarters in New Jersey, USA. Biopipe's mission is to develop and find innovative technologies that are cost- effective, scalable, decentralized solutions to water and wastewater treatment.

The Biopipe technology was invented by Enes Kutluca in 2012 during his thesis year at Bahçeşehir University in Turkey. After proof of concept, Environmental Technologies, Inc. was established in Turkey. In 2013, the company was reorganized as Biopipe AG in Zurich, Switzerland and Biopipe TR in Turkey with intellectual property transferred from Environmental Technologies, Inc. Several projects in Turkey at this early stage helped form the initial traction for Biopipe's start. In 2015, Biopipe DMCC was established in Dubai to enter the MENA (Middle East North Africa) market. Biopipe gained international acclaim as one of the most innovative technologies in sewage wastewater treatment. Present In 2019, Biopipe Global Corp, a United States of America Corporation acquired all the assets of Biopipe Global AG and Biopipe TR. Biopipe has now expanded its footprint with a presence in Bangladesh, India, the Philippines, South Africa, Ethiopia, and the United States.

Unlike activated sludge systems, MBR, SBR, MBBR, etc, Biopipe produces No Sludge, No Odor, and Low Noise. Biopipe brings energy consumption to a minimum as it can store wastewater in a horizontal position which better distributes water pressure and requires less energy as compared to other systems, which can only use vertical pipes.

Biopipe technology as shown in Figure 2 is an affordable, modular biological wastewater treatment solution in which treatment takes place in a series of pipes as shown in Figure 3. Domestic wastewater or sewage with elevated organic (Chemical Oxygen Demand- COD) are transferred with a pump into the circulation system. The circulation system is a series of pipes containing fixed media that assist with the attachment of biofilm for biological nutrient removal. Once treated, the treated effluent passes through a cartridge filter or sand filter / activated carbon filter and is disinfected by UV-light or chlorine before being reused in non-potable applications such as irrigation or car wash or discharged to receiving bodies.

Figure 2: Biopipe Technology STP

Biopipe utilizes a blend of the microbial population know as biofilm-forming bacteria and inactive dead bacteria for biological nutrient removal through nitrification, denitrification and phosphate removal processes.

The system produces no sludge unlike activated sludge or suspended growth biological treatment technologies. The only byproduct of the Biopipe system is water and minimal amounts of inactive dead bacteria. Because Biopipe's process takes place in a series of pipes, the system can be adapted for a wide range of footprint layouts, making installations easier in constrained spaces. In addition, there is no blower or aeration system required, hence it uses a venturi air absorption process to increase the circulation of oxygen for microbial growth and metabolism.

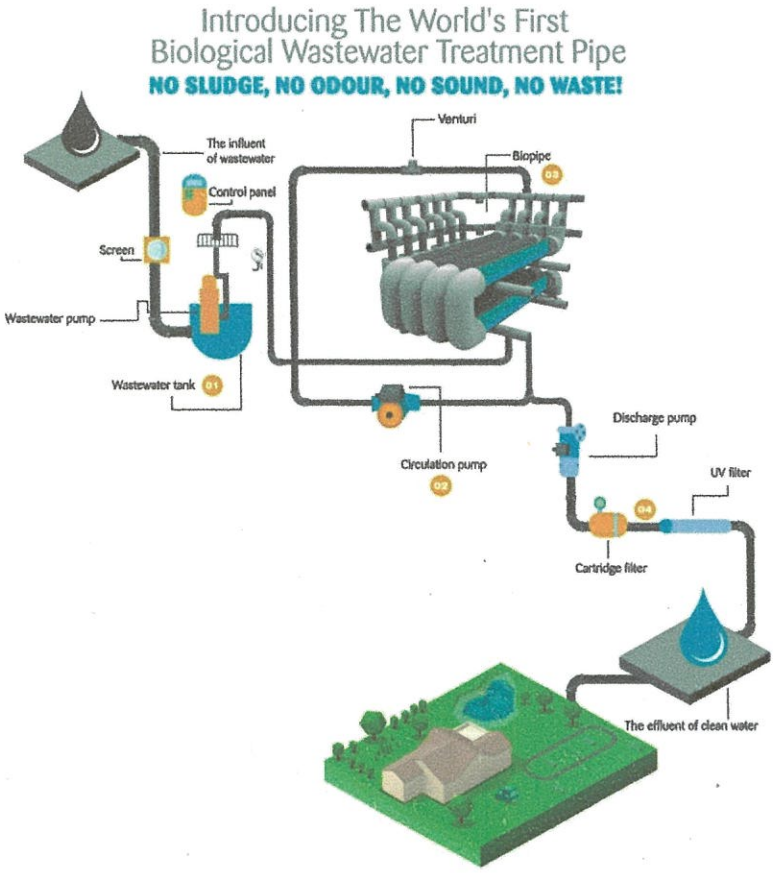

Figure 3: Biopipe Technology

Biopipe global Corporation has installations in Middle eastern Countries, Bangladesh, India, the Philippines, South Africa, Ethiopia, and the United States.

Process unit steps of Bipope are as follows;

- Bar screens filter out inorganic particles such as plastics etc.
- Submersible pump to propels water into Biopipe in batches to maintain the microbial and wetting condition.
- Biopipe biofilm bacteria (attached growth) engages with nutrients and remove them from wastewater through nitrification and denitrification process utilizing COD as carbon source.

- Air is automatically vacuumed in by the pressure difference through a venturi air injector to create an ideal ambient condition for the rapid growth of bacteria and accelerate aerobic digestion.
- The Biopipe STP consist of 2 modules whereby the 1st module handles BOD/COD reduction and the 2 and module handle Ammonia (NH3-N), Nitrogen (NO3), and Phosphate removal.
- The wastewater then passes through a cartridge filter or equivalent and a UV filter to complete the disinfection. Chlorination dosing units may be installed as residual disinfection in some countries.
- The treated water can then be used directly or stored in a clean water tank.
- The current process is modulated, simple to operate and maintain, eco-friendly and fully automatic as shown in Figure 5.

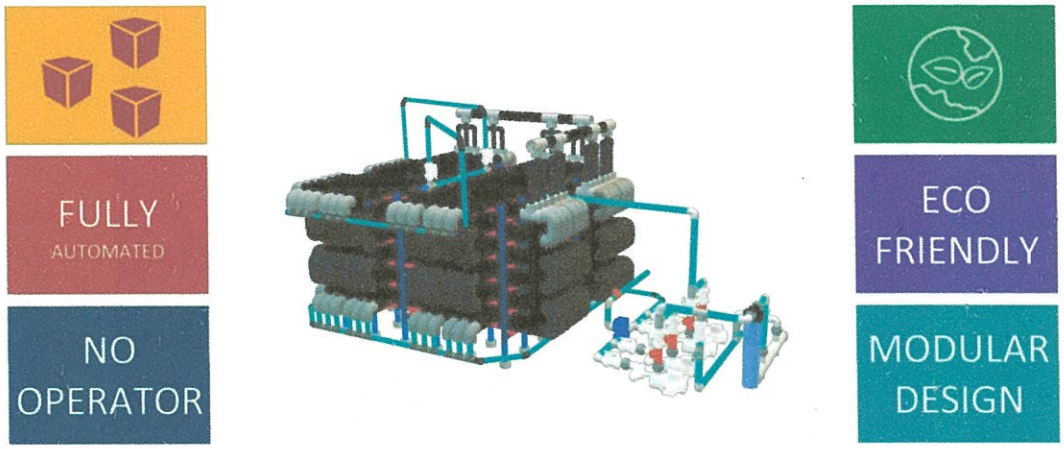

Figure 4: Biopipe System

4. Claims from Biopipe

- Biopipe plant does not require chemicals to treat the water
- Biopipe plant does not produce sludge during treatment of the wastewater
- Biopipe plant does not produce foul odor
- Biopipe Plant is relatively silent than other sewage treatment plants

- Biopipe's treated water meets water quality standards (Indian and European water standards) and can be reused for irrigation and other purposes.
- Biopipe system is fully - automatic with extremely low O&M cost, which results in the lowest lifetime cost among all STPs.
- Biopipe can also work as an upgrade to old STPs and can be installed on rooftops, elevated structure, in the basement, or service floor.
- Efficiency of Biopipe in treating the wastewater and water recovery

5. Assessment Report from IIT Mandi based on the data provided by Biopipe

The objective of the study is to assess the best practices and claims made by Biopipe Global on DWWT using natural treatment methods with minimal electricity usage. The documentation includes the case study of DWWT implemented at Pimpri Chinchwad municipal Corporation's pumping station providing a detailed understanding of the potential for local reuse.

Methodology

The report is underpinned by an interpretive understanding of knowledge, focusing on meaning that is situated in a particular context and acknowledges the subjective nature of real-world problems related to sustainable water management in rapidly urbanizing towns/cities in India. The aim is to clarify and deliberate about the problems and risks in respective settings and outline how wastewater treatment can be done sustainably.

For evaluation of the technology, the details of the selected plant operated by the Biopipe are shown in Table 1.

Table 1: Details of the invistagated plant

Project Description	Packaged Sewage Treatment Plant
Technology	Biopipe

Working principle	Batch
No. of batches per day	6
Batch capacity	2.500 liters / batch
Total capacity	15,000 liters/day (15 KLD)
Type of water	Grey + Black water (Kitchen, Bathroom, utility cleaning, Toilet Flush)
End-use of treated water	Irrigation/ Toilet Flush / Cleaning
Location	Pune, India
Implementing Agency	Biopipe Global Corporation

The Biopipe containerized plant at Delux Pumping station treats municipal / domestic wastewater (both black and grey) using 'Biopipe Technology' and it is a good example of DWWT and reuse of water at neighborhood scale, demonstrating the value of water and resource potential by local reuse.

Intermittent supply of water on rotational basis to different wards is common feature in Pune. Around 60-70 per cent sewage undergoes preliminary treatment before it is disposed in the rivers. Pimpri-Chinchwad is a city (Figure 1.1) in the Pune district of Maharashtra. The city comprises the twin towns of Pimpri and Chinchwad which are governed by a common municipal body (the Pimpri-Chinchwad Municipal Corporation or PCMC). The location can be indetified with Latitude : 18.61N Longitude : 73.80 E

Figure 5: Location of Biopipe plant in PCMC

The installed STP at PCMC pumping station is a factory assembled wastewater treatment plant based on the Biopipe Technology. The unit is self-contained (containerized), complete, transportable and ready to be installed on a prepared foundation slab, elevated platform or even a rooftop. The STP can be used in ULBs, municipal corporations, housing societies, industries, hostels, detached houses, apartments, hotels, commercial buildings and villas or wherever wastewater is generated, regardless of size and capacity.

The STP plant design includes a screen placed before wastewater is received into a Wastewater Collection Tank where it is equalized and then pumped into Biopipe. The plant is designed and sized based on anticipated flow-rate and biological oxygen on demand (BOD) concentration of a specific sewage wastewater influent and produces acceptable effluent, which is suitable for re-use in irrigation, re-flushing of toilets, outdoor cleaning or simply discharged into the municipal sewer system or the ground. Biopipe treats only domestic wastewater (toilet, lavatory, shower, etc.).

Treatment system, design and construction

The major component of system are Biopipes which is constructed from UPVC pipes and fittings. The Biopipe system can be placeson the ground, on the elevated structure /rooftop or in the container. The Biopipe system also consists of coarse or fine screen chambers/grit chamber for preliminary treatment, treated water tank, piping, pumps, sensors, disc filter, equalization / storage tanks and tertiary treatment system. The figure 2 explains the working of the Biopipe System. The Biopipe plant is located on 13sq.marea(20 feet container). The bar screens of 5 mm aperture size are used to remove the coarse and fine suspended solid particles from municipal wastewater. The treated wastewater gets collected in the collection tank and can be recirculated till desired quality is achieved.

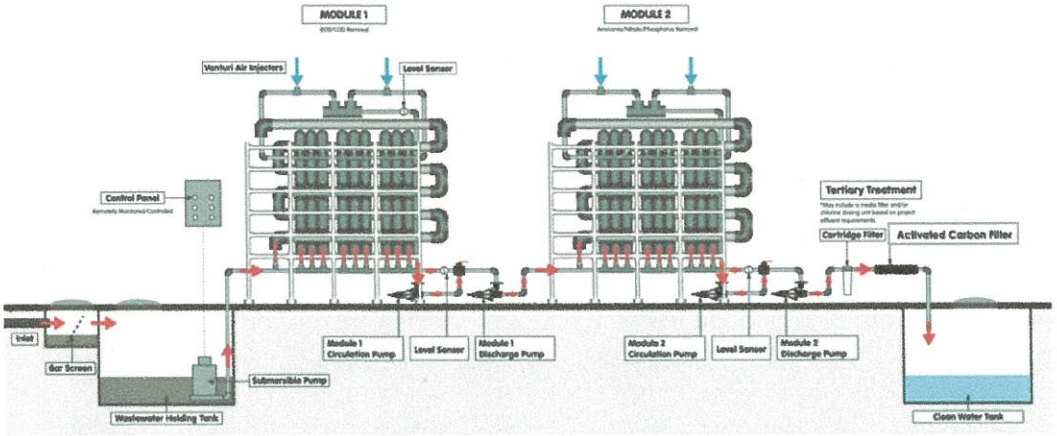

Figure 6: How Biopipe Works

Figure 7: Biopipe plant at Pimpari sewage pumping station

The Biopipe plant has been functional since October 2021. The treatment efficiency and overall performance of the system is being regularly monitored. The table below indicates the average parameters and average results.

Electrical Load Calculation

The Biopipe plant consist minimum electrical equipment and the pumps used in the Biopipe are energy efficient pumps. The robust PLC based program and automatic plant helps in reducing energy consumption of the plant.

Table 2: Electrical Load Calculations

Load Calculations for 15 KLD							
Sr no	**Component**	**Capacity (kW)**	**Flow Rate m3/h**	**Head meter**	**Number of Components**	**Working Hours**	**Total Consumption per Cycle (kWh)**
1	Filling Pump	0.75	10	10	1	0.5	0.4
2	Automated Valve	0.006	NA	NA	3	0.0056	0.00010
3	Circulation Pump	1.1	21	10	2	1.5	3.3
4	Discharge Pump	0.8	10	10	2	0.5	0.8
6	Control Panel	0.25	NA	NA	1	4	1.0
						Total	**5.5**

Total Number of Cycles	**6**	**Total Consumption Per Day (KWh**	**32.9**

Data collection and analysis

Firstly, the desk review identified a case study using decentralized natural wastewater treatment method such as Biopipe Technology. Second, the case study of Pimpri Chinchwad Municipal Corporation was finalized on the basis of a combination of criteria such as performance assessment, socio-economic sustainability (minimal or no electricity use), and reuse of wastewater. It is a containerized Biopipe plant, situated at Dulex Chowk Pumping Station, Pimpri. Biopipe system of capacity 15 cubic meters per

day is commissioned which treats the wastewater that comes to the pumping station from the nearby areas. The pumping station then delivers this water to the STP situated at Bhatnagar.

The data collected was both quantitative and qualitative.

Table 3: Water Parameters

S. N	Parameters	Unit	Inlet (Avg)	Outlet (Avg)	Limits for Bathing Water	Limits for Potable Water	Limits for STP Discharge Water
1	pH	--	6.5 - 7.5	7	6-9	6-9	5.5- 9.0 10mg/l.
2	BOD	mg/lit	140	5	3	NIL	10mg/l
3	COD	mg/lit	400	25	15	NIL	50mg/l
4	TSS	mg/lit	100	5	5	NIL	10mg/l
5	TDS	mg/lit	300	270	250	200	500mg/l
6	Chloride	mg/lit	60	45	1000	250	
7	Sulphate	mg/lit	35	20	400	200	
8	Total Ammonical Nitrogen	mg/lit	10	1.5	0.5	NIL	10mg/l
9	Phosphate	mg/lit	1.5	3	1	NIL	
10	Fecal Coliform	MPN/ 100 ml	5000 MPN/ 100 ml	100MPN/100 ml	100MPN/100 ml	<50MPN/100 ml	100 – 230 MPN/100 ml

As per IIT Mandi's suggestion Biopipe selected various NABL (National Accreditation Board for Testing and Calibration Laboratories) Labs for water testing. Following parameters were tested for inlet and outlet water over the period of time. Biopipe used Grab sampling method because it is the most common form of sampling flowing water. This method is reliable and easy to do.

- No special equipment was needed, a sampling container was used to take the sample.

- The container was dipped directly into the water
- Samples were then packed in a cooler box with ice and taken for testing.

Parameters :

1) pH
2) BOD
3) COD
4) TSS
5) TDS
6) Chloride
7) Sulphate
8) Total Ammonical Nitrogen
9) Phosphate
10) Fecal coliform

The wastewater and treated waster was collected from Pimpari Chinchwad in a plastic bottle as samples for testing as stated above. The wastewater and treated water was collected in the bottle was kept in cold temperature which helped to retain properties of wastewater / treated water.

The measured water quality parameters are presented in Table 2. The performance results indicate the reduction of BOD by 95 per cent in the system reveals good performance. The performance at outlet indicates that treated wastewater can be safely reused for horticulture purpose as it meets all the standards prescribed by MPCB/CPCB/NGT.

During the test period of biopipe outside temperature varied 10^0 to 35^0 degrees Celsius. Impact of the temperature was negligible in effect to overall treatment efficiency.

Biofilm bacteria uses the oxygen dissolved in water and oxygen is vacuumed by venturis during the treatment process. Flow rate of water inside the venturis maintained minimum 10m3/hour to achieve sufficient oxygen transfer. Venturis vacuum air during the circulations for total of 3 hours per batch.

To achieve the required parameters Biopipe system requires 3 hours circulation, if the circulation is increased by an hour then it gives more efficient result. The below table indicates the results achieved from 3 hours circulation.

Table 4: Water Parameters

S. N	Parameters	Unit	Inlet (Avg)	Outlet (Avg)
1	pH	--	6.5 - 7.5	7
2	BOD	mg/lit	140	3
3	COD	mg/lit	400	24
4	TSS	mg/lit	100	5
5	TDS	mg/lit	300	270
6	Chloride	mg/lit	60	45
7	Sulphate	mg/lit	35	20
8	Total Ammonical Nitrogen	mg/lit	10	1.5
9	Phosphate	mg/lit	1.5	3
10	Fecal Coliform	MPN/100 ml	450	100

System was stopped due to electricity outrages on 05th January 2022 for 36 hours. Despite that biopipe was able to treat the wastewater almost within the same efficiency shown in the table 5.

Table 5: Water parameters after power cuts

S. N	Parameters	Unit	Inlet	Outlet
1	pH	--	6.5 - 7.5	7
2	BOD	mg/lit	140	5

3	COD	mg/lit	400	25
4	TSS	mg/lit	100	5
5	TDS	mg/lit	300	270
6	Chloride	mg/lit	60	45
7	Sulphate	mg/lit	35	20
8	Total Ammonical Nitrogen	mg/lit	10	1.5
9	Phosphate	mg/lit	1.5	3
10	E.Coliform	MPN/100 ml	450	100

Bacterial culture and enzymes were added in the commissioning phase in the month of October and the tests were conducted immediacy after a week. The results were promising and the bacterial colonies were formed to perform the treatment on the wastewater. The tests were conducted periodically in 6 months, to test the stability of the performance. Even with diluted BOD and COD systems performed well and the results were recorded digitally. It was seen that Biopipe's treated water meets water quality standards (Indian and European water standards) and can be reused for irrigation and other purposes.

The Biopipe system has been working since October 2021, it was found that there was no sludge formation from the system, and it was not required to manage sludge at the plant during 8 month continuous operation of the plant. The Disc filter was cleaned twice till month of March, first was clean on 8th of December 2021 and then on the 4th March 2022, thus it made clear that the bacterial colonies formation was strong. Biopipe system was being monitored online, there was no dedicated operator at the site. However, the operator used to visit site once or twice in a week to check the system and collect the water samples. Biopipe System used 32 units per day to treat 15,000 liters of wastewater. The energy consumption for the system was on the lower side and the

automation of the Biopipe System is robust and runs without any interruption.

6. Benchmarking comparison of Biopipe technology operating parameters

Table 6: Comparative Table

15 KLD STP Required	Conventional STP	Biopipe Solution	Saving
Standard Capacity	15 KLD	15 KLD	Capex/ Opex
Approximate Area Needed	20 m2	12 m2	8 m2
Odour Problems	Heavy	No Odour	Opex
Noise Level	Very High	Extremely Silent	Opex
Sludge Generation	3 Tonns per year	Zero Sludge	Opex
Sludge Handling	Client Scope	Zero Sludge	Opex
STP Operation	Manual	Automatic	Opex
Electrical Consumption	75 kWh/day	32 kWh/day	43 kWh/day
Daily Chemicals	Poly, PAC, Hypo	No Chemicals	No Chemicals
Skilled Manpower	Compulsory	-	Not Required
Role	Plant Operation	-	NA
Un-Skilled	Comp	-	Not

Manpower	ulsory		Required
Role	Sludge Handling	-	NA
Semi-Skilled Manpower	-	Required	Required
Role	-	Monitoring	Monitoring
O&M Cost for STP	Very High	Lowest	Lowest
Civil Tanks Needed	Atleast 9 Nos	1 Nos	8 Nos
Can we move STP	Never	Yes	Yes
Can we scale up STP	Never	Yes	Yes
Blower Operation	24 x 7 x 365 days	No Blower	No Blower

7. Conclusion

Sewage Treatment Plant in Delux Pumping Station, Pimpari area was monitored for 8 months and the following conclusions have been drawn. The ranges of physical, chemical and biological characteristics of wastewater quality are in the permissible limits given by waste water/sewage effluent standard as per National Inventory of Sewage Treatment Plants, published by central pollution control board in March 2021[1]. The results of parameters i.e. pH, BOD, COD, TSS after the sewage treatment is under the prescribed limits. Hence, it is concluded that performance of Sewage Treatment Plant is good and it is working very well. Apart from the water treatment claims, the other claims made by Biopipe such as no sludge, no odour, no chemicals, low O&M cost; stands

[1] https://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvMTIyOF8xNjE1MTk2MzIyX21IZGlhcGhvdG85NTY0LnBkZg==

to be validated as per the project performance data provided from the Pimpari Chinchwad area WWT. Biopipe Technology can be a good solution on the existing problems of sewage treatment plants such a sludge management, odor issues, space requirement and higher O&M cost.

Biopipe can be the best suitable solution for dense populated cities as it requires less space and can be installed on elevated structures or rooftop. Biopipe can be the STP augmentation solution. Some of the old hospitals, establishments, societies will not have space for installing STPs due to space constraints and structural issues, so Biopipe might be a better solution for it.