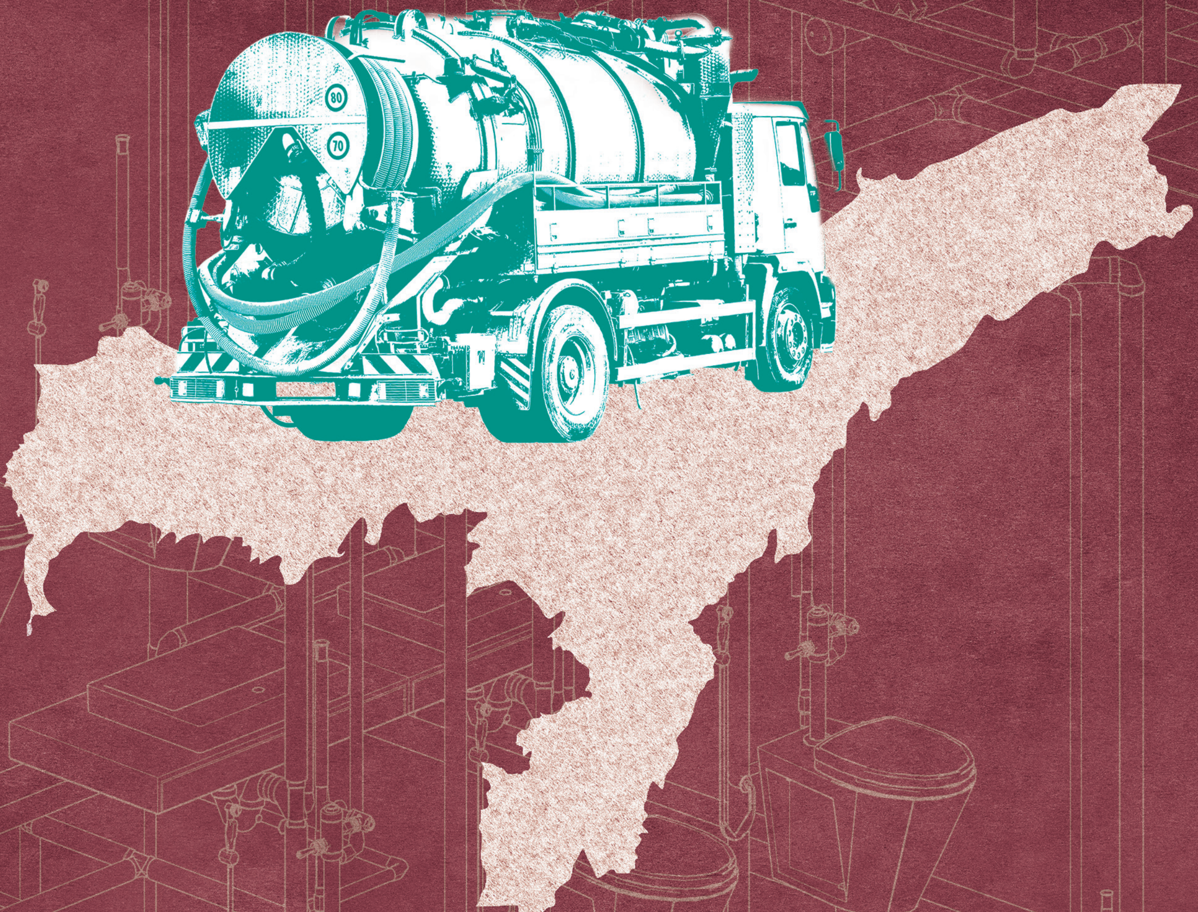

PERFORMANCE ASSESSMENT OF FSTPs OF ASSAM LEADING TO SAFE AND SUSTAINABLE SANITATION

A MULTI-SITE ASSESSMENT

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Contents

Abbreviations and acronyms

AAETI	Anil Agarwal Environment Training Institute
ABR	Anaerobic baffled reactor
ACF	Activated carbon filter
AF	Anaerobic filter
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AN	Ammoniacal nitrogen
APHA	American Public Health Association
As	Arsenic
ASF	Sand filter
BMGF	Bill & Melinda Gates Foundation
BOD	Biological oxygen demand
BS	Biosolid
C:N ratio	Carbon-to-nitrogen ratio
Ca	Calcium
CapEx	Capital expenditure
Cd	Cadmium
CFU	Colony forming unit
COD	Chemical oxygen demand
Cr	Chromium
CSE	Centre for Science and Environment
Cu	Copper
CU	Capacity utilization
DEWATS	Decentralized wastewater treatment system
E. coli	*Escherichia coli*
EC	Electrical conductivity
EML	Environment Monitoring Laboratory
FC	Faecal coliform
FCO	Fertilizer Control Order
FS	Faecal sludge
FSSM	Faecal sludge and septage management
FSTP	Faecal sludge treatment plant
Hg	Mercury
HRT	Hydraulic retention time
ICP-OES	Inductively Coupled Plasma Optical Emission spectroscopy
K	Potassium
KL	Kilolitre

KLD	Kilolitres per day
kW	Kilowatt
Mg	Magnesium
MLD	Million litres per day
MLG	Microbiology Laboratory Guidebook
Mn	Manganese
MoEF&CC	Ministry of Environment, Forest and Climate Change
MPN	Most probable number
Na	Sodium
NGT	National Green Tribunal
NH3-N	Ammoniacal nitrogen
NH4+N	Ammonium nitrogen
Ni	Nickel
O&M	Operations and maintenance
OpEx	Operational expenditure
OWW	Organic wet waste
P	Phosphorus
Pb	Lead
PGF	Planted gravel filter
pH	Potential of hydrogen
PP	Polishing pond
PPE	Personal protective equipment
SBM	Swachh Bharat Mission
SDB	Sludge drying bed
SeTP	Septage treatment plant
SF	Sand filter
SR	Stabilization reactor
SRT	Solids retention time
STT	Settling-thickening tank
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TP	Total phosphate
TS	Total solids
TSS	Total Suspended Solids
ULB	Urban local body
USDA	United States Department of Agriculture
USDB	Unplanted sludge drying bed
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
Zn	Zinc

1. Introduction

Faecal sludge management (FSM) continues to be a major long-term challenge in India, where the collection and treatment of waste are often overlooked. The country generates approximately 0.12 million tonnes of sludge every day. However, only about 30 per cent of urban areas are connected to a centralized sewage network, while the remaining 70 per cent still rely on on-site sanitation systems such as pit latrines and septic tanks. Once these containment systems reach capacity, the common practice is to dispose of untreated sludge directly into the open environment—often into nearby waterbodies—posing risks that can be even more severe than those from open defecation. This practice contributes to serious environmental and public health issues, including groundwater and drinking water contamination, and outbreaks of diseases like diarrhoea, cholera and typhoid.[1, 2]

To bridge the gap in safe sanitation management, particularly for non-sewered sanitation (NSS) systems, the Government of India launched the Swachh Bharat Mission (SBM) in 2014. While the initiative led to the construction of millions of toilets, it raised an important question: where does the waste from these containment systems go? In response, the Ministry of Housing and Urban Affairs (MoHUA) introduced the National Faecal Sludge and Septage Management Policy in 2017, which paved the way for establishing faecal sludge treatment plants (FSTPs).[3]

Currently, around 1,040 FSTPs are operational across the country, with at least 300 more in various stages of construction. Additionally, co-treatment of faecal sludge through existing sewage treatment plants (STPs) has been initiated in several locations. However, the mere construction of FSTPs and co-treatment facilities cannot be considered a definitive measure of success. Continuous monitoring and performance evaluation are essential to ensure treatment efficiency and compliance with discharge standards before releasing effluent into the environment.[4]

As part of this effort, the Centre for Science and Environment (CSE) has undertaken a study to evaluate the faecal sludge treatment plants (FSTPs) that have been constructed to safely manage faecal waste at several ULBs in the state of Assam.

Assam, in the foothills of the eastern Himalayas, is the second-largest state in northeast India, with a rapidly growing population of 31.20 million (according to the 2011 Census). The state is situated along the middle reaches of the Brahmaputra and Barak rivers. Renowned for its tea and temples, Assam is home to the Kamakhya Temple, a major Hindu pilgrimage site in Guwahati, and the Dhekiakhowa Bornamghar, known for its ancient ever-burning lamp. The state boasts of the world's largest contiguous tea-growing region, famous for producing tea with a rich, smooth and malty flavour.[5]

Assam accounts for nearly 2.4 per cent (70,634 sq. km) of India's total geographical area. The state borders Arunachal Pradesh in the east; West Bengal, Meghalaya and Bangladesh in the west; Arunachal Pradesh and Bhutan in the north; and Nagaland, Manipur, Mizoram, Meghalaya and Tripura in the south. The state has a diverse landscape ranging from hills to flood-prone plains.[6]

Sanitation systems in urban areas in Assam, particularly Guwahati, have grown rapidly, while much of the rural population still relies on traditional sanitation methods. As per recent reports, Assam has made progress in addressing sanitation issues but continues to face several obstacles in both urban and rural sanitation systems.

The government of Assam launched the **Total Sanitation Campaign** programme in **1999**. As on February 8, 2017—with over a decade and a half of implementation of the programme—nearly **37.10 lakh** families in the rural areas of the state have sanitary toilet facilities. More than 19.67 lakh families are however still to be provided with sanitary toilets. A significant portion of the toilets—around **637,264** (around 27.52 per cent)—of already constructed toilets are defunct. These were constructed at low costs and now need upgradation and/or reconstruction.[7]

History of sanitation in Assam

Before Independence, Assam, like many other parts of India, lacked organized sanitation systems. The waste disposal methods were rudimentary, with open defecation and manual handling of waste practised, especially in rural areas. Urban sanitation in towns like Guwahati was no better, with limited sewage treatment infrastructure.

From 1947 till 1980s the focus shifted towards improving sanitation and public health. However, Assam remained largely rural, with many areas lacking basic sanitation facilities. The Central Rural Sanitation Programme (CRSP), launched in the 1980s, aimed at improving rural sanitation by constructing individual latrines and promoting hygienic practices. After Independence, the Indian government focused on improving sanitation in rural and urban areas through various national programmes. The state of Assam in 1947 (which included parts of what is now Andhra Pradesh, Meghalaya, Nagaland and Mizoram) was largely rural at the time, and faced challenges like low literacy rates, poor infrastructure and insufficient government funding to address sanitation issues.

During the 1990s–2000s, the focus of the national sanitation campaigns was primarily on providing public toilets and improving access to clean drinking water. The launch of the Central Rural Sanitation Programme (CRSP) in the 1980s, followed by the Total Sanitation Campaign (TSC) in the 1990s, led to a gradual improvement in rural sanitation across the country, including Assam. In the 2000s, Assam's rural areas were targeted for sanitation improvements, with programmes to promote sanitary latrines and hygiene education. Nirmal Bharat Abhiyan (NBA), focusing on more sustainable sanitation systems, was introduced in 2012 to replace TSC.

The state government initiated the construction of rural toilets under these programmes. There was also a gradual push towards improving solid waste management and treating wastewater in urban areas like Guwahati. However, the lack of adequate sewage treatment infrastructure remained a significant challenge in urban areas.[8]

Swachh Bharat Mission (2014–present)

In 2014, the Swachh Bharat Mission (SBM), launched by the Indian government, aimed to eliminate open defecation, improve solid and liquid waste management and promote cleanliness. SBM was particularly effective in Assam, where a large percentage of people still practised open defecation, especially in rural areas. Through SBM, Assam made significant progress in constructing individual household latrines (IHHLs), community toilets and rural sanitation facilities. The mission also brought focus on hygiene awareness campaigns and the creation of local sanitation committees.

Urban sanitation in Assam

Urban areas like Guwahati, the largest city in Assam, face additional challenges related to rapid urbanization, lack of adequate sewage infrastructure and waste management systems. Despite some efforts to modernize sewage systems, many urban areas still lack fully developed and efficient sewage networks.

Current status of urban sanitation (2020–present)

In cities like Guwahati, where rapid urbanization has put pressure on existing infrastructure, the focus has shifted to improving sewage treatment. Guwahati faces a significant gap in sewage treatment capacity, with many areas relying on septic tanks and cesspools. The city has begun implementing faecal sludge treatment plants (FSTPs) to handle the untreated waste.

Sanitation infrastructure in Assam

Urban sanitation

Sewage systems in urban areas, particularly in Guwahati, are inadequate or underdeveloped. Much of the city depends on septic tanks and other localized systems.

The absence of a comprehensive sewage network means that a large portion of wastewater remains untreated.[9]

Faecal sludge management

With the introduction of faecal sludge treatment plants (FSTPs), some urban areas have begun to treat waste from septic tanks. Guwahati has one of Assam's first FSTPs that help in treating and disposing of faecal sludge in an environmentally safe manner

Storm-water drainage

Storm-water drainage systems are also poorly developed in many parts of Assam, contributing to flood-related sanitation issues.

Water supply and hygiene

The quality of water supply is a key factor in sanitation, and Assam faces significant challenges with groundwater contamination, especially in flood-prone areas. Arsenic contamination is an issue in some regions, and testing of water quality is inadequate in many rural areas.

Rural sanitation

Toilet construction

The Assam government, in partnership with the Swachh Bharat Mission (SBM), has made significant strides in constructing toilets across rural areas. However, the coverage is still not universal.

Lack of proper drainage systems

Many rural areas lack proper drainage systems, leading to stagnant wastewater and poor hygiene conditions.

Challenges due to flooding

Floods regularly disrupt sanitation infrastructure, damaging toilets and septic tanks, leading to contamination

Key challenges in Assam's sanitation system

Challenges in FSTP implementation

The development of FSTPs in Assam faces several challenges, including lack of awareness and need for behaviour change. There's still a gap in understanding the need for proper sanitation and the role of FSTPs, especially in rural areas. While national campaigns like Swachh Bharat Mission (SBM) have helped, there is still a cultural resistance to adopting hygienic sanitation practices, particularly in rural areas. There is also limited awareness about the dangers of open defecation and improper waste management. Infrastructural gaps also pose a challenge; many small towns and rural areas lack the infrastructure needed for regular sludge collection and transportation and finally treatment.[10]

Operational challenges

Running and maintaining FSTPs requires trained personnel and significant investment in technology, which can be challenging in resource-constrained regions.

Flood-prone areas

Assam's geography is heavily affected by the Brahmaputra River, and the state frequently experiences seasonal floods. This exacerbates sanitation problems as latrines and septic tanks overflow, contaminating water sources and spreading disease. Flooding can destroy sanitation infrastructure like toilets, septic tanks and latrines, further complicating the state's sanitation management efforts.

Urbanization and growing cities

Urbanization in cities like Guwahati, Dibrugarh and Jorhat has led to increased demand for sanitation infrastructure. Guwahati, the largest city in Assam, faces significant challenges in wastewater treatment, solid-waste management, and the proper disposal of faecal sludge.

Future outlook and opportunities

The Assam government is working to expand the use of FSTPs in smaller towns and rural areas, in alignment with national priorities under the **Atal Mission for Rejuvenation and Urban Transformation** (**AMRUT**) and the **Swachh**

Bharat Mission (**Urban**). With increasing urbanization and the move towards decentralized sanitation solutions, more cities and towns in Assam are likely to implement FSTPs to tackle the sanitation problem effectively.

While progress has been made, especially with the Swachh Bharat Mission, substantial gaps remain in terms of infrastructure, education, and behaviour change. The development of **faecal sludge treatment plants** (FSTPs) in Assam, such as the one in Guwahati, represents a localized approach to managing waste in areas lacking conventional sewage treatment systems. Scaling these solutions across the state, however, will require continued investment, infrastructure development and public awareness campaigns.

Sanitation in Assam is at the crossroads between significant progress and persistent challenges. While **rural sanitation** has improved under national schemes like SBM, **urban areas** face issues such as untreated wastewater, inadequate sewerage, and solid waste management. Expanding **decentralized sanitation solutions**, such as **FSTPs**, improving public awareness, and tackling **flood-related sanitation issues** will be critical for the state's sanitation future.

2. Objectives of the study

- To assess the treatment performance of the FSTPs plant in Assam;
- To verify if the quality of the treated effluent from an FSTP complies with the discharge standards prescribed by the Ministry of Environment, Forest & Climate Change (MoEF&CC) and the National Green Tribunal (NGT); and
- To evaluate the suitability of biosolids produced by the FSTPs plant for agricultural applications.

3. Significance of the study—Parameters monitored

This study is significant as it focuses on four key outcomes: first, it evaluates the performance of FSTPs in the state; second, it examines the potential for biosolid resource recovery from these plants.

Assessment of performance of FSTPs

Faecal sludge (FS) treatment plants are essential for removing contaminants from FS and sewage, thereby safeguarding both environmental and public health. Evaluating plant performance involves tracking key parameters such as chemical oxygen demand (COD), biological oxygen demand (BOD), and nutrients like nitrogen and phosphorus.

This assessment helps pinpoint areas needing improvement, allowing operators to enhance treatment efficiency, lower operational costs, and ensure compliance with regulatory standards. Regular monitoring of FSTP performance supports the effective and reliable treatment of FS, contributing to the protection of ecosystems and human health.

The following parameters are commonly used for plant performance monitoring:

Potential of hydrogen (pH): pH indicates the acidity (<7) or alkalinity (>7) of sludge, determined by the chemical activity of hydrogen ions in a solution. It strongly affects the chemical and biological processes that take place in wastewater and faecal sludge treatment plants, including precipitation, coagulation and disinfection.

Total solids: Solids refer to matter suspended or dissolved in water, wastewater or faecal sludge. Total solids (TS) is the term applied to the material residue left in the vessel after evaporation of a sample and its subsequent drying in an oven at a defined temperature. Total solids includes total suspended solids (TSS), which is the portion of total solids retained by a filter, and total dissolved solids (TDS), which is the portion that passes through the filter.

Chemical oxygen demand: Chemical oxygen demand (COD) is a measure of the oxygen equivalent of the total organic compounds that can be degraded by chemical processes. COD is often used as a measurement of pollutants in water, wastewater and aqueous hazardous wastes. The total COD in wastewater is critical for accurate modelling of biotransformation in wastewater treatment processes.

Biochemical oxygen demand: Biochemical oxygen demand (BOD) is a measure of oxygen used by microorganisms to degrade organic matter. The oxygen demand of the discharge water is an important parameter to be monitored, as discharge into the environment can deplete or decrease the oxygen content of waterbodies, resulting in the possible death of aquatic fauna. The oxygen demand is reduced through stabilization, and can be achieved by aerobic or anaerobic treatment.

Total Kjeldahl nitrogen: Nitrogen is an important parameter to consider in faecal sludge treatment, as the total nitrogen concentrations are typically quite high. Total Kjeldahl nitrogen (TKN) is the US EPA-approved parameter used to measure organic nitrogen and ammonia, which is the sum of organic nitrogen and ammoniacal nitrogen ([NH_3-N)/ammonium [NH_4^+N]). Excess nitrogen in water can cause eutrophication which promotes luxuriant growth of aquatic plants and algal blooms. This, in turn, reduces oxygen levels as microbes utilize oxygen to degrade large quantities of dead algae and plants and leads to the increase of toxic substances in water thereby making the water unsuitable for aquatic life. Hence, reducing nitrogen content in the effluent from FSTPs/ STPs is essential.

Total phosphates: Phosphate concentration must be measured to ensure effective FS/sewage treatment in treatment plants. The discharge from these plants in rivers and lakes leading to increased nutrient content in waterbodies is a significant concern. Excess nutrients, particularly phosphates, can stimulate unwanted algae growth, depleting oxygen levels in the water. This disruption in the ecological balance can cause long-term harm to the aquatic ecosystem. It is essential to implement measures to control nutrient runoff and promote sustainable water practices.

Faecal coliforms: Faecal sludge contains a large number of microorganisms, mainly originating from faeces. These microorganisms can be pathogenic, and exposure to untreated or partially treated faecal sludge creates a significant health risk to humans, either through direct contact or indirect exposure. Coliforms are a group of bacteria that are predominantly found in the gastrointestinal tract of warm-blooded animals including humans. Hence, coliform bacteria, including faecal coliforms (FC)/*Escherichia coli* (*E. coli*), are widely used as indicator organisms worldwide to test the sanitary quality (sewage contamination) of water and wastewater.

Assessment of biosolids' potential for resource recovery

Faecal sludge-derived biosolids are nutrient-rich organic materials, making them a valuable soil conditioner. Moreover, the rich organic content makes it a resourceful material for harnessing energy, thus making it suitable as a solid fuel. Biosolids can be utilized to improve the physical, chemical and biological properties of soils, especially degraded or disturbed ones. Organic materials in biosolids serve as a food source for microorganisms and are the major binding agents for aggregate formation and stabilization, thereby enhancing soil quality. The USEPA guidelines for the land application of biosolids states, 'The nutrients in the biosolids offer several advantages over those in inorganic fertilizers because they are organic and are released slowly to growing plants.'

Biosolids release nitrogen and other nutrients slowly over several growing seasons through soil bacteria by a process called decomposition. The primary nutrients in biosolids are in organic forms, not as soluble as those in chemical fertilizers, and released more slowly. This allows the nutrients to nourish plants over a longer period of time with higher use efficiency and a lower likelihood of polluting groundwater when the application rate is appropriate. Utilizing biosolids as soil amendments reduces the volume of waste that would otherwise require disposal in landfills, contributing to sustainable waste management practices. This practice promotes a closed-loop system, minimizing waste and promoting ecological balance.

The following parameters need to be analysed to check the usability of biosolids as an alternative to chemical fertilizers:

Potential of hydrogen: The p**otential of hydrogen** (**pH**) of biosolids can vary depending on several factors, including the origin of the biosolids (such as sewage/faecal sludge treatment plants), the treatment processes they undergo, and any amendments or treatments applied to them before use. Primary biosolids are the solids removed during the initial stages of wastewater treatment. They typically have a pH ranging from neutral to slightly alkaline (pH 7–8.5). Secondary biosolids undergo further treatment processes (such as biological treatment) and can have varying pH levels depending on the specific treatment methods used.

Electrical conductivity: Electrical conductivity (EC) is an important parameter in soil science, measuring the dissolved salts in the soil, fertilizers and biosolids. It is typically measured in deciSiemens per metre (dS/m) and indicates the ability of the soil to conduct electricity.

High EC values indicate high levels of dissolved salts, such as sodium, calcium and magnesium, which can affect soil structure, fertility and plant growth. Understanding EC is crucial for farmers and researchers to optimize fertilizer, manure and biosolids application rates, ensuring efficient and effective nutrient delivery to crops.

Moisture content: Moisture content or water content refers to the quantity of water present in a material, which is crucial in various fields. Accurate moisture content analysis helps in implementing efficient strategies for dryness control, quality assurance, and environmental sustainability. Moisture content of biosolids is an important parameter as high moisture content promotes microbial growth including pathogens.

Carbon-to-nitrogen ratio: The carbon-to-nitrogen (C:N) ratio is a crucial aspect in various biological and ecological processes. In soil science, it determines the nutrient availability for plants and microorganisms. A balanced C:N ratio from 15:1 to 20:1 enables optimal decomposition, as bacteria and fungi work together to break down organic matter. However, an imbalance can lead to inefficient decomposition and potential environmental issues. These two elements are essential for microbial growth and activity. Nitrogen, in particular, supports the synthesis of important biological compounds, such as amino acids, proteins and nucleic acids, while carbon serves as a structural component and energy source for microbes. Hence, the organic carbon and nitrogen has to be determined.[11]

Heavy metals: Biosolids can contain heavy metals, which are elements with high atomic weights and densities. These metals can come from various sources such as industrial processes, wastewater, disposing chemicals in septic tanks and even natural geological deposits. When organic matter is processed in wastewater treatment plants, heavy metals can accumulate in the resulting biosolids. Heavy metals in biosolids can pose both challenges and potential benefits, depending on their concentrations and management practices. They are not biodegradable and can persist in the environment. If biosolids containing elevated levels of heavy metals are applied to land, there is a risk of these metals leaching into the groundwater or adversely affect plants. This can potentially lead to contamination of crops and affect ecosystems.

Faecal coliform and *E. coli*: Faecal sludge (FS) contains an enormous diversity of pathogenic microorganisms that fall into four major groups—pathogenic bacteria, viruses, parasitic protozoa and helminths. These pathogens occur in raw FS and septage, and in liquid effluent and biosolids generated from FSTPs which require appropriate treatment before they are disposed of into the environment or before they are reused, particularly for agricultural purposes. When humans come in contact with water or food contaminated with improperly treated faecal sludge and its derivatives, the pathogenic organisms present in them can cause several diseases like diarrhoea, hepatitis and different types of fever, which are a public health concern globally.

Coliforms are a group of bacteria that are predominantly found in the gastrointestinal tract of warm-blooded animals, including humans, apart from a minor portion in soils and on plant surfaces. Faecal coliforms (FC), also known as thermos-tolerant coliforms, are a group of coliform bacteria that are exclusively found in the intestines and faeces of humans and other warm-blooded mammals and hence their presence specifically indicates faecal contamination. The predominant faecal coliform is *Escherichia coli* (*E. coli*). Hence, the coliform bacteria, FC/*E. coli* must be tested in biosolids.[12]

***Salmonella*:** *Salmonella* is a ubiquitous and hardy bacterium that can survive several weeks in a dry environment, several months in water and are frequently found in sewage. They actively grow within a wide temperature range (10–54°C). *Salmonella* spp. are resistant microorganisms that readily adapt to extreme and hostile environmental conditions. There has been a global increase in the number of outbreaks involving *Salmonella* spp. related to the fresh-cut produce industry and the consumption of fresh-cut vegetables. Such outbreaks are caused by a few *Salmonella* serotypes that have the ability to resist to environmental stresses, remaining viable for extended periods on field crops. It has been observed that *Salmonella* can regrow in the soil and remain viable for over two years after soil inoculation. These characteristics make it the indicator of choice for monitoring the effectiveness of pathogen reduction in biosolids. Hence, the overall danger posed by *Salmonella* spp. on public health mandates its monitoring and control in FS-derived biosolids, which is reused especially for agricultural purposes.[13]

Helminth eggs: Helminth eggs are the primary cause of helminthiases, a group of worm diseases that affect people worldwide. Despite being part of multicellular animals, helminth eggs are incredibly small, measuring between 20–80 micrometres in diameter. These microscopic eggs are often found in wastewater, sludge and excreta, and can be present in varying amounts, especially in areas with inadequate sanitation and waste management.

Helminth eggs are the infectious agents of various intestinal worms like hookworm, roundworm and whipworm, which will germinate into larval form inside the human host and cause diseases. Hence, these eggs can pose a risk of infection if ingested, leading to several diseases of intestinal parasites including ascariasis, schistosomiasis etc. Therefore, proper treatment and disposal of faecal sludge are crucial to prevent the spread of infections and maintain public health.[14, 15]

4. Sample collection and testing parameters

Environment Monitoring Laboratory (EML) scientists visited each site and collected, properly preserved and transported the samples at the earliest to the lab by adopting standard protocols for sampling, preservation and transportation. Personal protective equipment (PPE) like overalls, gloves, face masks, protective eyewear and hand sanitizers were included in the sampling kit and used accordingly during the sampling process. The sampling bottles were properly cleaned, sterilized and attached with appropriate labelling stickers. The sampling location, along with date and time, were accurately stated on each bottle after sampling. The samples were preserved with frozen ice-gel packs and transported in leak-proof iceboxes.

Sampling interval and duration of the visit

Sampling was done at the selected sites every alternate month in three replicates. The sampling process from each FSTP was carried out for a total duration of five months, i.e. February–June 2025.

Faecal sludge, inlet and outlet collection and testing

1. Raw faecal sludge samples were collected from the tanker when the tanker unloaded the faecal sludge into the receiving chamber of FSTPs.
2. Around 1 litre of the inlet and outlet of FSTPs was collected to assess the

CREDIT: CSE, LAB TEAM

Sample collection from the treatment plants performance of individual FSTPs. Inlet refers to the leachate entering the treatment modules after the solid–liquid separation process and outlet refers to the final discharge water emerging from the final stage of treatment process in the FSTPs. Liquid samples were collected in sterile polypropylene bottles, capped and preserved with ice packs. Biosolid samples were collected in sterile zip-lock bottles. They were transported to the laboratory thereafter in the shortest possible time for further analysis.

Testing parameters and methods

Physicochemical parameters such as pH, TS, TSS, TDS, COD, BOD, TKN, AN, TP and microbial parameter FC were analysed for the collected samples using standard methods (see *Table 1: Physicochemical parameters and standard methods used for testing*).

Table 1: Physicochemical parameters and standard methods used for testing

Parameters	Standard methods
pH	APHA 4500-H^+B, 24th Ed., 2023[16]
Total solids (TS)	APHA 2540-B, 24th Ed., 2023
Total suspended solids (TSS)	APHA 2540-D, 24th Ed., 2023
Total dissolved solids (TDS)	APHA 2540-C, 24th Ed., 2023
Chemical oxygen demand (COD)	APHA 5220-D, 24th Ed., 2023
Biological oxygen demand (BOD)	Automated BOD Analyser and APHA 5210-B, 24th Ed, 2023
Total Kjeldahl nitrogen (TKN)	APHA 4500-Norg C, 24th Ed., 2023
Ammoniacal nitrogen (TN)	APHA 4500-NH_3 C, 24th Ed., 2023
Total phosphorus (TP)	APHA 4500-P E, 24th Ed., 2023
Faecal coliform (FC)	APHA 9221 E, 24th Ed., 2023; USDA, MLG Appendix 2.05

Source: CSE

Biosolids

Biosolids (dried faecal sludge) generated in the treatment plants was collected from the FSTPs and STP co-treatment plants. Around 1 kg of sample was collected in plastic bags, sealed properly and transported to the lab and stored in a refrigerator at 4°C until analysis.

Testing parameters and methods

Physicochemical parameters such as pH, electrical conductivity, moisture content, carbon and nitrogen content, heavy metals were determined and microbiological

CREDIT: CSE, LAB TEAM

Collection of biosolids from drying bed and storage area

parameters, including faecal coliforms, *E. coli*, *Salmonella* and helminth eggs, were enumerated. In addition, calorific value was determined to assess the fuel potential (see *Table 2: Biosolid characterization methods and equipment used*).

Table 2: Biosolid characterization methods and equipment used

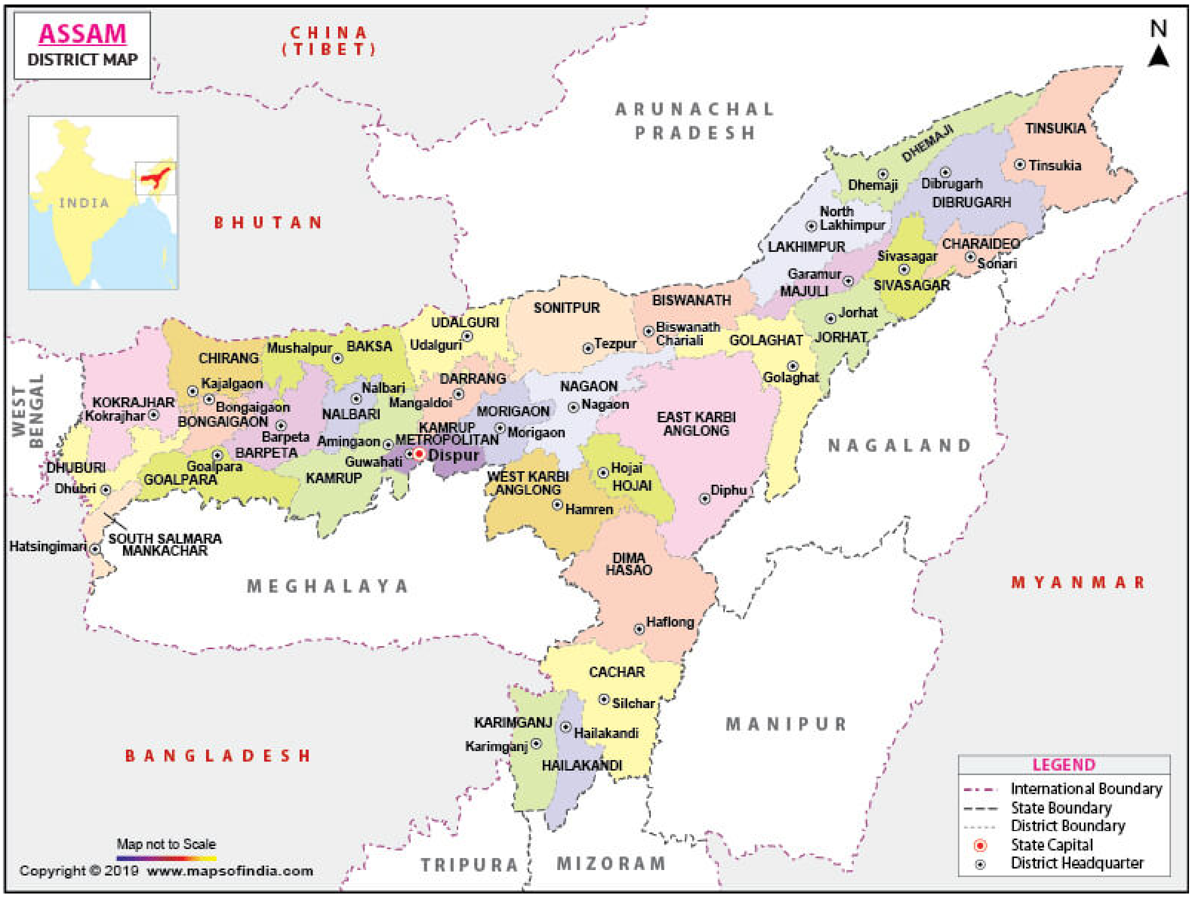
Parameters	Standard methods/equipment used
pH	APHA 4500-H^+B, 24^{th} Ed, 2023
Electrical conductivity (dS/m)	Conductivity meter (Cyberscan 200)
Carbon, nitrogen	CHN elemental analyser (LECO, USA, 828 series)
Heavy metals	ICP-OES (Perkin Elmer Avio® 200)
Faecal coliforms [17]	USEPA, Method 1680, 2014; USDA, MLG Appendix 2.05, 2014
E. coli	APHA 9221 B, 9221 F, 24^{th} Ed., 2023; USDA, MLG Appendix 2.05, 2014
Salmonella	Pour plate method using HiCrome *Salmonella* agar
Helminth eggs	Ambic-$ZnSO_4$ method[18]

Source: CSE

5. Faecal sludge treatment plants in Assam

Seven faecal sludge treatment plants were monitored in Assam in 2025 (see *Table 3: List of FSTPs systems evaluated in the current study*). This section provides detailed descriptions of the technologies used in each of the selected treatment plants.

Locations of FSTPs plants monitored in the present study



Source: https://compass.rauias.com/gk/districts-in-assam/

Table 3: List of FSTPs systems evaluated in the current study

S. no.	Location	Commissioned year	Operator	Design capacity	Capacity utilization*	Solid–liquid separation	Treatment technology	Tertiary treatment	Treated water reuse
1	Mariani	2024	Resolin Technology	5 KLD	20%	Sludge drying bed	MBBR	Chlorination, MSF, ACF followed by polishing pond	Gardening
2	Golaghat	2024	Greentech Enterprise	10 KLD	50%	Sludge drying bed	MBBR	Chlorination, PSF, MF	Gardening
3	North Lakhimpur	2024	Resolin Technology	10 KLD	20%	Sludge drying bed	MBBR	Chlorination, MSF, ACF followed by polishing pond	Gardening
4	Tinsukia	2024	Resolin Technology	20 KLD	15%	Sludge drying bed	MBBR	Chlorination, MSF, ACF followed by polishing pond	Gardening
5	Guwahati	2024	Banka Bioloo Ltd.	20 KLD	100%	Geobag	Geotube	Chlorination, SF, ACF	Gardening
6	Goalpara	2023	Environmental Solution Pvt. Ltd/TBF	7 KLD	60%	ABR & TBF	Tiger Bio Filter	Chlorination, PSF, ACF	Gardening
7	Kokrajhar	2024	Greentech Enterprise	10 KLD	10%	Sludge drying bed	MBBR	Chlorination, PSF, ACF	Gardening
ABR—Anaerobic baffled reactor; ACF—Activated carbon filtration; TBF—Tiger Bio Filter; KLD—Kilolitres per day; MBBR—Moving bed biofilm reactor; MSF—Multilayered sand filter; PSF—Pressure sand filtration; MF—Microfiltration; SF—Sand filter									
* Capacity utilization calculated based on the information collected during the study.									

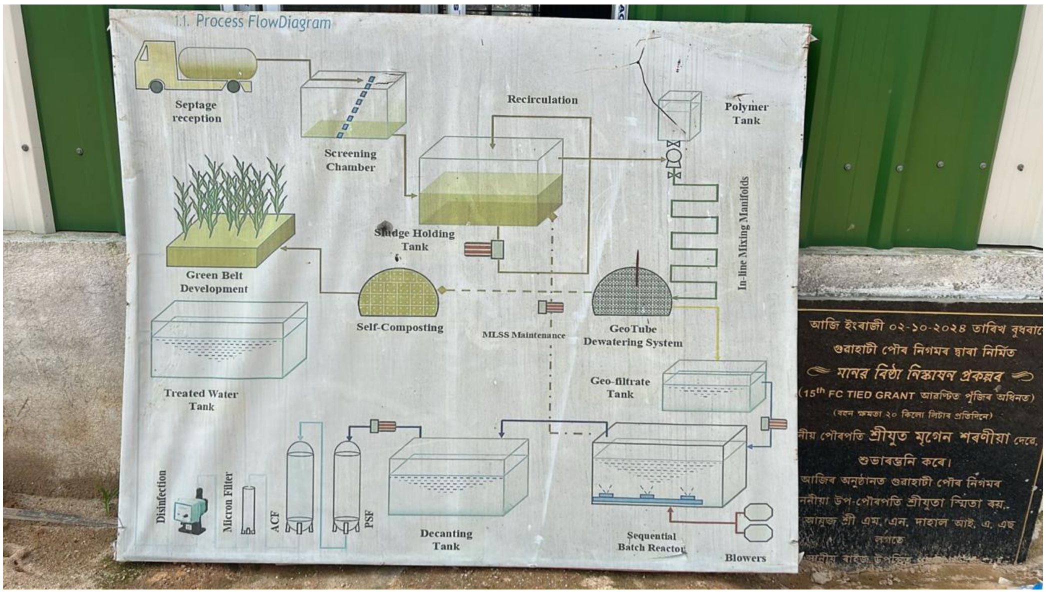
Source: CSE

FSTPs evaluated in the study

Guwahati

Guwahati is a sprawling city beside the Brahmaputra River in the northeast Indian state of Assam. It is known for holy sites such as the hilltop Kamakhya Temple and Brahmaputra River. Guwahati lies between 26° 10′ North latitude and 91° 44′ East longitude.[19]

Guwahati's first faecal sludge treatment plant (FSTP) was installed by Banka Bioloo Ltd in December 2024 and has been operational from July 2024 to address sanitation needs, especially in areas without centralized sewerage. This initiative is part of the city's larger smart city goals and infrastructure development projects, which include improving sanitation and solid waste management in the long term. The plant, with a capacity of 20 KLD, is fully operational and receives faecal sludge (FS) on a regular basis. Everyday seven to eight tankers, with an average capacity of 2 KL, empty faecal sludge into the receiving chamber of the plant. The faecal sludge received in the plant is mostly collected from public toilets, community toilets and household toilets.[20]



Location and process flow diagram; Geotube Technology, Guwahati FSTP

Photo credit: CSE

From the tanker, the faecal sludge is discharged into the screen chamber, where non-faecal matter is removed. After screening, the liquid sludge is transferred to the sludge holding tank, where it is mixed with recirculated sludge. Subsequently, a polymer is added to the liquid sludge, and the mixture is pumped into a geotube. Within the geotube, solid–liquid separation occurs. The liquid fraction proceeds for further treatment through the SBR (Sequential Batch Reactor) and tertiary treatment, while the solid fraction is digested and dried in the geobag. The effluent from the geobag is then pumped through a filtration system, including activated carbon and pressure sand filters. The filtered water is disinfected using chlorination or irradiation. Finally, the treated water is stored in a collection tank and reused within the FSTP premises, primarily for gardening purposes.

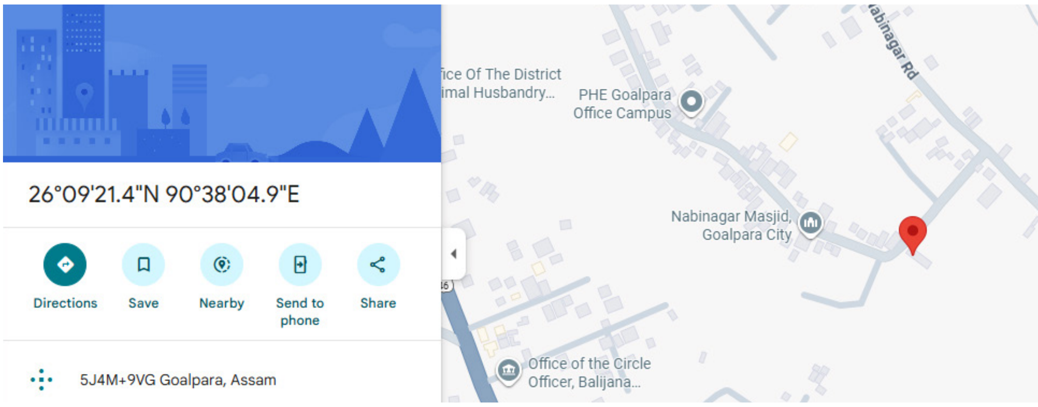
Goalpara

Goalpara is a city and the administrative headquarters of the Goalpara district in Assam. It is located on the banks of the Brahmaputra River, approximately 134 kilometres west of Guwahati. The city stands at an average elevation of 35 metres (114 feet) above sea level and is positioned at 26.0873° N latitude and 90.6394° E longitude.[21]

The Goalpara FSTP, with a treatment capacity of 7 KLD, was constructed in 2023 under the Goalpara Municipal Board by Environmental Solution Pvt. Ltd/ Tiger Bio-Filters (TBF) to improve local sanitation infrastructure. The plant is fully operational and regularly receives faecal sludge (FS) for treatment. On average, one tanker with a capacity of about 4 KL discharges FS into the plant's receiving chamber each day. The sludge received at the facility primarily originates from public toilets, community toilets and household septic tanks.

From the tanker, the faecal sludge is discharged into the screen chamber, where non-faecal materials are removed. The screened liquid sludge is then transferred to the sludge storage tank for stabilization before being directed to the Anaerobic Baffled Reactor (ABR) chamber. Subsequently, the sludge flows into the Tiger Biofilter-I, where biological digestion takes place, and then moves to the Tiger Biofilter-II for further treatment. The liquid fraction from this stage is conveyed to the tertiary treatment system. The effluent from the Tiger Biofilter-II is pumped through a filtration system consisting of pressure sand and activated carbon filters. The filtered water is then disinfected through chlorination. Finally, the treated water is stored in a collection tank and reused within the FSTP premises, mainly for gardening purposes.

Location and process flow diagram, TBF Technology, Goalpara FSTP



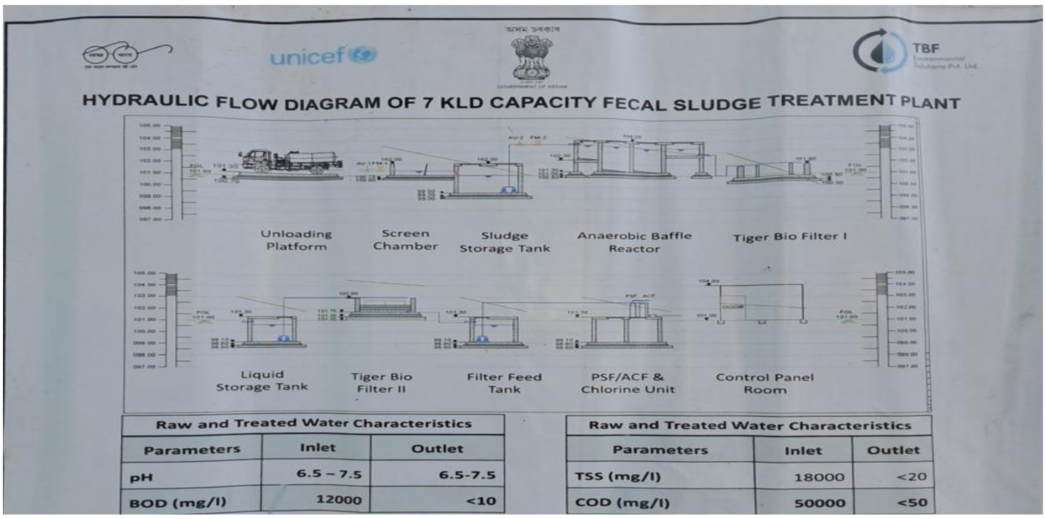


PHOTO CREDIT: CSE

Kokrajhar

Kokrajhar is the capital city of the Bodoland Territorial Region (BTR), an autonomous territory in the state of Assam, located in northeastern India. From the early 17th century until 1865, the area now known as Kokrajhar district was under the control of the Kingdom of Bhutan. Following the Duar Wars in 1865, the British ended Bhutanese rule, and in 1949, the region was merged into the undivided Goalpara district of the Indian Union. Kokrajhar is situated at 26.4° N latitude and 90.27° E longitude, with an average elevation of 38 metres (124 feet) above sea level.[22]

In August 2024, a 10-KLD FSTP employing Moving Bed Biofilm Reactor (MBBR) technology was inaugurated in Kokrajhar. This facility, the first of its kind in the Bodoland Territorial Region (BTR), was developed with technical support from UNICEF and constructed by Green Tech Enterprise to strengthen local sanitation infrastructure. The plant is now operational and receives faecal sludge for treatment on a regular basis. On average, one tanker with a capacity of approximately 1 KL discharges faecal sludge into the plant's receiving chamber each day. The collected sludge primarily originates from public toilets, community toilets, and household septic tanks.

From the tanker, faecal sludge is discharged into the screen chamber, where non-faecal materials are removed. The screened liquid sludge is then directed to the sludge collection tank for stabilization. Subsequently, solid–liquid separation takes place, with the solid fraction transferred to the sludge drying bed for dewatering, while the liquid fraction flows into the MBBR tank for biological treatment. The treated liquid is then conveyed to the filter feed tank and pumped through a filtration system comprising a pressure sand filter and a microfiltration

Location and process flow diagram, Kokrajhar FSTP

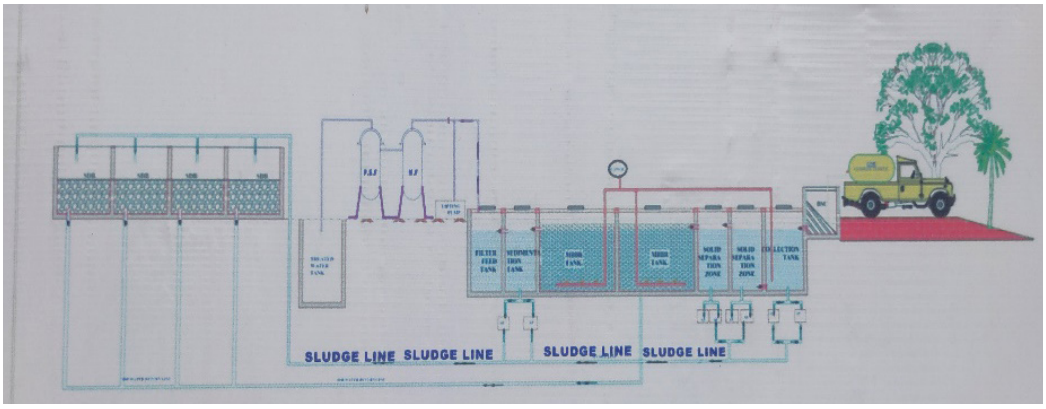


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PHOTO CREDIT: CSE

unit and chlorination. Finally, the treated water is stored in a collection tank and reused within the FSTP premises, primarily for gardening and other non-potable purposes.

Golaghat

Golaghat, one of the largest subdivisions in the Indian state of Assam, was elevated to a full-fledged district headquarter on October 5, 1987. It is a city and municipality that serves as the administrative centre of Golaghat district and forms a twin city with Jorhat, located about 55 kilometres away. As one of the oldest urban settlements in Assam, Golaghat was recently shortlisted for the Smart Cities nominations, along with Guwahati and four other major urban centres of the state, though it did not advance to the final selection. The Dhansiri River, a tributary of the Brahmaputra, flows through Golaghat and serves as the primary water source for the city's residents. Geographically, Golaghat is situated at 26.52°

Location and process flow diagram, Golaghat FSTP

PHOTO CREDIT: CSE

N latitude and 93.97° E longitude, with an average elevation of 95 metres (312 feet) above sea level.[23]

In November 2024, a 10-KLD faecal sludge treatment plant (FSTP) utilizing Moving Bed Biofilm Reactor (MBBR) technology was inaugurated in Golaghat. Developed with technical support from UNICEF and constructed by Green Tech Enterprise, the facility aims to enhance local sanitation infrastructure. The plant operates on the same technology as the Kokrajhar FSTP and is now fully functional, receiving faecal sludge (FS) for treatment on a regular basis. On average, one tanker with a capacity of about 2.5 KL discharges faecal sludge into the plant's receiving chamber each day. The faecal sludge primarily originates from public toilets, community toilets and household septic tanks.

From the tanker, the faecal sludge is discharged into the screen chamber, where non-faecal materials are removed. The screened liquid sludge is then directed to the sludge collection tank for stabilization. Subsequently, solid–liquid separation takes place, with the solid fraction transferred to the sludge drying bed for dewatering, while the liquid fraction flows into the MBBR tank for biological treatment. The treated liquid is then conveyed to the filter feed tank and pumped through a filtration system comprising a pressure sand filter and a microfiltration unit and chlorination. Finally, the treated water is stored in a collection tank and reused within the FSTP premises, primarily for gardening and other non-potable purposes.

Mariani

Mariani is a suburban town located near Jorhat, approximately 17.5 kilometres from the Jorhat Town railway station. Situated along the Assam–Nagaland border, Mariani is renowned for the Gibbon Wildlife Sanctuary, located about 5 kilometres away on the road to Nakachari.

The town is surrounded by some of the largest tea estates in India, contributing to its scenic beauty and economic significance. Mariani has a cosmopolitan character, with diverse communities speaking various languages and coexisting harmoniously for generations. Geographically, it lies at 26.67° N latitude and 94.33° E longitude, with an average elevation of 155 metres (509 feet) above sea level. According to the 2001 Census of India, Mariani had a population of 23,065, comprising 54 per cent males and 46 per cent females, with about 12 per cent of the population below six years of age.[24]

In July 2024, a 5-KLD faecal sludge treatment plant (FSTP) using Moving Bed Biofilm Reactor (MBBR) technology was inaugurated in Mariani. Developed and constructed by Resolin Technologies, the facility was established to strengthen local sanitation infrastructure. The plant is now fully operational and regularly receives faecal sludge (FS) for treatment. On average, seven to ten tankers, each with a capacity of approximately 3 KL, deliver FS to the plant every month. The collected sludge primarily comes from public toilets, community toilets and household septic tanks.

Location and process flow diagram, Mariani FSTP

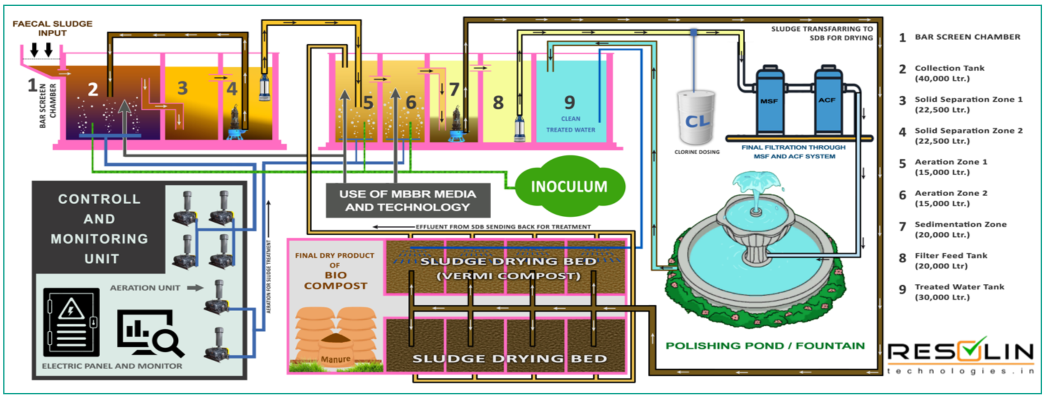


Photo credit: CSE

From the tanker, the faecal sludge (FS) is discharged into the screen chamber, where non-faecal materials are removed. The screened liquid sludge is then directed to the sludge collection tank for stabilization, where MBBR media and inoculum are added to promote biological activity. Solid–liquid separation takes place through sedimentation, allowing the supernatant to move to the next stage of treatment in the MBBR tank. The solid fraction is transferred to the sludge drying bed, while the liquid fraction percolating from the drying bed is recirculated to the MBBR chamber for further treatment. The treated water subsequently undergoes tertiary treatment processes, including chlorination, multilayer sand filtration and activated carbon filtration, before being stored in a polishing pond and clean water tank. The reclaimed water is reused within the FSTP premises, mainly for gardening and other non-potable applications. The dried solids are utilized for vermicomposting and ultimately converted into bio-compost or manure.

North Lakhimpur

North Lakhimpur is a city and municipal board located in the Lakhimpur district of Assam, India, approximately 394 kilometres northeast of Guwahati. It serves as the district headquarters and is also the administrative centre of the North Lakhimpur subdivision. Geographically, the city lies at 27°13’60” N latitude and 94°7’0” E longitude. Often referred to as the Gateway to Arunachal, North Lakhimpur is well connected by air, road and rail networks.[25]

Location and process flow diagram, North Lakhimpur FSTP

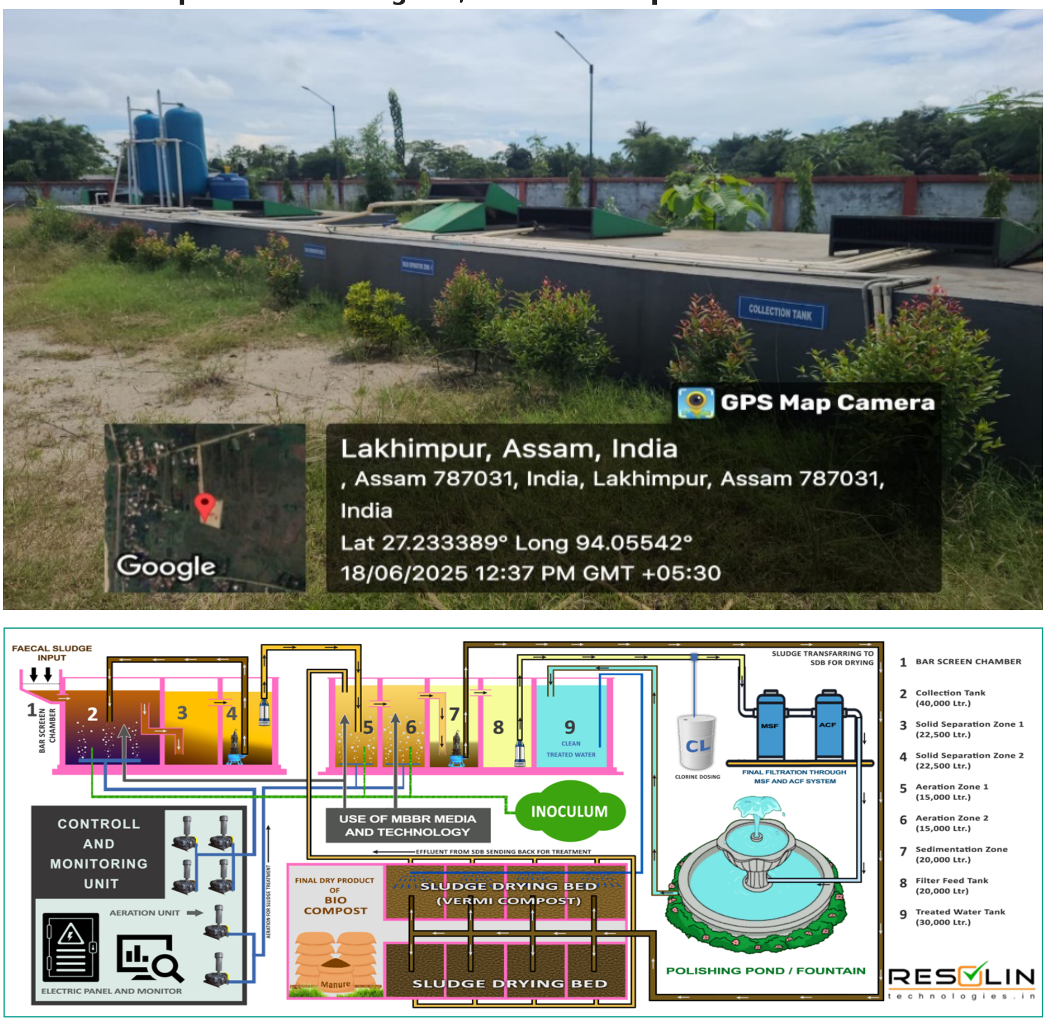


PHOTO CREDIT: CSE

In August 2024, a 10-KLD faecal sludge treatment plant (FSTP) utilizing Moving Bed Biofilm Reactor (MBBR) technology was inaugurated by the North Lakhimpur Municipal Board in Bogolijan village. Developed with technical support from UNICEF and constructed by Resolin Technology, the facility was established to enhance local sanitation infrastructure. The plant, which operates on the same technology as the Mariani FSTP, is now fully functional. On average, one to two tankers with a capacity of around 4 KL each discharge faecal sludge (FS) into the plant's receiving chamber every week. The sludge primarily originates from public toilets, community toilets and household septic tanks.

The treatment process is identical to that of the **Mariani FSTP**; faecal sludge (FS) from the tanker is first discharged into the screen chamber, where non-faecal materials are removed. The screened liquid sludge is then transferred to the sludge collection tank for stabilization, where MBBR media and inoculum are added to facilitate biological activity. Solid–liquid separation occurs through sedimentation, allowing the supernatant to proceed to the MBBR tank for further treatment. The solid fraction is directed to the sludge drying bed, while the liquid fraction percolating from the drying bed is recirculated back to the MBBR chamber. The treated water then undergoes tertiary treatment processes, including chlorination, multilayer sand filtration and activated carbon filtration, before being stored in a polishing pond and clean water tank. The reclaimed water is reused within the FSTP premises, primarily for gardening and other non-potable purposes, while the dried solids are used for vermicomposting and later converted into bio-compost or manure.

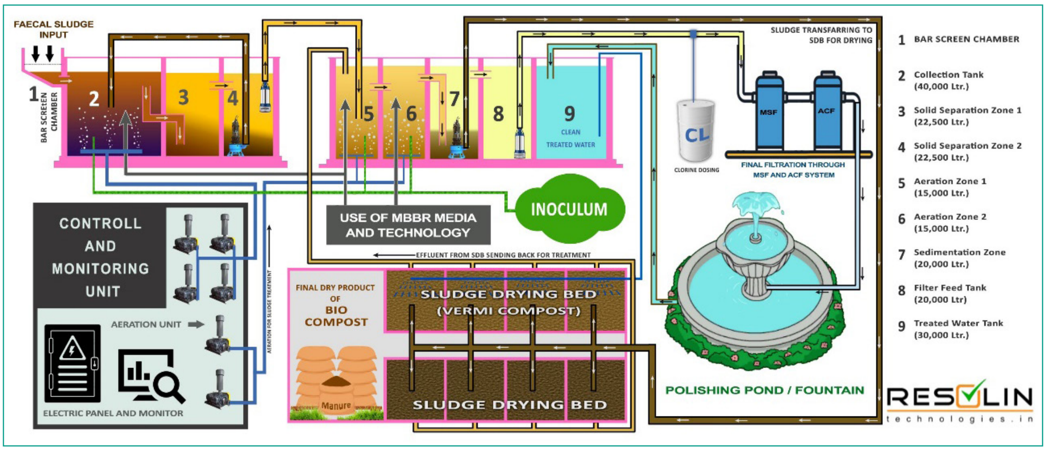
Tinsukia

Tinsukia is an industrial city situated 480 kilometres north-east of Guwahati and 84 kilometres from the border with Arunachal Pradesh. Tinsukia is located at 27.5° N 95.37° E. It has an average elevation of 116 metres (380 feet).[26]

It is the administrative headquarters of Tinsukia district of Assam, India. Tinsukia serves as the headquarters of the Moran Autonomous Council, which is the governing council of the Morans, an indigenous tribal group found predominantly in Tinsukia district and neighbouring Arunachal Pradesh).

In March 2024, the Tinsukia Municipal Board inaugurated a 20-KLD faecal sludge treatment plant (FSTP) at Tinrai Shivpur. Developed by Resolin Technologies with technical support from UNICEF, the facility also features a sanitation park and is designed to ensure the safe management of faecal sludge. The treated

Location and process flow diagram, Tinsukia FSTP



CREDIT: CSE

byproducts are intended for reuse as compost or soil conditioners in agriculture. The plant operates on the same technology as the Mariani and North Lakhimpur FSTPs and is now fully operational. On average, two tankers with a capacity of approximately 4 KL each discharge faecal sludge (FS) into the plant's receiving chamber daily. The sludge primarily originates from public toilets, community toilets and household septic tanks.

The treatment process is similar to that of the **Mariani** and **North Lakhimpur FSTPs**. Faecal sludge from the tanker is first discharged into the screen chamber, where non-faecal materials are removed. The screened liquid sludge is then conveyed to the sludge collection tank for stabilization, where MBBR media and inoculum are added to promote biological activity. Solid–liquid separation occurs through sedimentation, with the supernatant flowing to the MBBR tank for further treatment. The solid fraction is transferred to the sludge drying bed, while the liquid fraction percolating from the drying bed is recirculated to the MBBR chamber. The treated water subsequently undergoes tertiary treatment processes, including chlorination, multilayer sand filtration and activated carbon filtration before being stored in a polishing pond and clean water tank. The reclaimed water is reused within the FSTP premises, primarily for gardening and other non-potable applications, while the dried solids are used for vermicomposting and eventually converted into bio-compost or manure.

6. The results of the study

Faecal sludge samples collected from all FSTPs were analysed for ten parameters. In this section, the term 'per cent removal' refers to the reduction observed between the inlet and the final outlet. Similarly, biosolid samples from the FSTPs were examined for ten parameters. The figures presented in this section depict the average data collected over a three-month period.

The performance evaluation of FSTPs follows the regulatory standards prescribed by the MoEFCC standard 2017 for STP discharge. The physicochemical properties and heavy metal concentrations in biosolids were compared with the Fertilizer Control Order (2023) to assess their nutrient value for agricultural use. To determine pathogen levels in biosolids, the regulatory limits established by the United States Environmental Protection Agency (US EPA) and World Health Organization (WHO) for Class A biosolids were applied.

Wastewater and biosolids standard for evaluation of FSTPs

Table 4: MoEFCC Standard for STP Effluent Discharge, 2017

S. no.	Parameters	Metro cities*	Other areas
1.	pH	5.5–9.0	5.5–9.0
2.	Biochemical oxygen demand	20	30
3.	Total suspended solids (TSS)	<50	<100
4.	Chemical oxygen demand (COD)	NA	NA
5.	Total nitrogen	NA	NA
6.	Total phosphorus	NA	NA
7.	Faecal coliform (FC) most probable number per 100 mililitre, MPN/100 ml	<1,000	<1,000

Notes:

- Metro cities:* All state capitals except Assam and other Northeastern states and UTs such as Andaman and Lakshadweep.
- All value in mg/l except for pH and faecal coliform.
- These standards will be applicable for discharge into waterbodies as well as for land disposal/applications.

Table 5: Fertilizer Control Order standards for organic manure, 2023

S. no	Parameters	Standard
1.	Moisture per cent by weight, maximum	25
2.	Particle size	Minimum 90% material Should pass through 4.0 mm IS sieve
3.	Bulk density (g/cm^3)	<1.0
4.	Total organic carbon per cent by weight, minimum	14
5.	Total nitrogen (as N) per cent by weight, minimum	0.5
6.	Total phosphates (as P_2O_5) per cent by weight, minimum	0.5
7.	Total potash (as K_2O) per cent by weight, minimum	0.5
8.	NPK nutrients—Total N, P_2O_5 and K_2O nutrient should not be less than 3%	
9.	C:N ratio	<20
10.	pH	6.0–8.5
11	Pathogen	Nil
12	Heavy metal content, (as mg/kg), maximum	
	Arsenic (as As_2O_3)	10
	Cadmium (as Cd)	5
	Chromium (as Cr)	50
	Copper (as Cu)	300
	Mercury (as Hg)	0.15
	Nickel (as Ni)	50
	Lead (as Pb)	100
	Zinc (as Zn)	1000

* The parameter electrical conductivity and its limit is not mentioned in FCO 2023 for organic manure; however, it is mentioned in FCO 2013 for organic manure as <4 dS/m.

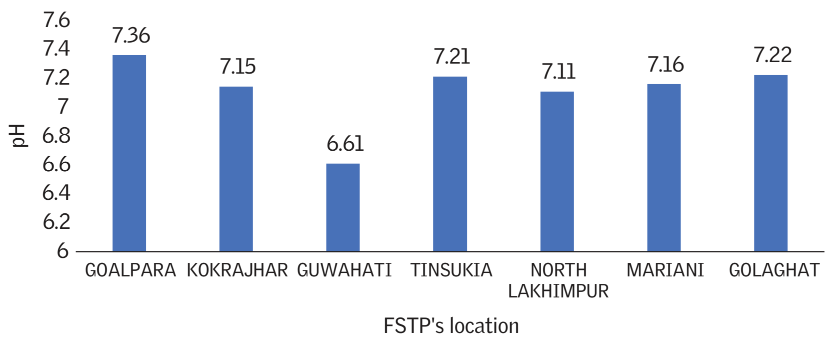
Table 6: Global standards for pathogens in biosolids

S. no.	Microorganism	Standard	Regulatory body	Remarks
1	Faecal coliform	1,000 MPN/dry gram solids	USEPA	Pathogen Class A (Ceiling Concentration Limits for All Biosolids Applied to Land). For all biosolids applied to all land types: agricultural land, forests, reclamation sites, and lawns and home gardens
2	*E. coli*	1,000/dry gram solids	WHO (2006)	Faecal sludge reuse in agriculture
3	*Salmonella*	3 MPN per 4 grams of dry solids	USEPA	Pathogen Class A (Ceiling Concentration Limits for All Biosolids Applied to Land) For all biosolids applied to all land types: agricultural land, forests, reclamation sites and lawns and home gardens
4	Helminth eggs	< 1 egg/4 gram dry solids	USEPA	Faecal sludge reuse in agriculture

Characterization of faecal sludge from FSTPs

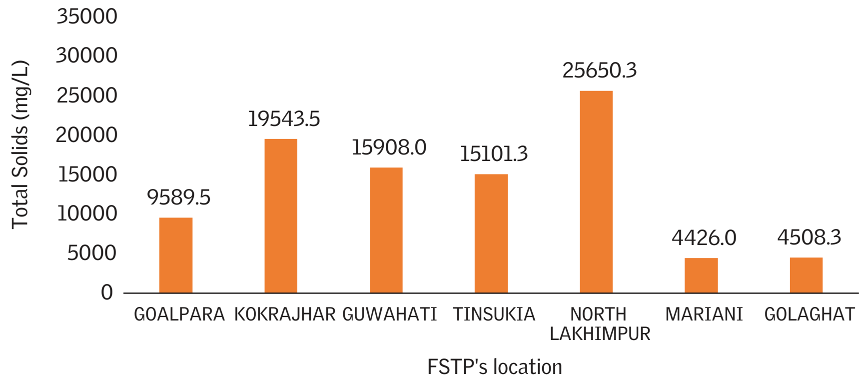
Faecal sludge (FS) samples collected from discharge vehicles at various FSTPs in Assam were analysed for multiple parameters, with key findings summarized in the following. The data represent average values of three replicates of FS samples collected in February–June 2024. The pH of FS ranged from 6.61 in Guwahati to 7.36 in Goalpara. The highest total solids (TS) and total suspended solids (TSS) were recorded at the North Lakhimpur FSTP, while the lowest TS and TSS were observed at Mariani and Golaghat FSTPs, respectively. Chemical oxygen demand (COD) values varied in the range of 26,050–68,025 mg/L, and biochemical oxygen demand (BOD) was in the range of 390–4,960 mg/L. The lowest COD and BOD were observed in Golaghat, while the highest were recorded at the Kokrajhar FSTP. Total phosphorus (TP) concentrations ranged from 36.6 mg/L in Goalpara to 135.0 mg/L in Kokrajhar, and total Kjeldahl nitrogen (TKN) values varied from 691 mg/L in Goalpara to 1,740 mg/L in Kokrajhar. Faecal coliform counts were found in the range of 50,430 (log 4.70) to 116,150,000 MPN/100 mL (log 8.07).

Graph 1: pH value of faecal sludge



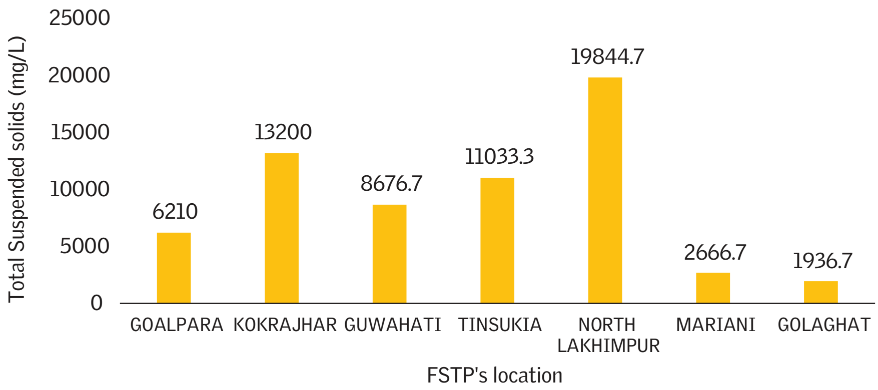
Source: CSE

Graph 2: Total solids in the faecal sludge



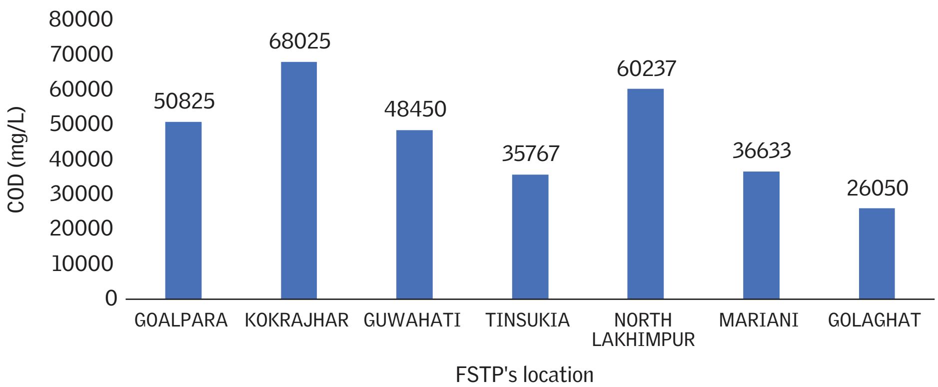
Source: CSE

Graph 3: Total suspended solids in the faecal sludge



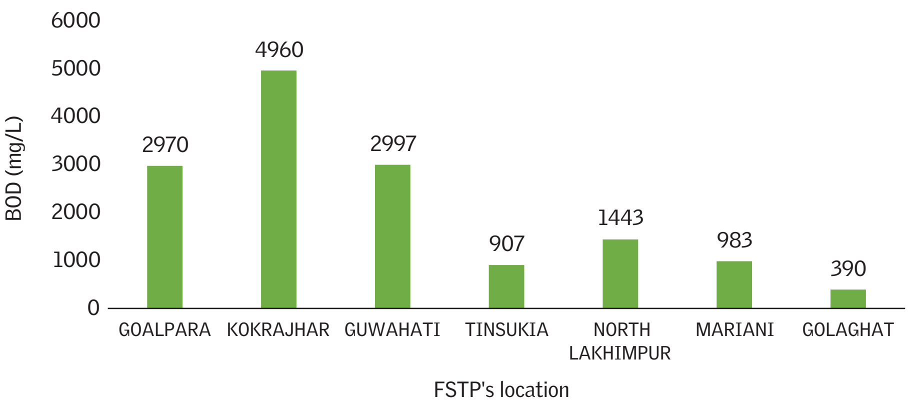
Source: CSE

Graph 4: Chemical oxygen demand (COD) of the faecal sludge



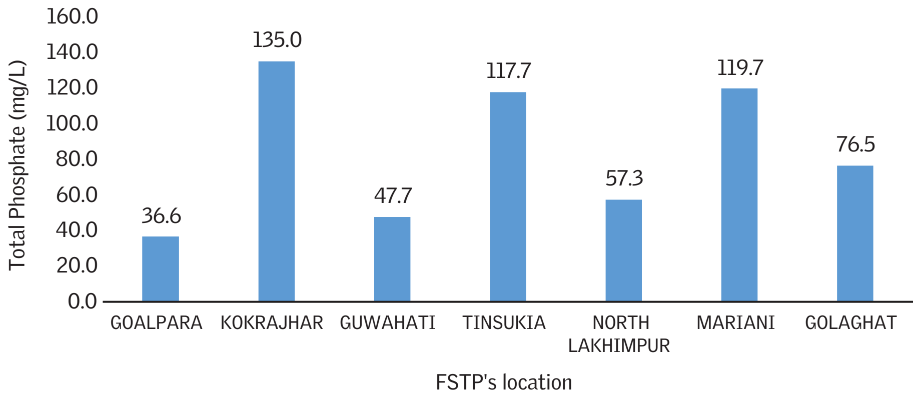
Source: CSE

Graph 5: Biochemical oxygen demand (BOD) of the faecal sludge



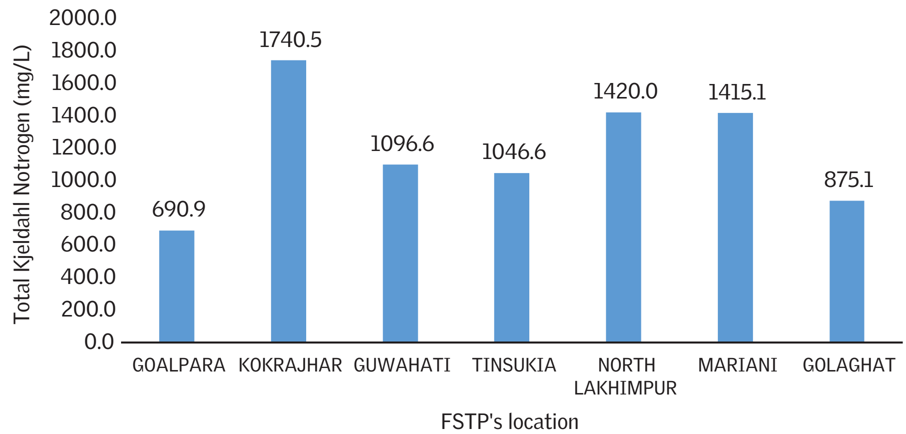
Source: CSE

Graph 6: Total phosphorus in the faecal sludge



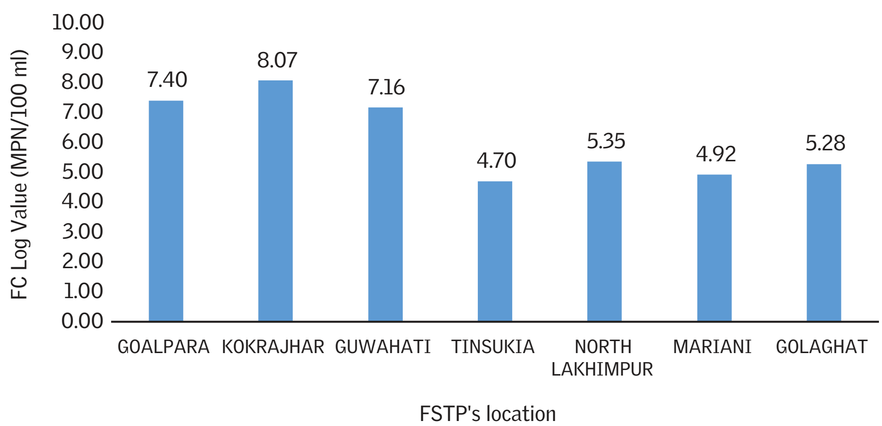
Source: CSE

Graph 7: Total Kjeldahl nitrogen of the faecal sludge



Source: CSE

Graph 8: Faecal coliform in the faecal sludge



Source: CSE

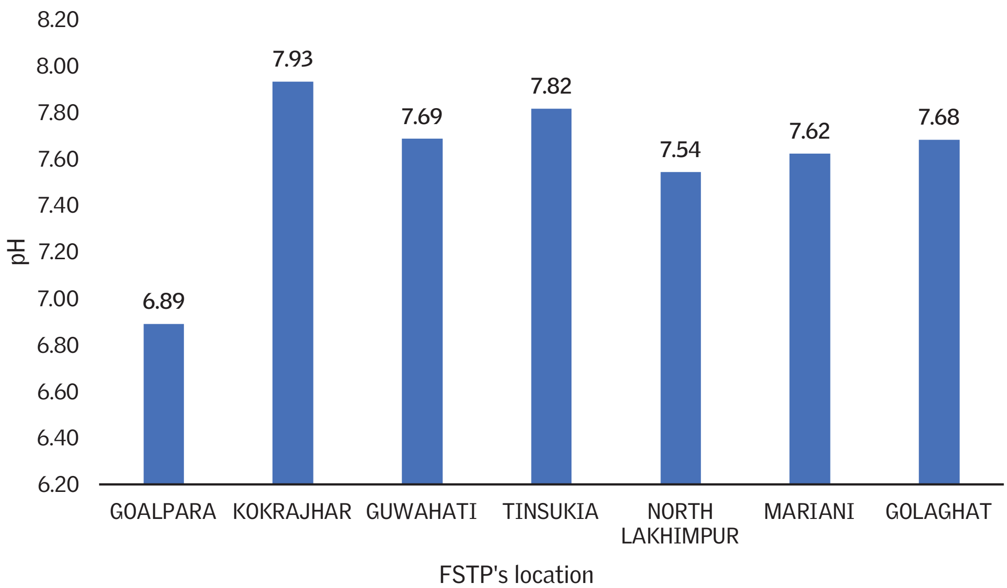
Performance evaluation of FSTPs plant for effluent quality

Ten parameters were selected for evaluation, including pH, total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total Kjeldahl nitrogen (TKN), ammoniacal nitrogen (AN), total phosphate (TP) and faecal coliform (FC). Among these, seven key parameters are presented here to assess the performance of the FSTPs.

pH

pH of the outlet water from the FSTPs is in the range of 6.89–7.93 (see *Graph 9: pH of FSTP outlet water*). There is little difference in the pH of the outlet water from the FSTPs with respect to each location except for Goalpara, which has the lowest pH (6.89). All the FSTPs have pH values within the discharge limit (pH 5.5–9) set by MoEFCC.

Graph 9: pH of FSTP outlet water

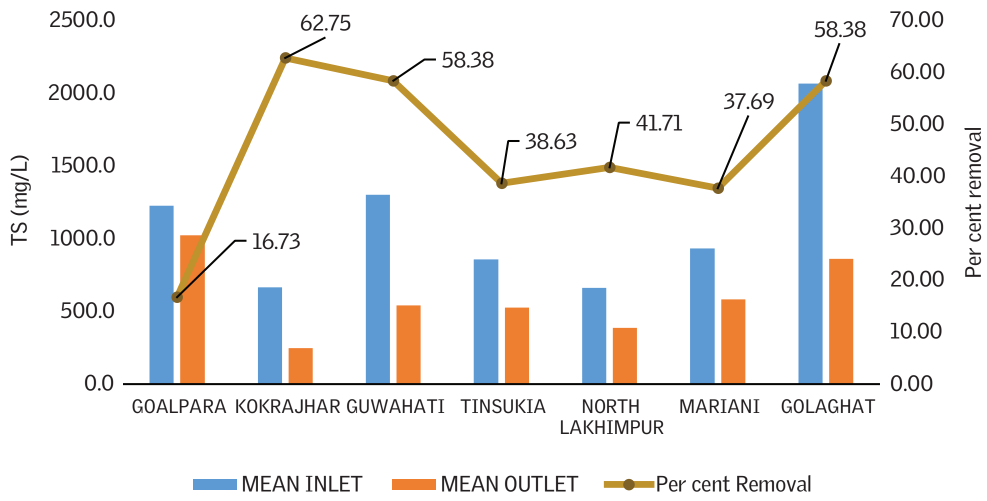


Source: CSE

Total solids

Graph 10 illustrates the inlet and outlet total solids (TS) concentrations, along with the percentage removal of TS, for the FSTPs in Assam. The average inlet TS values ranged from 662 mg/L in North Lakhimpur to 2,064 mg/L in Golaghat FSTP, while outlet TS concentrations varied from 247 mg/L in Kokrajhar to 1,022 mg/L in Goalpara FSTP. The TS removal efficiency ranged between 16.73 per cent and 62.75 per cent, with the lowest removal observed at Goalpara FSTP and the highest at Kokrajhar FSTP.

Graph 10: Total solids in inlet and outlet of FSTP and percentage removal from inlet to outlet



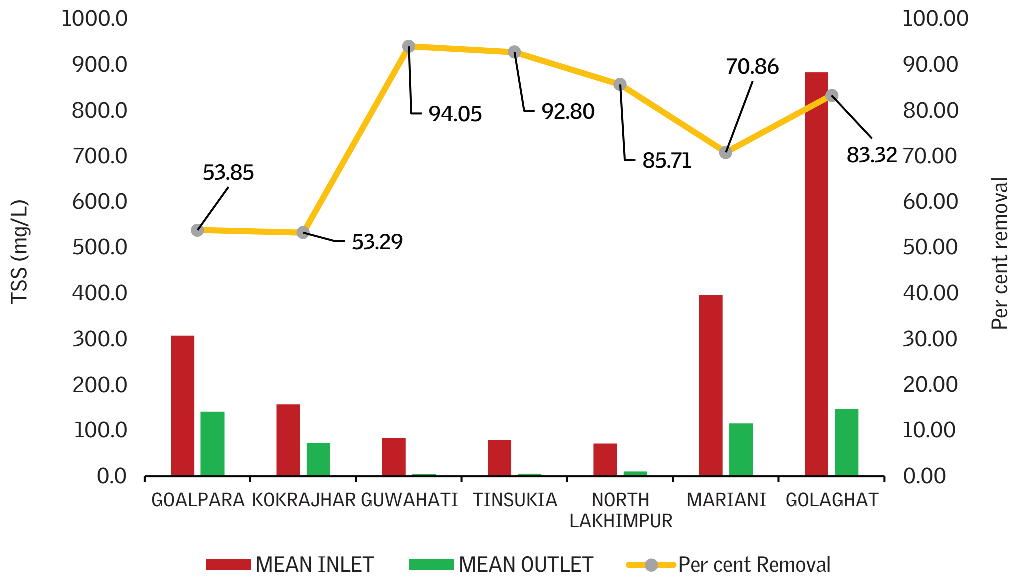
Source: CSE

Total suspended solids

Graph 11 presents the inlet and outlet total suspended solids (TSS) concentrations, along with the corresponding percentage removal for the FSTPs. The average inlet TSS ranged from 72.3 mg/L in North Lakhimpur to 883.3 mg/L in Golaghat FSTP. The outlet or treated water TSS values varied from 5.0 mg/L in Guwahati to 147.3 mg/L in Golaghat FSTP. The TSS removal efficiency ranged between 53.29 per cent and 94.05 per cent, with the lowest removal observed at Kokrajhar FSTP and the highest at Guwahati FSTP.

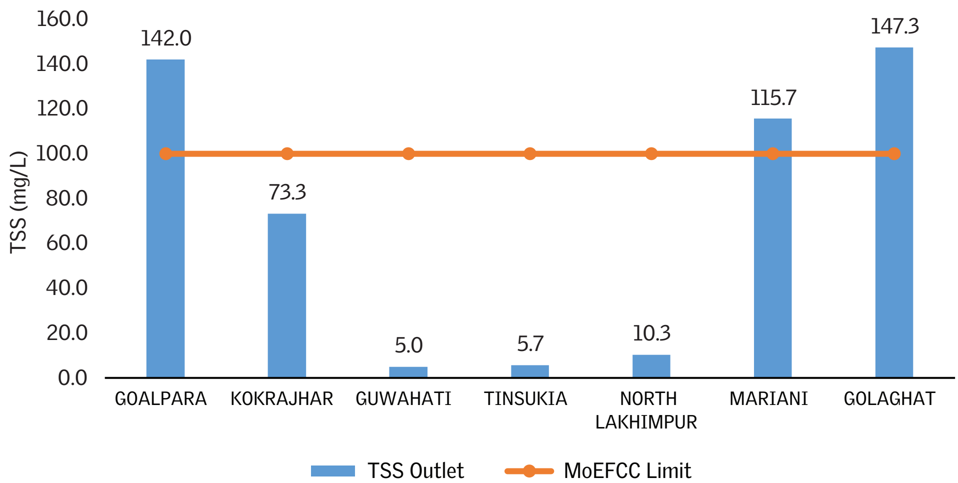
Graph 12 illustrates the TSS concentrations in the outlet water from the FSTPs. As per MoEFCC standards for STP discharge, the permissible limit for TSS is 100 mg/L for cities other than metro cities areas. The lowest outlet TSS of 5.0 mg/L was recorded at the Guwahati FSTP, while the highest was observed at Golaghat FSTP. Except for the Goalpara, Mariani and Golaghat FSTPs, all other plants complied with the MoEFCC discharge standards.

Graph 11: Total suspended solids in inlet and outlet of FSTP and percentage removal from inlet to outlet



Source: CSE

Graph 12: Total suspended solids in outlet of FSTP and regulatory limit

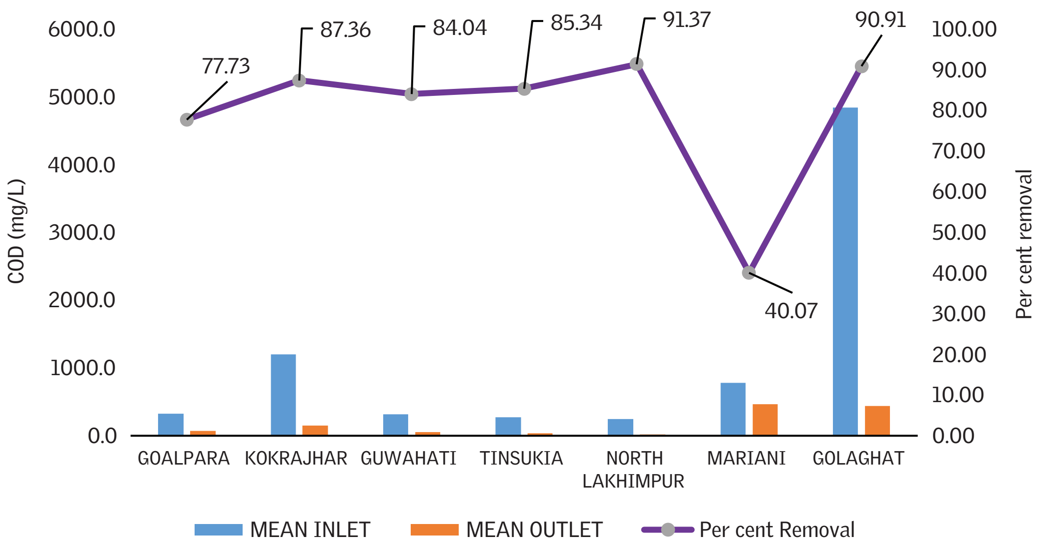


Source: CSE

Chemical oxygen demand (COD)

Graph 13 illustrates the inlet and outlet COD concentrations along with the corresponding percentage removal for each FSTP. The highest COD removal efficiency of 91.37 per cent was achieved at the North Lakhimpur FSTP, while the lowest efficiency of 40.07 per cent was recorded at the Mariani FSTP. Overall, the COD removal efficiency of six out of the seven evaluated FSTPs in Assam exceeded 70 per cent, with Mariani being the only exception, showing 40 per cent removal. The lowest outlet COD concentration of 21.0 mg/L was observed in North Lakhimpur, while the highest, 468.7 mg/L, was recorded in Mariani.

Graph 13: Chemical oxygen demand in inlet and outlet of FSTP and percentage removal from inlet to outlet



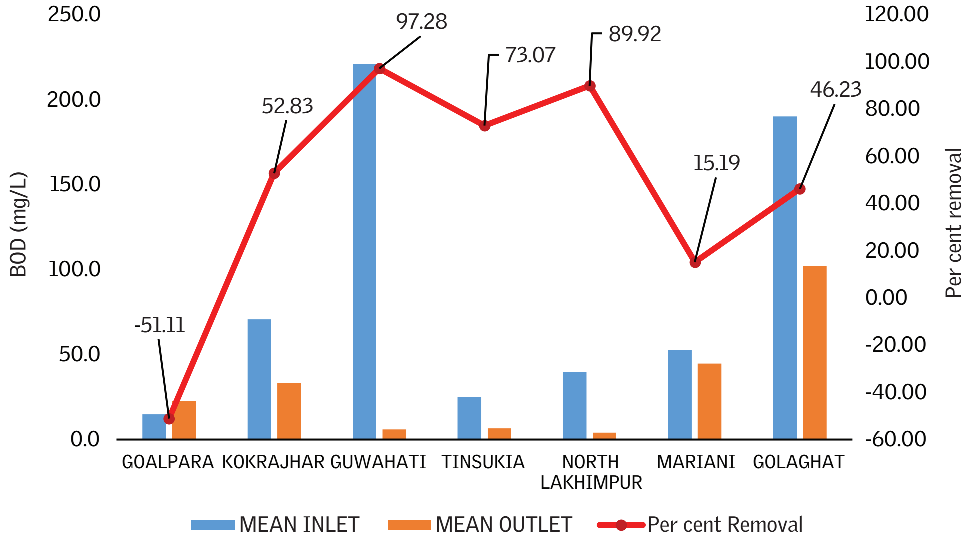
Source: CSE

Biochemical oxygen demand (BOD)

Graph 14 depicts the inlet and outlet BOD concentrations along with the corresponding percentage removal for each FSTP. The BOD removal efficiency across the FSTPs ranged from 15.19 per cent at Mariani FSTP to 97.28 per cent at Guwahati FSTP.

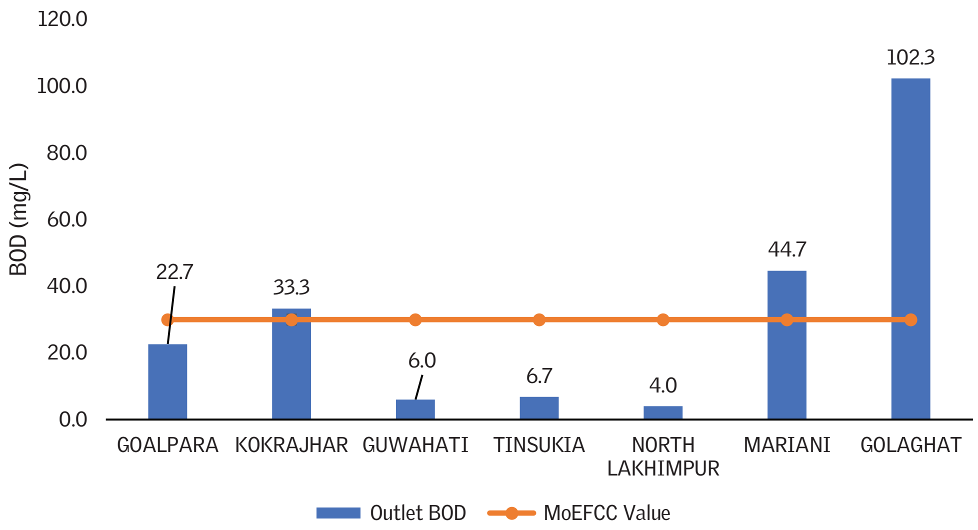
The Goalpara FSTP showed an anomalous result, with a negative removal efficiency (-51.11 per cent), indicating that the outlet BOD concentration was higher than the inlet. This may be attributed to contaminant accumulation in the outlet water tank or polishing pond, suggesting the need for proper cleaning and maintenance. Graph 15 presents the BOD concentrations in the outlet water from the FSTPs. The outlet BOD values ranged from 4.0 to 102.3 mg/L. As per MoEFCC discharge standards, the permissible BOD limit for areas other than metropolitan cities is 30 mg/L. When compared with these standards, it was observed that four out of seven FSTPs complied with the regulatory limit. Only the Kokrajhar, Mariani and Golaghat FSTPs exceeded the prescribed BOD standard of MoEFCC.

Graph 14: Biochemical oxygen demand in inlet and outlet of FSTP and percentage removal from inlet to outlet



Source: CSE

Graph 15: Biochemical oxygen demand in outlet of FSTP and regulatory limit

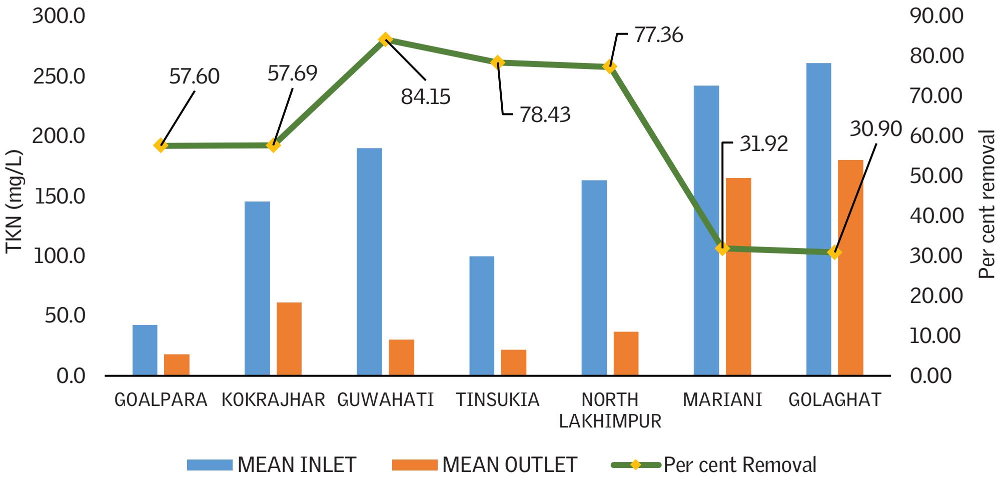


Source: CSE

Total Kjeldahl nitrogen (TKN)

Graph 16 illustrates the inlet and outlet TKN concentrations along with the corresponding percentage removal for each FSTP. The inlet TKN ranged from 42.5 mg/L in Goalpara to 261.0 mg/L in Golaghat, while the outlet TKN varied from 18.0 mg/L in Goalpara to 180.3 mg/L in Golaghat. The lowest TKN removal efficiency of 30.90 per cent was observed at the Golaghat FSTP, whereas the highest removal efficiency of 84.15 per cent was recorded at the Guwahati FSTP. Among the seven FSTPs evaluated, five demonstrated more than 50 per cent TKN removal efficiency.

Graph 16: Total kjeldahl nitrogen in inlet and outlet of FSTP and percentage removal from inlet to outlet

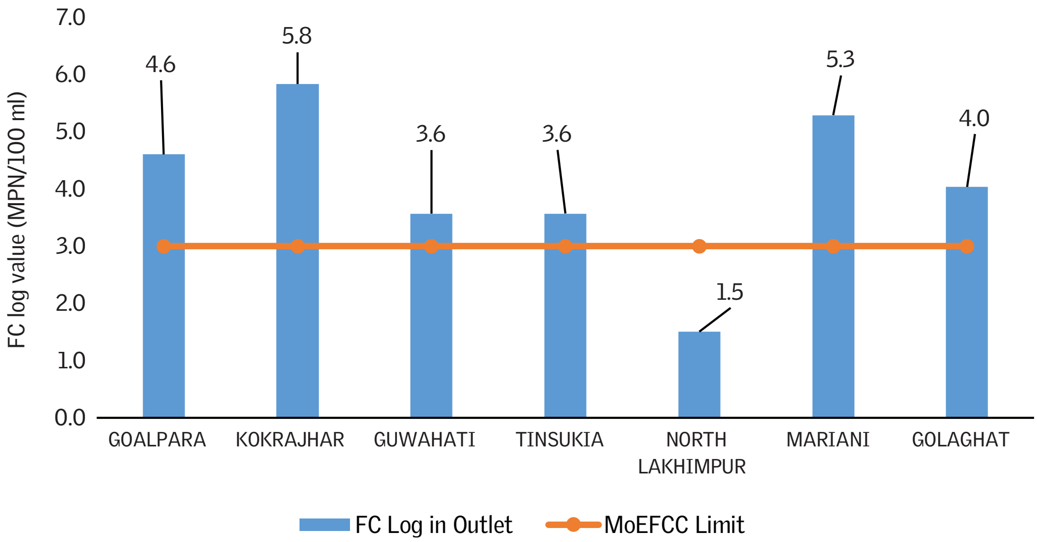


Source: CSE

Faecal coliforms

As per MoEFCC discharge standards, the permissible limit for faecal coliform bacteria in STP effluent is <1000 MPN/100 mL (log 3). The faecal coliform concentrations in the outlet water from various FSTPs are presented in Graph 17. Among the evaluated systems, only one FSTP recorded outlet values below 1000 MPN/100 mL (log 3). The highest faecal coliform count was observed in Kokrajhar FSTP, with an MPN of 676,677 (log 5.8). This elevated level may be attributed to inefficient disinfection, as hypochlorination used at this facility. To improve performance, the chlorine dosage should be optimized based on the fluctuating sludge load, and adequate contact time must be ensured for effective disinfection. In contrast, the North Lakhimpur FSTP showed the lowest faecal coliform count, with an MPN of 32 (log 1.5), indicating that its tertiary treatment process is highly efficient and well-maintained. Except for North Lakhimpur, all other FSTPs exhibited faecal coliform levels exceeding the MoEFCC standard, likely due to contamination in the outlet storage tanks or inefficiencies in the tertiary treatment system, both of which may require proper cleaning and maintenance.

Graph 17: Faecal coliforms in the outlet water from the FSTPs and regulatory limit



Source: CSE

Evaluation of quality of biosolids from FSTPs

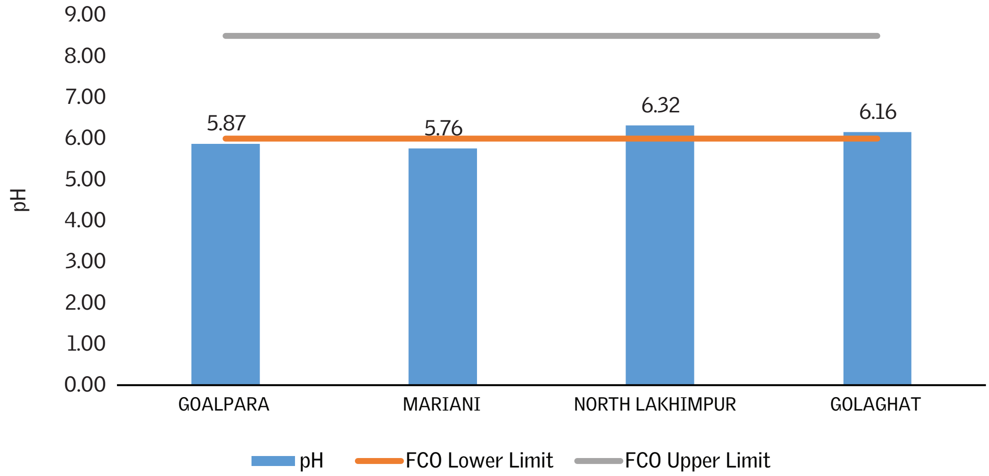
Biosolid samples were collected from four FSTPs; Goalpara, Mariani, North Lakhimpur and Golaghat, directly from the drying beds. At the Goalpara FSTP, biosolids were collected three times during each sampling visit (February, May and June 2025). Samples from the Mariani FSTP were collected twice, during the second and third visits (April and June 2025). For the North Lakhimpur and Golaghat FSTPs, biosolid samples were collected once each, both in June 2025. Biosolid samples from the other FSTPs were not collected due to their unavailability, as the biosolids were either not adequately dried or not ready for sampling at the time of the visit.

The biosolid quality evaluation was conducted using the average values of samples collected from Goalpara and Mariani, while for the other locations the original single-sample values were used.

pH

As per FCO 2023, the pH of organic manure should be in the range of 6–8.5. Graph 18 shows that the pH of biosolids collected from the FSTPs were in the range of 5.76–6.32. This indicates that the biosolids from Goalpara and Mariani have a pH slightly below the FCO standard, while those from North Lakhimpur and Golaghat fall within the acceptable range of FCO standards.

Graph 18: pH of the biosolids

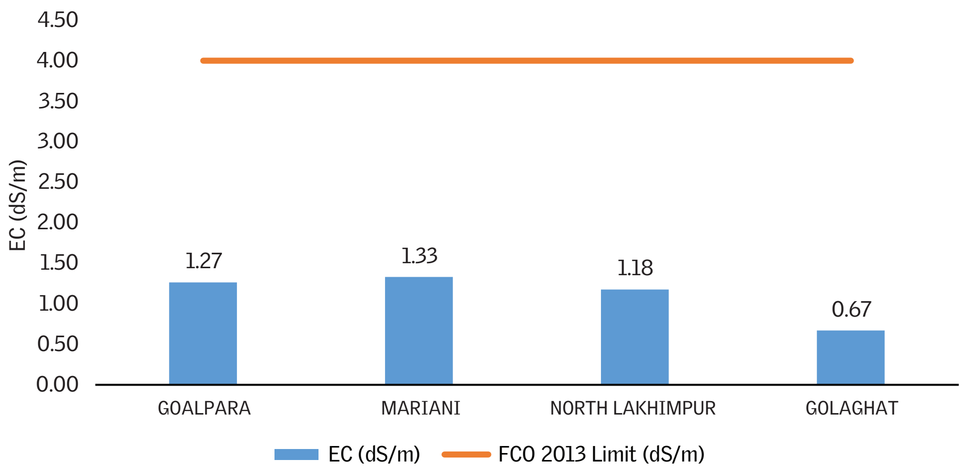


Source: CSE

Electrical conductivity

Graph 19 presents the electrical conductivity (EC) of the biosolids. The recommended EC limit for organic manure is below 4 dS/m. The EC values of biosolids collected from different FSTP locations in Assam were in the range of 0.67–1.33 dS/m. These results indicate that the EC of all biosolid samples from the evaluated sites fell within the acceptable limit.

Graph 19: Electrical conductivity of the biosolids

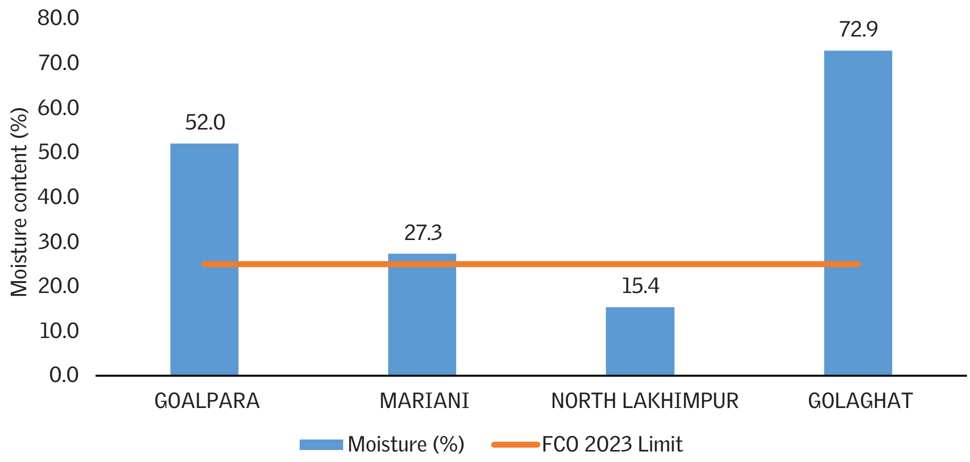


Source: CSE

Moisture content

Moisture content is a critical parameter in biosolids as it affects microbial activity. Graph 20 shows the moisture content, expressed as per cent by weight, which ranged from 15.4 per cent in North Lakhimpur to 72.9 per cent in Golaghat. Moisture content is influenced by drying time and conditions. In all the evaluated FSTPs, sun drying was used to reduce moisture. For the effective use of biosolids as organic manure, a moisture content of less than 25 per cent is recommended. The results indicate that only one out of four locations met this criterion. Therefore, adequate sun drying time should be ensured to lower the moisture content.

Graph 20: Moisture content of the biosolids



Source: CSE

Carbon–nitrogen ratio

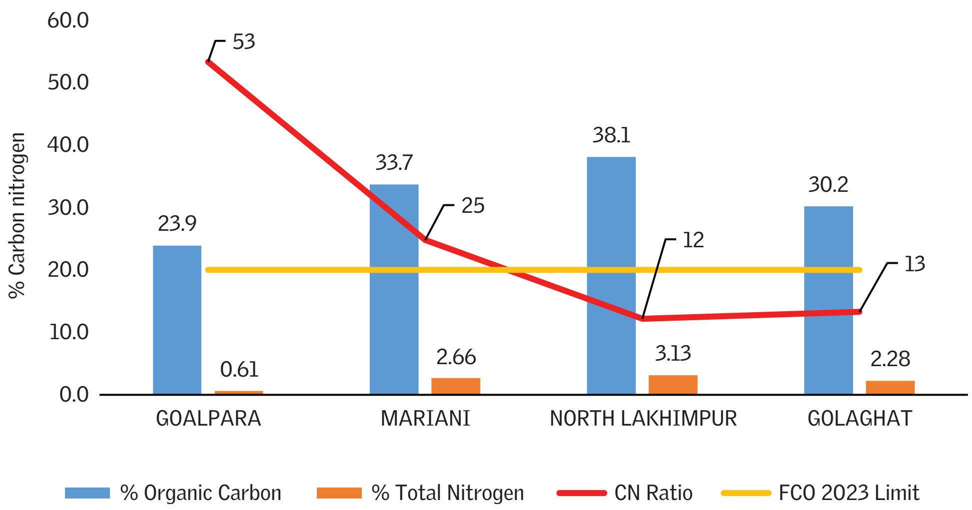
Organic matter is an important parameter in biosolids, especially when applied as a soil amendment for agricultural purposes. It affects soil microbial diversity, which directly influences crop productivity. As shown in Graph 21, the total organic content of the biosolids ranged from 23.9 per cent to 38.1 per cent by weight, while the total nitrogen content varied between 0.61 per cent and 3.13 per cent by weight. The C:N ratio of the evaluated biosolids was in range of 12–53, with Goalpara and Mariani showing ratios higher than the FCO-prescribed limit of 20, while the other FSTPs remained within the standard.

A high C:N ratio (>20) indicates a high carbon content, which can lead to nitrogen immobilization, whereas a low C:N ratio promotes nitrogen mineralization, making it more available for plant uptake. For optimal utilization of both carbon and nitrogen by plants and soil microbes, an equilibrium between mineralization and immobilization is necessary. Therefore, the ideal C:N ratio is considered to be between 15:1 and 20:1.

The higher C:N ratio in Goalpara and Mariani biosolids is due to relatively higher carbon content and lower nitrogen content in the faecal sludge, which increases carbon availability while limiting nitrogen, resulting in slower nitrogen mineralization.

The higher carbon content in faecal sludge is typically due to the presence of undigested organic matter, fibre and other plant-based residues, while the lower nitrogen content results from the partial degradation of nitrogenous compounds during storage or treatment, as well as losses through ammonia volatilization. Additionally, differences in diet, water content, and sludge composition at different FSTPs can also contribute to this imbalance.

Graph 21: Per cent carbon–nitrogen ratio (C/N) of the biosolids



Source: CSE

NPK value

The NPK value represents the proportion of nitrogen (N), phosphorus (P) and potassium (K) in biosolids or fertilizers, these three essential macronutrients required for plant growth. Under Indian soil conditions, the recommended NPK ratio for fertilizers is 4:2:1. As shown in Table 7, the biosolids from Golaghat exhibited an NPK ratio of 7:2:1 which is near to Indian fertilizers recommendation, while the lowest ratio was observed in Goalpara, and the highest in North Lakhimpur. The elevated NPK ratios are primarily due to the low potassium content in the biosolids.

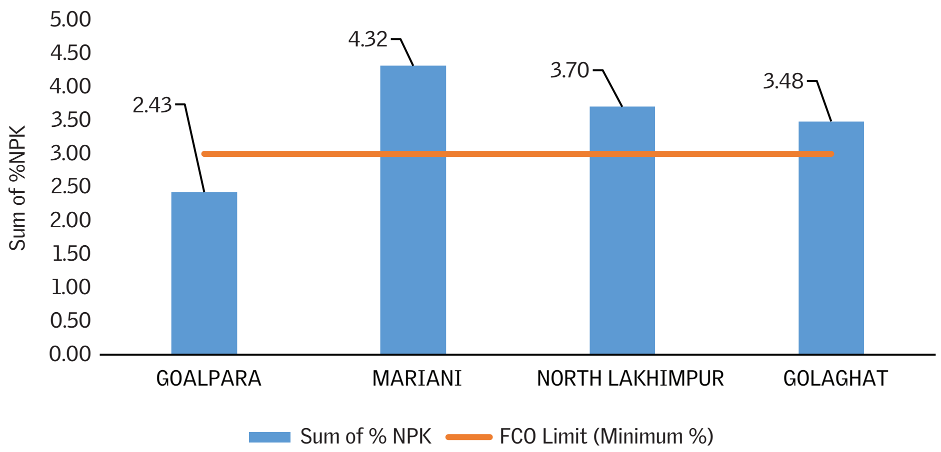
According to FCO 2023 standards, the sum of N, P and K percentages should not be less than 3 per cent. All the analysed sites met this requirement, except Goalpara, where the total NPK content was 2.43 per cent, falling slightly below the prescribed limit of FCO standard. Overall, the NPK content of the biosolids ranged from 2.43 per cent to 4.32 per cent.

Table 7: NPK profile in biosolids

Location	% Total nitrogen ß	% Total phosphates	% Total potassium	Sum of % NPK	NPK ratio
Goalpara	0.606	1.463	0.358	2.43	2:4:1
Mariani	2.655	1.468	0.192	4.32	14:8:1
North Lakhimpur	3.130	0.497	0.076	3.70	41:7:1
Golaghat	2.280	0.859	0.346	3.48	7:2:1

Source: CSE

Graph 22: NPK in the biosolids



Source: CSE

Heavy metals

The application of biosolids to soil is a common practice in agricultural areas. However, their use should not lead to an increase in heavy metal concentrations in the soil, as crops grown in such soils are directly or indirectly consumed by humans. The biosolids were analysed for arsenic, mercury, cadmium, chromium, lead, zinc, copper and nickel, as presented in Table 8.

Results showed that, except for Goalpara, mercury concentrations in biosolids from all other locations exceeded the FCO (2023) limits, while zinc levels were also above the prescribed limit in Mariani and Golaghat. The concentrations of other heavy metals were found to be within the permissible limits (FCO, 2023) across all sites. The presence of heavy metals in biosolids may be attributed to the use of toilet cleaners, detergents and other non-faecal materials disposed of in toilets, as well as pre-contaminated water sources used for flushing.

Table 8: Heavy metal content in biosolids

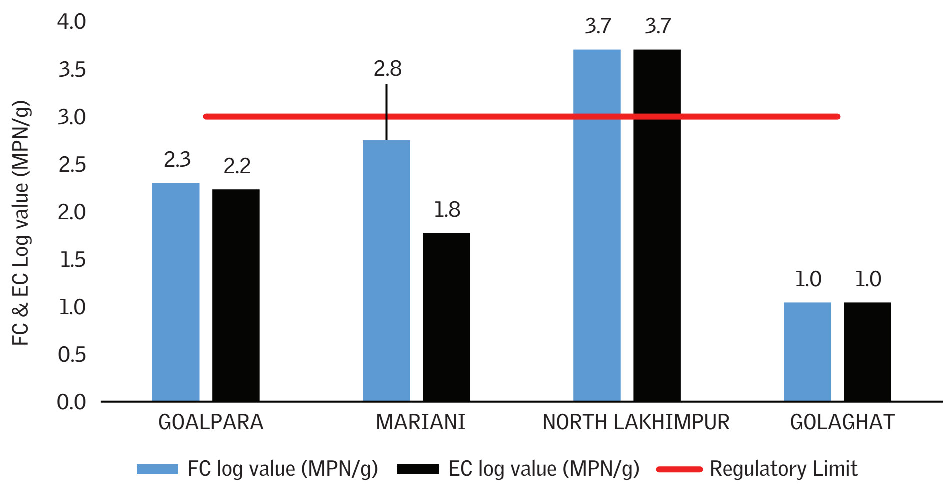
Location	Arsenic (mg/kg) max. 10.00	Mercury (mg/kg) max 0.15	Cadmium (mg/kg) max. 5	Chromium (mg/kg) max. 50	Lead (mg/kg) max. 100	Zinc (mg/kg) max. 1000	Copper (mg/kg) max. 300	Nickel (mg/kg) max. 50
Goalpara	0.25	0.10	0.38	18.1	7.9	341	81.1	15.6
Mariani	2.76	2.62	2.12	11.4	10.2	1375	162.0	22.8
North Lakhimpur	5.57	0.18	0.91	9.0	8.4	462	66.0	8.8
Golaghat	2.07	1.77	1.91	24.7	11.7	1200	112.0	23.4

Source: CSE

Faecal coliform and *E. coli*

To evaluate the pathogenicity of biosolids, indicator microorganisms were analysed. Faecal coliforms and *E. coli* serve as microbial indicators that reflect the potential presence of other pathogens. The most probable number (MPN) of microbes per gram of biosolids was determined, and their log values are presented in Graph 23.

Graph 23: Faecal coliforms and *E.coli* in biosolids



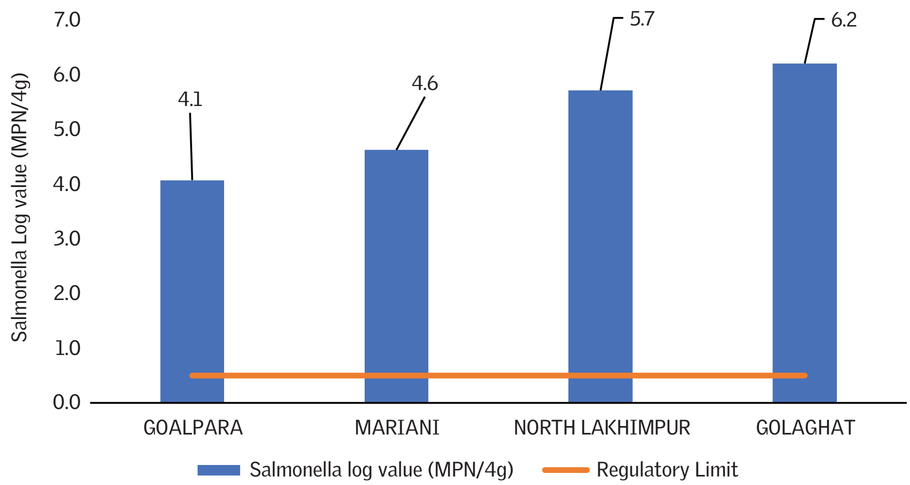
Source: CSE

According to US EPA/WHO standards for the land application of biosolids, the concentration of faecal coliforms and *E. coli* should be below 1000 MPN/g (log 3). All locations, except North Lakhimpur, were found to be within this regulatory limit. The elevated FC and EC values in North Lakhimpur biosolids indicate a need for further sun drying to effectively reduce microbial activity. Therefore, adequate sun drying time should be ensured before the biosolids are used for land application.

Salmonella

Salmonella is a pathogenic bacterium responsible for salmonellosis. For the land application of Class A biosolids, the *Salmonella* concentration should be below 3 MPN/4 g (log 0.5), as per US EPA standards. Graph 24 illustrates the *Salmonella* levels in biosolids collected from all evaluated locations. The results indicate that *salmonella* counts in all sampled FSTPs were significantly higher than the prescribed limit. These levels can be effectively reduced through adequate heat treatment or by implementing disinfection methods such as lime stabilization or pasteurization.

Graph 24: *Salmonella* in biosolids



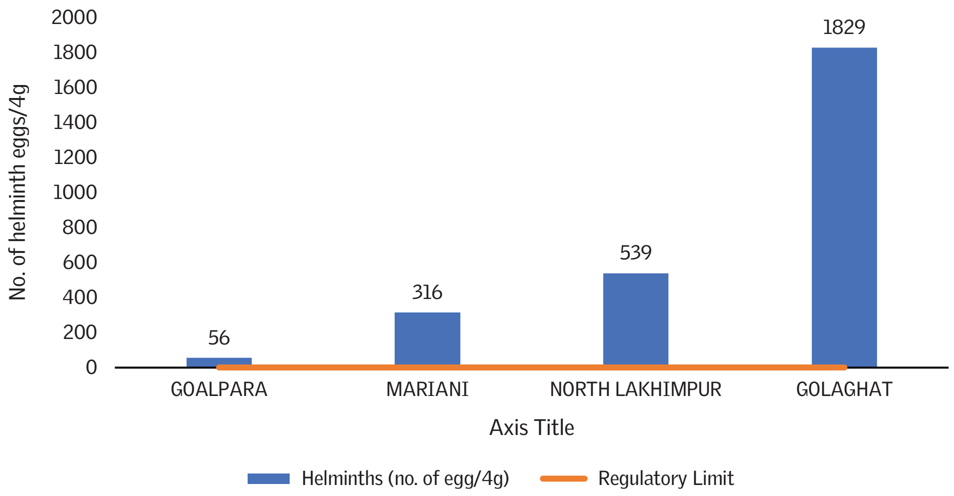
Source: CSE

Helminth eggs

The concentration of helminth ova tends to be higher in sludge than in wastewater due to their greater settling velocity. Helminth eggs were detected in most of the dried biosolid samples, as shown in Graph 25. According to the FCO (2023) standards, the presence of pathogens in organic manure should be nil. However, as per US EPA regulations, the acceptable limit for helminth eggs in biosolids is less than 1 egg per 4 g dry weight. The results indicate that helminth eggs were present in significant numbers, ranging from 56 eggs/4 g in Goalpara to 1,829 eggs/4 g in Golaghat.

Helminth eggs are difficult to eliminate completely from sludge, but their numbers can be substantially reduced through extended sun drying. It is recommended to crush the biosolids collected from the drying beds to reduce particle size, which enhances drying efficiency by increasing the surface area exposed to sunlight. Additionally, lime treatment and pasteurization are effective methods for further reducing helminth eggs in biosolids.

Graph 25: Helminth eggs in biosolids



Source: CSE

Comprehensive performance of FSTPs in Assam

1. A total of seven FSTPs in Assam were visited thrice in February–June 2025 for sample collection and analysis.
2. Among the seven evaluated FSTPs, all FSTPs except Guwahati and Goalpara employed the MBBR system combined with sludge drying bed technology for faecal sludge treatment. In contrast, the Guwahati FSTP utilized Geotube technology, while the Goalpara FSTP adopted the Tiger Biofilter technology for treatment.
3. Faecal sludge samples collected from tankers at all locations were characterized for key physicochemical and microbiological parameters. The results showed that pH was in the range of 7.11–7.36, total solids (TS) 4,426–25,650 mg/L, total suspended solids (TSS) 1,937–19,845 mg/L, chemical oxygen demand

(COD) 26,050–68,025 mg/L, biochemical oxygen demand (BOD) 390–4,960 mg/L, total Kjeldahl nitrogen (TKN) 691–1,740 mg/L, and faecal coliforms (FC) 50,430–116,150,000 MPN/100 mL.

4. In the evaluated FSTPs, pH of outlet water is in the range of 6.89–7.93. The percentage removal of TS varied in the range of 16.73–62.75 per cent while TSS removal was in the range of 53.29–94.05 per cent.
5. The COD concentration in the outlet water was in the ranged of 21.0–468.7 mg/L. The COD removal efficiency of all FSTPs was found to be above 70 per cent, except for Mariani, which showed a removal efficiency of 40 per cent.
6. The outlet BOD varied between 4.0 and 102.3 mg/L. Among the seven FSTPs studied, Goalpara, Guwahati, Tinsukia and North Lakhimpur recorded BOD levels within the regulatory limits. BOD removal efficiency was in the range of 15.19–97.28 per cent. The Goalpara FSTP showed a higher BOD in the outlet than in the inlet, likely due to the accumulation of organic solids in the storage tank.
7. The total Kjeldahl nitrogen (TKN) concentration in the effluent from the FSTPs ranged from 18.0 to 180.3 mg/L. Over 50 per cent TKN removal efficiency was achieved in five out of the seven FSTPs.
8. Among the seven FSTPs, only the North Lakhimpur facility recorded faecal coliform levels within the regulatory limits prescribed by the MoEFCC. However, the results from Kokrajhar, Tinsukia and Mariani showed an unusual trend, with faecal coliform levels in the outlet samples higher than those in the inlet.
9. The pH of biosolids collected from the FSTPs were in the range of 5.76–6.32, while the electrical conductivity (EC) was in the range of 0.67 to 1.33 dS/m. The EC values of biosolids from all evaluated locations were within the limits prescribed by the FCO (2023). However, the pH levels at Goalpara and Mariani were found to be below the specified FCO limits, while those from the other sites complied with the standard.
10. The moisture content of the biosolids ranged from 15.4 per cent to 72.9 per cent. According to FCO guidelines, the moisture content should be below 25 per cent. Among all the sites, only the North Lakhimpur facility met this requirement.
11. The C:N ratio of the evaluated biosolids ranged from 12:1 to 53:1. For agricultural application, the recommended range is between 15:1 and 20:1. Therefore, the C:N ratio of the biosolids needs to be adjusted to comply with the FCO (2023) standards. The samples from Goalpara and Mariani exhibited particularly high C:N ratios, exceeding the prescribed limits of FCO.
12. All sites showed nutrient-rich biosolids with NPK values meeting the recommended limits set by the FCO (2023), except for Goalpara, where the NPK levels were slightly lower than the prescribed standards.

13. In all the evaluated locations, the concentrations of arsenic, cadmium, chromium, lead, copper and nickel were found to be below the limits prescribed by the FCO (2023). However, mercury and zinc exceeded the recommended levels at certain sites as mercury levels were above the FCO limit in Mariani, North Lakhimpur and Golaghat, while zinc concentrations were elevated in Mariani and Golaghat.
14. Biosolids from all locations, except North Lakhimpur, exhibited faecal coliform and *E. coli* levels within the regulatory limits prescribed by the US EPA and WHO.
15. The levels of *salmonella* and helminth eggs in biosolids from all locations were significantly higher than the regulatory limits for Class A biosolids set by the US EPA.

This report outlines critical performance gaps at seven key FSTPs in Assam and provides targeted, multi-faceted recommendations for achieving compliance with CPCB effluent and biosolid quality standards, aligning with the spirit of the state's faecal sludge and septage management (FSSM) objectives.

Universal scientific and technological lacunae

The performance analysis reveals systemic failure across the treatment chain in all operational FSTPs in Assam, stemming from a lack of stabilization and proper post-treatment mechanisms.

Scientific evaluation and performance deficiencies

1. **Inadequate pathogen inactivation:** The most critical failure is the inability to eliminate pathogens. Biosolids consistently show extremely high counts of helminth eggs (averaging 685 eggs/4 gm) against a safe limit of 1 live egg/4 gm) and high faecal coliform (FC) in the effluent (averaging 1,32,586 MPN/100 ml) against a limit of 1,000 MPN/100 ml. This means the final products, both liquid and solid pose a severe public health and environmental risk and are unsuitable for reuse, directly contravening the goal of resource recovery.
2. **Organic and nutrient overload in effluent:** Treated effluent consistently fails on key parameters, particularly BOD average of 31.4 mg/L (standard limit being vs. 30 mg/L) but when each individual values are considered FSTP by FSTP we find most of the time they fail comply to the standards. Although for total Kjeldahl nitrogen (TKN) there are no standard norms , however the average of 73.3 mg/L implies that the removal of TKN from effluent is only 60 per cent. With such high organic and nitrogen load, if this effluent is taken for discharge into waterbodies, it would definitely lead to eutrophication and oxygen depletion in receiving waterbodies.

3. **Biosolid instability**: The average moisture content is 41.9 per cent (as opposed to a standard FCO limit of 25 per cent) and C:N ratio averaging to 26 (as opposed to the target FCO ratio ranging between15:1 to 20:1) indicate incomplete stabilization. The sludge is too wet for cost-effective handling and transport, and its nutritional profile is poor due to a lack of proper composting.

Technology and operational lacunae

1. **Missing biosolid reuse (co-composting) infrastructure:** The primary technical gap is the failure to implement mandatory co-composting. The current treatment sequence, likely involving only drying beds, is insufficient to reach the sustained thermal threshold (55°C for several days) required to kill helminth eggs.
2. **Inadequate post-dewatering treatment:** The consistently high pathogen load (FC) in the final liquid effluent suggests the absence or failure of a final disinfection step, such as a well-maintained polishing pond or an optimised post-treatment chemical dosing.
3. **Process upsets due to irregular loading:** Many FSTPs are operating below their designed capacity, while others experience unstable influent quality. This irregular hydraulic and organic loading prevents the microbial processes within the plant from stabilizing and achieving consistent performance.

FSTP-specific performance analysis and recommendations

The following sections detail the unique challenges for the seven FSTPs, with detailed data and targeted recommendations.

Goalpara FSTP

Problems identified: This plant exhibits comprehensive failure across the value chain. Effluent quality fails consistently on TSS, COD, and FC. Biosolids are extremely poor, marked by very high moisture (>50 per cent) and the high helminth load of around 56 live cells/ 4 grams. This clearly states that the TBF is ineffective in converting the sludge into vermi-compost safe for agricultural use.

Recommendations to improve performance:

- **O&M:** The efficiency of Tiger Biofilter (TBF) technology is significantly affected by flow rate, HLR and HRT. Apart from these, other factors that influence the performance of TBF are optimum stocking density of worms, health and maturation conditions of earthworms. Maintaining optimal earthworm density is crucial for effective wastewater treatment, as low densities may not sufficiently stimulate microbial activity. Earthworms that are bigger in size can treat more efficiently compared to the smaller ones due to their voracious eating patterns. The optimum stocking density of earthworms lies between 15,000 and 20,000 worms/m in a vermi filter bed. Similarly, in TBF-II, the HLR and HRT must be maintained as mentioned in the DPR for effective action of microbes on organic matter present in the effluent from TBF-I.

- **Administrative:** An initiation of documenting daily O&M logs that record chemical dosages and operational parameters to prevent poor dewatering and finally this would ensure accountability and enhanced performance of the FSTP.
- **Policy:** Mandating a scheduled, GPS-monitored desludging plan and execution for the Goalpara service area would guarantee stable, adequate inflow and prevent process upsets.

Golaghat FSTP

Problems identified: The data for Golaghat indicates significant challenges in the liquid treatment line. Influent is highly variable, and treatment efficiency for organic load reduction is insufficient. Pathogen removal in the final effluent is a key concern, though its C:N ratio in biosolids is more moderate than in other plants.

Recommendations to improve performance:

- **O&M:** Introduction of a chemical pre-treatment in the receiving tank would enhance coagulation and settling of fine solids. This will in turn reduce COD/BOD and solids carryover into the liquid train.
- **Administrative:** Reviewing and amendment of the O&M contract to include a penalty, reward or subsidy clause for failure or consistent satisfactory performance to maintain effluent FC and BOD standards, using compliance data as the primary payment metric may be done. This will ensure performance quality from the operator of the plant.
- **Policy:** Conduct operator training specifically focused on the chemistry of flocculation and sedimentation, alongside proper maintenance of mechanical pre-treatment units.

Guwahati FSTP

Problem identified: Based on the performance data and the FSTP's technology mix (Geotube and SBR), the following problems are identified: Ineffective Liquid Effluent Treatment (SBR Failure) due to sludge bulking and foaming, inadequate aeration and mixing and poor decanting phase control. Inefficient and un-optimized disinfection is depicted by the high FC content in the effluent (3,700 MPN/mL).

Recommendations to improve performance:

- **O&M:** Stabilization of the SBR performance by optimizing aeration/DO levels and implementing regular Sludge Volume Index (SVI) testing. Adjusting the Sludge Retention Time (SRT) by varying the sludge wastage rate would maintain a healthy biomass and improve settling. Ensure the final disinfection unit (Chlorination/UV) is operating at required dosage/intensity to meet the FC limit. Once the dried geobag is opened it is mandatory to ensure the dewatered cake is allowed a minimum 10–15 days of aerobic curing. Implementing regular turning (e.g. once or twice a week) to provide necessary oxygen for stabilization.
- **Administrative:** Mandating regular, independent third-party audits focusing on O&M practices (polymer dosing, SBR cycle times etc.) would ensure compliance and performance consistency of the FSTP. Provide some financial incentives to ensure the facility meets the standards set by the CPCB/FSM Policy, moving away from simple attendance-based contracts.
- **Policy:** The FSSM policy of Assam may be amended to enforce the compliance of treated water and biosolids for safe reuse applications.

Kokrajhar FSTP

Problems identified: The plant struggles with inconsistent treatment efficiency, particularly in pathogen removal (FC). COD and BOD levels in the effluent frequently exceed limits, suggesting that stabilization is not robust. Some sample results showed unusual outcomes where outlet FC values exceeded inlet values, pointing to organic accumulation and contamination in the outlet structures.

Recommendations to improve performance:

- **O&M:** Thorough cleaning and disinfection of all outlet storage/polishing ponds and tertiary treatment units would ensure elimination of accumulated organic matter that contributes to the high outlet BOD and FC. Implementing and ensuring co-composting with a bulking agent should be done to the dewatered sludge which will help in quality ensured biosolids.
- **Administrative:** Establishing a weekly reporting mechanism to track the difference between inlet and outlet parameters would help in quickly identifying and addressing re-contamination issues.
- **Policy:** Prioritization of development of a local market with the agriculture department or local farmers to guarantee uptake of the certified, composted biosolid product would create a resource-based revenue incentive.

Mariani FSTP

Problems identified: Effluent quality is a major issue, with high BOD and FC indicating poor biological treatment and disinfection. The biosolid quality is compromised by high C:N ratio, indicating insufficient stabilization, which is likely related to poor process control in the solids line. Mariani FSTP is situated in a domestically landlocked area where there is no proper approach road for the desludging vehicles to reach the FSTP.

Recommendations to improve performance (O&M, Administrative, Policy):

- **O&M:** Introduction of a standard SOP which indicates regular aeration by turning of the drying beds to facilitate aerobic decomposition. This will lower the C:N ratio and help the sludge reach pasteurization temperature for pathogen kill.
- **Administrative:**
  - Construction of a proper approach road to the plant is mandatory and an immediate necessity. This will ensure the desludgers will bring in the collected faecal sludge and decant it at the FSTP
  - Implementation of a zero-tolerance policy for the discharge of non-compliant effluent would help regular optimal performance. The operator must maintain a contingency stock of disinfection chemicals for immediate effluent polishing during process upsets.
- **Policy:** The ULB must allocate dedicated land and resources for a mature co-composting yard adjacent to the FSTP, ensuring the stabilization process can be completed before land application.

Tinsukia FSTP

Problems identified: Tinsukia struggles primarily with FC in the final effluent, indicating a lack of proper tertiary disinfection. Due to lack of consistent and very low sludge loading at the plant, the separated dewatered sludge could never reach a volume to be treated and converted to reusable biosolids.

Recommendations to improve performance (O&M, Administrative, Policy):

- **O&M:** Installation of a simple gravel filter or polishing pond as a tertiary treatment step to reduce residual FC before discharge will help improve the quality of treated water to comply to the standards. Optimizing FS input at the FSTPs and then processing the drying beds by regularly breaking up the sludge cake into smaller particles will help to promote uniform quality of reusable biosolids.
- **Administrative:** Creating and enforcing a Standard Operating Procedures

(SOPs) for solids management, including detailed instructions on sludge application depth, turning frequency, and moisture monitoring would ensure quality assured safe biosolids for reuse applications

- **Policy:** Adopting a 'safe reuse framework' aligned with the Assam FSM Policy, requiring biosolid stabilization to WHO Class A standards before any commercial or agricultural application, and establishing a biosolid certification process needs to be implemented.

North Lakhimpur FSTP

Problems identified: While the effluent achieves relatively better compliance on BOD, COD, and TSS and FC signifies that the water teatement modules are working to their design efficiency. The biosolid quality is acceptable in some parameters but requires sustained pathogen management.

Recommendations to improve performance (O&M, Administrative, Policy):

- **O&M:** Optimization of the existing disinfection unit and ensuring the required contact time (as specified by the manufacturer) is to be met to achieve final FC compliance. Regular harvest/trimming of plants from the planted drying beds to maintain hydraulic conductivity is to be done as stipulated in the approved SOP/O&M plan of the plant.
- **Administrative:** Implementation of a performance-based contract that links operator payment directly to achieving compliance to BOD and FC standards would definitely improve the output quality and eventually the performance of the FSTP
- **Policy:** Addressing the observation that all FSTPs, including this one, are operating below capacity development of a City Sanitation Plan (CSP) for scheduled desludging of North Lakhimpur area would ensure consistent sludge inflow from both urban and peri-urban areas.

Recommendations for restricted use of treated water and biosolids from the FSTPs of Assam

This report offers crucial insights into the potential and challenges of reusing treated water from the FSTPs of Assam. While the report emphasises that there is a significant untapped resource of treated water with potential for reuse, it also highlights the need for a nuanced and restricted approach to its reuse, primarily due to existing quality concerns and the need for a circular economy framework.

Key recommendations for restricted safe use of treated water revolve around prioritizing specific applications based on the quality of treated effluent and the local context of water scarcity and demand. The report indicates that the FSTPs struggle to consistently meet stringent discharge standards, particularly for faecal coliform (FC) and sometimes COD/BOD. Therefore, the primary recommendation for restricted safe use is to prioritize non-potable applications that minimize direct human exposure and align with the principles of a circular economy. These include:

1. **Agricultural irrigation (for non-edible crops or crops consumed after cooking)**: As agriculture constitutes a huge percentage of Assam's land area and is a major water consumer (especially rice cultivation), treated wastewater presents a significant opportunity. However, strict monitoring of water quality, particularly for pathogens and heavy metals, is crucial. Strict adherence to the recommended norms by the CPCB for treated sewage quality for irrigation of non-edible crops and some edible ones (consumed after cooking) should be practised.
2. **Groundwater recharge and lake and/or waterbody rejuvenation**: This is identified as a high-priority reuse option, especially in districts facing severe groundwater depletion. Secondary treated water is considered adequate for this purpose, as the approach not only replenishes vital aquifers but also contributes to environmental and biodiversity considerations.
3. **Industrial use (non-potable processes)**: Industries can significantly reduce their freshwater footprint by utilizing treated wastewater for cooling systems, boiler feed water, and other industrial processes.
4. **Horticulture and green belt development**: Treated wastewater can be effectively used for maintaining parks, gardens and green belts, reducing the demand for potable water in urban landscaping.
5. Construction activities: The construction sector is a significant consumer of freshwater. Convincing the construction contractors to use treated wastewater for construction (such as during curing, mixing, etc.) can substantially reduce the strain on freshwater resources.

To ensure the safety and sustainability of these restricted uses, several overarching recommendations remain vital:

- **Stringent monitoring and compliance**: Regular and robust monitoring of treated water quality (BOD, COD, FC, heavy metals) by independent bodies is paramount. This ensures compliance with prescribed standards for each specific reuse application.
- Clear policy and regulatory framework: Assam should introduce a clear comprehensive state-level policy that defines clear reuse priorities, quality standards for different applications, and robust enforcement mechanisms.
- Infrastructure for conveyance: Adequate infrastructure, such as dedicated pipelines and storage reservoirs, is necessary to transport treated water from

FSTPs to demand centres. This would prevent contamination and ensure efficient delivery.

- Capacity-building and awareness: Training for FSTP operators on maintaining optimal treatment processes and awareness campaigns for end users (such as farmers, industries) on the safe handling and benefits of treated water are critical.
- Financial sustainability: Implementing user charges for treated water, exploring public–private partnership (PPP) models, and providing incentives for its adoption can ensure the economic viability of reuse projects.
- By focusing on these restricted and carefully monitored applications, Assam can effectively transform its wastewater into a valuable resource, contributing significantly to water security, environmental protection, and a circular economy.

The biosolids generated at the FSTPs of Assam fail to comply with the USEPA Class A standards which is a mandate in the Assam FSSM policy. Most of them are laden with pathogens, and often high levels of certain heavy metals are reported as well. However, the biosolids do comply with the Class B standards of USEPA, which clearly states restricted usage in terms of volume, application, duration and specific agricultural use. Biosolids of Class B standards shall not be used for agricultural land application, especially food crops. However, it may be utilized for purposes other than growing food crops, like cash crops (cotton, jute, tobacco, etc.), for soil reclamation at reforestation and afforestation sites. Such Class B biosolids may also be used in landfills, green fuel, building and construction materials, etc.

Some of the recommended reuses of such Class B biosolids are mentioned below:

- Soil conditioner for growing only cash crops—jute, cotton, tobacco, etc.;
- Soil conditioner for growing non-edible crops;
- Soil reclamation for reforestation and afforestation sites;
- As fillers in restricted landfill (such as landfill for industrial sites);
- As green fuel (if calorific value complies), like briquette, biochar, etc.; and
- As building and construction material.

ANNEXURES

Annexure 1: Consolidated three-month data of FSTPs in Assam

FSTP location	Month	Type of sample	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TP (mg/L)	TKN (mg/L)	AN (mg/L)	FC (MPN/100 ml)
GOALPARA	Feb 2025	FS	7.39	17,966	5,966	12000	78400	5850	41.1	1346.5	258.6	46,000,000
		INLET	7.51	1,364	1,274	90	664	23	1.5	34.7	11.2	93,000
		OUTLET	7.98	1,196	1,158	38	67	54	24.2	18.8	3.7	110,000
	May 2025	FS	7.33	1,213	793	420	23,250	90	32.0	35.3	246.7	4,300,000
		INLET	6.54	1,452	1,422	30	138	12	16.7	63.2	19.5	93,000
		OUTLET	6.03	1,410	1,383	27	96	7	14.6	17.9	12.3	210
	Jun 2025	FS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		INLET	6.48	867	64	803	186	10	20.0	29.7	20.7	43,000
		OUTLET	6.66	461	100	361	57	7	15.6	17.3	6.3	9,300
	Mean	MEAN FS	7.36	9,589.5	3,379.5	6,210.0	50,825.0	2,970.0	36.6	690.9	252.7	25,150,000
		MEAN INLET	6.84	1,227.7	920.0	307.7	329.3	15.0	12.7	42.5	17.1	76,333
		MEAN OUTLET	6.89	1,022.3	880.3	142.0	73.3	22.7	18.1	18.0	7.4	39,837
		Per cent removal	NA	16.73	4.31	53.85	77.73	-51.11	-42.41	57.60	56.57	47.81
KOKRAJHAR	Feb 2025	FS	7.12	28,217	9,217	19,000	94,650	7,120	102	1834.6	864.0	230,000,000
		INLET	7.29	1,307	907	400	3,315	183	10.95	214.0	148.4	930,000
		OUTLET	7.63	493	313	180	308	87	11.9	135.5	113.9	1,100,000
	May 2025	FS	7.17	10,870	3,470	7,400	41,400	2,800	168.0	1,646.4	1,685.3	2,300,000
		INLET	8.01	264	233	31	124	10	7.0	151.4	78.4	230,000
		OUTLET	7.8	119	93	26	118	8	3.9	20.0	23.9	930,000
	Jun 2025	FS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		INLET	7.53	421	381	40	176	19	12.3	70.3	42.6	43,000
		OUTLET	8.37	130	116	14	31	5	2.7	28.8	6.4	30

FSTP location	Month	Type of sample	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TP (mg/L)	TKN (mg/L)	AN (mg/L)	FC (MPN/100 ml)
	Mean	MEAN FS	7.145	195,43.5	6,343.5	13,200.0	68,025.0	4,960.0	135.0	17,40.5	1,274.6	116,150,000
		MEAN INLET	7.61	664.0	507.0	157.0	1,205.0	70.7	10.1	1,45.2	89.8	401,000
		MEAN OUTLET	7.93	247.3	174.0	73.3	152.3	33.3	6.2	61.4	48.0	676,677
		Per cent removal	NA	62.75	65.68	53.29	87.36	52.83	38.84	57.69	46.50	-68.75
GUWAHATI	Feb 2025	FS	6.83	29,811	9,811	20,000	82,550	5,150	38	14,52.4	272.8	43,000,000
		INLET	7.11	1,720	1,610	110	458	413	0.75	199.9	155.3	110,000,000
		OUTLET	7.58	208	207	1	46	4	3.52	63.2	3.8	11,000
	May 2025	FS	6.41	9,608	4,508	5,100	31,700	1,810	59.0	852.6	275.7	230,000
		INLET	7.9	1,356	1,298	58	230	61	26.4	2,41.7	201.0	750
		OUTLET	7.45	466	462	4	29	10	1.7	11.2	12.3	30
	Jun 2025	FS	6.59	8,305	7,375	930	31,100	2,030	46.0	984.9	144.9	430,000
		INLET	7.77	826	742	84	258	189	31.5	127.9	110.2	1,100,000
		OUTLET	8.03	950	940	10	76	5	1.4	15.9	4.7	30
	Mean	MEAN FS	6.61	15,908	7,231.3	86,76.7	48,450.0	2,996.7	47.7	1,096.6	231.1	14,553,333
		MEAN INLET	7.59	1,300.7	1,216.7	84.0	315.3	221.0	19.6	189.8	155.5	37,033,583
		MEAN OUTLET	7.69	541.3	536.3	5.0	50.3	6.0	2.2	30.1	6.9	3,687
		Per cent removal	NA	58.38	55.92	94.05	84.04	97.28	88.71	84.15	95.54	99.99
TINSUKIA	Mar 2025	FS	7.39	1,714	714	1,000	16,850	130	39.5	405.7	328.5	150,000
		INLET	7.51	718	708	10	216	36	25.2	85.8	61.6	920
		OUTLET	7.56	386	385	1.0	9.0	1.7	1.1	2.6	4.2	30
	Apr 2025	FS	6.51	2,917	1,817	1,100	20,600	270	61.5	661.5	260.3	360
		INLET	7.18	1,004	896	108	296	23	15.9	67.3	55.6	2,300
		OUTLET	8.17	498	492	6.0	23.0	7.5	2.7	7.9	2.9	92
	Jun 2025	FS	7.74	40,673	9,673	31,000	69,850	2,320	252.0	2072.7	710.5	930
		INLET	7.67	851	733	118	300	16	27.0	146.7	108.4	2,300
		OUTLET	7.72	695	685	10	87	11	9.1	54.1	20.6	11,000

FSTP location	Month	Type of sample	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TP (mg/L)	TKN (mg/L)	AN (mg/L)	FC (MPN/100 ml)
	Mean	MEAN FS	7.21	15,101.3	4,068.0	11,033.3	35,766.7	906.7	117.7	1,046.6	433.1	50,430
		MEAN INLET	7.45	857.7	779.0	78.7	270.7	25.0	22.7	100.0	75.2	1840
		MEAN OUTLET	7.82	526.3	520.7	5.7	39.7	6.7	4.3	21.6	9.2	3707
		Per cent removal	NA	38.63	33.16	92.80	85.34	73.07	81.18	78.43	87.73	-101.49
NORTH LAKHIMPUR	Mar 2025	FS	6.46	247	233	14	16,750	10	29.5	276.4	198.4	230,000
		INLET	6.71	606	545	61	136	42	17.4	127.3	118.3	920
		OUTLET	7.01	363	352	11	NA	NA	6.7	27.9	25.5	36
	Apr 2025	FS	7.2	75,600	16,600	59,000	163,000	4,260	107.5	3,189.9	267.1	430,000
		INLET	8.12	810	700	110	452	69	19.0	182.6	143.6	9,300
		OUTLET	7.93	338	328	10	NA	NA	5.0	39.7	28.0	30
	Jun 2025	FS	7.67	1,104	584	520	960	60	35.0	793.8	287.0	15,000
		INLET	8.38	569	523	46	142	8	14.7	179.6	135.2	36
		OUTLET	7.69	456	446	10	21	4	6.8	43.2	2.6	30
	Mean	MEAN FS	7.11	25,650.3	5,805.7	19,844.7	60,236.7	1,443.3	57.3	1,420.0	250.9	225,000
		MEAN INLET	7.74	661.7	589.3	72.3	243.3	39.7	17.0	163.2	132.3	3,419
		MEAN OUTLET	7.54	385.7	375.3	10.3	21.0	4.0	6.1	36.9	18.7	32
		Per cent removal	NA	41.71	36.31	85.71	9,1.37	89.92	63.97	77.36	85.87	99.06
MARIANI	Mar 2025	FS	6.53	2,556	1,356	1,200	18,700	200	71.5	394.0	9.9	15,000
		INLET	7.11	787	686	101	278	54	27.2	175.5	142.4	1500
		OUTLET	7.46	149	109	40	290	35	22.6	145.8	132.9	150
	Apr 2025	FS	7.13	6,174	2,974	3,200	60,200	2,270	220.5	1,808.1	449.0	230,000
		INLET	7.97	767	677	90	618	19	18.8	148.5	111.6	23,000
		OUTLET	7.61	633	596	37	192	48	4.8	132.3	206.3	430,000
	Jun 2025	FS	7.82	4,548	948	3,600	31,000	480	67.0	2,043.3	304.1	4300
		INLET	8.01	1,248	248	1,000	1,450	85	34.6	402.8	202.9	1,500
		OUTLET	7.80	964	694	270	924	51	28.3	216.7	183.9	150,000

FSTP location	Month	Type of sample	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TP (mg/L)	TKN (mg/L)	AN (mg/L)	FC (MPN/100 ml)
	Mean	MEAN FS	7.16	4,426	1,759.3	2,666.7	36,633.3	983.3	119.7	1,415.1	254.4	83,100
		MEAN INLET	7.70	934.0	537.0	397.0	782.0	52.7	26.9	242.3	152.3	8,667
		MEAN OUTLET	7.62	582.0	466.3	115.7	468.7	44.7	18.5	164.9	174.4	193,383
		Per cent removal	NA	37.69	13.16	70.86	40.07	15.19	31.00	31.92	-14.47	-2,131.35
GOLAGHAT	Mar 2025	FS	6.39	2,177	2,167	10	21,700	150	40.5	232.3	173.4	430,000
		INLET	7.11	900	580	320	2,445	58	17.1	21.5	114.2	430,000
		OUTLET	7.15	768	716	52	248	190	5.4	76.4	175.6	30
	Apr 2025	FS	7.33	2,035	1,035	1,000	21,200	310	28.0	364.6	30.8	93,000
		INLET	7.82	2,026	26	2,000	3,740	177	15.1	269.0	171.9	93,000
		OUTLET	7.88	778	558	220	410	70	7.3	176.4	133.7	9,300
	Jun 2025	FS	7.95	9,313	4,513	4,800	35,250	710	161.0	2,028.6	247.3	43,000
		INLET	7.77	3,266	2,936	330	8,355	336	69.6	492.5	158.0	9,200
		OUTLET	8.02	1,031	861	170	664	47	27.4	288.1	194.1	23,000
	Mean	MEAN FS	7.22	4,508.33	2,571.7	1,936.7	26,050.0	390.0	76.5	875.1	150.5	188,667
		MEAN INLET	7.57	2,064.0	1,180.7	883.3	4,846.7	190.3	33.9	261.0	148.0	177,400
		MEAN OUTLET	7.68	859.0	711.7	147.3	440.7	102.3	13.4	180.3	167.8	10,777
		Per cent removal	NA	58.38	39.72	83.32	90.91	46.23	60.53	30.90	-13.34	93.93

Source: CSE

Annexure 2: Consolidated three-month data of biosolids collected from Assam

Location	Month	pH	EC (dS/m)	Moisture (%)	Organic Carbon (% by weight)	Total Nitrogen (% by weight)	CN Ratio	Helminths (no. egg/4 g) (dry solids)	FC (MPN/g) dry solids	EC (MPN/g) (dry solids	*Salmonella* (MPN/4g) dry solids
Goalpara	Feb 2025	6.83	1.23	63.1	22.2	0.25	87	49	117	117	100
	May 2025	5.47	1.49	41.4	24.1	0.49	49	68	393	393	63
	Jun 2025	5.32	1.08	51.6	25.4	1.07	24	50	89	7	35,547
	Mean value	5.87	1.27	52.0	23.9	0.61	53	56	199	172	11,903
Mariani	Apr 2025	5.75	2.56	19.6	39.2	3.75	10	508	1,493	4	104,512
	Jun 2025	5.65	0.16	10.3	38.0	3.61	11	383	3	3	10,697
	Mean value	5.76	1.33	27.3	33.7	2.66	25	316	565	60	42,371
North Lakhimpur	Jun 2025	6.32	1.18	15.4	38.1	3.13	12	539	5,080	5,080	519,858
Golaghat	Jun 2025	6.16	0.67	72.9	30.2	2.28	13	1,829	11	11	1,622,876

Source: CSE

Annexure 3: Heavy metals in biosolids

Location	Month	Arsenic (mg/kg) max. 10.00	Mercury (mg/kg) max 0.15	Cadmium (mg/kg) max. 5	Chromium (mg/kg) max. 50	Lead (mg/kg) max. 100	Zinc (mg/kg) max. 1000	Copper (mg/kg) max. 300	Nickel (mg/kg) max. 50	Calcium per cent by weight	Magnesium per cent by weight	Manganese per cent by weight	Sodium per cent by weight
Goalpara	Feb 2025	Nil	0.195	0.475	27.6	8.67	386.0	110.0	20.2	2.620	0.633	0.052	0.079
	May 2025	0.246	NIL	0.349	14.9	6.63	378.0	71.3	13.7	2.710	0.697	0.057	0.071
	Jun 2025	Nil	0.01	0.312	11.8	8.54	260.0	62.1	12.8	2.020	0.478	0.055	0.050
	Mean value	0.246	0.103	0.379	18.1	7.95	341.3	81.1	15.6	2.450	0.603	0.055	0.067
Mariani	Apr 2025	Nil	4.710	2.470	8.1	10.7	1680	190.0	23.1	2.500	0.317	0.061	0.138
	Jun 2025	2.76	0.524	1.760	14.8	9.8	1070	134.0	22.5	1.160	0.192	0.038	0.078
	Mean value	2.760	2.617	2.115	11.4	10.23	1375.0	162.0	22.8	1.830	0.255	0.050	0.108
North Lakhimpur	Jun 2025	5.57	0.18	0.91	9.0	8.4	462	66.0	8.8	0.63	0.10	0.021	0.032
Golaghat	Jun 2025	2.07	1.77	1.91	24.7	11.7	1200	112.0	23.4	0.84	0.19	0.023	0.092

Source: CSE

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The Centre for Science and Environment (CSE) evaluated seven faecal sludge treatment plants (FSTPs) in Assam as part of its nationwide monitoring of FSSM systems. The assessment showed mixed performance; some plants improved while others declined in effluent and biosolids quality against national standards.

This study offers an overview of operational performance, technological adequacy and compliance, identifying key gaps, best practices and policy needs. It provides actionable insights to strengthen faecal sludge management in Assam and support broader sanitation and public health goals.

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