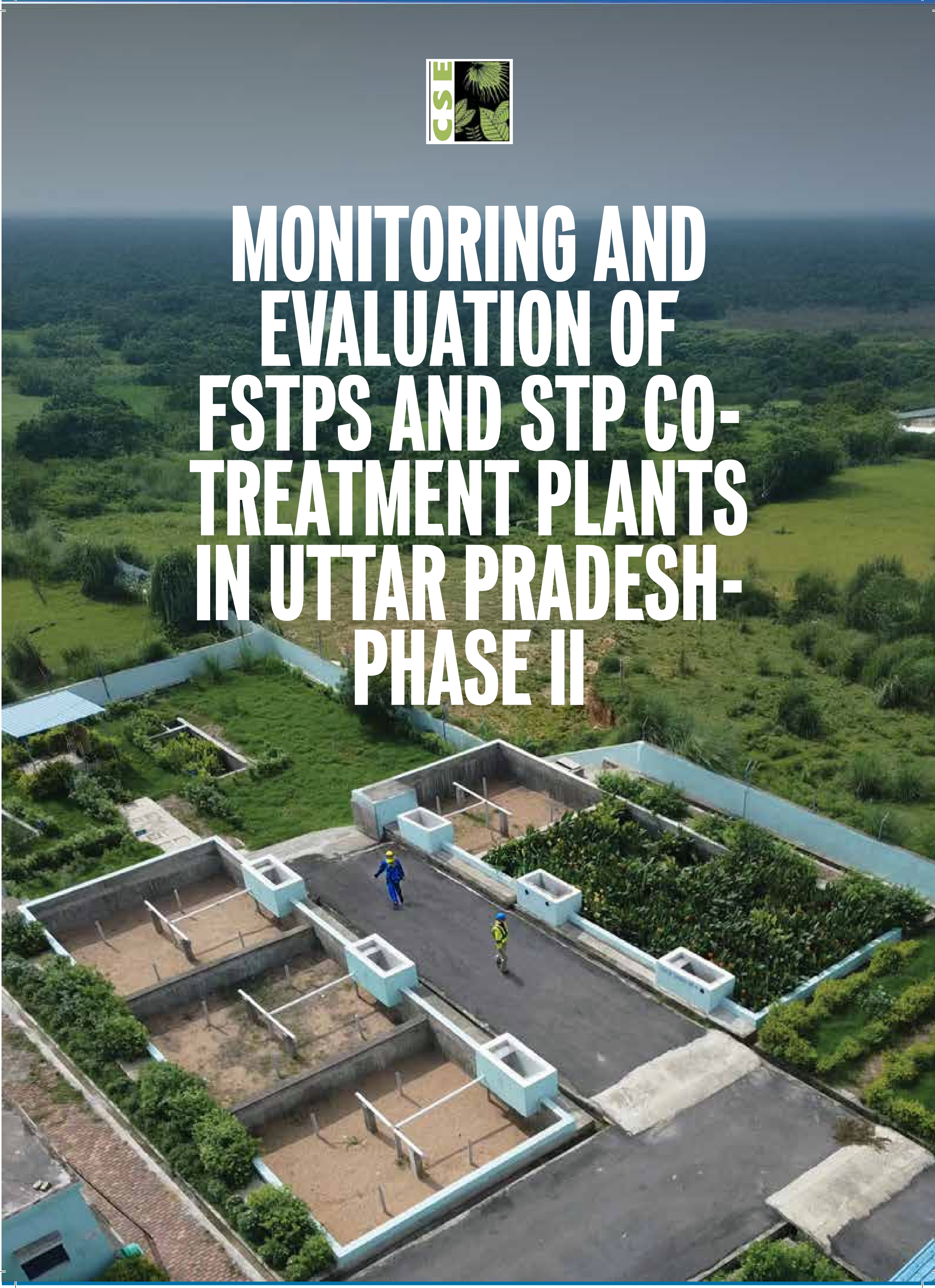
# MONITORING AND EVALUATION OF FSTPS AND STP CO-TREATMENT PLANTS IN UTTAR PRADESH-PHASE II



# MONITORING AND EVALUATION OF FSTPS AND STP CO-TREATMENT PLANTS IN UTTAR PRADESH-PHASE II

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**Production:** Rakesh Shrivastava and Gundhar Das

Gates Foundation

This Protocol is based on research funded by Gates Foundation. The findings and conclusions are those of the authors and do not necessarily reflect positions or policies of the foundation.



**Citation:** Saumya, Rajarshi Banerjee et al, 2025, *Monitoring and Evaluation of FSTPs and STP co-treatment plants in Uttar Pradesh- Phase II*, Centre for Science and Environment, New Delhi

Published by
**Centre for Science and Environment**
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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ABR | Anaerobic Baffled Reactor |
| ACF | Activated Carbon Filter |
| AMRUT | Atal Mission for Rejuvenation and Urban Transformation |
| BR | Baffled reactor |
| BOD | Biological Oxygen Demand |
| COD | Chemical Oxygen Demand |
| CSE | Centre for Science and Environment |
| Ca | Calcium |
| C:N | Carbon to Nitrogen ratio |
| Cd | Cadmium |
| Cu | Copper |
| E. coli | Escherichia coli |
| EC | Electrical conductivity |
| FC | Faecal Coliform |
| FSTP | Faecal sludge treatment plant |
| FSSM | Faecal sludge and septage management |
| FCO | Fertilizer Control Order |
| FS | Faecal sludge |
| Hg | Mercury |
| HRT | Hydraulic Retention Time |
| ISAF | Integrated Settler and Anaerobic Filter |
| KLD | Kilo litres per day |
| K | Potassium |
| MBBR | Moving Bed Biofilm Reactor |
| MGF | Multigrade Filter |
| MoHUA | Ministry of Housing and Urban Affairs |
| Mg | Magnesium |
| NSS | Non-sewered sanitation |
| NGT | National Green Tribunal |
| Ni | Nickel |
| PDB | Planted Drying Bed |
| PSF | Pressure Sand Filter |
| PGF | Planted Gravel Filter |
| Pb | Lead |
| pH | Potential of hydrogen |
| PPE | Personal protective equipment |

| | |
|---|---|
| SBR | Sequential Batch Reactor |
| SBM | Swachh Bharat Mission |
| STP | Sewage treatment plant |
| SR | Stabilization reactor |
| TDS | Total Dissolved Solids |
| TKN | Total Kjeldahl Nitrogen |
| TP | Total Phosphate |
| TS | Total Solids |
| UV | Ultra Violet irradiation |
| USEPA | United States Environmental Protection Agency |
| UBD | Unplanted Drying Bed |
| Zn | Zinc |

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# Executive summary

This report presents an evaluation of 14 faecal sludge treatment plants (FSTPs) in Uttar Pradesh—11 FSTPs and three sewage treatment plants (STP) with co-treatment facilities. A diverse range of treatment technologies was adopted, categorised as nature-based (e.g., anaerobic baffled reactors, wetlands, planted gravel filters), hybrid systems, and advanced mechanical units such as sequential batch reactors (SBR) and moving bed biofilm reactors (MBBR). Most plants use screw press for solid-liquid separation and sun drying for biosolid treatment. Plants such as Chunar and Raebareli showcased effective use of sequential treatment steps, including Anaerobic Baffled Reactor (ABR), Planted Gravel Filter (PGF), and UV disinfection—ensuring robust effluent treatment and safe sludge handling. The integration of these technologies varied by site, based on capacity, source of faecal sludge (FS), and local conditions.

The treated water quality from FSTPs and co-treatment plants was assessed against standards set by the Ministry of Environment, Forest and Climate Change (MoEFCC) and the National Green Tribunal (NGT). While many plants demonstrated high removal efficiency for Biological Oxygen Demand (BOD) (up to 99.7 per cent) and Chemical Oxygen Demand (COD) (up to 99.3 per cent); others like Bakshi Ka Talab and Bahraich underperformed. Inadequate tertiary treatment, poor disinfection infrastructure, and structural flaws (e.g., open tanks and algal blooms) led to non-compliance in some plants, particularly for BOD, COD, and Total Suspended Solids (TSS). Pathogen removal was also inconsistent—only three FSTPs achieved Faecal Coliform (FC) levels within the desirable NGT limit, while seven complied with MoEFCC's relaxed criteria. Plants with UV or optimised chlorination performed better in disinfection.

The study revealed significant variation in biosolid quality across sites. Only five of the 14 plants produced biosolids with moisture content within the standards (<25%) set by the Fertilizer Control Order (FCO) in 2023. Elevated moisture in the remaining samples hindered effective drying and encouraged microbial regrowth. Electrical conductivity (EC), pH, and C:N ratios were mostly within acceptable ranges, but C:N exceeded optimal limits in some sites (e.g., Bahraich). Heavy metal analysis showed non-compliance for chromium, mercury, and zinc in several plants, especially Rampur and Khurja. Alarmingly, all biosolid samples showed pathogen levels above the World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) safety thresholds, including excessive helminths (up to 3,574 eggs/4g) and high *E. coli* and *Salmonella* loads, making them unsafe for agricultural reuse without further treatment.

## Recommendations for improved performance

To enhance the performance and sustainability of FSTPs and co-treatment plants, the following actions are recommended:

- **Upgrade tertiary treatment**: Incorporate and improve disinfection units (UV, chlorination) and filtration systems to consistently meet effluent standards, especially for TSS, and FC.

- **Improve sludge management**: Invest in improved drying infrastructure (e.g., mechanical drying or covered beds) to reduce moisture content and microbial regrowth in biosolids.

- **Pathogen control**: Implement pathogen reduction techniques (e.g., composting, thermophilic processes) and ensure hygienic storage of dried biosolids.

- **Monitoring and compliance**: Conduct regular performance audits using standard protocols, and introduce regular monitoring systems to track water quality, biosolid safety, and heavy metal levels.

- **Capacity building**: Train local staff in process control, maintenance, and emergency response to sustain high operational efficiency.

- **Control industrial discharge at source**: Identify and control upstream contributors of industrial waste that may introduce heavy metals or toxic contaminants into the FS stream.

# 1. Background

Faecal sludge management (FSM) remains a long-term challenge in India, where collection and treatment of waste is often neglected. Around 0.12 million tonnes of sludge is generated in India per day. However, only 30 per cent of urban India has a well-connected sewage system; the remaining 70 per cent is still dependent on on-site sanitation systems, like pit latrines and septic tanks.[1,2] Once these containment systems are filled, the general practice is to discharge the untreated sludge in an open environment—mostly in the waterbodies, which could be far more dangerous than open defecation. This practice can lead to more pronounced effects on the environment like contamination of groundwater and drinking water, leading to disease outbreaks such as diarrhoea, cholera, and typhoid.

To address this gap in safe sanitation management, especially non-sewered sanitation (NSS), the Government of India launched the Swachh Bharat Mission (SBM) in 2014. Under SBM, millions of toilets were built but a critical question emerged: where will the waste generated by these containment system go? In response to this, the Ministry of Housing and Urban Affairs (MoHUA) introduced the National Faecal Sludge and Septage Management policy back in 2017, which eventually led to the introduction of faecal sludge treatment plants (FSTPs).

Currently, around 1,040 FSTPs are operational, with at least 300 more under various stages of construction. Co-treatment of faecal sludge through sewage treatment plants (STPs) has also been initiated in many locations. However, construction of FSTPs and co-treatment plants alone cannot be seen as the ultimate measure of success. Regular monitoring and evaluation of these treatment plants is crucial to ensure treatment efficacy and that the final discharge effluent lies within the prescribed standards before being released into the environment.

Centre for Science and Environment (CSE) has been working closely with the state administration of Uttar Pradesh to strengthen capacity of its urban and sanitation planners. About 59 treatment plants have been built in Uttar Pradesh under schemes such as the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and the National Mission for Clean Ganga (NMCG). CSE has also supported the construction and commissioning of one FSTP situated in Chunar and one STP co-treatment plant located in Bijnor—both of which are now operational.

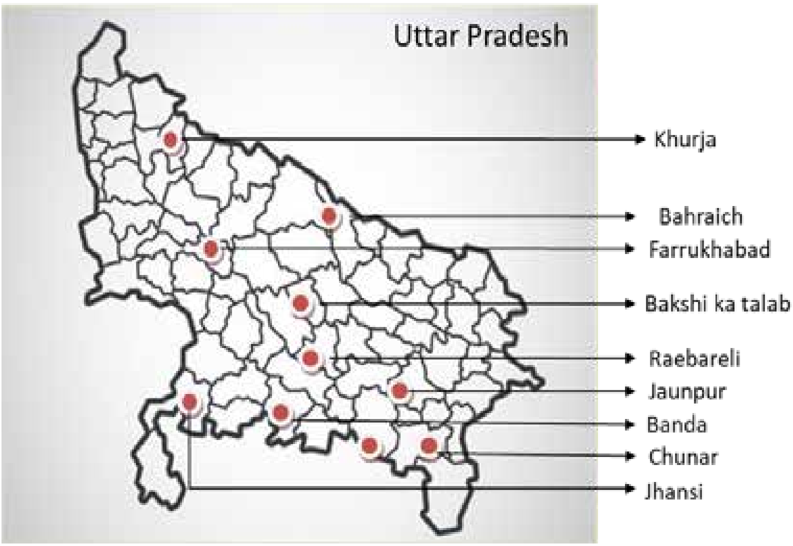
# 2. Introduction

Nestled in north-central India, stretched across the fertile Gangetic plains, Uttar Pradesh is the country's fourth largest state by area. With 75 districts and a population of 0.23 billion, it is also the most populous state. It is estimated that the state generates around 5,500 MLD of sewage, out of which 3,296 MLD is treated by the STPs.[3] Data on untreated wastewater remains undocumented, as nearly 95 per cent of the population is majorly dependent on non-sewerage sanitation systems, and only 31 towns have partial sewerage systems. Since most of the septage is generated by households, it is necessary to treat these at decentralised treatment systems (FSTP) in order to avoid groundwater and environmental contamination. Uttar Pradesh has been actively working towards improving its sanitation system.

Since 2016, CSE has been working with the state administration to build capacity of its urban and sanitation planners. By 2022, Uttar Pradesh had initiated around 62 faecal sludge and septage management (FSSM) projects, with 59 treatment plants built under schemes such as AMRUT and NMCG or through funding from urban local bodies (ULBs).[4] Uttar Pradesh has adopted either nature-based (nature based-1 and nature based-2) or hybrid (hybrid-1 and hybrid-2) treatment technologies.

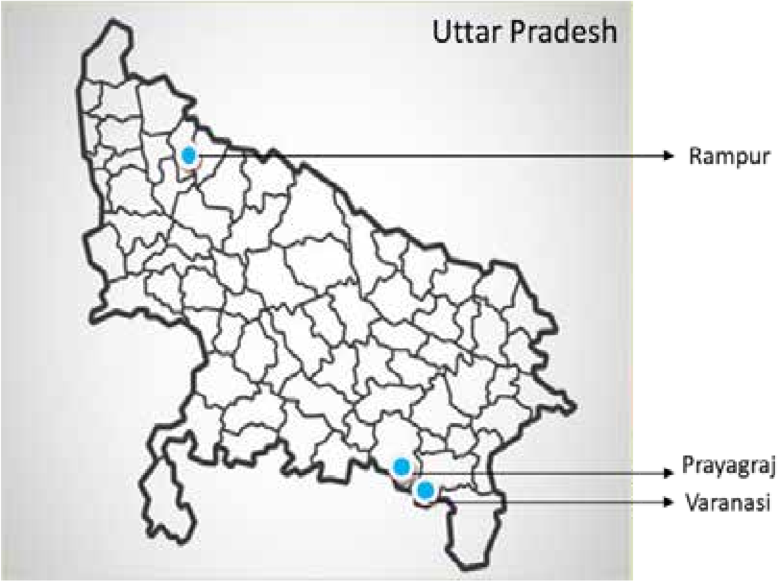
In this report by CSE's Environment monitoring laboratory, a total of 14 treatment plants (three co-treatment plants and 11 faecal sludge treatment plants) were evaluated over a period of five months.

**Map 1: Locations of FSTPs monitored in the study**




Source: CSE

### Map 2: Locations of STP co-treatment plants monitored in the study




Source: CSE

### Table 1: List of FSTPs and STP co-treatments along with treatment techniques involved in the study

| List of FSTPs and STP co-treatment plants in the recent study | | | | | | | |
|---|---|---|---|---|---|---|---|
| S. no. | FSTP/STP location | Capacity | Solid-liquid separation | Treatment technology | Tertiary treatment | Biosolid treatment method | Coordinates of the treatment plants |
| Faecal sludge treatment plants | | | | | | | |
| 1. | Jaunpur | 32 KLD | Screw press | ABR, SBR, and phytorid | Chlorination, ACF and MGF | Sun drying | Lat 25.752705° Long 82.651213° |
| 2. | Chunar | 10 KLD | PDB | ABR and PGF | ACF and PSF, followed by UV-disinfection | Sun drying | Lat 25.10075° Long 82.868199° |
| 3. | Farrukhabad | 32 KLD | Screw press | ABR and wetland | Chlorination, ACF and MGF | Sun drying | Lat 26.366372° Long 90.224827° |

| List of FSTPs and STP co-treatment plants in the recent study | | | | | | | |
|---|---|---|---|---|---|---|---|
| S. no. | FSTP/STP location | Capacity | Solid-liquid separation | Treatment technology | Tertiary treatment | Biosolid treatment method | Coordinates of the treatment plants |
| 4. | Bahraich | 32 KLD | Lamella clarifier | Scum remover, ABR, lamella clarifier and PGF | ACF and PSF | Sun drying | Lat 27.694965° Long 81.530048° |
| 5. | Bakshi Ka Talab | 25 KLD | UDB | ABR, facultative chamber and maturation tank | -- | Sun drying | Lat 27.000895° Long 80.93813° |
| 6. | Raebareli | 32 KLD | Screw press | Stabilization tank, equalization tank and ABR | PSF and polishing pond | Sun drying | Lat 26.201069° Long 81.263018° |
| 7a. | Jhansi (6+12 KLD) | 6+12 KLD | PDB | ISAF and PGF | Polishing pond | Sun drying | Lat 25.372747° Long 78.549135° |
| 7b. | Jhansi (32 KLD) | 32 KLD | Screw press | Baffled reactor and wetlands | ACF, chlorination, and MGF | Sun drying | Lat 25.28492° Long 78.35346° |
| 8. | Khurja | 32 KLD | Screw press | Baffled reactor and wetlands | ACF, DMF, and chlorination | Sun drying | Lat 28.196192° Long 77.830814° |
| 9. | Banda | 32 KLD | Screw press | Anaerobic filters, SBR, and phytorid | Chlorination, followed by ACF and MGF | Sun drying | Lat 25.439091° Long 80.327653° |
| STP co-treatment plants | | | | | | | |

| List of FSTPs and STP co-treatment plants in the recent study | | | | | | | |
|---|---|---|---|---|---|---|---|
| S. no. | FSTP/STP location | Capacity | Solid-liquid separation | Treatment technology | Tertiary treatment | Biosolid treatment method | Coordinates of the treatment plants |
| 10. | Prayagraj | 50 KLD | Screw pump | Screening chamber and screw pump in FSTP, MBBR in STP | Chlorination | Sun drying | Lat 25.458129° Long 81.879201° |
| 11. | Varanasi | 50 KLD | Screw pump | Screening chamber and screw pump in FSTP, SBR in STP | Chlorination | Sun drying | Lat 26.366372° Long 90.224827° |
| 12. | Rampur | 25 KLD | Screw press | PGF | Chlorination | Sun drying | Lat 28.790953° Long 79.053291° |

## Previously evaluated FSTP and co-treatment plant in Uttar Pradesh

There are 59 treatment plants in Uttar Pradesh which comprises of 39 FSTPs and 20 STP co-treatment plants. Our recent report consists of 14 treatment plants (11 FSTP and three co-treatment plants). Of the 11 FSTPs, two plants—Chunar and Jhansi (6+12 KLD) are re-evaluated to monitor the consistency in their performance.[4]

# 3. Objectives of the study

FSTPs are designed and implemented to treat FS in a manner that ensures that the by-products post treatment are safe for reuse or environmental discharge. To confirm the quality and safety of the by-products, ten crucial parameters are analysed for both FS and treated water. These indicators are critical in determining whether the final effluent, which is used for green belt development or discharged into water bodies—meets regulatory standards.

The analysis is conducted based on well-documented methods and standardised protocols**:**

- Biological Oxygen Demand (BOD): Automated BOD analyser and APHA 5210-B, 24th, 2023
- Chemical Oxygen Demand (COD): APHA 5220-D, 23rd Ed, 2017
- Total Kjeldahl Nitrogen (TKN): APHA 4500-Norg C
- Ammoniacal Nitrogen: APHA 4500-$NH_3$ C
- Total Phosphorus: APHA 4500-P E
- Total Solids: APHA 2540-B, 24th Ed,2023
- Total suspended solids: APHA 2540- D, 23$^{rd}$ Ed, 2017
- Total dissolved solids: APHA 2540- C, 23$^{rd}$ Ed, 2017
- pH: APHA 4500-H+B, 23$^{rd}$ Ed, 2017
- Faecal Coliform: APHA 9221 E, 21$^{st}$ Ed., 2005; USDA, MLG Appendix 2.05

## Environmental significance of the parameters is discussed below

**Biological Oxygen Demand (BOD)**: Biological Oxygen Demand is the measure of the amount of dissolved oxygen required by microorganisms (like bacteria) to break down organic matter in a water sample over a specific time and temperature, indicating the level of organic pollution. BOD is a very important parameter that indicates indirectly the level of organic chemicals that might enter a water body as the final effluent is discharged. This organic content can deplete or decrease the oxygen content of water bodies, resulting in imbalance that affects the aquatic flora and fauna.

**Chemical Oxygen Demand (COD):** Chemical Oxygen Demand is a water quality parameter that measures the amount of oxygen needed to chemically oxidise organic and inorganic matter in a water sample, essentially indicating the potential for oxygen depletion. High COD levels indicate a greater amount of oxidisable organic matter, which can lead to reduced Dissolved Oxygen (DO) levels in the water, potentially harming aquatic life.

While both COD and BOD (expressed as mg/L) measure the oxygen-depleting potential of organic matter, COD measures the total amount of oxygen required for chemical oxidation, while BOD measures the amount of oxygen consumed by microorganisms during the biological decomposition of organic matter.

**Total Kjeldahl Nitrogen (TKN):** One of the leading factors responsible for eutrophication in water bodies is the presence of organic dissolved forms of nitrogen, which leads to the rapid growth of simple plant life like algae. This eventually leads to the deterioration of quality of water bodies and imbalance in aquatic ecosystem. Therefore, TKN—which is a combination of both organic nitrogen and ammonia—can be used for the determination of nitrogen content in wastewater.

**Total phosphate:** Since phosphorus is one of the most essential elements for the growth of plants, it is the amount of total phosphate—whether in dissolved or particulate state—that is measured. Excess presence of phosphate can lead to the growth of algae eutrophication and deplete the oxygen level in water. Hence, monitoring of phosphate in wastewater or FS is necessary to make sure the wastewater treatment is done efficiently and adheres to environmental standards.

**Total solids (TS):** Total solids in wastewater are environmentally significant because they can negatively impact water quality, aquatic life, and human health. High levels of total solids, including both suspended and dissolved solids, can reduce light penetration, decrease dissolved oxygen levels, increase water temperature, and potentially carry harmful pathogens and pollutants. Total solids is a sum of total suspended solids (TSS) and total dissolved solids (TDS). The presence of TS can be felt due to numerous reasons like natural process, industrial discharge, and agricultural runoff.

**Total suspended solids (TSS):** It refers to the suspended solid particles present in wastewater. TSS can cause turbidity, making water appear cloudy, and reducing the amount of sunlight that can penetrate the water. This can harm aquatic plants and algae that rely on sunlight for photosynthesis, potentially leading to a decline in oxygen production and the creation of "dead zones". TSS can absorb heat from the sun, causing water temperatures to rise, which can be harmful to cold-water aquatic species. The decomposition of organic matter in TSS can consume dissolved oxygen in the water, further stressing aquatic life. TSS can accumulate in fish gills, causing them to malfunction and leading to stress and death. It alters the balance of aquatic ecosystems by affecting the growth and distribution of plants, animals, and microorganisms.

**Total dissolved solids (TDS)**: It refers to the sum of both organic and inorganic substances dissolved in water. High TDS levels, particularly from suspended solids, decrease penetration of light into the water, which is crucial for aquatic plants like algae to produce food and oxygen. Solids absorb more heat, causing water to warm up more rapidly, potentially leading to thermal stress on aquatic organisms. This can also deplete dissolved oxygen, further stressing aquatic life. High TDS levels can negatively impact the spawning and survival of fish, particularly juvenile species. Some dissolved solids can be toxic to aquatic life, even at relatively low concentrations.

**pH:** Potential of hydrogen (pH) is a measurement of the acidity (<7) or alkalinity (>7) of sludge based on the chemical activity of hydrogen ions in a solution. pH has a strong influence on biological processes, including pathogen inactivation. Measurement of pH is essential to understand the chemistry of water processes such as acid-base chemistry, alkalinity, neutralisation, biological stabilisation, precipitation, coagulation, disinfection, and corrosion control. In wastewater treatment, maintaining a pH between 6.5 and 8.5 is crucial for effective biological processes, with a neutral to slightly alkaline range (7 to 8) being ideal for bacteria and other organisms involved in the treatment.

**Faecal Coliform (FC):** As the name suggests, Faecal Coliform is a group of bacteria which form colonies in the colon. These are rod shaped, gram-negative, lactose-fermenting, and non-spore forming microorganisms—originating from faeces. One of the dominant subgroups of this bacteria is *Escherchia coli* 0157:H7, which resides in warm-blooded animals. They are an ideal indicator of faecal contamination. Presence of FC in wastewater indicates faecal contamination, either from human or other sources. They can enter the water bodies through direct waste discharge of mammals, birds, storm runoff, etc. Therefore, faecal sludge needs to be treated to an adequate hygienic level based on its reuse at the end or its disposal.

## Assessment of biosolids resource recovery potential

One of the earliest resource recovery potential from faecal sludge was to use the solids as soil amendment. This is due to the presence of essential plant nutrients and organic matter in the FS, which boost both the nutrient content as well as the water retaining capacity of the soil. The primary nutrients in biosolids are present in organic form, which are less soluble than chemical fertilisers and are released more slowly through decomposition by soil bacteria. However, raw faecal sludge cannot be applied directly to the soil, as it contains pathogenic microorganisms that can create a health risk to farmers and other people who are dependent on the crop which is grown under the influence of biosolids. Therefore, certain parameters must be analysed before biosolids can be used for soil amendment.

- **pH:** The pH of biosolids differs depending on the source (FSTP or STP). To reduce the pathogen load, biosolids are often alkaline stabilised. Therefore, the pH of biosolid can change, which should be considered to determine the end use of it.

- **Electrical Conductivity (EC):** It measures the concentration of salts and electrolyte, which indicates the ability of the soil to conduct electricity. It can also be stated as the amount of ions available to the plant in the root zone. It is measured in decisiemens per metre (dS/m).

  High EC can serve as an indication of salinity problems, which impede crop growth (inability to absorb water even when present) and microbial activity. Soils with high EC, resulting from a high concentration of sodium, generally have poor structure and drainage, and sodium becomes toxic to plants; whereas low EC can stunt the growth of the plant. Therefore, understanding EC can help the farmers to map out the application rate of manure/fertilisers/ biosolids, ensuring efficient and effective nutrient delivery to crops.

- **Moisture content**: It is defined as the amount of water which is present in the pores of soil. It is one of the essential parameters, as it governs the microbial activity of soil. Lack of moisture can hinder the microbial growth, reducing the degradation rate of organic content present in the soil. Moisture content in biosolids is crucial for several reasons, including its impact on microbial activity, the suitability of biosolids for various applications like fuel or compost, and the potential for odour and smouldering problems. A moderate moisture content is generally optimal for promoting microbial activity, while excessive moisture can hinder oxygen transfer and potentially lead to problems.

- **Carbon:Nitrogen (C:N):** Both carbon and nitrogen are considered important for both crop growth and microbial growth. Carbon is required as an energy source and nitrogen is necessary for the synthesis of nitrogen-containing cellular components by microbes and plants. Therefore, these elements should be present in equilibrium.

In case C:N ratio is >20 in biosolids, it may result in reduced nitrogen availability for the plants, leading to immobilisation of nitrogen. Conversely, a lower C:N ratio leads to higher mineralisation of nitrogen uptake for the plants, which may result in loss of nitrogen. Therefore, a balanced C:N ratio between 15:1 to 20:1 ensures optimal decomposition.[4]

- **Heavy metals**: Heavy metals in soil refer to naturally-occurring and human-introduced metals and metalloids that can contaminate soil and pose risks to human and environmental health. Common examples include arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. These metals can enter the soil through various sources, including natural processes, industrial activities, and agricultural practices. Releasing untreated faecal sludge and biosolids can result in heavy metal contamination, which can lead to human health risks, plant phytotoxicity, groundwater contamination, and decline in crop production. Heavy metal present in biosolids can both be a challenge and have potential benefits, depending on the concentration.

- **Faecal Coliform and *E. coli*:** Faecal sludge (FS) consists of numerous pathogens. There are four major groups of pathogens which are commonly found in faecal sludge, including bacteria, viruses, fungi, and parasitic protozoa. These pathogens occur in raw sludge, septage, liquid effluent and biosolids generated from FSTPs. The land application of untreated effluent and biosolids can pose health risks through direct or indirect human exposure. These pathogenic organisms can trigger diseases like diarrhoea, hepatitis, and fever. Coliform are a group of bacteria which are predominantly found in the gastrointestinal tract of warm-blooded animals including humans, though they may also occur in soil and on plant surfaces. Faecal Coliforms (FC) is a group of coliform bacteria, exclusively found in the intestine and faeces of humans and other warm-blooded mammals; hence their presence specifically indicates faecal contamination. The predominant FC is *Escherichia coli (E. coli)*. Their specific habitat, ease of cultivation, and generally non-pathogenic nature, E.coli and FC are widely used for indication of pathogen determination in biosolids.[5]

- **Salmonella:** Salmonella are gram-negative, anaerobic bacteria commonly found in sewage and wastewater. They belong to the genus *Salmonella* within the family *Enterobacteriaceae* and include a range of closely related strains. Enteric fever—typhoid and paratyphoid—is a collective term given to invasive infection caused by *S. typhi* and *S. paratyphi*. They have the capability to resist environmental stress and can stay viable in soil or crops for extended periods. These characteristics make them an indicator of choice.[6]

- **Helminth eggs:** Helminths are multicellular parasites that depend on a host—human, animal, or plant—for nutrition and development. They produce microscopic eggs which are the causative agent of helminthiasis, a disease transmitted from one human to another. Helminths are broadly classified into geo-helminths (transmitted through soil) and platyhelminthes (transmitted through consumption of improperly cooked beef or pork). *Ascaris lumbricoides* is a common indicator species, with a single female capable of producing up to 200,000 eggs per day. These eggs, ranging from 20–80 micrometres in size, have a monogenic life cycle, requiring only one host (human) for their further development and growth. These eggs can cause helminthiasis if consumed, and can lead to life-threatening diseases like neurocysticercosis, haemorrhagic colitis, schistosomiasis, etc. Therefore, proper treatment of biosolids prior to reuse or disposal of faecal sludge is crucial to prevent the spread of infections and maintain public health.[7, 8]

## Sample collection and testing parameters

A total of 14 treatment plants—11 faecal sludge treatment plants (FSTPs) and 3 co-treatment plants—were evaluated over a period of five months. Samples were collected from each site thrice over five months by EML scientists. For sample collection, standard protocols for sampling, transportation and preservation were followed. Personal protective equipment like gloves, face mask, lab coat, eyewear

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***Sample collection from both inlet and outlet of FSTPs***

and protective shoes were used during sample collection. Each sterile sample collection bottle was properly labelled with the date, location, time, and type of sample. Samples were then transported in a leak-proof ice-box along with an ice-gel packs.

## Physico-chemical parameters and standard methods used for testing

Physico-chemical parameters were analysed for the collected samples such as TS, TSS, TDS, AN, TKN TP, COD, BOD and microbial parameters were analysed by using standard methods listed below (see *Table 2*).

**Table 2: Physico-chemical parameters and standard methods used for testing**

| Parameters | Standard methods |
|---|---|
| pH | APHA 4500-H+B, 24th Ed, 2023 10 |
| 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 Analyzer & APHA 5210-B, 24th Ed, 2023 |
| Total Kjeldahl Nitrogen (TKN) | APHA 4500-Norg C, 24th Ed, 2023 |
| Ammoniacal Nitrogen (TN) | APHA 4500-NH3 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

## Physico-chemical parameters and standard methods used for testing of biosolids

The treatment plants are designed to first homogenise different loads of FS, followed by solid-liquid separation. The effluent (liquid) is treated to meet the discharge standards while the solid portion of the faecal sludge is dried, either in the presence of sunlight or mechanically.

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***Storage and collection of biosolids***

**Table 3: Biosolid characterisation methods and equipment used**

| Parameters | Standard methods/Equipment used |
|---|---|
| pH | APHA 4500-H+B, 24th 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 Coliform[9] | USEPA, Method 1680, 2014; USDA, MLG Appendix 2.05, 2014 |
| E. coli | APHA 9221 B, 9221 F, 23rd Ed., 2023; USDA, MLG Appendix 2.05, 2014 |
| Salmonella | Pour plate method using Hi-chrome Salmonella agar |
| Helminths eggs[10] | Ambic-ZnSO4 method |

Source: CSE

# 4. Introduction of faecal sludge treatment plants (FSTPs)

In this report, CSE's laboratory team evaluated 14 treatment plants—comprising 11 faecal sludge treatment plants (FSTPs) and three co-treatment plants—between November 2024 and March 2025. From each site, samples were collected over a period of five months. In Uttar Pradesh, where majority of the population depends on on-site sanitation systems, FSTPs have been introduced to manage faecal sludge (FS) from different on-site sanitation systems, households, and public toilets. At these facilities, FS is received and subjected to homogenisation and dewatering, involving solid-liquid separation as the initial step. From here, depending upon the type of technology implemented at the plant, further treatment of effluent and solids takes place. Detailed description of each treatment plant has been provided below:

## JAUNPUR

Jaunpur is one of the largest cities in the southeastern part of Uttar Pradesh.

A 32 KLD FSTP was commissioned here in November 2022. The plant receives three to four trucks of sludge per day (approximately 3000 litres). The faecal sludge is collected from various sources like household toilets, community toilets, hospital sludge, and public toilets. The treatment technology consists of a screening chamber which removes non faecal matters or debris. The sludge is then collected into a raw septage collection tank, where it is mixed with polymer to facilitate agglomeration of solids. It is subsequently transferred to a screw press for solid-liquid separation. The separated solids are dried using sun-drying beds and later used for gardening within the facility, whereas the liquid effluent is passed to an anaerobic baffled reactor (ABR) where the degradation of organic matter takes place. The liquid effluent is further passed to sequential batch reactors (SBR1 and SBR2) where the effluent is treated in a single tank in batches, followed by chlorination for disinfection. To remove small suspended solids from the treated water, it is further passed through multi-grade filter (MGF) and activated carbon filter (ACF). The final effluent is transferred to phytorid bed to remove the excess chlorine present in the treated water. The final treated water is used for groundwater recharge and green belt development within the campus.

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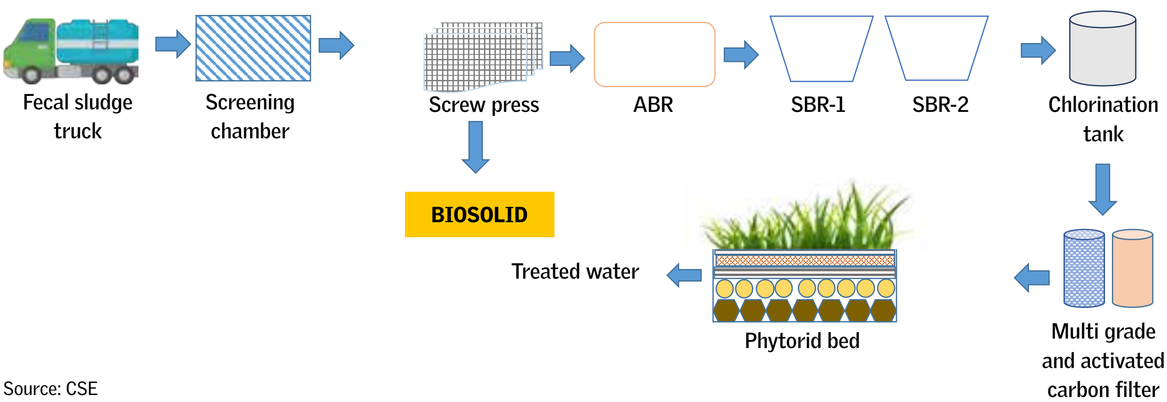
***Desludging the faecal sludge in the screening chamber initiating the preliminary stage***

**Figure 1: Jaunpur FSTP process-flow diagram**




Source: CSE

## CHUNAR

Surrounded by the banks of rivers Ganga and Jargo, Chunar is a small town in Mirzapur district of Uttar Pradesh.

In 2021, a 10 KLD FSTP was commissioned in Chunar. The plant receives on an average nine kilolitres of faecal sludge per day. Faecal sludge is collected from various sources like household toilets, public and community toilets. Chunar has adopted nature-based technology for the treatment of faecal sludge. It includes the screening chamber which screens out the non-faecal matter or debris. The sludge

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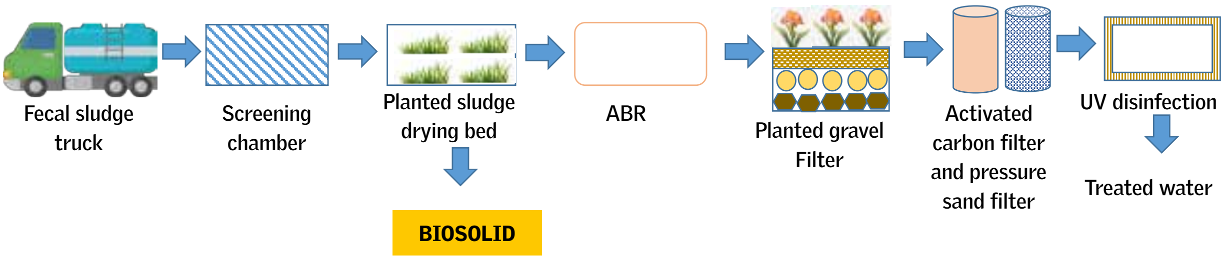
***Desludging of FS in the screening chamber, further FS has been transferred to PDB initiating solid- liquid separation***

**Figure 2: Chunar process-flow diagram**




Source: CSE

then flows to the planted drying bed (PDB) where solid-liquid separation takes place. The solids are dried up in PDBs, whereas the leachate enters the ABR and then flows into the planted gravel filter (PGF) for nutrient reduction. To remove small suspended solids, the effluent is further pumped to a filtration unit consisting of activated carbon filters (ACF) and pressure sand filter (PSF). The treated water gets disinfected under the influence of UV irradiation. The final effluent is stored in the collection tank and reused in the FSTP premises for gardening.

## FARRUKHABAD

Farrukhabad is a district in Uttar Pradesh, located between 26°46' and 27°43' North latitude and 79°7' and 80°2' East longitude. It is surrounded by rivers Ganga and Ramganga towards the east, and Kali Nadi towards the south. As per the 2011 Census, the district holds a population of 1.8 million.

In April 2023, a 32 KLD FSTP was commissioned. The plant receives around three to four trucks per day, with each truck having an average capacity of three kilolitres. The faecal sludge is received from different sources including household toilets, public toilets, and community toilets. The treatment technology comprises of a faecal sludge collection tank where FS is mixed with cationic polymer, which facilitates coagulation of solids. It is then passed through a screw press for solid-liquid separation. The solid part separated in the dewatering step is stored and used for gardening.

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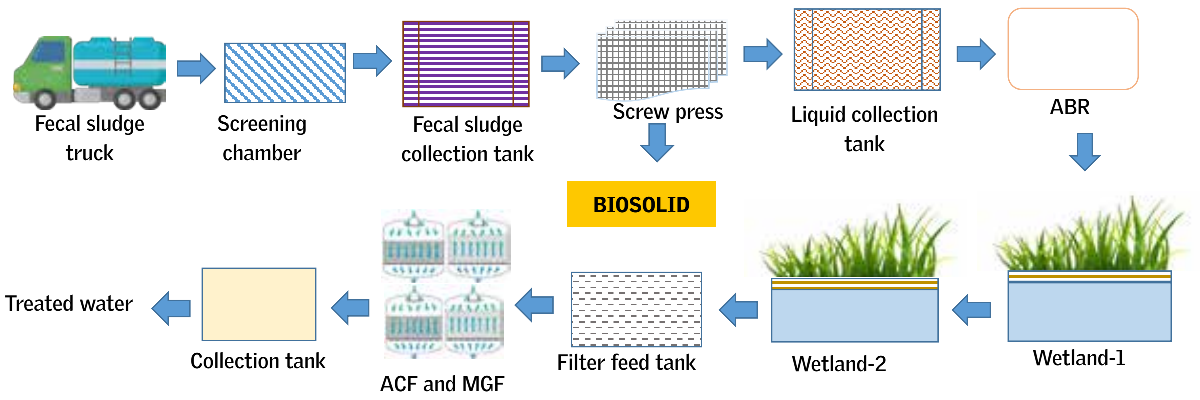
***The primary treatment stage in Farrukhabad***

Once dewatering is done, the liquid effluent passes to the liquid collection tank (LSC), followed by treatment in a baffled reactor for organic matter reduction. It then flows through two constructed wetlands (Wetland 1 and Wetland 2), where nutrients and pollutants are naturally removed by plant roots and microbial activity. The effluent is collected in a filter feed tank and is further treated in four sand filters for reduction of total suspended solids (TSS). The treated water is stored in a collection tank which is used in the greenbelt within the premises.

**Figure 3: Farrukhabad process-flow diagram**




Source: CSE

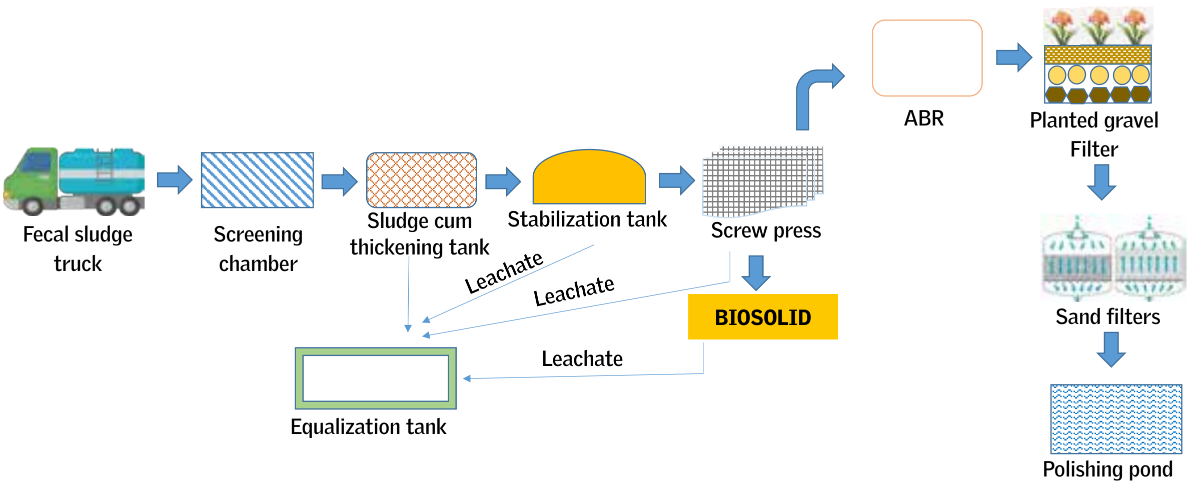
## RAEBARELI

The district occupies the central part of Ganga-Ghaghra and Gomti-Sai basins. It lies between 26° 13' 48.00" North latitude and 81° 14' 24.00" East longitude. It holds a population of 2.9 million, as per the latest Census.

A faecal sludge treatment plant holding the capacity of 32 KLD has been implemented in Raebareli to manage FS collected from various sources. The treatment technology consists of a screening chamber in which non-faecal matters are first removed. The sludge is then passed to a sludge-cum-thickening tank, where heavier particles of sludge settles down, while the lighter parts remain on the surface. Now stabilisation of sludge takes place where FS is stored for 10–15 days in the stabilisation reactor. Moreover, the FS is also mixed or homogenised using a rotator. From here, the sludge is passed to a polymer mixing unit where it is mixed with a cationic polymer. The sludge agglomerates in the presence of polymer and this agglomerates form goes in the screw press. In the screw press, dewatering of the sludge occurs, which is then conveyed to the drying bed. In order to balance the load and flow of sludge equalisation tank is introduced which receives the leachates from screw press, sludge drying bed, stabilisation tank and settling cum thickening tank. After which, the effluent from the screw press goes in ABR, where degradation of organic matter takes place. This is followed by transfer into PGF for nutrient reduction. It is then stored in a collection tank. For further removal of the TSS, the effluent from the collection tank is transferred to a pressure sand filter, which uses layered sand and gravel as a filtration medium. The effluent is pumped into the filter media, and then transferred to the polishing pond where residual organics are removed by oxidation and pathogens in the presence of sunlight. The treated water is used within the premises for gardening purposes.


***PGF initiates both physical and biological treatment of the effluent***

## Figure 4: Raebareli process-flow diagram




Source: CSE

## BAHRAICH

Bahraich, nestled in the northeastern part of Uttar Pradesh, lies between 28.24 to 27.4 North latitude and 81.65 to 81.3 East longitude. It is bounded by the Sarju and Ghaghra rivers. As per the 2011 Census, it has a population of 1.86 lakhs.

In 2023, a 32 KLD FSTP was introduced in Bahraich. The treatment process begins at the receiving chamber, where faecal sludge (FS) is collected. It then passes through a screening chamber to remove non-faecal debris, followed by a scum remover that eliminates floating materials such as oil, grease, and other organics.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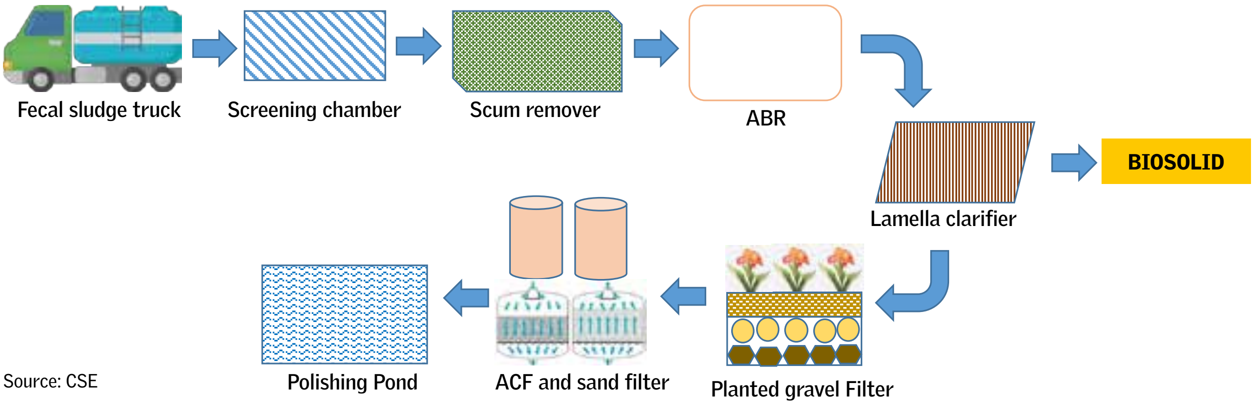
*Filtration module in the Bahraich FSTP*

Subsequently, the sludge is passed to ABR, where degradation of organic matter takes place with the help of anaerobic microbes. Supernatant or effluent from ABR is passed to a lamella clarifier, which promotes the settling of suspended solids. the effluent is then transferred to PGF which helps in nutrient reduction, followed by filtration with the help of activated carbon and sand filter. The effluent finally reaches the polishing pond where removal of residual organics by oxidation and pathogens in the presence of sunlight is carried out in an open pond that receives sufficient sunlight and oxygen. The treated water is used within the premises for gardening purposes.

**Figure 5: Bahraich process-flow diagram**




Source: CSE

## BANDA

Banda, a city located in the southern parts of Uttar Pradesh, lies between 24º 53’ to 25º 55’ North latitude and 80º 07’ to 81º 34’ East longitude. It is located near the Ken river, a tributary of the Yamuna.

Back in 2023, a 32 KLD FSTP was commissioned. The plant receives five truckloads of faecal sludge per day and each truck holds a capacity of 3.5 kilolitres. It receives sludge from various sources like household and community toilets, hospital sludge, public toilets, etc.

The treatment technology consists of several stages which initiates with screening, which removes non-faecal matter. From here, the sludge enters a raw septage tank. It is mixed with the polymer which results in agglomeration of the sludge. This is done so that proper solid-liquid separation may occur. It is then passed through a screw press for dewatering. The solid part separated in the dewatering stage is dried under the influence of sunlight and then goes to the storage room. After dewatering, the liquid flows to an ABR, where degradation of organic matter takes place. From there, the effluent flows into the intermediate tank, and then to two sequential batch reactors (SBR-1 and SBR-2). Disinfection of treated water is carried out through chlorination in a chlorine contact tank. After disinfection, it undergoes filtration in an activated carbon filter, followed by a multi grade filter. Post filtration, it enters the phytorid bed to remove the excess chlorine present in the treated water. The treated water is then used for maintaining the green belt within the premises.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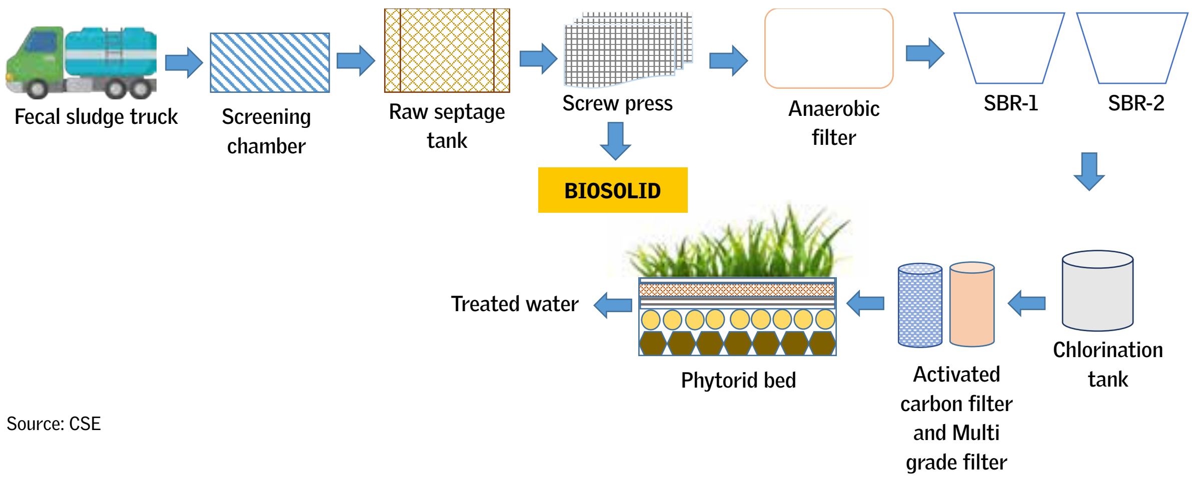
*Primary, secondary and tertiary modules in Banda*

**Figure 6: Banda process-flow diagram**




Source: CSE

## JHANSI (6, 12, and 32 KLD)

Jhansi is located in the Bundelkhand region of Uttar Pradesh. It is situated on the plateau of central India, on the banks of the Pahuj River, between the rivers Pahuj and Betwa. Three FSTPs with different capacities have been implemented and all were evaluated in this study, with their process-flow described below:

## JHANSI (32 KLD)

A 32 KLD FSTP has been set up in Jhansi. On an average, the plant receives around 21,000 litres of faecal sludge per week from household toilets, community and public toilets, etc. The faecal sludge is first passed through the screening chamber where the non-faecal matter is removed. Then the FS is transferred to the faecal

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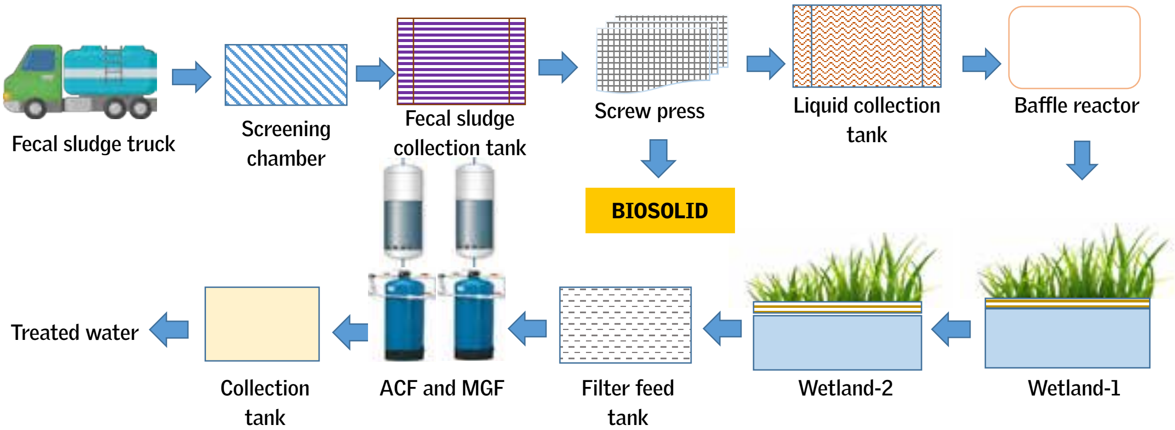
***Different treatment modules in Jhansi 32 KLD FSTP***

**Fig 7a: Jhansi (32KLD) process-flow diagram**




Source: CSE

sludge collection tank. Before dewatering, the sludge is mixed with the polymer to agglomerate the sludge for proper solid-liquid separation. Dewatering is done in a screw press. Afterwards, the liquid goes into the liquid collection tank which further goes to a baffled reactor (BR), where organic degradation occurs. The effluent flows sequentially into wetland-1 and wetland-2 for further treatment. The outlet of wetland-2 is then transferred to the filtrate collection tank. From here, the effluent undergoes the process of filtration by first passing through ACF, where both colour and odour associated with the effluent is removed; followed by multi-grade filtration (MGF) for further degradation of TSS.

## Jhansi (6 and 12 KLD)

Other FSTPs in Jhansi include a 6 KLD plant commissioned in 2018, which was later augmented with another 12 KLD plant in 2022. The plant works under the influence of gravity, following the principles of decentralised waste water treatment.

The plant receives 12–15 KL of FS per day. The FS is mostly collected from public toilets, community toilets, and household toilets.

The sludge is conveyed to a planted drying bed, where both stabilisation and dewatering of raw faecal sludge takes place. Specific varieties of plants are planted like *Typha, Canna indica,* etc. The sludge undergoes solid-liquid separation and gets dried in the planted sludge drying beds (SDBs). PDB remains common for both the plants (6 KLD and 12 KLD). From here, the percolate enters integrated settler and anaerobic filters where the it undergoes the process of sedimentation,

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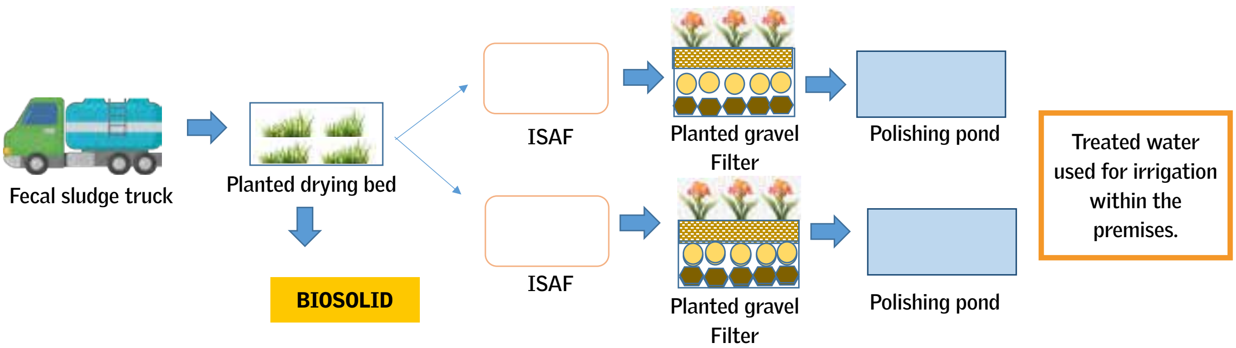
***Secondary and tertiary treatment modules in Jhansi (6+12 KLD)***

**Figure 7b: Jhansi (6+12 KLD) process-flow diagram**




Source: CSE

followed by further treatment in a three-chambered anaerobic filter (AF), where pipes are designed to direct the flow to the bottom of the tank, enabling organic degradation. Post anaerobic filtration, the liquid flows in the horizontal planted gravel filter, where the removal of nutrients—such as nitrogen and phosphorus—takes place. It is one of the essential steps as the presence of nutrients can promote the growth of the microbes.

Then the effluent flows into the polishing pond, where its main purpose is to remove the residual organics by oxidation and pathogens in the presence of sunlight—carried out in an open pond that receives sufficient sunlight and oxygen. The treated water is used for the purpose of irrigation within the premises.

## KHURJA

Khurja, situated in the northwest region of Uttar Pradesh, is a district in Bulandshahr. It has a population exceeding 1.45 lakhs. It has a 32 KLD FSTP which receives faecal sludge from various sources like household toilets, community toilets, hospital sludge, and public toilets. The plant receives two trucks per day, each with a capacity of 4000 litres.

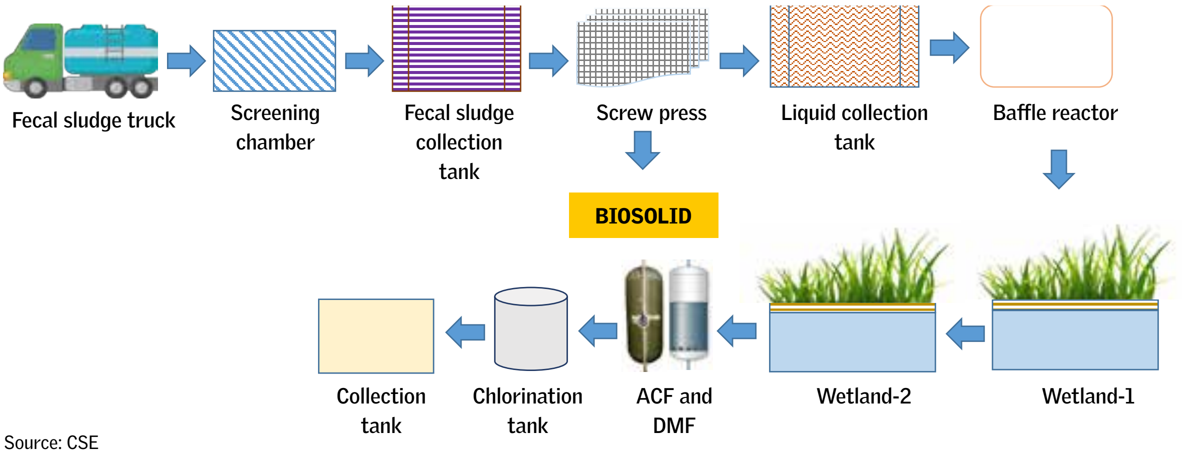
The treatment technology used in Khurja is Hybrid-1, which begins with screening of faecal sludge to remove non-faecal matter. This is followed by stabilisation in a FS collection tank, from where it is carried for dewatering in a screw press. Before dewatering, the sludge is mixed with a polymer for agglomeration to ensure solid-liquid separation. The solid part separated during dewatering is transferred to the sludge drying bed, where the sludge gets dried under the influence of sunlight.

After dewatering, the effluent is pumped to a baffled reactor (BR), where the degradation of organic content takes place. The effluent from the BR passes through two stages of wetlands—Wetland-1 and Wetland-2. In these wetlands, nutrients like nitrogen and phosphorus are absorbed by the plants, while the microbes present in the filter media degrade the organic content and help in trapping the sediments. The effluent then enters the activated carbon filter (ACF), which helps in the elimination of odour, colour, and micro pollutants. Post ACF, the effluent reaches the dual media filter (DMF)—comprising of sand and a second filter media such as anthracites—where both turbidity and suspended solids are removed. Finally, the treated water is disinfected in the chlorination tank. It is stored in a storage tank, further used for horticultural purposes within the premises of the plant.

CSE

***Primary (baffled reactor) and secondary (wetland) treatment modules in Khurja FSTP***

**Figure 8: Khurja process-flow diagram**




Source: CSE

## Bakshi Ka Talab

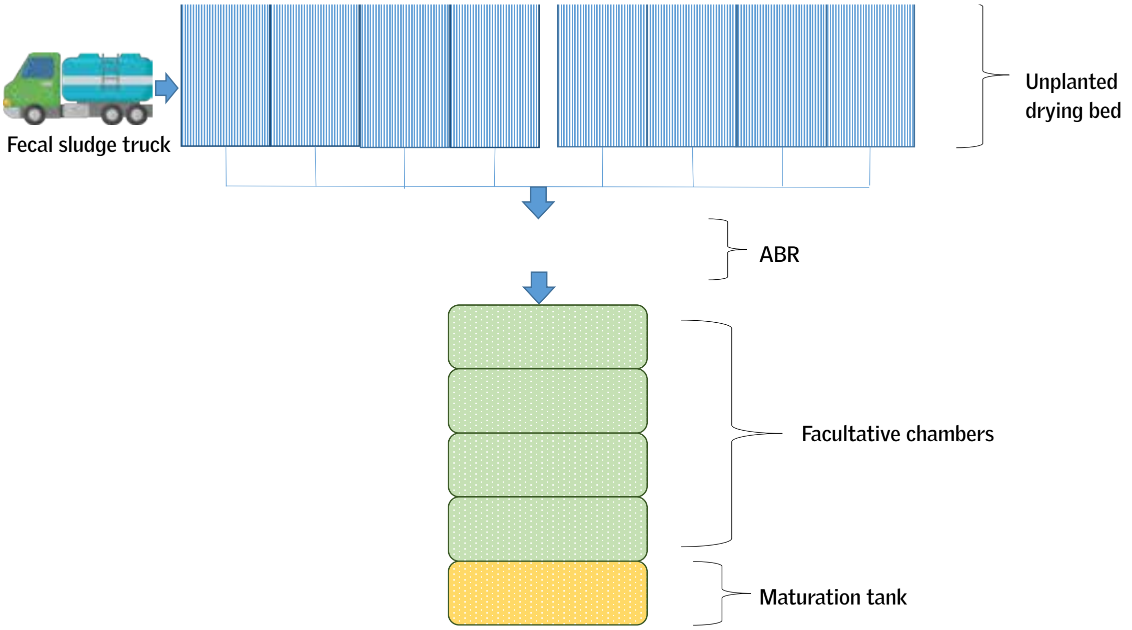
Bakshi Ka Talab, located in northern part of Lucknow, consists of both residential and business settlements. A 25 KLD FSTP is operational here. On an average, the plant receives three to four trucks per week, each holding the capacity of 3000 litres.

The treatment begins with decanting sludge into unplanted drying beds composed of layers of sand and gravel, where dewatering of sludge occurs through evaporation


CSE

***Decanting the faecal sludge in unplanted drying bed***

**Figure 9: Bakshi Ka Talab process-flow diagram**




Source: CSE

and filtration. From here, the liquid moves to the facultative chambers. Each facultative chamber consists of suspended material (gunny sacks) made up of nylon, which acts as a surface for biofilms. Once biofilms are formed, the organic content starts degrading. From the facultative chambers, the effluent is directed to a maturation tank. This aerobic unit enables pathogen reduction and further stabilisation, aided by sunlight penetration that enhances pathogen inactivation. The treated effluent is then used for gardening purposes within the premises.

# 5. Introduction to STP co-treatment plants

STP co-treatment plants refers to a combination of treatment of both domestic sewage and faecal sludge at a sewage treatment plant (STP).

In the absence of sewers, the households are dependent on on-site sanitation systems, as a result of which over 95 per cent of UP's towns and cities are dependent on these systems. Due to the presence of existing STPs which are underutilised, it has opened up the potential for co-treatment.

The treatment technology first focuses on the treatment of faecal sludge which includes receiving of FS, followed by screening to remove non-faecal matter. Then solid-liquid separation is done, where the solid matter is dried in sludge drying beds and the liquid effluent is treated in ABR and PGF.

Now, the treated effluent from FSTP serves as the inlet of STP, where it undergoes further treatment. Therefore, the entire process is termed as STP co-treatment.

## VARANASI

Varanasi, located in northern India along the banks of the river Ganga, is one of the oldest inhabited cities in the world. Its geographical coordinates are 25.3176° North latitude and 82.9739° East longitude. The population of Varanasi is estimated to be 4.11 million.

It has a 50 KLD faecal sludge treatment plant which receives FS from different sources. Desludging is performed through trucks, holding a capacity of 3,000 to 4,000 litres. On an average, the plant receives around 12,500 litres sludge per day.

The treatment process begins with the collection of FS at the receiving chamber, from where it is passed to the screening chamber for removal of non-faecal matter or inert materials. The sludge is then mixed with a cationic coagulator, which aids the agglomeration of sludge. The agglomerated sludge is dewatered using sets of parallel screw pump. The separated liquid gets collected in the filtrate tank, whereas the solid matter is transferred to the drying bed where it is dried in the presence of sunlight. The outlet of FSTP acts as an inlet of STP. The effluent is further treated in a sequential batch reactor (SBR).

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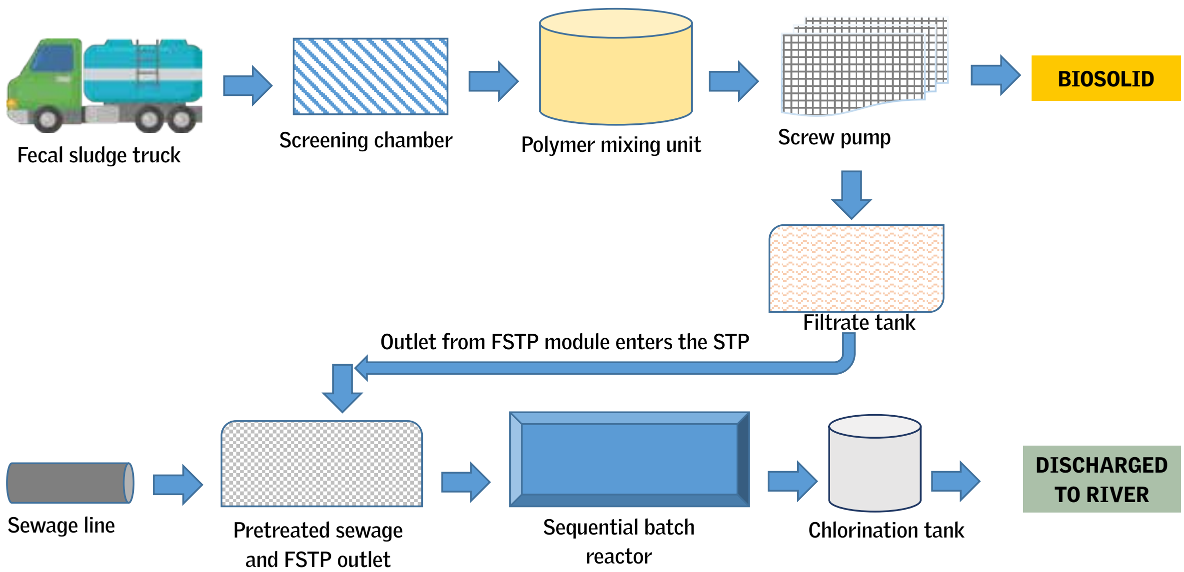
*The primary treatment and drying beds in Varanasi*

### Figure 10: Varanasi co-treatment plant process-flow diagram




Source: CSE

## PRAYAGRAJ

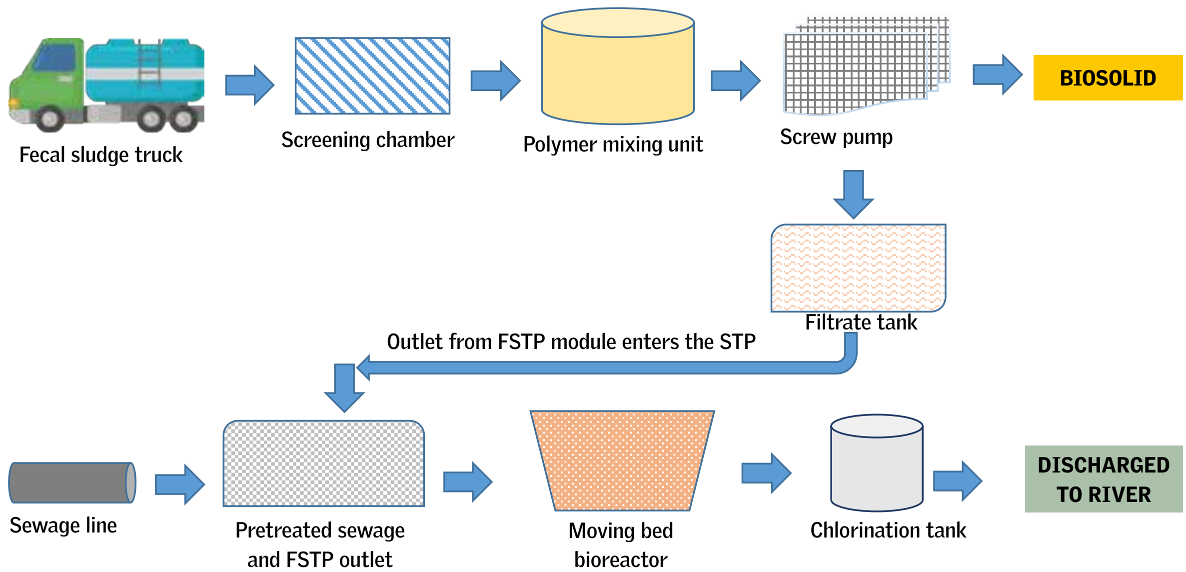
Located at the confluence of the rivers Ganga and Yamuna in Uttar Pradesh, Prayagraj lies at 25.4421877 North latitude and 81.84092 East longitude. The population is estimated at over 1.4 million.

A 50 KLD co-treatment plant has been established, which receives sludge from different on-site sanitation systems. The plant receives seven to ten trucks daily, with holding capacity of 3000 to 4000 litres. The FS is collected in the FS chamber, which further goes through a screening chamber. Once the FS is screened, it is mixed with a cationic polymer which helps in the agglomeration of sludge. The agglomerated sludge is dewatered in the screw pump. After the screw press, the liquid part is transferred to the filtrate bed, whereas the solid part is taken to the sludge drying bed and dried for a week under sunlight. The treated effluent from

CSE

*The filtrate tank and sludge drying bed in Prayagraj*

**Figure 11: Prayagraj co-treatment plant process-flow diagram**




Source: CSE

FSTP is pumped into the inlet of STP, where it gets further treated by moving bed biofilm reactor (MBBR). The final treated water is discharged in the Ganga river.

## RAMPUR

Located in the Moradabad district, Rampur has a 25 KLD co-treatment plant, which receives sludge from different on-site systems. The plant receives four to five trucks daily, with a holding capacity of 4000 litres. The tanker decants the sludge in the screening chamber, where the non-faecal sludge matter is removed. The sludge is conveyed to a raw septage tank from the screening chamber. From here, the sludge is transferred for dewatering. Before dewatering, the sludge mixed with a polymer to aid flocculation, ensuring proper solid-liquid separation. Solids are transferred to the sludge drying beds, whereas the residual water is collected in a collection tank. The effluent now moves to the PGF, where major nutrients like nitrogen and phosphate are removed. The treated effluent is then pumped into the inlet of STP where it gets treated by SBR.

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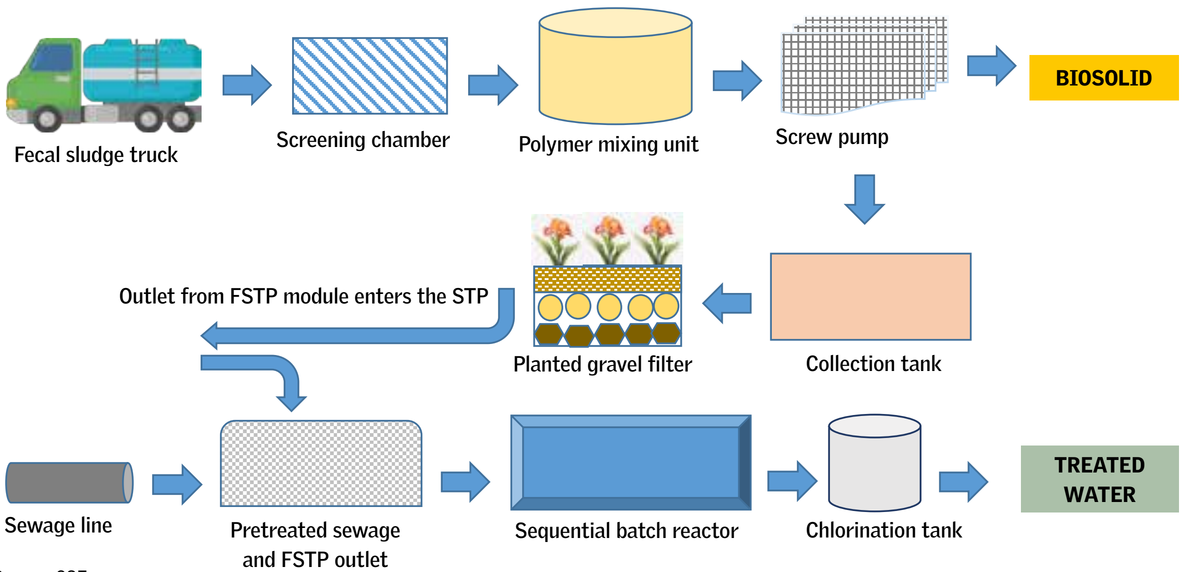
*The primary treatment along with the tertiary treatment modules in Rampur*

**Figure 12: Rampur co-treatment plant process-flow diagram**




Source: CSE

# 6. Results and discussion

Faecal sludge (FS) samples were collected from each site and analysed for ten parameters. The data presented here represents the average values of FS collected from November 2024 till March 2025. The term “per cent reduction” denotes the removal that has occurred from the inlet to the final outlet. Similarly, biosolids were collected from each FSTP and STP co-treatment plants, and were evaluated for nine parameters.

To assess the performance of the FSTPs and the co-treatment plants, the output quality was compared against regulatory standards set by the National Green Tribunal (NGT) and the Ministry of Environment, Forest and Climate Change (MoEFCC) for the discharged effluent of STP. Compliance was evaluated for each analysed parameter. For biosolids, the physico-chemical parameters were compared against the Fertilizer Control Order (FCO), 2023. Pathogen levels in biosolids were assessed in this report as per the standards set by the WHO, 2006 and US Environmental Protection Agency (USEPA).

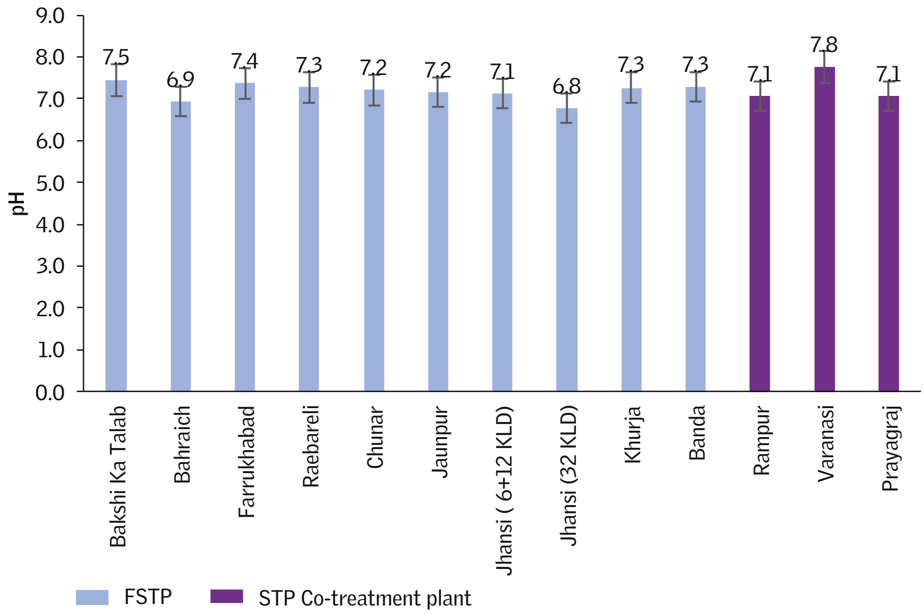
## 6.1 Characterisation of faecal sludge collected from FSTP and STP co-treatment plants

The pH of faecal sludge ranged from 6.8 in Jhansi (32 KLD FSTP) to 7.8 in Varanasi. Khurja recorded the highest level of both total solids (103,775 mg/L) and total suspended solids (32,833 mg/L). The lowest number of total solids was recorded in Bakshi Ka Talab (1,601 mg/L), and the lowest total suspended solids were recorded in Prayagraj (900 mg/L).

BOD varied significantly, from just 33 mg/L in Rampur to a high of 9,237 mg/L at the Varanasi plant. For COD, the lowest was in Bakshi Ka Talab at 18,495 mg/L, and the highest was in Varanasi at 51,525 mg/L.

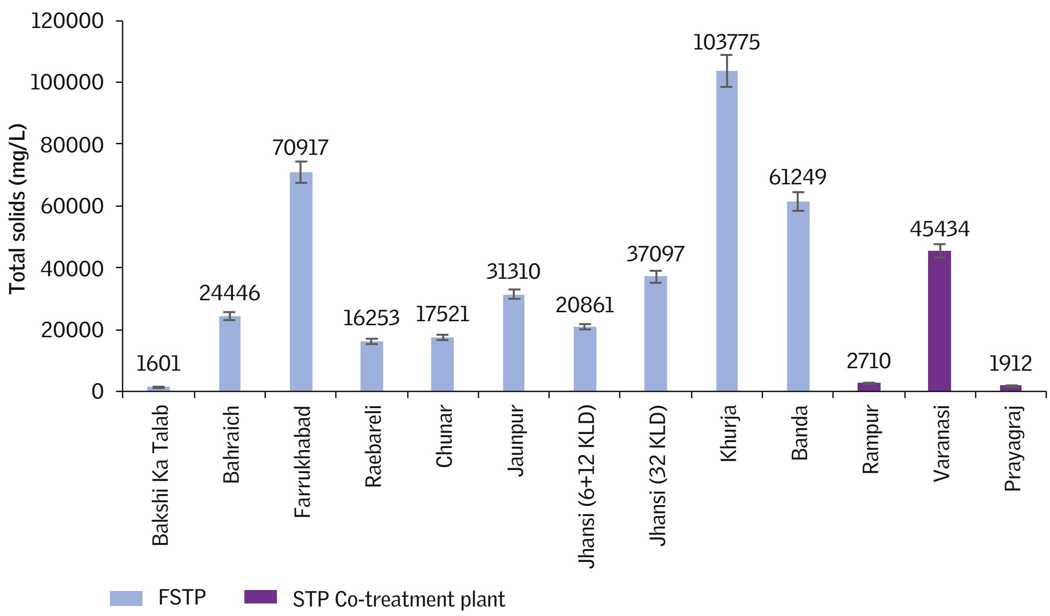
TKN ranged from 2,432 mg/L in Khurja, and down to 51 mg/L in Rampur co-treatment plant. Finally, Faecal Coliforms were found in quantities ranging from log 5.2 to log 8.5 MPN/100 ml.

## Graph 1: pH value for faecal sludge



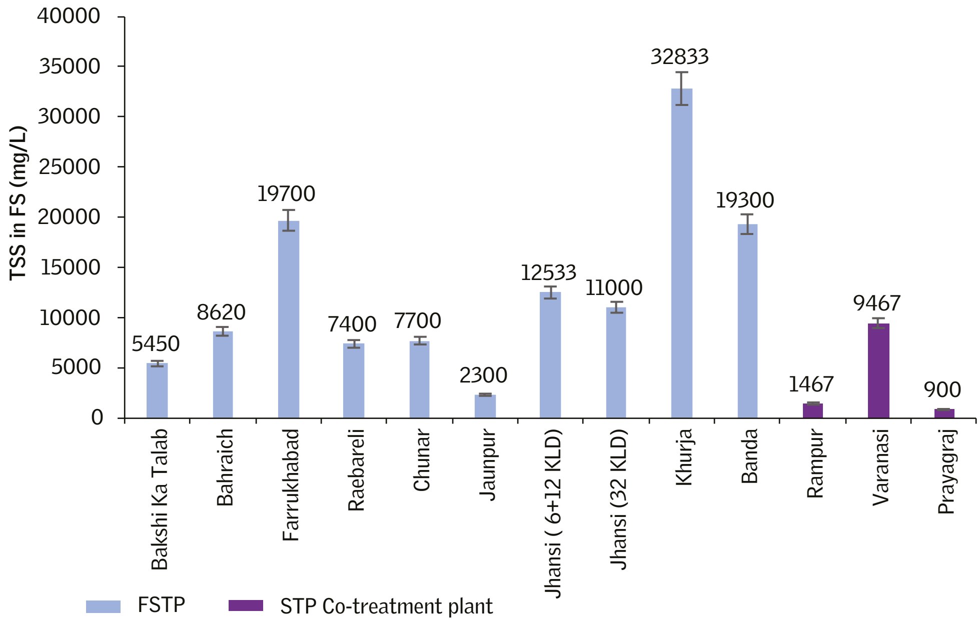

Source: CSE

## Graph 2: Total solids in faecal sludge



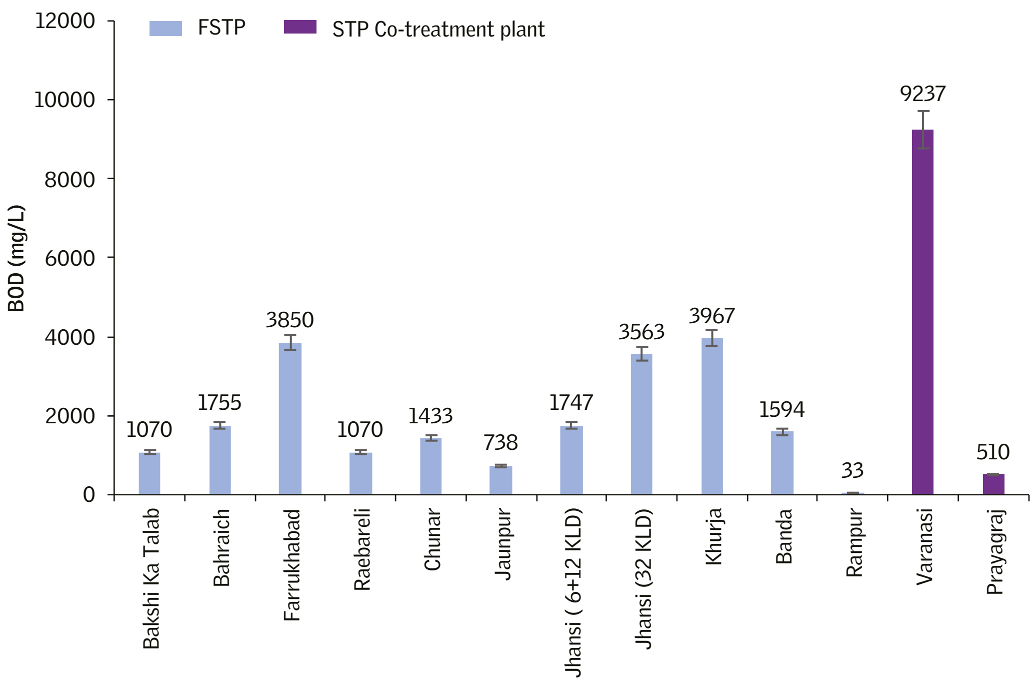

Source: CSE

### Graph 3: Total suspended solids in faecal sludge



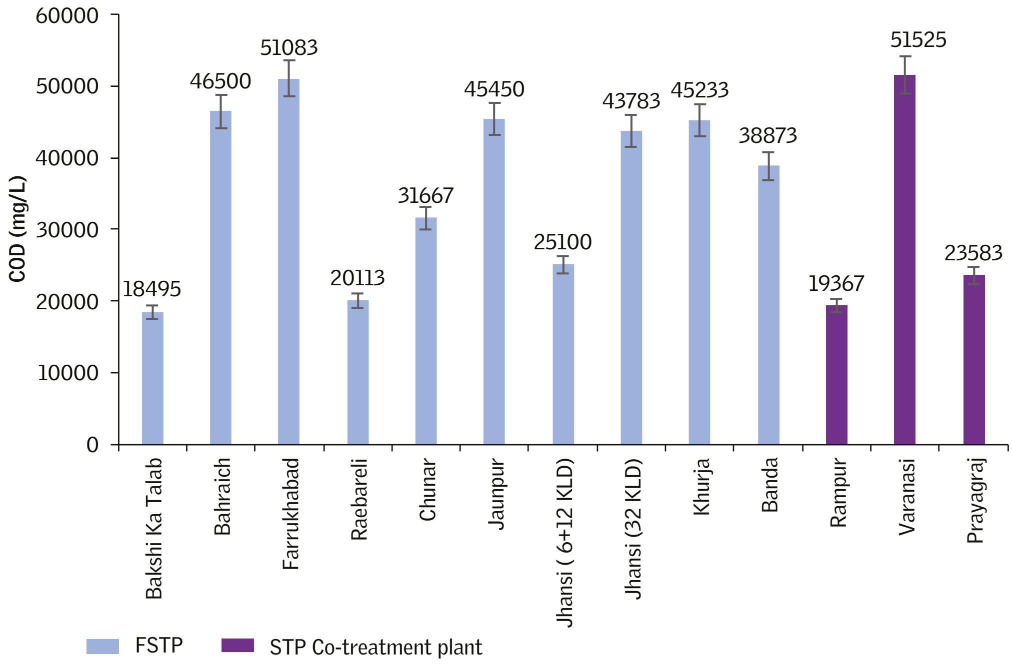

Source: CSE

### Graph 4: Biochemical Oxygen Demand of faecal sludge



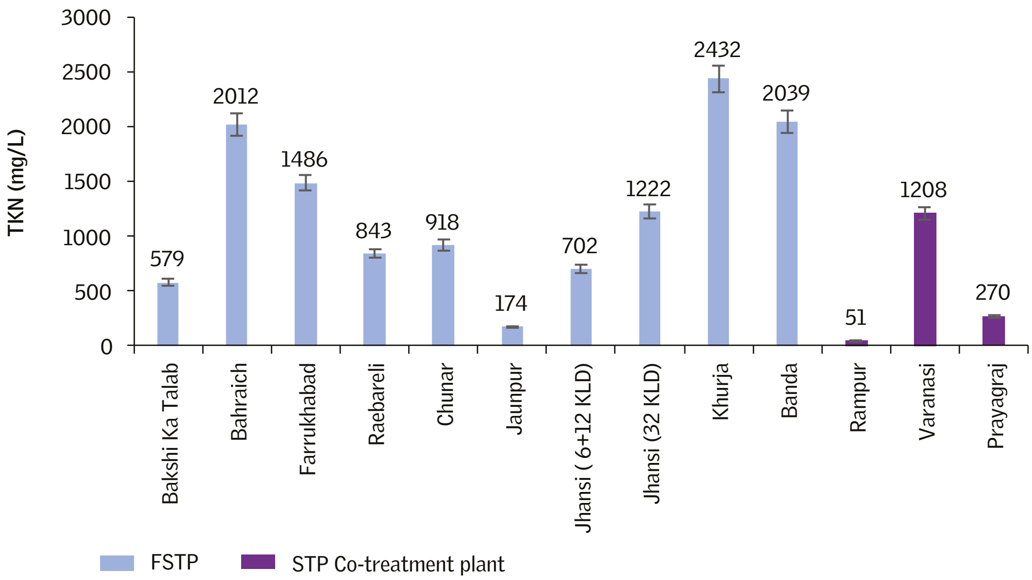

Source: CSE

### Graph 5: Chemical Oxygen Demand of faecal sludge



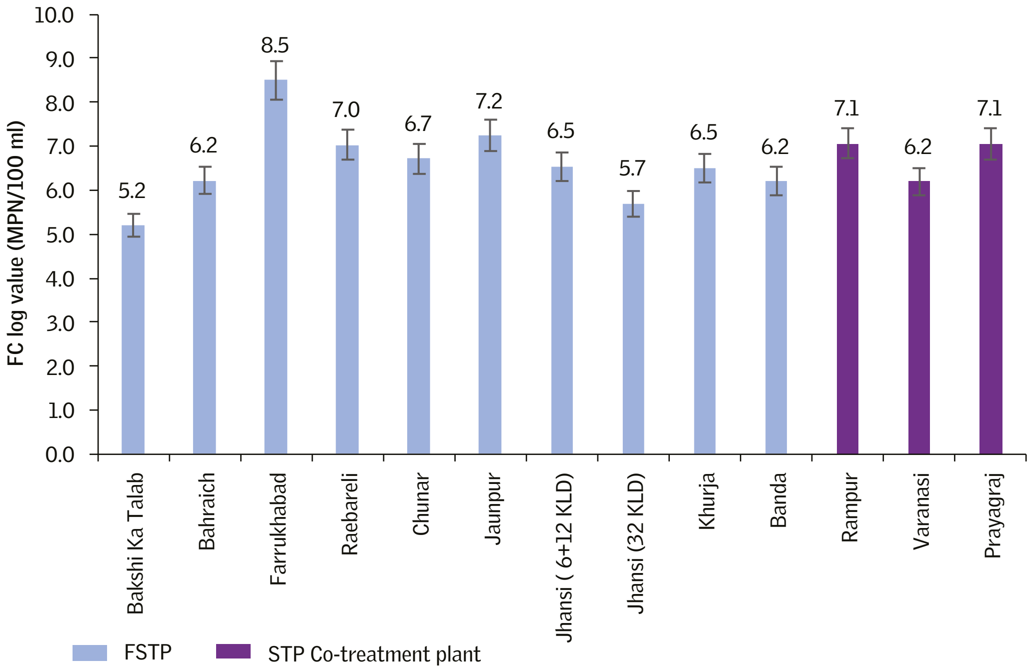

Source: CSE

### Graph 6: Total Kjeldahl Nitrogen of faecal sludge




Source: CSE

**Graph 7: Faecal Coliform in faecal sludge**




Source: CSE

## 6.2 Performance of FSTPs

To evaluate the performance of FSTPs, ten parameters were tested—Total Suspended Solids (TSS), Total Solids (TS), Ph, Total Dissolved Solids (TDS), Total Kjeldahl Nitrogen (TKN), Ammoniacal Nitrogen (AN), Total Phosphorus (TP), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and Faecal Coliform (FC). Some of these parameters are represented below:

### Total Solids (TS)

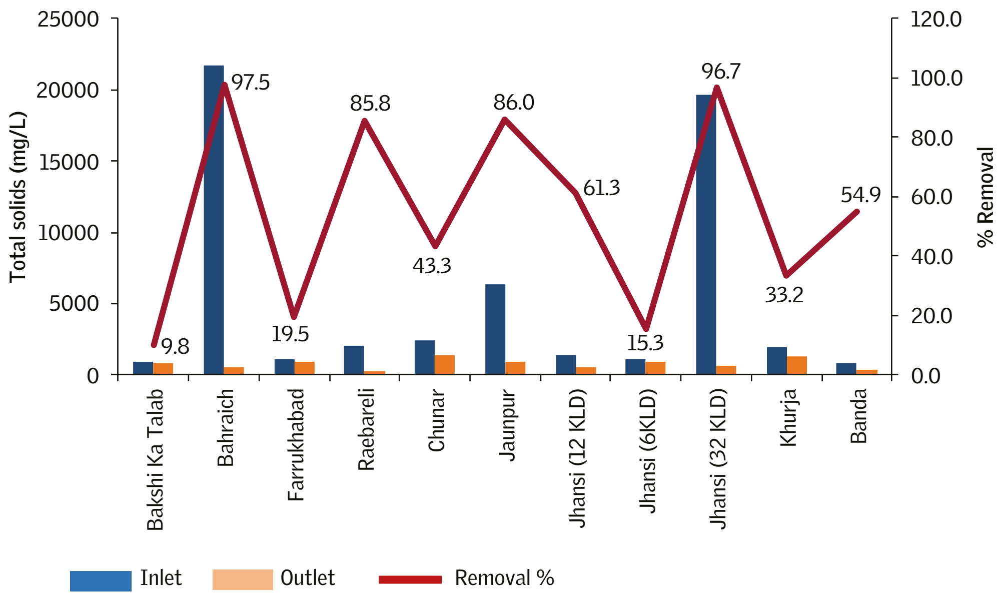
The inlet, outlet, and the percentage removal of TS for all FSTPs are provided in the graph below (see *Graph 8*). The average value of TS in the inlet sample was found to be in the range 862mg/L in Banda, to 21680 mg/L in Bahraich. In the outlet, TS was in the lowest range of 284mg/L in Raebareli, to the highest range in Chunar with 1373 mg/L.

### Total Suspended Solids (TSS)

For TSS, two sets of standards have been suggested—MoEFCC and NGT. The MoEFCC limits are set at 50 mg/L for metro cities (referred to as 'Category-1 cities/ towns'), and 100 mg/L for other cities (referred to as 'Category-2 cities/towns'). According to the NGT norms, the standards set for TSS final discharge is 20 mg/L.

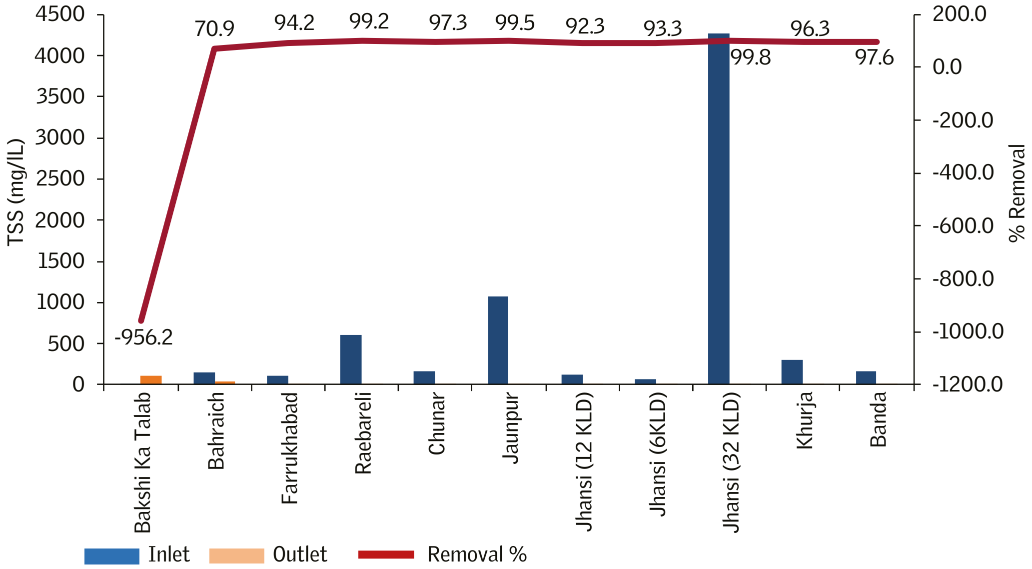
In the current study, the maximum TSS removal was seen at Jhansi (32 KLD) plant. The initial TSS 4273 mg/L reduced to 7 mg/L, which accounts for almost 99.8 per cent removal. The TSS removal percentage for all the other FSTPs was in the range of 70.9 to 99.5 per cent. However, in Bakshi Ka Talab, the outlet TSS exceeded the inlet value, as a result of which percentage reduction was not observed in the plant. Outlet discharges from both Bakshi Ka Talab (112 mg/L) and Bahraich (44 mg/L) exceeded the NGT regulatory limits. The remaining outlet discharges met the regulatory standards.

**Graph 8: Total Solids in inlet, outlet of FSTPs and percentage removal from inlet to outlet**



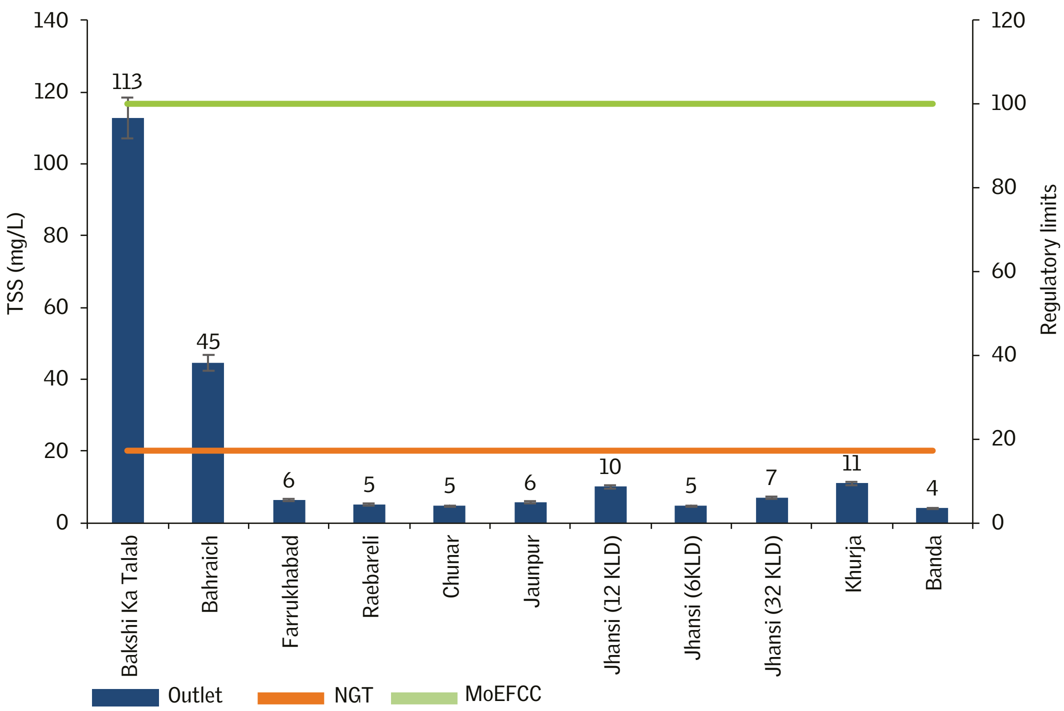

Source: CSE

### Graph 9: Total Suspended Solids in inlet, outlet of FSTPs and percentage removal from inlet to outlet




Source: CSE

### Graph 10: Total Suspended Solids in FSTPs outlet

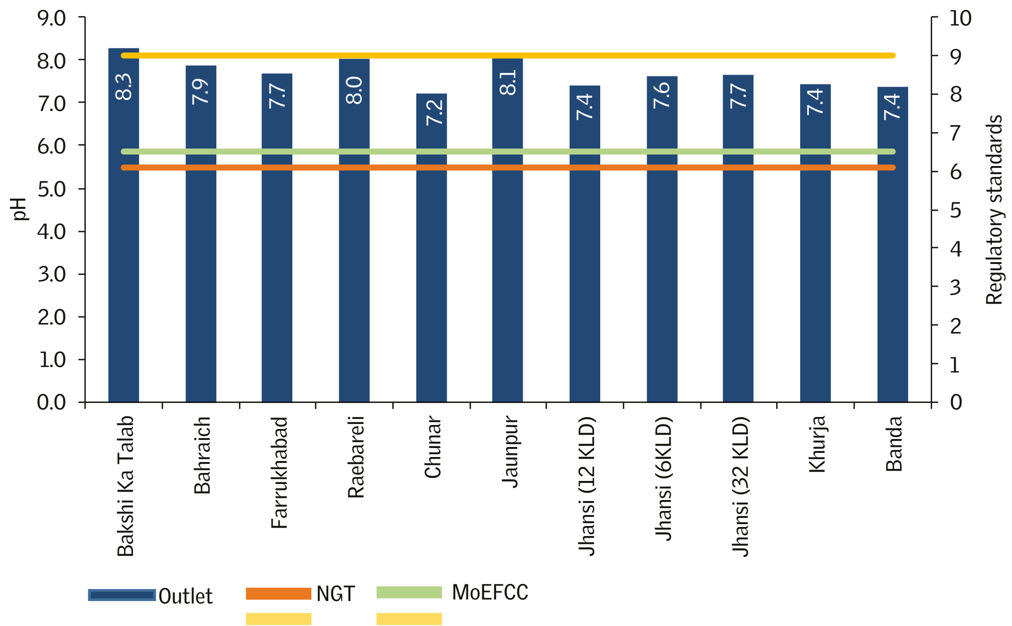



Source: CSE

## pH of FSTP outlet

The pH levels in the FSTPs varied, with Chunar measuring 7.2 and Bakshi ka Talab at 8.3. The pH of treated effluent across all FSTPs remained within the permissible limits set by NGT (5.5–9) and MoEFCC (6.5–9).

**Graph 11: pH of FSTPs outlet water**




Source: CSE

## Biochemical Oxygen Demand (BOD)

The inlet, outlet and percentage removal of BOD has been provided in the graph below (see *Graph 12*).

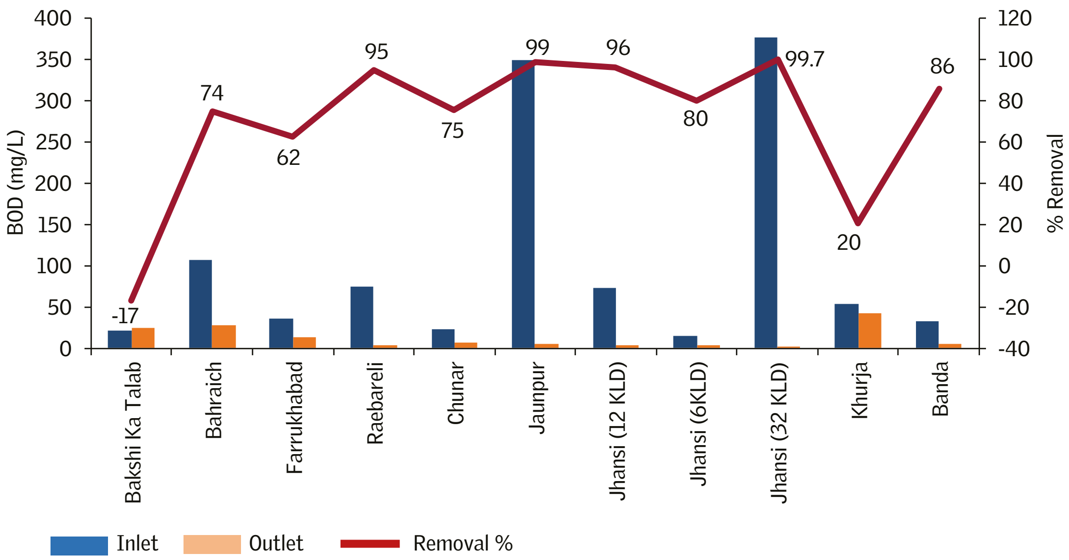
Inlet BOD was found in the range of 15 mg/L in Jhansi (6 KLD) to 377 mg/L in Jhansi (32 KLD). The outlet BOD of FSTPs ranged from 1 mg/L in Jhansi (32 KLD) to 42 mg/L in Khurja. This signifies a maximum per cent removal of BOD was 99.7 per cent in Jhansi (32 KLD), with the lowest observed in Bakshi Ka Talab.

In Bakshi Ka Talab, the final treatment chamber had the major presence of mud and rich algal bloom, resulting in higher levels of BOD.

As per the NGT, 2019, the standards set for BOD is 10 mg/L whereas, MoEFCC states that the BOD of discharged effluent should be within 20 mg/L for metro and state capitals, and 30 mg/L for other cities. By following these standards, seven

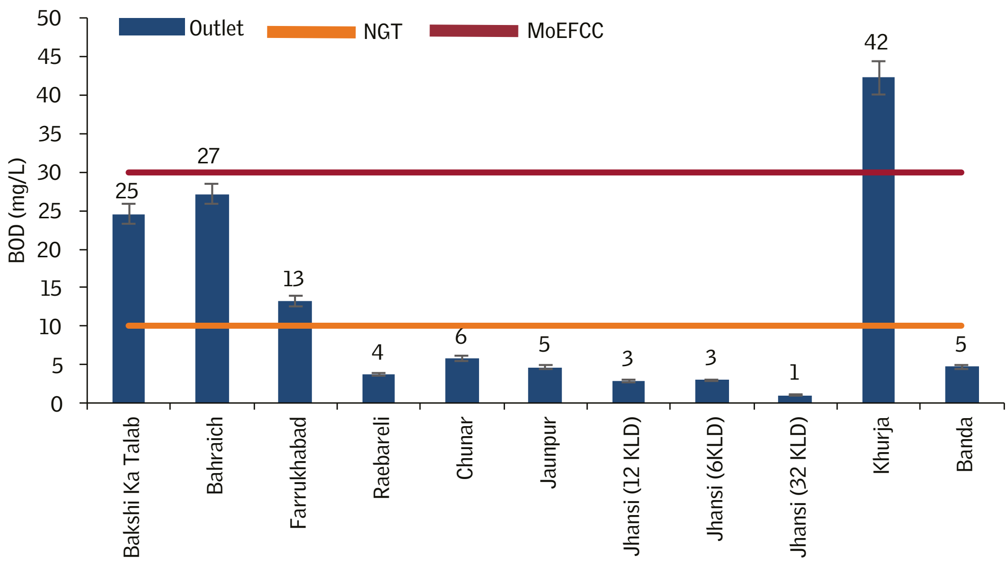
FSTPs—Raebareli, Chunar, Jaunpur, Jhansi (6,12, and 32 KLD), and Banda—have met the NGT standards for BOD (10 mg/L); whereas Bakshi Ka Talab, Bahraich, and Farrukhabad had values within 30 mg/L (MoEFCC).

### Graph 12: Biological oxygen demand of inlet, outlet, and percentage removal from inlet to outlet of FSTPs




Source: CSE

### Graph 13: Biological oxygen demand of outlet water from FSTPs




Source: CSE

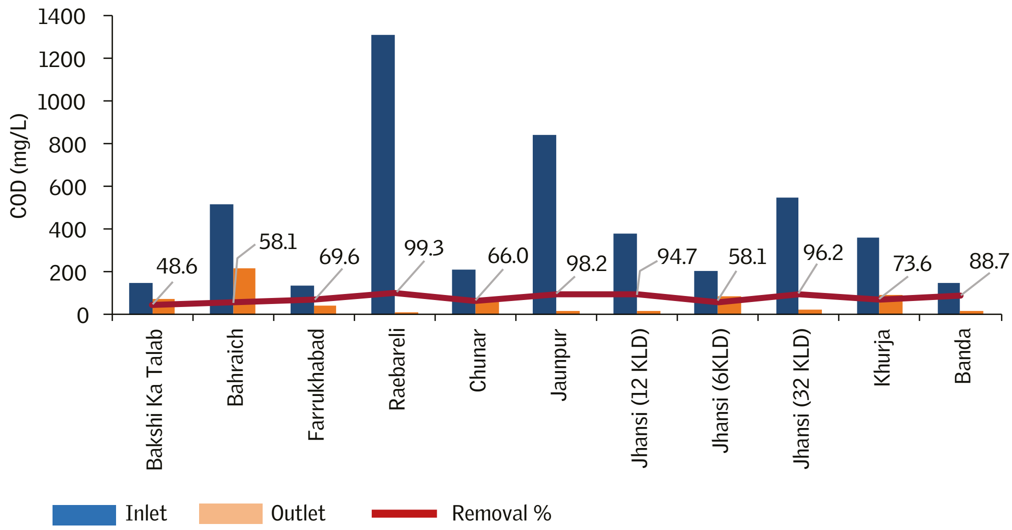
## Chemical Oxygen Demand (COD)

Significant variation was observed in the performance of FSTPs with respect to COD. The inlet (COD) levels at the FSTPs varied significantly, ranging from 1310 mg/L in Raebareli to 133 mg/L in Farrukhabad. However, after treatment, the outlet COD levels were much lower; which ranged from 9 mg/L in Raebareli to 217 mg/L in Bahraich.

This implies that the FSTPs showed a wide range in COD removal efficiency. The removal efficiency ranged from 48.6 per cent in Bakshi Ka Talab (the lowest) to 99.3 per cent in Raebareli (the highest). The reduced efficiency at Bakshi Ka Talab was due to an open tank without a concrete base, which resulted in mud accumulation and algal bloom growth, affecting the outlet sample chamber.

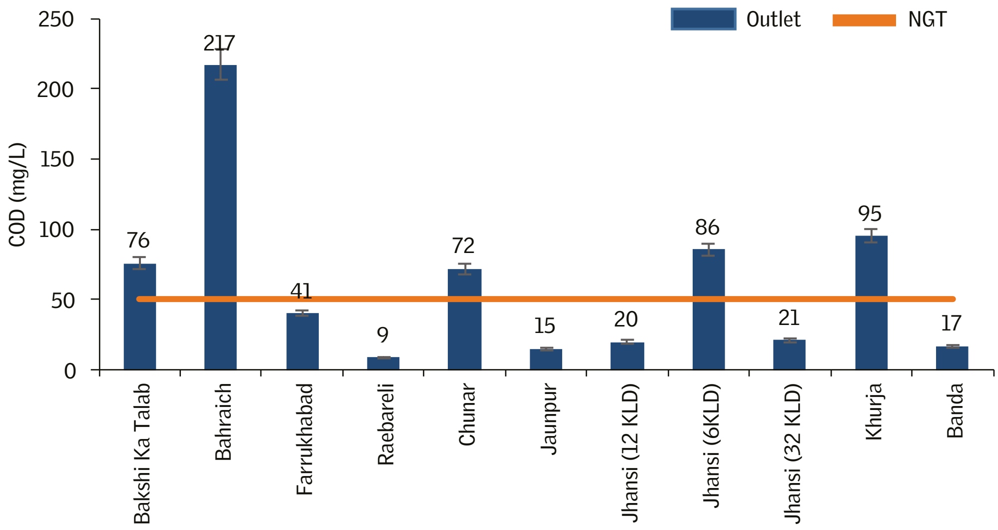
According to the NGT, 2019 standards, the final discharge for COD from STPs should be 50 mg/L. Six of the plants successfully met this standard—Farrukhabad, Raebareli, Jaunpur, Jhansi (both 6+12 KLD and 32 KLD units), and Banda; while the other five needed improvement in performance to meet the discharge standards.

**Graph 14: Chemical Oxygen Demand Of inlet, outlet and percentage removal from inlet and outlet**




Source: CSE

**Graph 15: Chemical Oxygen Demand of outlet water from FSTPs**

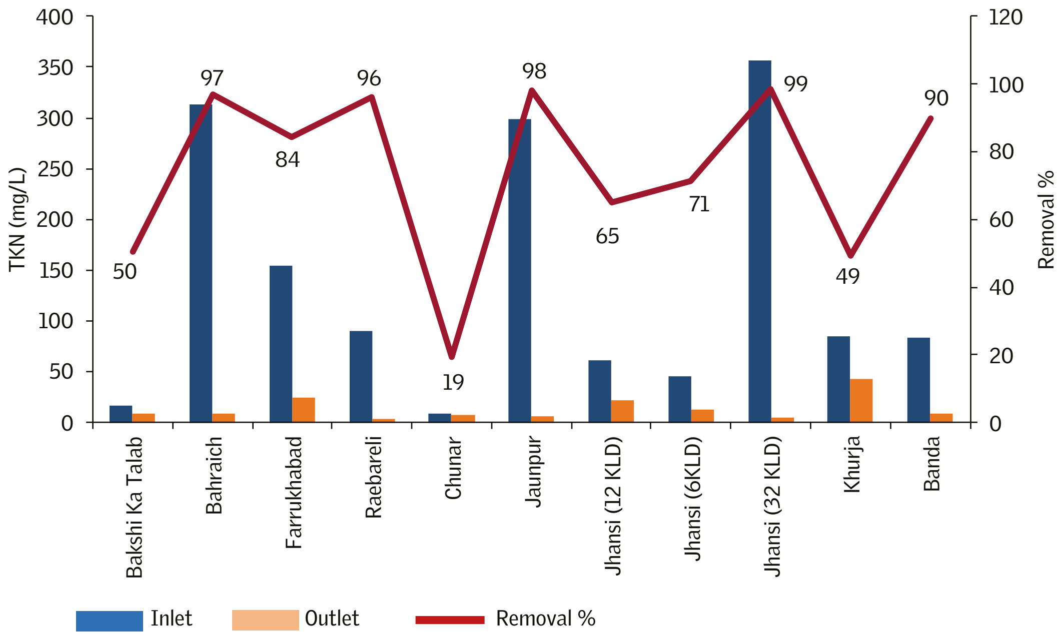



Source: CSE

**Total Kjeldahl Nitrogen (TKN):** Graph provided below (see *Graph 16*) reflects the presence of TKN in inlet, outlet, and the percent reduction in the FSTPs. The TKN levels varied significantly across the FSTPs. At the inlet, TKN ranged from 356 mg/L in Jhansi to 9 mg/L in Chunar. After treatment, outlet TKN levels were between 5 mg/L in Jhansi and 43 mg/L in Khurja.

In terms of removal efficiency, Jhansi (32 KLD) achieved the highest TKN reduction at an impressive 99 per cent. In contrast, Chunar showed the lowest removal, with only 19 per cent of TKN reduced from inlet to outlet.

**Graph 16: Total Kjeldahl Nitrogen of inlet, outlet and percentage removal from inlet and outlet of FSTPs**




Source: CSE

## Faecal Coliform (FC):

For the compliance with respect to pathogenic bacterial content, especially FC content, NGT has proposed the following two standards:

- Desirable limit: 100 MPN/100 mL ($\log_{10}100=2$)
- Permissible limit: 230 MPN/100 mL ($\log_{10}230=2.36$)

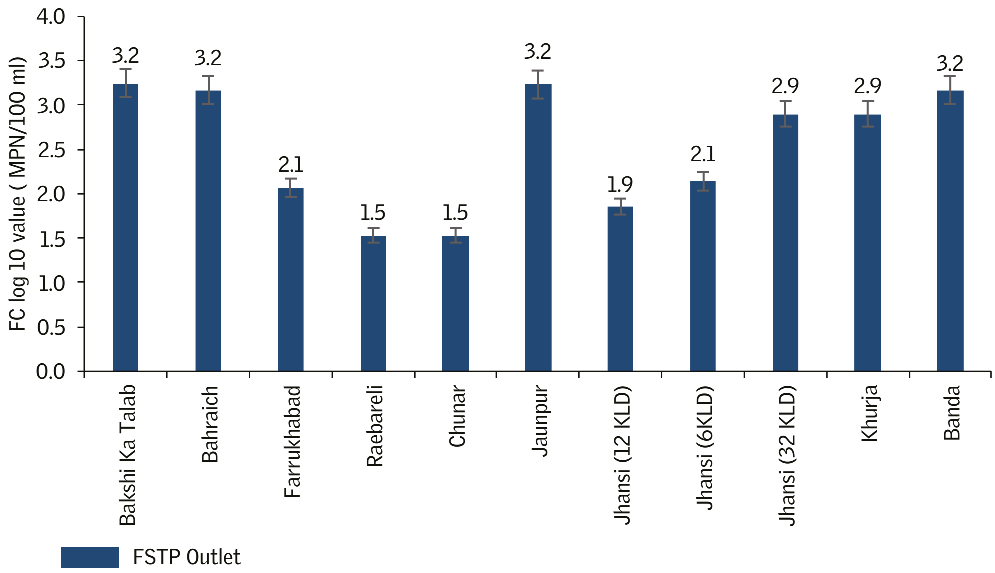
While for the same Faecal Coliforms, MoEFCC's limit for FC in final discharge is 1000 MPN/100 mL ($\log_{10}1000=3$).

In this study, only three FSTPs met the NGT's desirable limit—Raebareli, Chunar, and Jhansi (12 KLD). Additionally, Farrukhabad and Jhansi (6 KLD) fell within the NGT's permissible limits. Overall, seven out of the eleven FSTPs met the MoEFCC's less stringent standard.

The highest FC levels were found in Bakshi Ka Talab at 1753 MPN/ 100 mL ($\log_{10}$ 1753=3.24). This was mainly because Bakshi Ka Talab did not have any disinfection unit implemented. The lowest levels were observed in Raebareli and Chunar, both at 34 MPN/100 mL ($\log_{10}34=1.53$), indicating effective tertiary treatment stages in Chunar and Raebareli.

However, FC levels were higher in Jaunpur, Banda, and Bahraich. Since Jaunpur and Banda use chlorination for disinfection, it is suggested that their chlorine dosage and contact time need to be optimised for better disinfection.

**Graph 17: Faecal Coliform in the outlet water from the FSTPs**




Source: CSE

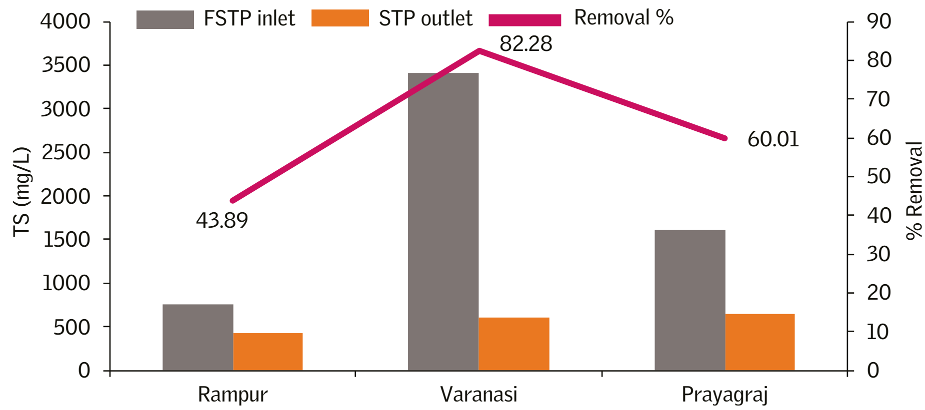
## 6.3 Performance evaluation of STP co-treatment plants

This study comprises three STP co-treatment plants. From each treatment plant, samples were collected from tanker (FS), FSTP inlet, and STP outlet. Parameters included Total Solids (TS), Total Suspended Solids (TSS), Ph, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Kjeldahl Nitrogen (TKN) and Faecal Coliform (FC).

**Total Solids (TS)**: The graph provided below (see *Graph 18*) represents the TS content in FSTP inlet, STP outlet, and per cent reduction of TS observed in the final treated effluent. Initial TS found in the inlet of co-treatment plants were as follows—Rampur at 763 mg/L, Varanasi at 3405 mg/L, and Prayagraj at 1608 mg/L. After treatment, TS in the co-treatment outlet varied from 603 mg/L in Varanasi to 643 mg/L in Prayagraj.

Highest per cent removal was obtained by Varanasi (76.1 per cent), followed by Prayagraj (69.4 per cent), and lowest per cent removal was observed in Rampur (49.6 per cent).

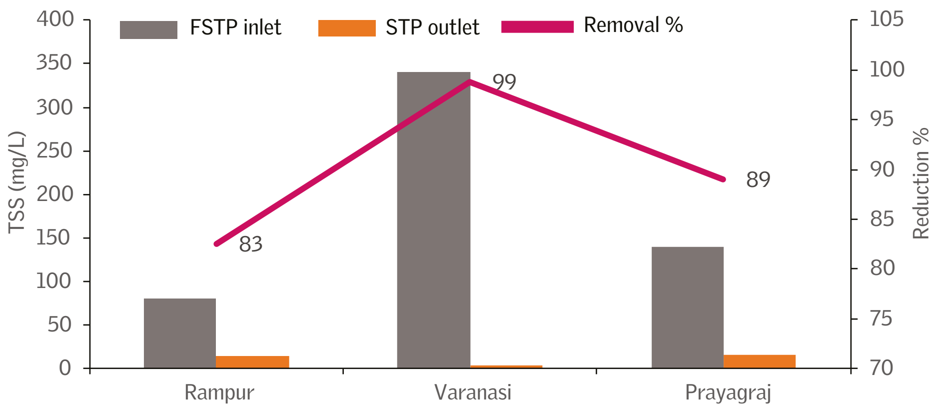
**Graph 18: Presence of total solids in FSTP inlet, STP outlet and percentage removal**




Source: CSE

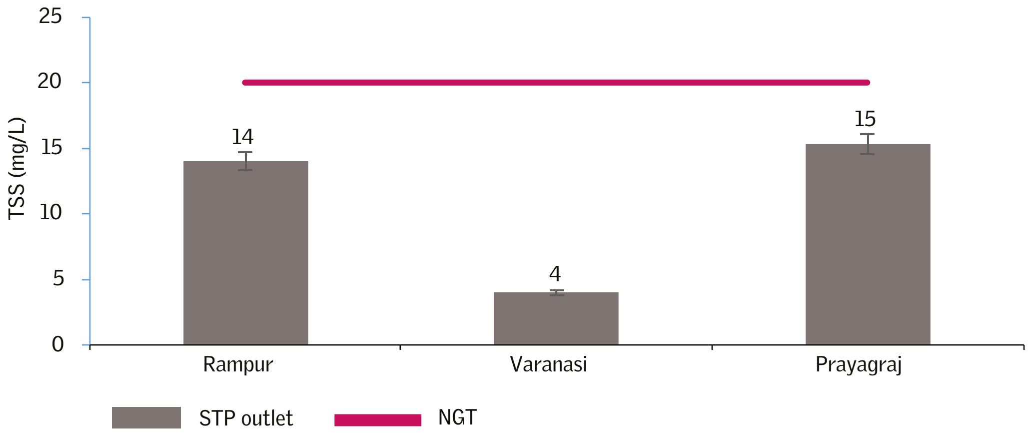
**Total Suspended Solids (TSS):** Graph provided below (see *Graph 19*) depicts the presence of TSS in inlet, outlet, and the percentage removal of TSS in the final treated effluent. In this study, maximum TSS per cent removal was seen in Varanasi—accounting for 99 per cent removal of TSS from the final treated discharge. Initially the TSS in Varanasi was found to be 341 mg/L, which was reduced to 4mg/L. In the other two co-treatment plants, the per cent removal of TSS was found to be in the range of 83 per cent in Rampur, and 89 per cent in Prayagraj. There is a considerable reduction in TSS from FSTPs to STPs. Moreover, it was observed that all the three discharge effluents collected from the STP co-treatments were within the NGT standards (20 mg/L).

**Graph 19: Presence of total suspended solids in FSTP inlet, STP outlet and percentage removal**




Source: CSE

### Graph 20: Total suspended solids in outlet discharge

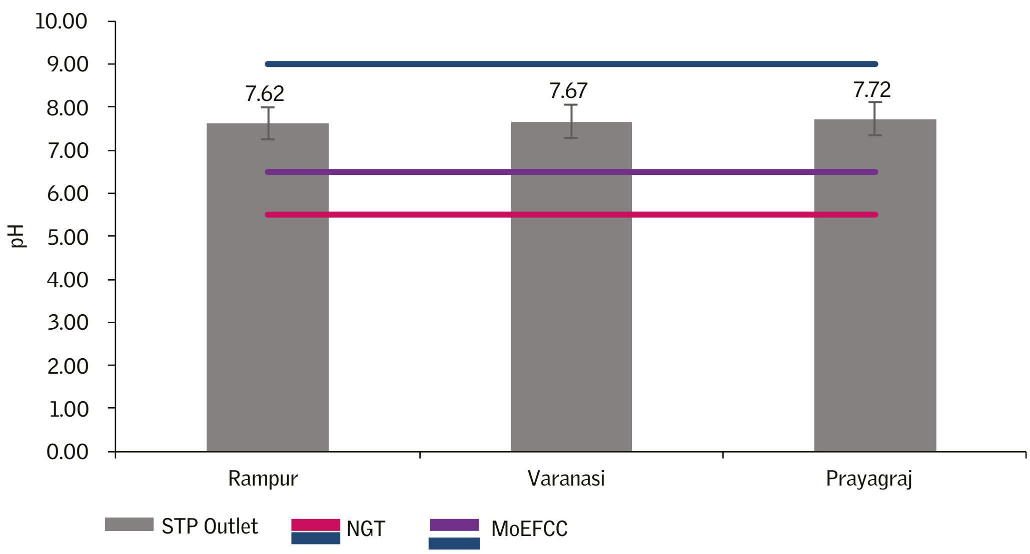



Source: CSE

**pH:** The pH observed for different STP final discharge was observed to be in the range of 7.6 in Rampur, to 7.7 in both Varanasi and Prayagraj.

In terms of pH, the standards set by the NGT, 2019, states the pH of treated discharge from STP should range from 5.5–9, whereas the MoEFCC has given the range of pH for treated discharge from STP from 6.5–9. In the current study, all the effluent from co-treatment plants have met the given range of standards.

### Graph 21: pH of STP outlet discharge



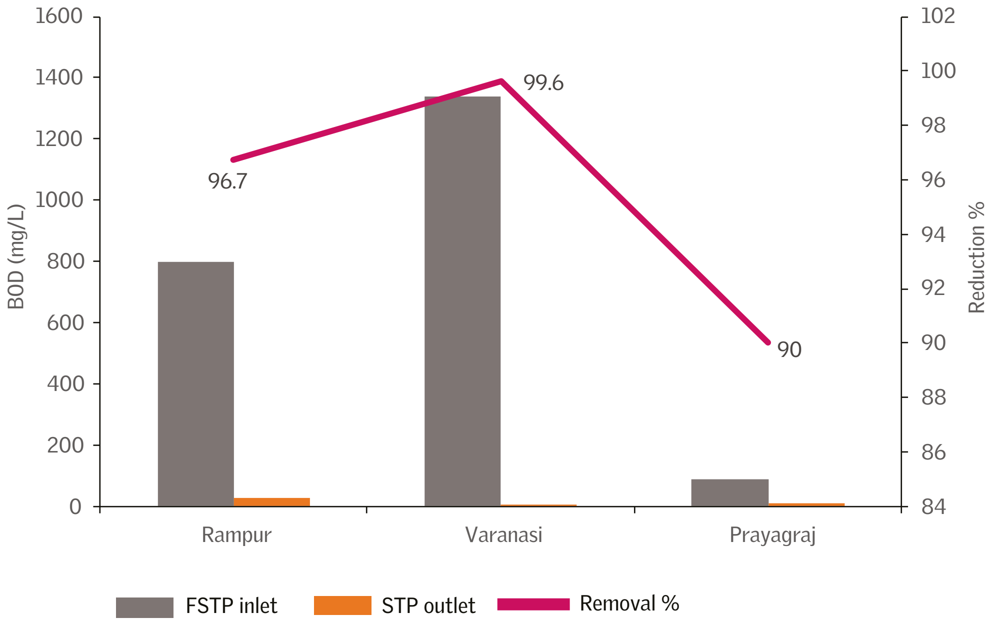

Source: CSE

**Biological Oxygen Demand (BOD):** The graph provided below (see *Graph 22*) describes the BOD in FSTP inlet, STP outlet, and percentage removal of BOD in the treated outlet effluent. Highest removal of BOD was seen Varanasi, with 99.6 per cent removal of BOD from inlet to outlet. Initially in Varanasi, the BOD of inlet was 1342 mg/L, which was reduced to 5 mg/L after the treatment.

In the other two plants, the per cent removal of BOD varied from 96.7 per cent in Rampur to 90 per cent in Prayagraj.

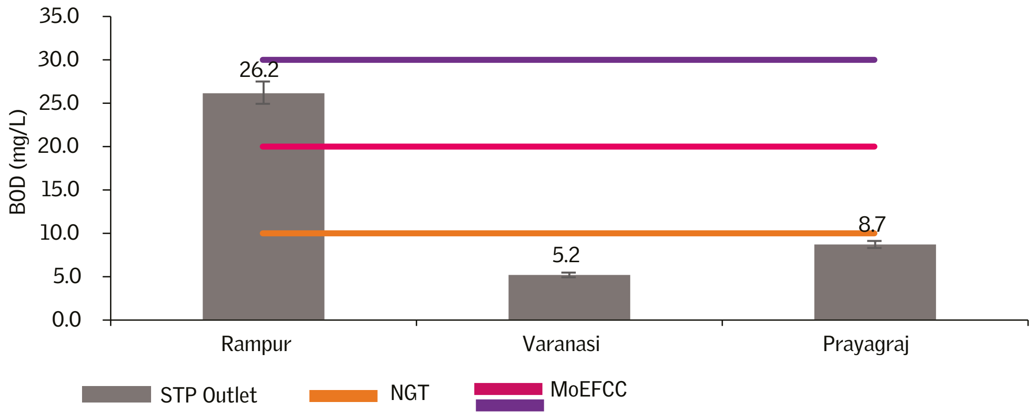
According to the NGT, 2019 standards, the final discharge for BOD from STPs should be 10 mg/L, whereas the MoEFCC, 2017 standards recommend 20 mg/L BOD for final discharge from STPs.

**Graph 22: BOD of FSTP inlet, STP outlet and percentage removal**




Source: CSE

### Graph 23: BOD of STP outlet discharge

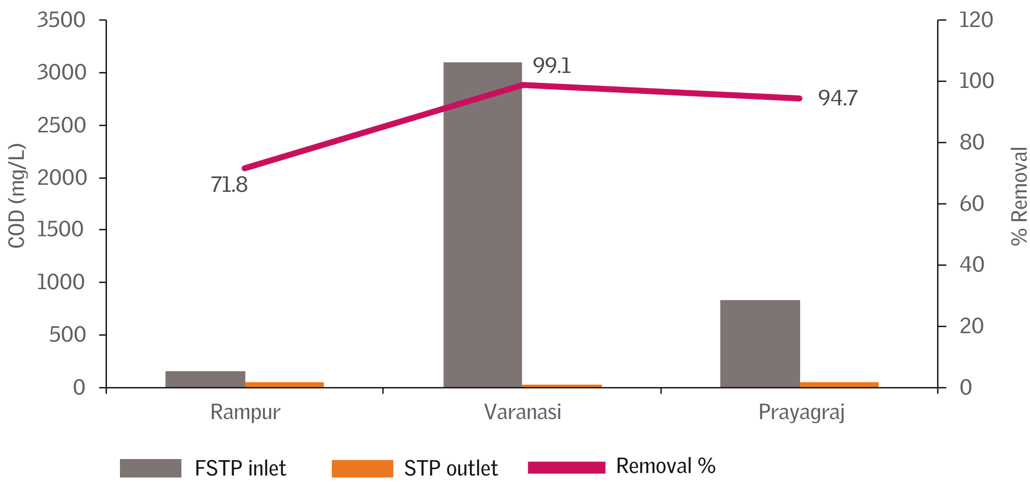



Source: CSE

**Chemical Oxygen Demand (COD):** Graph provided below (see *Graph 24*) represents the COD of FSTP inlet, STP outlet and per cent removal of the final treated effluent. The range of COD in the inlet varied from 3102 mg/L in Varanasi, followed by 158 mg/L in Rampur, which was eventually reduced to 27 mg/L in Varanasi and 44.5 mg/L in Rampur. The percentage removal of COD from final treated effluent was found to be 99.6 per cent in Varanasi (highest) and 72 per cent in Rampur (lowest).

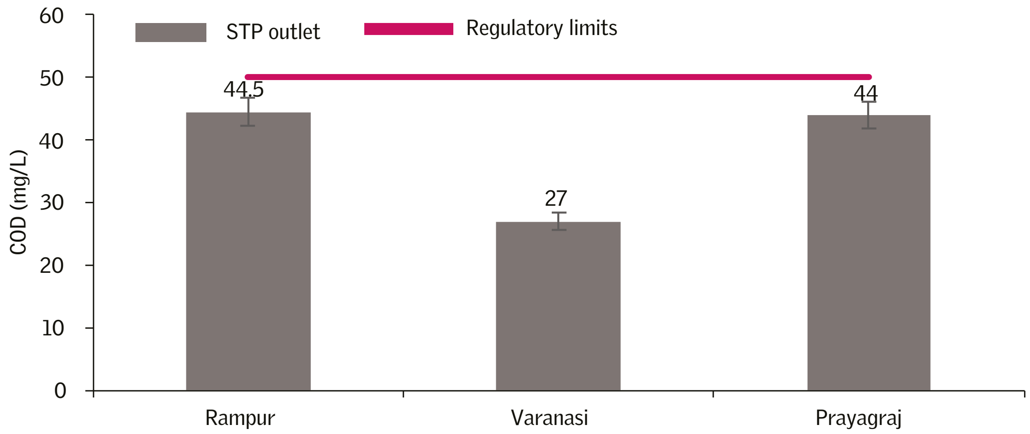
As per the NGT, 2019 standards, the limits set for final discharge effluent from STP is 50 mg/L. All three co-treatment plants fall within the standards.

### Graph 24: COD of FSTP inlet, STP outlet and per cent removal




Source: CSE

**Graph 25: COD of STP outlet discharge**

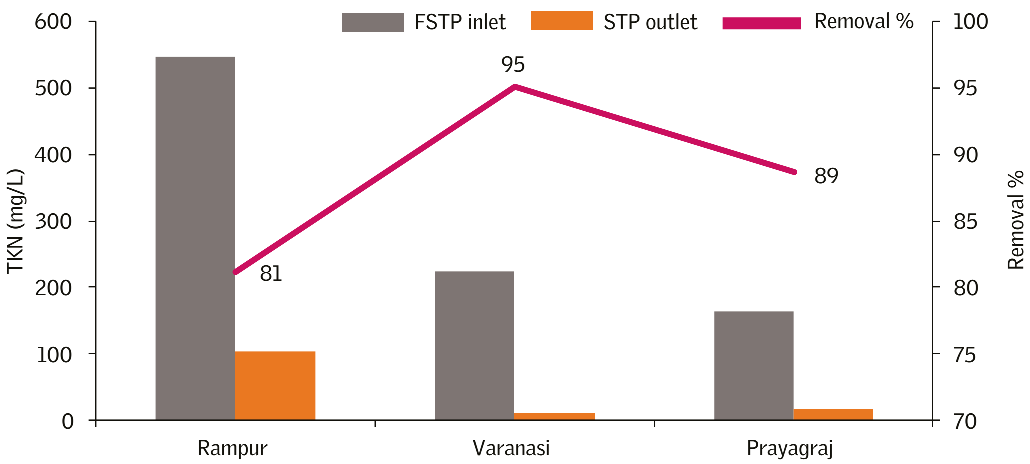



Source: CSE

**Total Kjeldahl Nitrogen:** The inlet, outlet, and per cent removal of TKN from their respective STP co-treatment plants are shown in the graph below (see *Graph 26*). TKN in the inlet of STP co-treatment ranged from 223.8 mg/L in Varanasi to 547 mg/L in Rampur. A significant reduction in final treated discharge was observed in Varanasi (11 mg/L) and lowest was seen in Rampur (103 mg/L).

The maximum per cent removal of TKN was observed in Varanasi (95 per cent) whereas the minimum per cent removal of TKN was seen in Rampur (81 per cent). In all three STP co-treatment plants, it was observed that the percent removal of TKN achieved by each of them was greater than 80 per cent.

**Graph 26: TKN of FSTP inlet, STP outlet, and per cent removal**



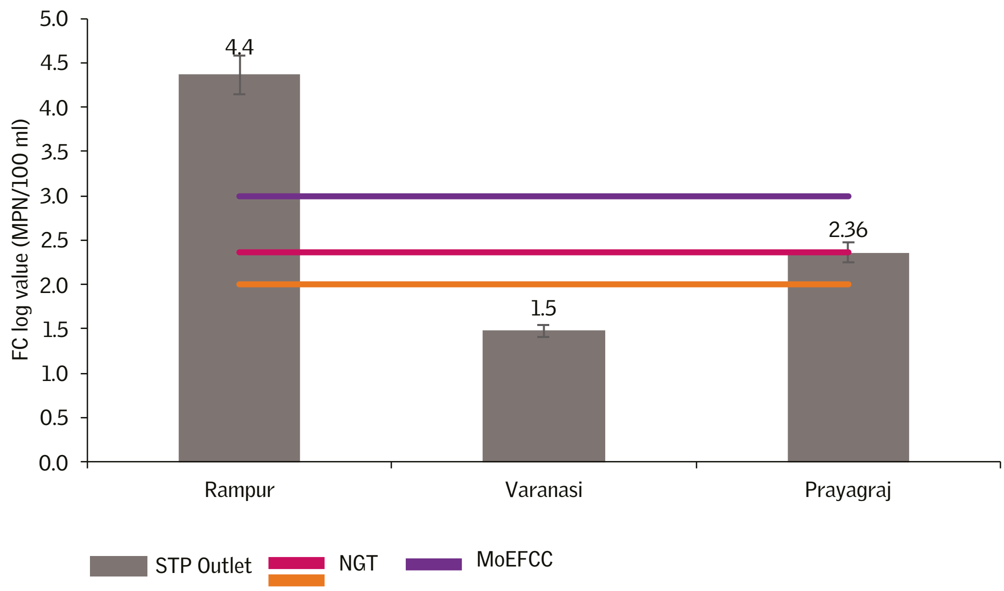

Source: CSE

**Faecal Coliform (FC):** The graph provided below (see *Graph 27*) shows the presence of FC in FSTP inlet, STP outlet, and percentage removal of FC in the final discharge.

Initially highest load of FC was found in Prayagraj (log 1980000= 6.2) and lowest FC was seen in Varanasi (log 81464= 4.9). In outlet discharge, it was seen that a significant reduction of FC was seen in the outlet discharge of Varanasi (log 30= 1.5) and lowest was seen in Rampur (log 23477= 4.4)

Moving onto the per cent removal of FC, both Varanasi and Prayagraj met the permissible limit set by MoEFCC by achieving 99.9 per cent; Rampur achieved 97 per cent removal of FC. However, in Rampur outlet discharge, effluent did not fall under the given standards. This shall be addressed in the *recommendation section*, with suggested measures ensure compliance with the given sets of standards.

**Graph 27: Faecal Coliform in FSTP inlet, STP outlet, and percentage removal**




Source: CSE

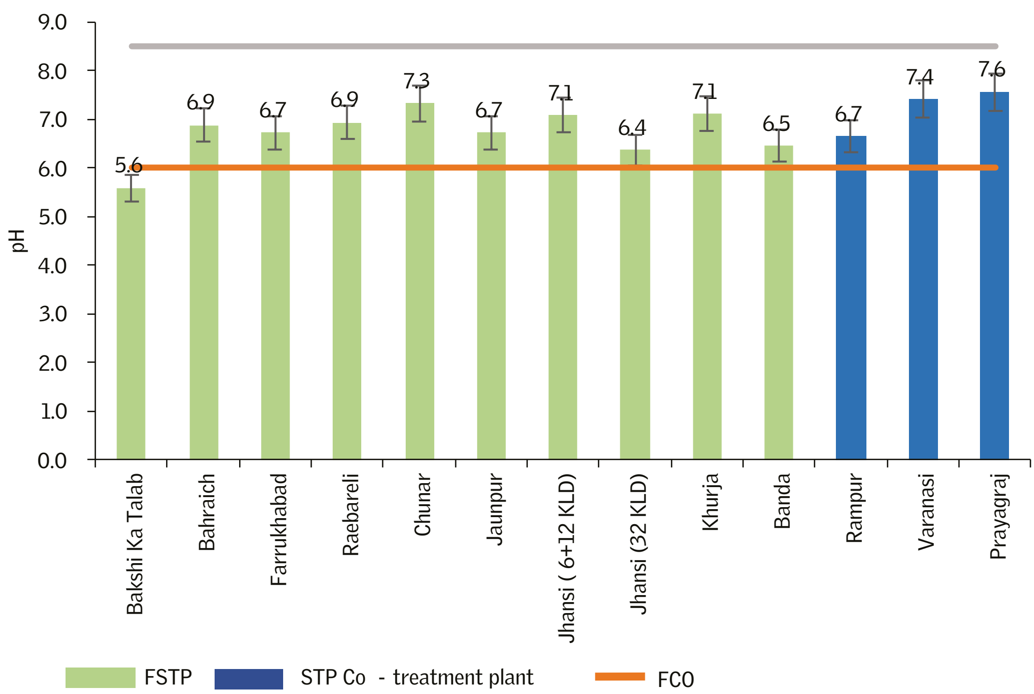
## Evaluation of biosolids

Biosolids were collected from each treatment plant included in this study, between November 2024 till March 2025. All plants adopted sun drying as the method for moisture reduction. In order to ensure the resource recovery from biosolids, parameters assessed included moisture content, electrical conductivity, presence of heavy metal, helminths load, CN ratio, *E. coli*, and *Salmonella*. Since there are no Indian standards for the quality of biosolids, it was compared with the Fertilizer Control Order (FCO), 2023.

## pH

In the current study, pH of the biosolids that were collected from the associate treatment plants were found to be in the range of standards provided by FCO, 2023. As per FCO, 2023, the pH of organic manure should lie in the range of 6–8.5. In the graph given below (see *Graph 28*), the pH of biosolids range from 6.4–7.6. However, the pH of Bakshi Ka Talab was slightly less (5.6) than the range given by the FCO standards.

**Graph 28: pH of biosolids**



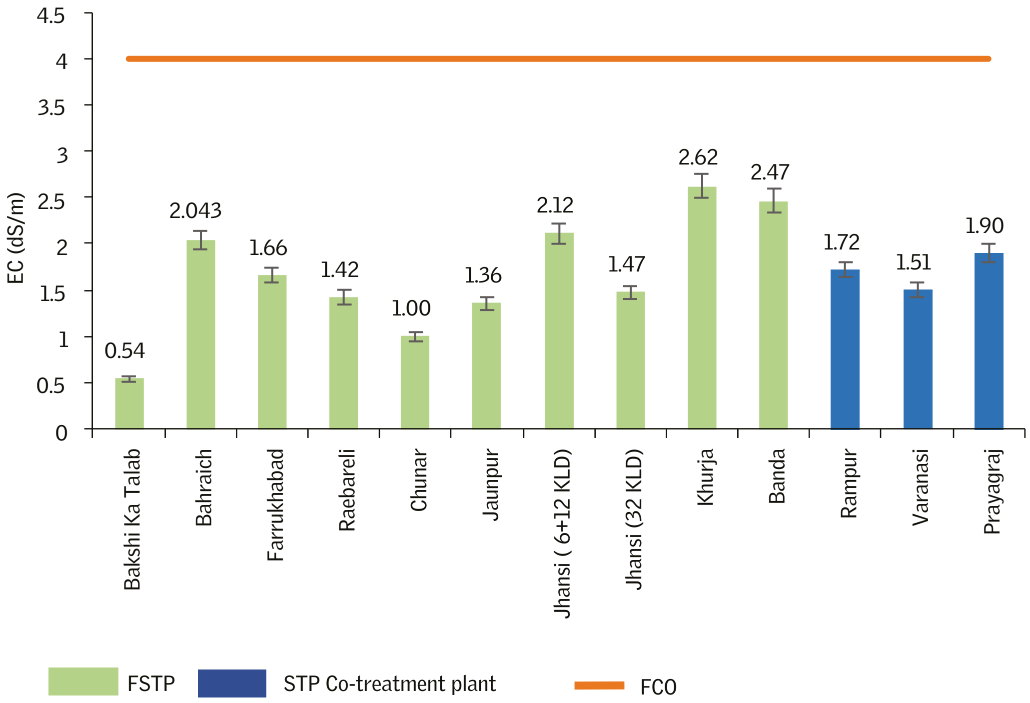

Source: CSE

## Electrical Conductivity (EC)

The graph provided below (see *Graph 29*) depicts the EC of biosolids. Biosolids collected from different treatment plants reflected the EC in the range of 0.54 dS/m in Bakshi Ka Talab to 2.62 dS/m in Khurja.

FCO, 2023, does not mention the term electrical conductivity. However, it is mentioned in FCO, 2013 for organic manure as <4 dS/m, indicating that all the biosolids collected from each site lies within the standards.

**Graph 29: Electrical conductivity of biosolids**



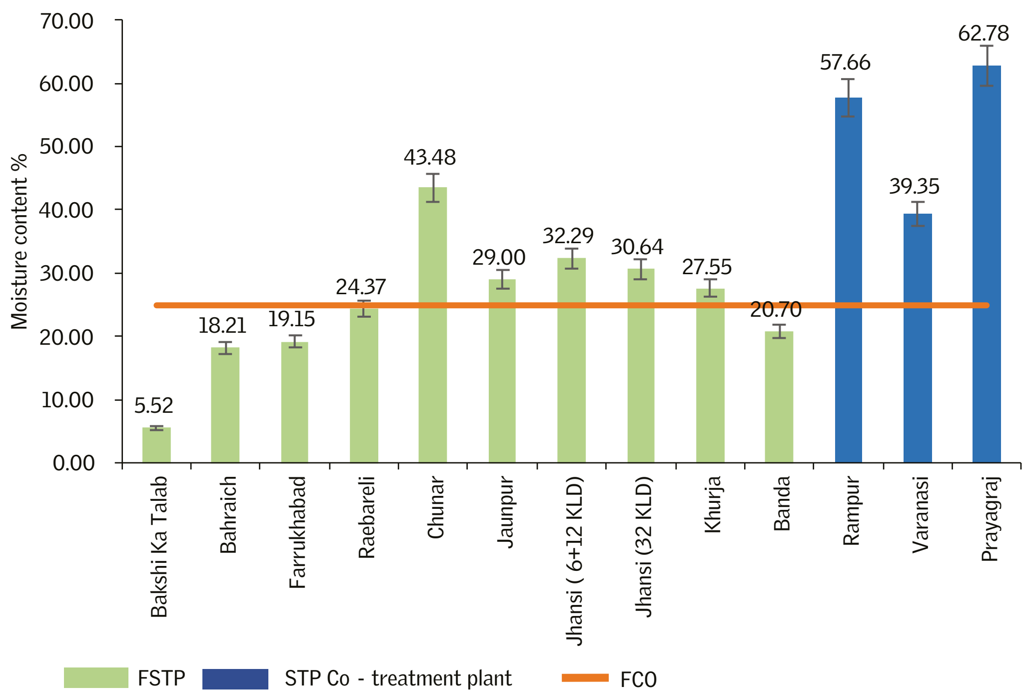

Source: CSE

## Moisture content

Moisture content in all the biosolids associated with the treatment sites has been provided in the graph below (see *Graph 30*). The range varies from 5.52 per cent in Bakshi Ka Talab to 62.78 per cent in Prayagraj. Out of the 14 sites, only five plants—Banda, Bakshi Ka Talab, Bahraich, Raebareli and Farrukhabad—fall within the standards.

FCO, 2023 standards state that the moisture content in organic manure should not be more than 25 per cent. As per the FCO standards, the moisture content is set at under 25 per cent by weight. The graph provided below (see *Graph 30)* shows that only five sites—Bakshi Ka Talab, Bahraich, Farrukhabad, Raebareli and Banda—fall under the range.

**Graph 30: Moisture content of biosolids**



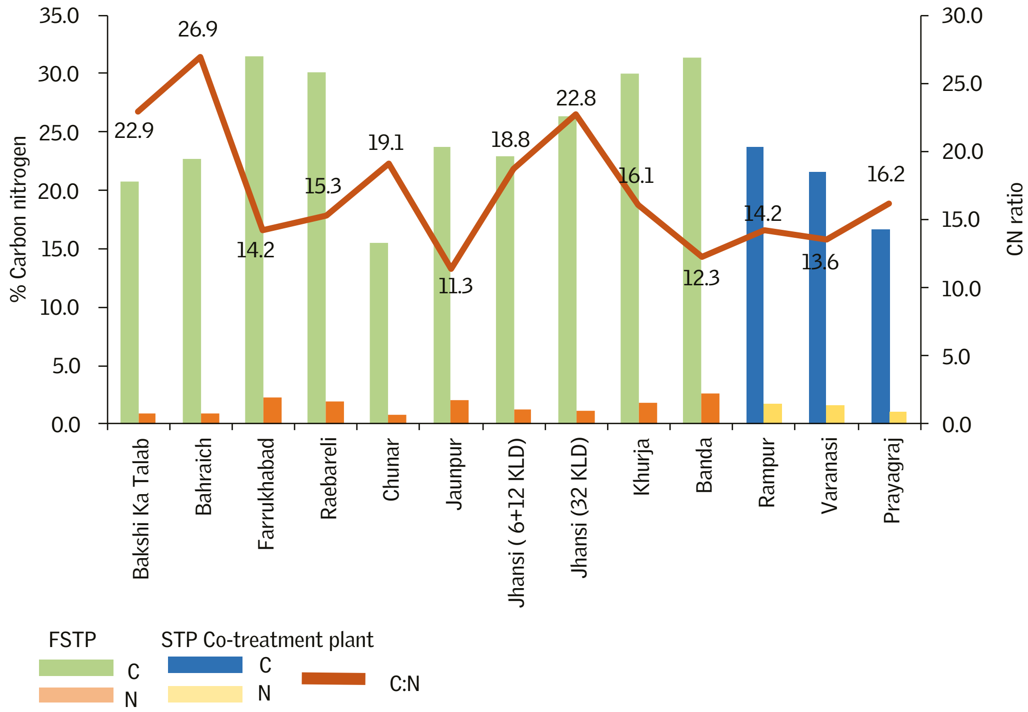

Source: CSE

## Carbon:Nitrogen ratio

The standards set by the FCO, 2023, recommend that the C:N ratio should not be greater than 20. It is recommended that 15:1 or 20:1 should be followed for the optimal growth of the plant.

In the current study, C:N ratio observed in the biosolids collected from each treatment plant ranges from 11.3 in Jaunpur to 26.9 in Bahraich.

**Graph 31: Carbon nitrogen content of biosolids**




Source: CSE

## Heavy metals

The presence of heavy metals in biosolids can be attributed to various factors, like industrial discharge, agriculture runoffs, and urban waste. Although heavy metals occur naturally in places, they are widely distributed through mining, manufacturing, and energy production. The range of heavy metals found in biosolids of different treatment plants is represented in the table below (see *Table 4*). Arsenic, lead, and cadmium was found to be within the limits of the standards set by FCO, 2023.

However, in Rampur, excess presence of chromium (191.42 mg/Kg) was observed. For zinc, only Bahraich and Prayagraj were meeting the FCO limits. In most of the sites, mercury, zinc and copper—Khurja, Jhansi (32 KLD), and Rampur—were observed to be above the FCO standards.

**Table 4: Presence of heavy metals in biosolids**

| Locations | As | Hg | Cd | Cr | Pb | Zn | Cu | Ni |
|---|---|---|---|---|---|---|---|---|
| | (mg/kg) max. 10.001 | (mg/kgmax 0.15 | (mg/kg) max.5 | (mg/kg) max.50 | (mg/ kg) max. 100 | (mg/ kg) max. 1000 | (mg/kg) max. 300 | (mg/ kg) max. 50 |
| Varanasi | 0.52 | 1.20 | 2.43 | 53.03 | 42.10 | 1696.67 | 234.67 | 29.47 |
| Chunar | 0.73 | 1.81 | 1.67 | 29.57 | 55.57 | 1460.00 | 208.33 | 18.43 |
| Jaunpur | 1.29 | 1.53 | 3.46 | 33.90 | 45.83 | 1589.00 | 286.67 | 21.23 |
| Raebareli | 0.56 | 2.03 | 3.07 | 59.27 | 48.93 | 1894.67 | 265.00 | 31.60 |
| Khurja | 1.35 | 2.63 | 2.67 | 35.70 | 82.27 | 2560.00 | 310.67 | 25.63 |
| Banda | 1.16 | 1.98 | 2.54 | 39.43 | 36.97 | 1965.00 | 259.67 | 23.37 |
| Farrukhabad | 1.64 | 2.27 | 2.25 | 59.87 | 46.37 | 2143.33 | 263.00 | 30.10 |
| Bahraich | 1.34 | 1.38 | 1.18 | 26.70 | 62.40 | 719.00 | 139.70 | 14.83 |
| Jhansi (6+12 KLD) | 1.35 | 1.85 | 2.17 | 33.77 | 34.31 | 2098.33 | 273.33 | 23.33 |
| Jhansi (32 KLD) | 1.50 | 4.17 | 3.05 | 40.92 | 50.67 | 1942.78 | 336.11 | 27.04 |
| Varanasi | 0.52 | 1.20 | 2.43 | 53.03 | 42.10 | 1696.67 | 234.67 | 29.47 |
| Prayagraj | 1.39 | 1.33 | 1.66 | 43.37 | 33.33 | 914.00 | 155.13 | 23.97 |
| Rampur | 1.91 | 2.00 | 2.99 | 191.42 | 54.83 | 1886.33 | 309.67 | 86.76 |

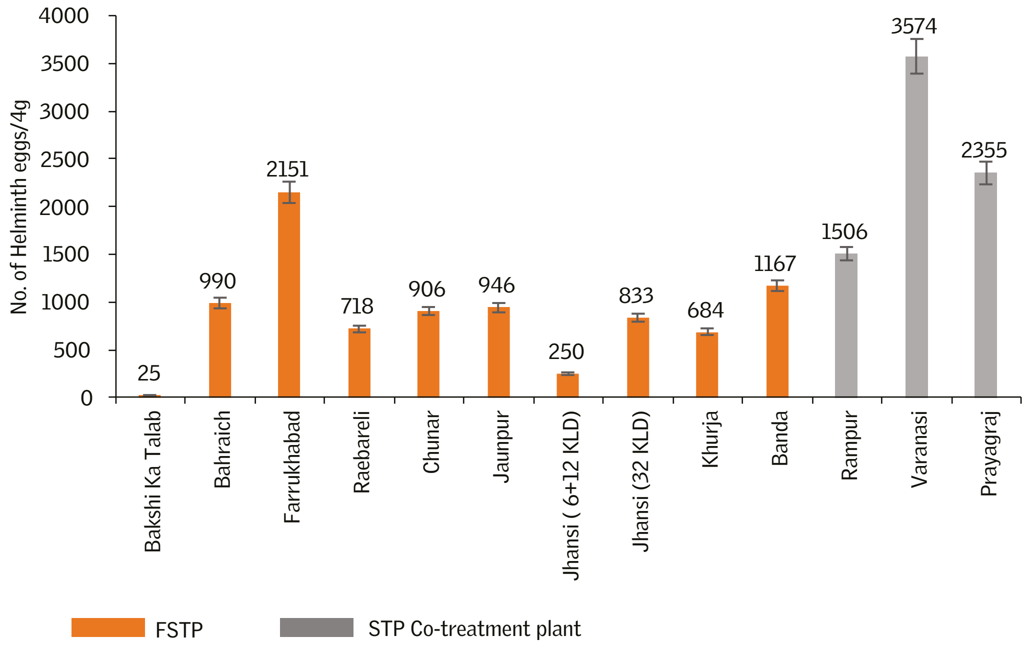
Source: CSE

## Helminths

In the prescribed standards of the FCO, 2023, the presence of 'pathogens' for organic manure is marked as 'NIL'. To evaluate the presence of pathogens in biosolids, the regulatory limits set by the USEPA for class-A biosolids in terms of helminths is <1 viable eggs/4g.

In the current study, it was observed that the presence of helminths in biosolidswere exceeding the standards. The range varied from 25 eggs/4g in Bakshi Ka Talab to 3,574 eggs/4g in Varanasi, indicating insufficient drying of biosolids.

**Graph 32: Presence of helminths in biosolids**




Source: CSE

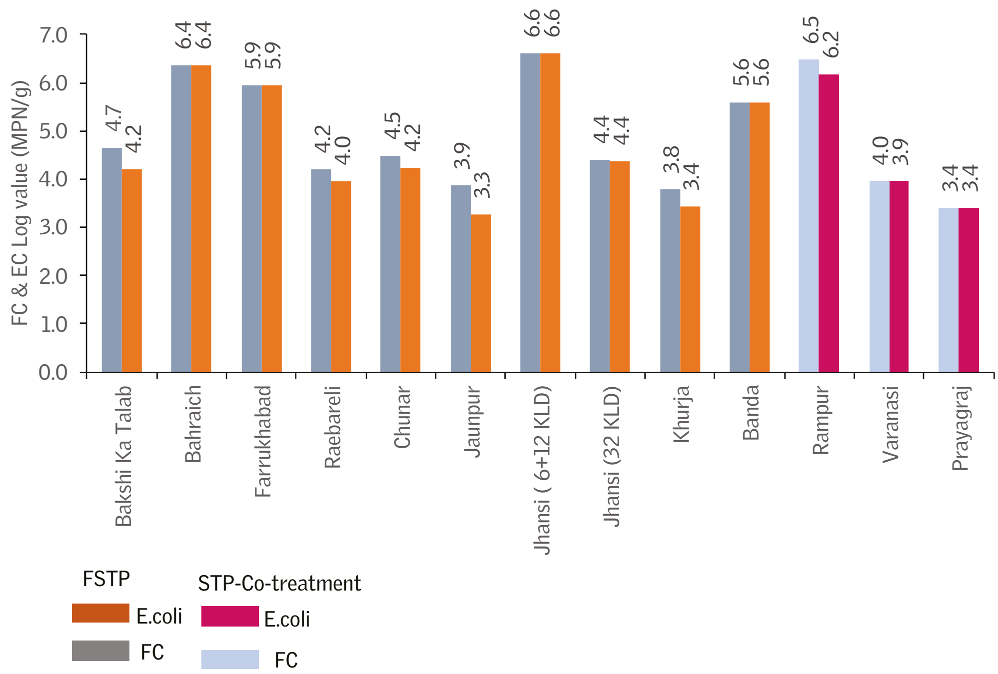
## Faecal Coliform (FC) and *E. coli*

According to the USEPA/WHO standards for land application for biosolids, the number of FC and *E. coli* must be below 1,000 MPN/g (log 1000 = 3).

The range of FCs and *E. coli* ranges from log3.4 MPN/4g in Prayagraj to log 6.6 MPN/4g in Jhansi (6+12 KLD).Biosolids collected from each site show that the presence of both FC and *E. coli* is above the regulatory standards.

The high load of microbes in biosolids reflects inadequate drying, as higher moisture content initiates the regrowth of microbes and the other condition can be improper storage of biosolids.

**Graph 33: Faecal Coliform and E. coli in biosolids**

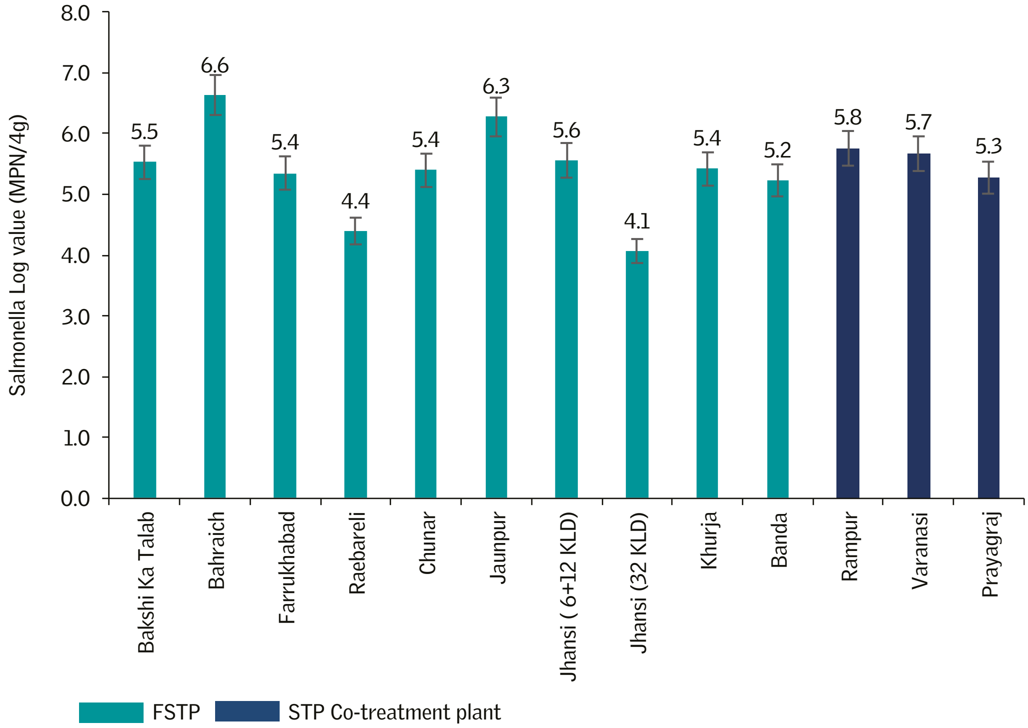



Source: CSE

## Salmonella

Standards set by the FCO, 2023 state that the presence of pathogens in organic manure should be 'NIL'. As the biosolids analysed in this study were not completely pathogen-free, their suitability for agricultural activity has been compared with the USEPA standards. In case of *Salmonella*, the USEPA standard set for biosolids (type A) should not be more than 3 MPN per 4 grams of the total dry solids. The graph given below (see *Graph 34*) shows that all biosolids collected from both FSTPs and co-treatment plants have *Salmonella* above the regulatory limits. The range varied from log 4.1MPN/4g in Jhansi 32 KLD to as high as log 6.6 MPN/4g in Bahraich.

## Graph 34: Presence of Salmonella in biosolids




Source: CSE

# 7. Recommendations

## 7.1 Recommendations for improving treatment units to ensure final treated water quality in FSTPs

Based on the performance evaluation presented in the report, the following recommendations are suggested for each FSTP and co-treatment plant to enhance their treatment efficiency and ensure compliance with regulatory standards:

**Bakshi Ka Talab (25 KLD)**: The FSTP at Bakshi ka Talab, with a capacity of 25 KLD, utilises unplanted drying beds, facultative chambers, and a maturation tank. The report highlights several areas which require improvement for both treated water quality and biosolids. The report indicates that Bakshi Ka Talab shows higher TSS in the outlet (112 mg/L), as compared to the inlet. BOD removal was the lowest among all the FSTPs, with an outlet BOD of 25 mg/L—exceeding the NGT standards (10 mg/L) and nearing the MoEFCC threshold (30 mg/L) for other cities. These inefficiencies are linked to the presence of mud and rich algal bloom in the open-air final treatment chamber.

It is crucial to address the structural integrity of the final treatment chamber, ensuring a concrete base to prevent mud accumulation. Additionally, implementing measures to control algal growth, such as providing shading, or regular removal of algae would significantly improve TSS and BOD removal efficiency. The COD removal efficiency at Bakshi Ka Talab (48.6 per cent) is the lowest among the evaluated FSTPs, with an outlet COD of 76 mg/L exceeding the NGT standard of 50 mg/L. This is directly linked to the issues causing high TSS and BOD. Enhancing the performance of the facultative chambers by ensuring optimal conditions for organic degradation, alongside addressing the structural issues in the final tank, will be key to improving COD removal.

Bakshi Ka Talab recorded the highest FC levels (log 3.24 MPN/100 mL or 1753 MPN/100 mL) among all FSTPs, primarily because it lacks a dedicated disinfection unit. Given that the treated effluent is used for gardening within the premises, the absence of disinfection poses a significant health risk. It is strongly recommended to install a proper disinfection unit, such as chlorination or UV irradiation, after the maturation tank. Optimising the contact time and dosage for the chosen disinfection method is critical to ensure pathogen inactivation to meet relevant standards for safe reuse.

The technology description mentions that the plant relies on unplanted drying beds, facultative chambers, and aerobic maturation tanks. The challenges with solids, organic matter, and pathogen removal suggest a need to re-evaluate the design and operational parameters of these units. Ensuring optimal hydraulic loading rates, sufficient retention times, and maintaining appropriate environmental conditions (e.g., maintaining low oxygen levels in facultative chambers) are vital for improving overall treatment efficiency.

**Jaunpur (32 KLD):** While Jaunpur FSTP generally meets NGT standards for BOD and shows good removal efficiency for other parameters, the report indicates higher FC levels in the outlet discharge, despite using chlorination.

It is recommended that the chlorine dosage and contact time in the disinfection unit be thoroughly optimised. Regular monitoring of chlorine residual levels in the final treated water with simple chlorine test kits, and FC levels post-disinfection in the laboratory should be implemented to ensure consistent and effective pathogen inactivation. Moreover, the SOP of the FSTP should mandate the utilisation of the treated water within 24–48 hours of its generation.

**Chunar (10 KLD):** Chunar FSTP demonstrates effective tertiary treatment, achieving low levels of BOD and FC, meeting NGT's desirable limits for FC. However, the report indicates a relatively low TKN reduction (19 per cent).

To improve nitrogen removal, it is recommended to investigate the efficiency of the ABR and PGF stages for nitrogen transformation. If feasible, operational adjustments or the potential for additional anaerobic or anoxic zones to enhance nitrification and denitrification processes should be considered. This means that an ideal hydraulic loading rate (HLR), holding time (HT) within the unit, and hydraulic flow rate (HFR)—as mentioned in the SOP/ DPR—should be maintained. This will ensure an ideal volume and enough contact time within the treatment unit, enabling effective biological breakdown and nitrogen removal in the ABR and PGF units, as per their optimum designed performance levels.

**Farrukhabad (32 KLD):** Farrukhabad FSTP successfully meets NGT standards for COD and shows good TSS removal. However, its BOD levels, while within MoEFCC limits, exceed NGT standards.

It is recommended to further optimise the baffled reactor and wetland performance for more comprehensive organic matter degradation, ensuring that stricter BOD standards are consistently met. Maintaining optimum HLR, HT and HFR in these units is essential for enhanced biological degradation, as specified in the DPR.

The plants used in the wetlands should be maintained in an optimum plant density. Although in a constructed wetland, plant species used in the wetland can vary depending on the specific goals of the treatment (e.g., removal of TSS, BOD, COD, or nutrients) and the type of wetland (surface flow, subsurface flow). However, it is suggested to maintain a higher plant density, which generally leads to better pollutant removal efficiency. Majority of the published technical guidelines suggest that the majority (around 70 per cent) of a constructed wetland, especially the final 20 per cent, should be shallow and densely vegetated. A water depth of 0.3 meters is considered ideal for most emergent wetland plant species.

Ultimately, the ideal plant-to-area ratio is a balance that promotes microbial activity, provides sufficient surface area for contaminant sorption, and allows for efficient nutrient uptake by the plants, all while maintaining adequate hydraulic flow.

**Raebareli (32 KLD):** Raebareli FSTP shows impressive COD removal efficiency (99.3 per cent) and meets NGT standards for BOD and FC. However, the report highlights elevated levels of heavy metals, like mercury, zinc, and copper, in the biosolids.

While the treatment of liquid effluent is effective, it is crucial to investigate the sources of these heavy metals entering the plant and implement strategies such as industrial discharge monitoring or pre-treatment at source to prevent their accumulation in the biosolids, ensuring safe reuse or disposal.

**Bahraich (32 KLD)**: Bahraich FSTP, while meeting MoEFCC standards for BOD, exceeds the NGT limits for TSS and shows high levels of heavy metals in biosolids, particularly zinc. To improve performance, it is recommended to optimise the lamella clarifier by maintaining the flow rate within the system such that the suspended solids get enough time to settle down. Filtration units—specifically the ACF and sand filter—require regular backwashing, as mentioned in the SOP by the manufacturer, to achieve stricter TSS removal targets.

**Banda (32 KLD)**: Banda FSTP generally performs well, meeting NGT standards for BOD and MoEFCC standards for FC, and showing good overall TKN reduction.

Similar to Jaunpur, the report suggests optimising chlorine dosage and contact time due to higher FC levels than desirable NGT limits. Regular monitoring of chlorine residual levels in the final treated water with simple chlorine test kits, and FC levels post-disinfection in the laboratory should be implemented to ensure consistent and effective pathogen inactivation. Moreover, the SOP of the FSTP should mandate the utilisation of the treated water within 24–48 hours of its generation.

**Jhansi (32 KLD):** The Jhansi 32 KLD FSTP demonstrates commendable performance in several aspects of treated water quality, especially in TSS, BOD, and COD removal. This plant demonstrates excellent TSS (99.8 per cent) and BOD (99.7 per cent) reduction, meeting NGT standards. However, there are specific areas where further optimisation can lead to even better performance and ensure full compliance with all regulatory standards. The high removal efficiencies for TSS, BOD, and COD suggest that the baffle reactor and wetlands are performing effectively in organic matter degradation and solids separation. The report indicates that its FC levels (log 2.90 MPN/100ml) meet the MoEFCC's less stringent standard but are still above the NGT's desirable limit of 100 MPN/100 mL (log 2). Although the plant uses the ACF and the MGF as tertiary treatment, it does not explicitly mention a disinfection unit like chlorination or UV.

To consistently meet stricter pathogen standards (e.g., NGT desirable limits for FC), it is recommended to introduce or optimise a dedicated disinfection step, such as chlorination or UV irradiation, after the filtration units. This would ensure effective inactivation of residual pathogens. However, any persistent presence of pathogens implies that the final polishing steps might need fine-tuning.

Regular monitoring of the entire treatment train, from the baffled reactor through the wetlands and filters, for microbial growth and potential short-circuiting could reveal areas for further enhancement. Ensuring optimal hydraulic retention times in all stages, especially in the wetlands, can also contribute to better pathogen die-off.

**Jhansi (6+12 KLD)**: This plant shows good TSS removal and meets NGT permissible limits for FC. A comprehensive review of the PDB operations, including sludge application rates, drying time, and environmental factors, is crucial. This FSTP in Jhansi utilises a treatment train that includes PDBs, integrated settlers, anaerobic filters (AFs), horizontal PGFs, and a polishing pond. While the plant shows some effectiveness, there are critical areas for improvement in its treated water quality, especially concerning pathogen removal. The report states that the

Jhansi (6+12 KLD) FSTP's outlet FC levels (log 2.14 MPN/100ml) fall within the NGT's permissible limits (230 MPN/100 mL, log 2.36) but do not meet the more desirable limit of 100 MPN/100 mL (log 2). Given that the final treated water is used for irrigation within the premises, achieving a higher level of pathogen reduction is crucial for public health and safety. It is strongly recommended to:

- **Introduce a dedicated disinfection unit:** As the current process relies primarily on natural pathogen die-off in the polishing pond, adding a chemical disinfection step (e.g., chlorination with proper contact time) or UV irradiation after the polishing pond would significantly enhance pathogen inactivation to meet stricter standards.

- **Optimise polishing pond efficiency:** Ensure the polishing pond is designed and operated to maximise sunlight exposure and hydraulic retention time, which are critical for natural pathogen removal. Regular desludging and maintenance to prevent short-circuiting are also important.

The report indicates that this plant in Jhansi does meet NGT standards for BOD (3 mg/L). Its COD removal is also good, with outlet levels at 20 mg/L, falling within NGT standards. This suggests that the biological processes (such as ABR and PGF) are largely effective in organic matter degradation. However, continued monitoring of these parameters is essential to ensure consistent performance, especially if influent (FS) characteristics change. The plant achieves an impressive 98 per cent TKN removal, with outlet levels at 5 mg/L, indicating effective nitrogen transformation. Maintaining optimal conditions in the anaerobic filters and planted gravel filters is critical key for sustaining high level of nutrient removal and preventing potential eutrophication in receiving water bodies. The PDBs and anaerobic filters are foundational to the treatment process. While PDBs are effective for solid-liquid separation, their efficiency in pathogen reduction through liquid percolate needs to be continuously assessed. Regular maintenance of the PDBs—maintaining optimum ratio of plants to PDB area, harvesting of overgrown plant tubers, and desludging—and ensuring proper flow distribution in the anaerobic filters can contribute to overall system stability and improved effluent quality.

**Khurja (35 KLD):** Khurja FSTP generally achieves good overall performance in terms of liquid effluent quality, with its COD, BOD, and FC levels either meeting or approaching regulatory standards. It utilises a hybrid treatment technology including a baffled reactor, wetlands, ACF, dual media filter (DMF), and chlorination. While the plant has some effective stages, there are specific areas

that require attention to improve both treated water quality and biosolids.
The report indicates that Khurja FSTP has an outlet BOD of 42 mg/L, which exceeds the NGT standard of 10 mg/L, and the MoEFCC standard of 30 mg/L for other cities. This suggests that the biological degradation of organic matter in the baffled reactor and wetlands may not be consistently sufficient. Hence it is recommended to:

- **Optimise baffled reactor and wetland performance:** Investigate and optimise the operational parameters (as specified in the SOP provided by the manufacturer) of the baffled reactors and wetlands, such as hydraulic retention time, organic loading rates, and nutrient balance. This will enhance microbial activity and organic matter removal. Ensure proper maintenance of the wetlands, including plant health and media integrity, to maximise their treatment efficiency.

- **Evaluate influent characteristics:** A consistent high BOD in the outlet might also suggest variability or high strength in the incoming faecal sludge. Regular monitoring of influent (FS) BOD can help in adjusting the treatment process accordingly. Similar to BOD, Khurja's outlet COD is 95 mg/L, exceeding the NGT standard of 50 mg/L. This further supports the need for optimising organic matter degradation.

The recommendations for BOD improvement also apply here, focusing on the efficiency of the baffled reactor and wetlands in breaking down complex organic compounds. While Khurja uses chlorination for disinfection, the report notes that its FC levels (log 2.90 MPN/100ml) are above the NGT desirable (log 2) and permissible (log 2.36) limits, though it meets the less stringent MoEFCC standard (log 3). This suggests that the chlorination process might not be fully optimised. It is recommended to optimise the chlorine dosage and ensure sufficient contact time in the chlorination tank to achieve effective pathogen inactivation. Regular monitoring of chlorine residual in the outlet can confirm proper disinfection. It is also recommended to verify that chlorine is adequately mixed with the effluent to ensure uniform distribution and contact with all pathogens. The use of ACF and DMF is a good tertiary treatment approach for removing odour, colour, micropollutants, turbidity, and suspended solids. Ensure these filters are regularly backwashed and maintained to prevent clogging and maintain their efficiency in polishing the effluent.

## 7.2 Recommendations for improving the treatment units to ensure final treated water quality of the co-treatment STPs

This section provides specific recommendations for the co-treatment plants in Prayagraj, Varanasi, and Rampur. It focuses on both their water treatment units and the quality of their biosolids.

**Prayagraj (50 KLD):** Prayagraj co-treatment plant shows strong performance in TSS and COD removal, meeting NGT standards. It also achieves high FC removal (99.9 per cent). The plant achieves 90 per cent of BOD removal, with an outlet of 8.70 mg/L, which is within the NGT standard of 10 mg/L. This indicates good performance in organic matter degradation by the MBBR unit. Continued monitoring and maintenance of the MBBR are crucial to ensure the health and activity of the biofilm for consistent BOD removal. Prayagraj also achieves a very high FC removal of 99.9 per cent, with an outlet of log 2.36 MPN/100ml. While this meets the MoEFCC permissible limit, it falls at the very edge of the NGT permissible limit (log 2.36). Since the final treated water is discharged into the Ganga river, aiming for the NGT's desirable limit (log 2 or 100 MPN/100ml) is highly recommended. This can be achieved by:

- **Optimising chlorination:** Review and potentially increase the chlorine dosage and ensure sufficient contact time in the chlorination tank. Regular monitoring of chlorine residual should be a standard practice.

- **Ensuring proper mixing:** Verify that chlorine is adequately mixed with the effluent to ensure uniform disinfection.

**Varanasi (50 KLD):** Varanasi co-treatment plant demonstrates excellent performance in BOD, COD, and TSS removal, consistently meeting NGT standards. It also achieves significant FC removal. Varanasi demonstrates excellent removal efficiencies for BOD (99.6 per cent), COD (99.1 per cent), and TSS (99 per cent), with outlet values consistently meeting NGT standards (BOD 5.20 mg/L, COD 27 mg/L, TSS 4 mg/L). This indicates that the SBR and preliminary treatment stages are highly effective.

Strict adherence to the current SOP is essential to ensure optimal operational parameters for the SBR, including aeration cycles, sludge age, and nutrient levels. This will help sustain the high level of organic matter and solids removal. Varanasi achieves a remarkable 99.9 per cent FC removal, with an outlet of log 1.5 MPN/100ml (30 MPN/100ml). This successfully meets both the NGT's desirable limit and the MoEFCC's permissible limit. It is suggested to ensure proper and continued chlorination dosage, contact time, and mixing to sustain this excellent disinfection performance. Regular calibration and maintenance of the disinfection units are important.

**Rampur (25 KLD):** Rampur co-treatment plant performs well in TSS and COD removal. However, it falls short of the NGT standards for BOD and its outlet discharge for FC does not meet the prescribed standards, despite achieving 97 per cent removal. It is critical to enhance the PGF efficiency for BOD reduction and investigate the root cause of high FC in the final effluent, potentially through optimising the chlorination unit. Rampur has the lowest BOD removal efficiency among co-treatment plants (96.7 per cent), with an outlet BOD of 26.20 mg/L. This exceeds both NGT (10 mg/L) and MoEFCC (20 mg/L) standards. The PGF at the co-treatment site of the FSTP is the main biological treatment unit before the SBR.

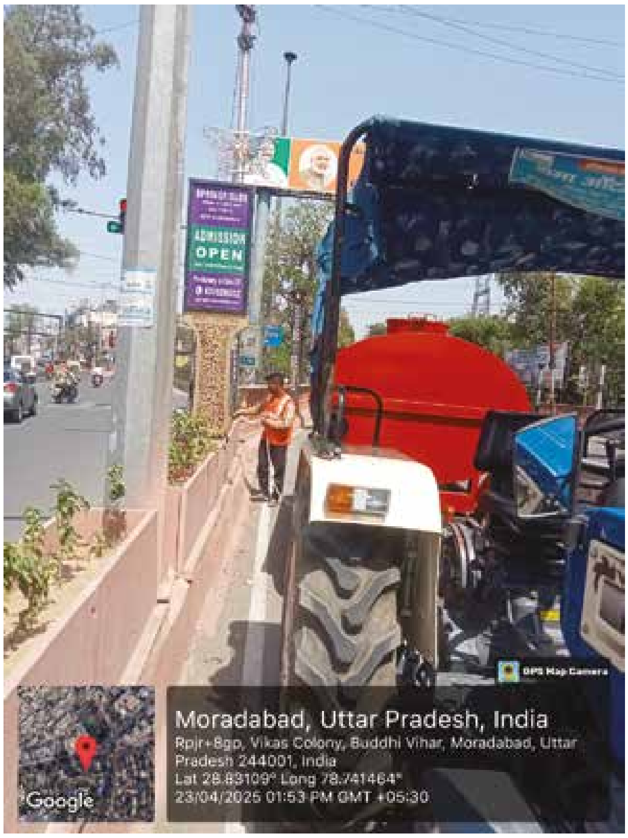
Optimisation of the performance of the PGF and the SBR is required. Ensuring proper maintenance of the PGF (e.g., healthy plant growth, preventing clogging of media) to maximise its organic removal capacity is mandatory. For the SBR, optimising the aeration cycles, mixing, and sludge retention time to enhance BOD reduction is crucial as well. Rampur achieves 97 per cent FC removal, but its outlet FC level (log 4.4 MPN/100ml) and the MoEFCC standard (log 3) are significantly above NGT desirable/permissible limits. This indicates a major failure in disinfection.

It is critical to implement a chlorination system immediately. Thereafter, optimising the chlorine dosage, contact time, proper mixing, and the functionality of the dosing equipment is mandatory. If implementation of a chlorination system does not yield satisfactory results, alternate disinfection methods like UV irradiation—especially given the plant's capacity and the intended discharge/reuse—is recommended.

## 7.3 Recommendations for restricted safe use of treated water from the FSTPs in Uttar Pradesh

The report offers crucial insights into the potential and challenges of reusing treated water from FSTPs and STPs in Uttar Pradesh. While the report emphasises that the treated water at FSTPs and co-treatment plants are a significant untapped resource of treated water with a potential for reuse, they also highlight 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 prioritising specific applications based on the quality of treated effluent and the local context of water scarcity and demand. The report indicates that many FSTPs and co-treatment plants in UP struggle to consistently meet stringent discharge standards, particularly for FC and sometimes COD/BOD. Therefore, the primary recommendation for restricted safe use is to prioritise non-potable applications that minimise direct human exposure and align with the principles of a circular economy. These include:




CSE

***Treated from FSTP being used in maintaining urban greenery***

1. **Agricultural irrigation (for non-edible crops or crops consumed after cooking):** As agriculture constitutes 73 per cent of Uttar Pradesh's land area and is a major water consumer, 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 CPHEEO for treated sewage quality for irrigation of non-edible crops and some edible ones (consumed after cooking) should be practiced.

2. **Groundwater recharge and lake/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 utilising 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. Many FSTP sites in UP are already utilising treated water for gardening within their premises.

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:** Uttar Pradesh needs a 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, Uttar Pradesh can effectively transform its wastewater into a valuable resource, contributing significantly to water security, environmental protection, and a circular economy.

## 7.4 Recommendations for improving treatment units to ensure biosolids quality from FSTPs

Based on the analysis of biosolids quality in the report, the following recommendations are suggested for each FSTP and co-treatment plant to improve the quality of their biosolids, ensuring compliance with regulatory standards for safe reuse or disposal:

**Bakshi Ka Talab (25 KLD)**: The pH of biosolids from Bakshi ka Talab is 5.6, which is slightly less than the FCO, 2023 standard range of 6–8.5 for organic manure. While not a severe deviation, maintaining the pH within the optimal range is beneficial for microbial activity and nutrient availability in soil. Minor adjustments to the dewatering or drying process, or an assessment of the influent sludge characteristics may contribute in its improvement.

Bakshi Ka Talab's biosolids have a moisture content of 5.52 per cent, which is well within the FCO, 2023 standard of less than 25 per cent. This indicates efficient drying, which is positive for overall quality and handling. Maintaining this efficiency is important, as lower moisture content generally correlates with better pathogen reduction and ease of storage or handling. Despite efficient drying in terms of moisture content, the biosolids from Bakshi Ka Talab show high levels of helminths (25 eggs/4g), FC/*E.coli* (log 4.7 MPN/g for FC, log 4.2 MPN/g for *E.coli*), and *Salmonella* (log 5.5 MPN/4g)—all of which is above the USEPA/WHO standards for Class A biosolids and FCO 'NIL' standard for *Salmonella*. This indicates that the current drying method alone is insufficient for complete pathogen inactivation. Methods to increase the temperature or duration of drying, or supplementary treatment—co-composting, thermal treatment, or lime stabilisation—to achieve greater pathogen reduction should be assessed and explored. A covered shade (tin or asbestos) over the drying area would allow heat retention for a longer time.

Ensuring proper storage conditions (e.g., covered storage, adequate aeration) will prevent pathogen regrowth and maintain the quality of the dried biosolids. The EC (0.54 dS/m) is within FCO, 2013 standards (<4 dS/m), which is a good sign. The C:N ratio (22.9) is slightly above the recommended optimal range of 15:1 to 20:1, which can lead to nitrogen immobilisation if applied directly to soil. While the primary concern for Bakshi Ka Talab's biosolids is pathogen load, exploring options to adjust the C:N ratio, such as co-composting with carbon-rich materials, could enhance its agricultural value in the long term.

**Jaunpur (32 KLD):** The report indicates that Jaunpur's biosolids have helminths, FC, *E. coli*, and Salmonella above regulatory standards. While the C:N ratio is good (11.3), the pathogen levels are a concern. It is recommended to optimise the sun-drying process to ensure complete drying and proper pathogen inactivation. This may involve longer drying periods, more frequent turning of the sludge.

**Chunar (10 KLD)**: Chunar's biosolids show high levels of helminths, FC, *E.coli*, and *Salmonella*. Despite an acceptable C:N ratio of 19.1, the pathogen load is high. A comprehensive review of the PDB operation is crucial. This should include assessing sludge application rates, ensuring sufficient drying time, and investigating if environmental factors (such as heat or rainfall) are hindering effective pathogen reduction. Implementing practices to achieve complete drying is paramount.

**Farrukhabad (32 KLD):** Farrukhabad's biosolids have chromium and zinc levels above FCO limits, along with high levels of helminths, FC, *E. coli*, and *Salmonella*. The C:N ratio is good at 15.3.
Recommendations include a thorough investigation into the source of heavy metals to implement pre-treatment steps, if necessary. For pathogen reduction, the sun-drying process needs optimisation (in terms of sludge depth, time of drying, etc.) to reduce moisture content and inactivate pathogens effectively. For the biosolids, a more thorough investigation into the source of heavy metals and potential pre-treatment steps to reduce heavy metal accumulation in the sludge is advisable.

**Raebareli (32 KLD):** Raebareli's biosolids highlight elevated levels of mercury, zinc, and copper, along with high helminth, FC, *E. coli*, and *Salmonella* counts. The C:N ratio is slightly above optimal at 22.8. It is crucial to identify and address the sources of these heavy metals to prevent their accumulation. Furthermore, significant improvements are needed in the drying and stabilisation process of biosolids to achieve proper pathogen inactivation and meet the standards.

**Bahraich (32 KLD):** Bahraich's biosolids show high levels of zinc and extremely high levels of helminths, FC, *E. coli*, and *Salmonella*. The C:N ratio is high at 26.9, indicating potential nitrogen immobilisation.

Recommendations include identifying and addressing the source of zinc contamination. More critically, the biosolids treatment process, specifically the drying and stabilisation methods, must be significantly improved to reduce pathogen loads to acceptable levels. Adjusting the C:N ratio through co-composting with a carbon-rich material could also be beneficial.

**Banda (32 KLD):** Banda's biosolids contain high levels of mercury, zinc, and copper, and exceed standards for helminths, FC, *E. coli*, and *Salmonella*. The C:N ratio is within the optimal range at 12.3. Efforts should focus on investigating the sources of heavy metals to mitigate their presence in the biosolids. Additionally, the sun-drying and storage practices need to be enhanced to ensure effective pathogen reduction and lower moisture content.

**Jhansi (32 KLD)**: While this plant performs well in effluent quality, its biosolids have high levels of *Salmonella*. The C:N ratio is 16.1. It is recommended to evaluate and optimise the current biosolids drying process and storage conditions, ensuring effective Salmonella inactivation. Enhancements to the sun-drying methods, such as improved turning frequency or extended drying periods, or exploring alternative/supplementary drying techniques, should be considered to ensure adequate pathogen inactivation in biosolids.

**Jhansi (6+12 KLD):** This plant's biosolids show exceptionally high levels of helminth eggs, FC, *E. coli*, *Salmonella*, and high moisture content. The C:N ratio is 18.8. A comprehensive and urgent review of the PDB operation is required. This should encompass sludge application rates, ensuring sufficient drying time and addressing any factors hindering complete drying and pathogen inactivation to meet USEPA/WHO standards. Moreover, implementing measures to ensure complete drying and proper storage of biosolids is essential to meet USEPA/WHO standards for pathogen reduction.

**Khurja (35 KLD):** Khurja's biosolids exhibit elevated levels of zinc and copper, along with high pathogen counts for helminths, FC, *E. coli*, and Salmonella. The C:N ratio is 22.8, slightly above the ideal range.

Recommendations include investigating and controlling the sources of heavy metal contamination. Furthermore, the sludge drying and stabilisation processes need optimisation to significantly reduce pathogen loads and achieve a more balanced C:N ratio for potential agricultural reuse. Optimising the sludge drying and stabilisation processes could also help in reducing pathogen load in biosolids. However, the presence of elevated levels of zinc and copper in the biosolids is a concern. The biosolids from Khurja show high levels of zinc (2560 mg/kg) and copper (310.67 mg/kg), both exceeding FCO limits (1000 mg/kg for zinc and 300 mg/kg for copper). This is a significant concern for the safe reuse or disposal of biosolids. It is highly recommended to conduct a thorough investigation to identify the primary sources of zinc and copper entering the FSTP. This may involve tracing industrial discharges or specific types of faecal sludge being collected. Implementing source control measures or pre-treatment at the source could reduce heavy metal loads. If source control is not entirely feasible, new methods should be explored to reduce heavy metal mobility or concentration in the biosolids, such as further stabilisation, chemical precipitation, or specialised treatment technologies.

Khurja's biosolids have a moisture content of 27.55 per cent, which is slightly above the FCO, 2023 standard of less than 25 per cent. While close, consistently meeting this standard is important for stability and pathogen reduction.

Recommendations include enhancing the sun-drying process by ensuring adequate drying bed area, optimising sludge application thickness, and implementing frequent turning to promote evaporation. Exploring covered drying beds or forced aeration could also be beneficial in achieving lower moisture content more consistently.

The biosolids show high levels of helminths (684 eggs/4g), FC/*E. coli* (log 3.8 MPN/g for FC, log 3.4 MPN/g for E. coli), and *Salmonella* (log 5.4 MPN/4g)—all exceeding USEPA/WHO Class A standards and FCO's 'NIL' standard for *Salmonella*. This indicates that the current sun-drying method is not fully effective in pathogen inactivation. It is highly recommended to implement enhanced stabilisation techniques beyond simple sun-drying. Implementing advanced stabilisation methods such as composting (thermophilic composting can achieve high temperatures for pathogen kill), lime stabilisation, or other thermal treatment options can ensure comprehensive pathogen inactivation and meet stringent standards for safe biosolids reuse.

It is also recommended to ensure post-drying storage conditions; prevent recontamination and pathogen regrowth. Proper handling procedures should also be in place.

The C:N ratio of Khurja's biosolids is 16.1, which falls within the optimal range of 15:1 to 20:1 recommended by FCO, 2023 for optimal plant growth and microbial decomposition. Maintaining this balance is good for the potential agricultural value of the biosolids.

## 7.5 Recommendations for improving treatment units to ensure biosolids quality from co-treatment STPs

**Prayagraj (50 KLD):** Prayagraj's biosolids have high moisture content and excessive levels of helminths, FC, and *E. coli*. The C:N ratio is 16.2. It is crucial to optimise the sludge drying bed operation to consistently reduce moisture content below 25 per cent and enhance pathogen inactivation. This includes improving turning frequency and extending drying periods to ensure biosolids are safe for reuse. Prayagraj's biosolids have a high moisture content of 62.78 per cent, significantly exceeding the FCO, 2023 standard of less than 25 per cent. This high moisture content directly contributes to inadequate pathogen inactivation.

It is crucial to implement strategies to enhance the drying process, such as reducing sludge application thickness, increasing turning frequency, and potentially extending drying periods. Exploring covered or greenhouse drying beds could significantly improve moisture removal by providing a controlled environment. The biosolids show very high levels of helminths (2355 eggs/4g), FC/*E. coli* (log 3.4 MPN/g for both FC and *E. coli*), and *Salmonella* (log 5.3 MPN/4g)—all well above regulatory standards. This is directly linked to the high moisture content and insufficient drying.

Beyond simple sun-drying, considering robust stabilisation methods such as thermophilic composting or lime stabilisation would be suggested. These methods can achieve higher temperatures and/or pH levels necessary for comprehensive pathogen destruction, ensuring the biosolids meet health-based standards for safe agricultural reuse. While generally within limits, the report states that Prayagraj's biosolids (914 mg/kg) are at the higher end of the FCO limit for zinc (1000 mg/kg). Continued vigilance and monitoring of influent (FS) sources are important to prevent future exceedances.

**Varanasi (50 KLD):** Varanasi's biosolids show extremely high levels of helminths, FC, *E. coli*, and *Salmonella*, coupled with high moisture content and high zinc levels. The C:N ratio is 13.6. Immediate and significant action is needed to review and optimise the drying bed design and operational practices. This includes maximising drying efficiency and exploring supplementary disinfection methods to ensure biosolids meet health-based guidelines.

Varanasi's biosolids show high levels of zinc (1696.67 mg/kg) and chromium (53.03 mg/kg), both exceeding FCO limits (1000 mg/kg for zinc and 50 mg/kg for chromium). A thorough investigation is crucial to identify the primary sources of zinc and chromium entering the FSTP, especially if industrial or commercial waste streams are part of the influent. Implementing source control measures or pre-treatment at the source is critical. If source control is not entirely feasible, exploring methods to reduce heavy metal mobility or concentration in the biosolids, such as further stabilisation or chemical precipitation is advisable.

The biosolids show extremely high levels of helminths (3574 eggs/4g), FC/*E. coli* (log 4.0 MPN/g for FC, log 3.9 MPN/g for *E. coli*), and *Salmonella* (log 5.8 MPN/4g). These are all significantly above regulatory standards, despite the use of sun-drying. The current sun-drying method is clearly inadequate for pathogen reduction. It is imperative to implement more rigorous stabilisation methods such as thermophilic composting, pasteurisation, or advanced alkaline stabilisation to achieve Class A biosolids standards. Reviewing and optimisation of the drying bed design and operational practices to ensure maximum moisture removal and pathogen die-off is crucial. This includes optimising sludge application rates, sludge depth, improving turning frequency, and potentially extending drying periods under controlled conditions.

**Rampur (25 KLD):** Rampur's biosolids contain excess chromium and high levels of helminths, FC, *E. coli*, and *Salmonella*. The C:N ratio is 14.2. A comprehensive approach is needed to address heavy metal contamination, especially chromium, by identifying and controlling its source. Furthermore, the pathogen reduction in biosolids requires significant improvement through enhanced drying and stabilisation methods to meet regulatory standards.

### 7.6 Recommendations for restricted safe use of the generated biosolids at the FSTPs of Uttar Pradesh

None of the biosolids generated at the FSTPs and co-treatment units of Uttar Pradesh comply with the USEPA Class A standards. 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 utilised 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 reuse of such Class B biosolids are mentioned below:

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

# 8. ANNEXURES

## Annexure 1

### Table 1: National Green tribunal (NGT) standards, 2019 for effluent discharge from STP 11

| S. no. | Parameters | Standards (Applicable to all mode of disposal) | | | |
|---|---|---|---|---|---|
| | | Mega and metropolitan cities | Class I cities | Others | Deep marine outfall |
| 1. | pH | 5.5–9.0 | 5.5–9.0 | 5.5–9.0 | 5.5–9.0 |
| 2. | Bio chemical oxygen demand | 10 | 20 | 30 | 30 |
| 3. | Total suspended solids (TSS) | 20 | 30 | 50 | 50 |
| 4. | Chemical oxygen demand (COD) | 50 | 100 | 150 | 150 |
| 5. | Total nitrogen | 10 | 15 | - | - |
| 6. | Phosphorus: Total (for discharge into ponds and lakes) | 1 | 1 | 1 | |
| 7. | Faecal Coliform (FC): Most probable number per 100 millilitre, MPN/100 ml | Desirable:100 Permissible: 230 | Desirable: 230 Permissible: 1000 | Desirable: 1000 Permissible: 10,000 | Desirable: 1000 Permissible: 10,000 |

Notes:
(i) Mega-metropolitan cities have population more than one crore; metropolitan cities—population more than ten lakhs; and Class-1 population more than one lakh.
(ii) All value in mg/l except for pH and Faecal Coliform.
(iii) These standards will be applicable for discharge into water bodies as well as for land disposal/applications.
(iv) These standards shall apply to all new STPs for which construction is yet to be initiated.
(v) The existing/under construction STPs shall achieve these standards within seven years from the date of notification.
(vi) In case where the marine outfall provides a minimum initial dilution of 150 times at the point of discharge and a minimum dilution of 1500 times at a point 100 metres away from discharge point, then norms for deep sea marine discharge shall be applied.
(vii) Reuse/recycling of treated effluent shall be encouraged.
(viii) State Pollution Control Boards/Pollution Control Committees may make these norms more stringent taking into account the local conditions.

## Table 2: Fertilizer Control Order standards for organic manure, 202312

| 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/cm3) | <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 P205) per cent by weight, minimum | 0.5 |
| 7 | Total potash (as K20) per cent by weight, minimum | 0.5 |
| 8 | NPK nutrients – Total N, P205 and K20 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 As203) | 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 term 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.

# Annexure 1

## Table 3: Global standards for pathogens in biosolids4

| S. No. | Type of organism | Standard | Regulatory body | Remarks |
|---|---|---|---|---|
| 1 | Faecal coliform | 1000 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 | 1000/gram total solids | WHO (2006) | Faecal sludge reuse in agriculture |
| 3 | Salmonella | 3 MPN per 4 grams of total 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 total dry solids | USEPA | Faecal sludge reuse in agriculture |

# Annexure 2

## Table 1: Consolidated data of FSTPs in Uttar Pradesh

| S. no. | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Chunar | November, 2024 | FS | 7.69 | 37684 | 26084 | 11600 | 53500 | 1600.0 | 197 | 2128.6 | 227.93 | 2400000 |
| | | | Inlet | 6.75 | 3091 | 2651 | 440 | 318 | 28.0 | 5.94 | 14.112 | 1.8189 | 740 |
| | | | Outlet | 6.69 | 1775 | 1769 | 6 | 104 | 4.8 | 5.02 | 9.702 | 1.5915 | 36 |
| | | January, 2025 | FS | 7.38 | 10755 | 1955 | 8800 | 22050 | 1200 | 108 | 382.2 | 126.75 | 2400000 |
| | | | Inlet | 7.62 | 2601 | 2591 | 10 | 202 | 36 | 11.32 | 5.88 | 3.0694 | 15000 |
| | | | Outlet | 8.02 | 2336 | 2335 | 1 | 40 | 4 | 5.44 | 8.526 | 1.1368 | 36 |
| | | March, 2025 | FS | 6.56 | 4124 | 1424 | 2700 | 19450 | 1500.0 | 3.61 | 244.02 | 223.44 | 11000000 |
| | | | Inlet | 6.83 | 1567 | 1507 | 60 | 116 | 6.0 | 13.2 | 7.35 | 4.998 | 1500 |
| | | | Outlet | 6.96 | 8 | 1 | 7 | 72 | 9.0 | 8.8 | 3.822 | 1.68 | 30 |
| | | | Mean FS | 7.21 | 17521 | 9821 | 7700 | 31667 | 1433.3 | 102.9 | 918.26 | 192.71 | 5266667 |
| | | | Mean inlet | 7.067 | 2419.7 | 2249.67 | 170 | 212 | 23.3 | 10.2 | 9.1 | 3.3 | 5747 |
| | | | Mean outlet | 7.223 | 1373 | 1368.33 | 4.667 | 72 | 5.8 | 6.4 | 7.4 | 1.5 | 34 |
| | | | Per cent removal | NA | 43.257 | 39.1762 | 97.25 | 66.038 | 75 | 36.93 | 19.355 | 55.41 | 99.41 |
| 2 | Jaunpur | November, 2024 | FS | 7.12 | 17547 | 14947 | 2600 | 20500 | 650.0 | 50 | 414.54 | 159.72 | 11000000 |
| | | | Inlet | 7.23 | 2649 | 1969 | 680 | 1354 | 125.0 | 17.35 | 263.13 | 126.75 | 430000 |
| | | | Outlet | 7.93 | 792 | 788 | 4 | 9 | 7.1 | 0.13 | 5.586 | 2.2168 | 2400 |
| | | January, 2025 | FS | 7.18 | 45072 | 43072 | 2000 | 70400 | 1400 | 492 | 329.28 | 183.59 | 24000000 |
| | | | Inlet | 8.06 | 2193 | 1853 | 340 | 662 | 65 | 19.28 | 211.68 | 139.71 | 230000 |
| | | | Outlet | 8.28 | 978 | 970 | 8 | 21 | 2 | 0.61 | 6.762 | 3.183 | 430 |
| | | March, 2025 | Inlet | 7.58 | 14238 | 12048 | 2190 | 508 | 332.0 | 40.2 | 270.48 | 186.69 | 93000 |
| | | | Outlet | 8.07 | 904 | 899 | 5 | 15 | 4.9 | 1.4 | | | 2300 |
| | | | Mean FS | 7.15 | 31310 | 29009.5 | 2300 | 45450 | 737.5 | 271.0 | 174.3 | 119.5 | 17500000 |
| | | | Mean inlet | 7.623 | 6360 | 5290 | 1070 | 841.33 | 349.0 | 25.6 | 298.9 | 151.1 | 251000 |
| | | | Mean outlet | 8.093 | 891.33 | 885.667 | 5.667 | 15 | 4.7 | 0.7 | 6.2 | 2.7 | 1710 |
| | | | Per cent removal | NA | 85.985 | 83.2577 | 99.47 | 98.217 | 98.663 | 97.28 | 97.934 | 98.213 | 99.32 |

| S. no. | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Bahraich | November, 2024 | FS | 6.81 | 45354 | 30114 | 15240 | 69050 | 3280.0 | 264 | 3866.1 | 2958.5 | 2100000 |
| | | | Inlet | 6.98 | 61789 | 61739 | 50 | 344 | 48.0 | 11.08 | 186.4 | 120.27 | 43000 |
| | | | Outlet | 7.12 | 411 | 409 | 2 | 185 | 16.0 | 0.14 | 8.82 | 1.3642 | 30 |
| | | January, 2025 | Inlet | 7.82 | 1356 | 1236 | 120 | 490 | 165 | 23.12 | 252.84 | 175.86 | 9300 |
| | | | Outlet | 8.12 | 586 | 584 | 2 | 249 | 16 | 0.17 | 9.114 | 0.9094 | 36 |
| | | March, 2025 | FS | 7.05 | 3537 | 1537 | 2000 | 23950 | 230.0 | 1.69 | 158.76 | 120.54 | 1200000 |
| | | | Inlet | 8.02 | 1896 | 1606 | 290 | 718 | 105.0 | 17.6 | 501.56 | 448.35 | 23000 |
| | | | Outlet | 8.36 | 603 | 473 | 130 | 217 | 49.5 | 0.28 | 9.702 | 5.88 | 4300 |
| | | | Mean FS | 6.93 | 24446 | 15825.5 | 8620 | 46500 | 1755.0 | 132.8 | 2012.4 | 1539.5 | 1650000 |
| | | | Mean inlet | 7.607 | 21680 | 21527 | 153.3 | 517.33 | 106.0 | 17.3 | 313.6 | 248.2 | 25100 |
| | | | Mean outlet | 7.867 | 533.33 | 488.667 | 44.67 | 217 | 27.2 | 0.2 | 9.2 | 2.7 | 1455 |
| | | | Per cent removal | NA | 97.54 | 97.73 | 70.87 | 58.054 | 74.371 | 98.86 | 97.063 | 98.905 | 94.20 |
| 4 | Bakshi Ka Talab | November, 2024 | Inlet | 7.51 | 549 | 537 | 12 | 132 | 30.0 | 3.53 | 10.29 | 3.6378 | 30 |
| | | | Outlet | 7.76 | 672 | 565 | 107 | 109 | 16.3 | 0.35 | 11.76 | 1.1936 | 4300 |
| | | January, 2025 | FS | 7.75 | 7014 | 2314 | 4700 | 14040 | 800 | 64 | 593.88 | 306.37 | 92000 |
| | | | Inlet | 7.64 | 1171 | 1161 | 10 | 128 | 26 | 9.56 | 29.694 | 11.652 | 2300 |
| | | | Outlet | 8.07 | 932 | 756 | 176 | 43 | 11 | 0.18 | 6.174 | 1.2505 | 930 |
| | | March, 2025 | FS | 7.15 | 7088 | 888 | 6200 | 22950 | 1340.0 | 5.12 | 564.48 | 441.00 | 230000 |
| | | | Inlet | 7.58 | 915 | 905 | 10 | 184 | 7.0 | 11.9 | 9.114 | 8.23 | 430 |
| | | | Outlet | 8.98 | 772 | 717 | 55 | 76 | 46.5 | 0.31 | 6.468 | 3.41 | 30 |
| | | | Mean FS | 7.45 | 1601 | 1601 | 5450 | 18495 | 1070.0 | 34.6 | 579.2 | 373.7 | 161000 |
| | | | Mean inlet | 7.577 | 878.33 | 877 | 10.67 | 148 | 21.0 | 8.3 | 16.4 | 7.8 | 920 |
| | | | Mean outlet | 8.27 | 792 | 679.333 | 112.7 | 76 | 24.6 | 0.3 | 8.1 | 2.0 | 1753 |
| | | | Per cent removal | NA | 9.8292 | 22.539 | -956.2 | 48.649 | -17.06 | 96.63 | 50.299 | 75.11 | -90.58 |

| S. no. | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Raebareli | November, 2024 | FS | 7.22 | 20924 | 8924 | 12000 | 29350 | 3280.0 | 125 | 964.32 | 405.84 | 23000000 |
| | | | Inlet | 7.59 | 2357 | 1497 | 860 | 2880 | 105.0 | 16.9 | 46.746 | 32.399 | 43000 |
| | | | Outlet | 7.63 | 326 | 318 | 8 | 9 | 7.8 | 0.01 | 4.116 | 1.421 | 30 |
| | | January, 2025 | FS | 7.32 | 19425 | 12225 | 7200 | 10540 | 1250 | 52 | 343.98 | 81.85 | 4600000 |
| | | | Inlet | 8.12 | 3062 | 2172 | 890 | 1004 | 103 | 22.4 | 208.15 | 134.37 | 240000 |
| | | | Outlet | 8.34 | 301 | 300 | 1 | 9 | 3 | 0.12 | 4.41 | 1.8757 | 36 |
| | | March, 2025 | FS | 7.29 | 8411 | 5411 | 3000 | 20450 | 920.0 | 1.16 | 1220.1 | 261.46 | 4600000 |
| | | | Inlet | 7.76 | 577 | 507 | 70 | 46 | 15.0 | 4.18 | 13.524 | 12.054 | 430 |
| | | | Outlet | 8.14 | 226 | 220 | 6 | 9 | 1.0 | 0.09 | 2.352 | 1.47 | 36 |
| | | | Mean FS | 7.277 | 16253 | 8853.33 | 7400 | 20113 | 1816.7 | 59.4 | 842.8 | 249.7 | 10733333 |
| | | | Mean inlet | 7.823 | 1998.7 | 1392 | 606.7 | 1310 | 74.3 | 14.5 | 89.5 | 59.6 | 94477 |
| | | | Mean outlet | 8.037 | 284.33 | 279.333 | 5 | 9 | 3.8 | 0.1 | 3.6 | 1.6 | 34 |
| | | | Per cent removal | NA | 85.774 | 79.933 | 99.18 | 99.313 | 94.933 | 99.49 | 95.947 | 97.334 | 99.96 |
| 6 | Khurja | November, 2024 | FS | 7.37 | 2345 | 845 | 1500 | 17300 | 869.8 | 41 | 229.32 | 110.84 | 230000 |
| | | | Inlet | 7.44 | 1822 | 1782 | 40 | 202 | 48.0 | 1.22 | 32.634 | 4.1493 | 36 |
| | | | Outlet | 7.59 | 2040 | 2032 | 8 | 95 | 7.0 | 2.27 | 10.584 | 1.762 | 2300 |
| | | January, 2025 | FS | 7.21 | 107057 | 67057 | 40000 | 64950 | 8130 | 1292 | 3924.9 | 321.15 | 9300000 |
| | | | Inlet | 7.35 | 1485 | 1465 | 20 | 170 | 15 | 10.2 | 119.95 | 92.649 | 23000 |
| | | | Outlet | 7.49 | 218 | 207 | 11 | ..... | ..... | 6.7 | 47.334 | 23.304 | 36 |
| | | March, 2025 | FS | 7.74 | 201922 | 144922 | 57000 | 53450 | 2900.0 | 40.5 | 3142.9 | 2322.6 | 230000 |
| | | | Inlet | 6.20 | 2532 | 1702 | 830 | 706 | 58.0 | 35.2 | 102.61 | 75.029 | 430000 |
| | | | Outlet | 7.25 | 1641 | 1627 | 14 | 95 | 77.5 | 22.3 | 71.148 | 39.902 | 36 |
| | | | Mean FS | 7.44 | 103775 | 70941.3 | 32833 | 45233 | 3966.6 | 457.8 | 2432.4 | 918.2 | 3253333 |
| | | | Mean inlet | 7.00 | 1946.3 | 1649.67 | 296.7 | 359.33 | 53.0 | 15.5 | 85.1 | 57.3 | 151012 |
| | | | Mean outlet | 7.443 | 1299.7 | 1288.67 | 11 | 95 | 42.3 | 10.4 | 43.0 | 21.7 | 791 |
| | | | Per cent removal | NA | 33.225 | 21.8832 | 96.29 | 73.562 | 20.283 | 32.93 | 49.424 | 62.19 | 99.48 |

| S. no. | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Banda | December, 2024 | FS | 7.26 | 68010 | 54410 | 13600 | 5695 | 3380.0 | 318 | 1564.1 | 289.88 | 930000 |
| | | | Inlet | 7.52 | 808 | 738 | 70 | 278 | 33.0 | 11.72 | 108.78 | 70.254 | 93000 |
| | | | Outlet | 7.48 | 333 | 328 | 5 | 5 | 1.0 | 0.16 | 10.878 | 0.7389 | 36 |
| | | February, 2025 | FS | 7.31 | 54488 | 29488 | 25000 | 72050 | 5940 | 606 | 2513.7 | 358.09 | 2300000 |
| | | | Inlet | 7.53 | 382 | 362 | 20 | 50 | 3 | 0.58 | 10.878 | 3.8651 | 36 |
| | | | Outlet | 7.69 | 252 | 251 | 1 | 29 | 3 | 0.08 | 9.408 | 1.5915 | 30 |
| | | March, 2025 | Inlet | 6.34 | 1396 | 976 | 420 | 124 | 63.0 | 18.5 | 132.01 | 92.365 | 150000 |
| | | | Outlet | 6.98 | 582 | 576 | 6 | 17 | 10.5 | 2.6 | 4.998 | 4.3767 | 4300 |
| | | | Mean FS | 7.285 | 61249 | 41949 | 19300 | 38873 | 4660.0 | 462.0 | 2038.9 | 324.0 | 1615000 |
| | | | Mean inlet | 7.13 | 862 | 692 | 170 | 150.67 | 33.0 | 10.3 | 83.9 | 55.5 | 81012 |
| | | | Mean outlet | 7.383 | 389 | 385 | 4 | 17 | 4.8 | 0.9 | 8.4 | 2.2 | 1455 |
| | | | Per cent removal | NA | 54.872 | 44.3642 | 97.65 | 88.717 | 85.556 | 90.94 | 89.953 | 95.971 | 98.20 |
| 8 | Farrukhabad | December, 2024 | FS | 7.32 | 3419 | 1319 | 2100 | 19200 | 650.0 | 63 | 173.46 | 68.776 | 2300000 |
| | | | Inlet | 7.36 | 1087 | 897 | 190 | 90 | 53.0 | 7.86 | 82.614 | 59.17 | 93000 |
| | | | Outlet | 7.53 | 830 | 826 | 4 | 22 | 2.0 | 6.76 | 22.344 | 16.825 | 230 |
| | | February, 2025 | FS | 7.54 | 173442 | 134442 | 39000 | 88450 | 7840 | 129.6 | 3087 | 312.62 | 930000000 |
| | | | Inlet | 7.61 | 1295 | 1235 | 60 | 224 | 27 | 12.88 | 264.01 | 221.28 | 15000 |
| | | | Outlet | 7.84 | 815 | 813 | 2 | 59 | 12 | 7.42 | 28.224 | 22.679 | 30 |
| | | March, 2025 | FS | 7.27 | 35891 | 17891 | 18000 | 45600 | 3060.0 | 118.5 | 1196.6 | 558.6 | 9300000 |
| | | | Inlet | 7.91 | 906 | 826 | 80 | 86 | 25.0 | 18.5 | 116.42 | 89.376 | 93000 |
| | | | Outlet | 7.67 | 1003 | 990 | 13 | 40.5 | 25.5 | 19.7 | 22.638 | 13.23 | 92 |
| | | | Mean FS | 7.377 | 70917 | 51217.3 | 19700 | 51083 | 3850.0 | 103.7 | 1485.7 | 313.3 | 313866667 |
| | | | Mean inlet | 7.627 | 1096 | 986 | 110 | 133.33 | 35.0 | 13.1 | 154.4 | 123.3 | 67000 |
| | | | Mean outlet | 7.68 | 882.67 | 876.333 | 6.333 | 40.5 | 13.2 | 11.3 | 24.4 | 17.6 | 117 |
| | | | Per cent removal | NA | 19.465 | 11.1224 | 94.24 | 69.625 | 62.19 | 13.66 | 84.19 | 85.741 | 99.82 |

| S. no. | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Jhansi (12 KLD) | December, 2024 | FS | 7.01 | 19752 | 17852 | 1900 | 33750 | 1100.0 | 177 | 726.18 | 215.99 | 930000 |
| | | | Inlet | 7.44 | 572 | 522 | 50 | 384 | 151.0 | 10.4 | 52.92 | 36.946 | 2300000 |
| | | | Outlet | 7.49 | 260 | 258 | 2 | 31 | UR | 2.67 | 2.058 | 0 | 150 |
| | | January, 2025 | FS | 7.35 | 2046 | 1346 | 700 | 16800 | 320 | 34 | 144.06 | 24.441 | 230000 |
| | | | Inlet | 7.51 | 2128 | 2058 | 70 | 420 | 31 | 18.72 | 65.268 | 40.811 | 4300000 |
| | | | Outlet | 7.55 | 569 | 542 | 27 | 9 | 1.2 | 0.18 | 9.996 | 0.4547 | 30 |
| | | March, 2025 | FS | 7.01 | 40785 | 5785 | 35000 | 24750 | 3820.0 | 126.0 | 1234.8 | 411.6 | 9300000 |
| | | | Inlet | 7.15 | 1590 | 1320 | 270 | 330 | 35.0 | 17.0 | 67.326 | 57.579 | 4600000 |
| | | | Outlet | 7.19 | 831 | 830 | 1 | 20 | 4.5 | 3.4 | 53.214 | 10.584 | 36 |
| | | | Mean FS | 7.123 | 20861 | 8327.67 | 12533 | 25100 | 1746.7 | 112.3 | 701.7 | 217.3 | 3486667 |
| | | | Mean inlet | 7.367 | 1430 | 1300 | 130 | 378 | 72.3 | 15.4 | 61.8 | 45.1 | 3733333 |
| | | | Mean outlet | 7.41 | 553.33 | 543.333 | 10 | 20 | 2.8 | 2.1 | 21.8 | 3.7 | 72 |
| | | | Per cent removal | NA | 61.305 | 58.2051 | 92.31 | 94.709 | 96.06 | 86.45 | 64.818 | 91.843 | 99.998 |
| 10 | Jhansi (6 KLD) | December, 2024 | Inlet | 8.12 | 1643 | 1533 | 110 | 346 | 21.0 | 14.04 | 98.49 | 57.522 | 21000 |
| | | | Outlet | 7.98 | 1420 | 1418 | 2 | 162 | 2.0 | 12.32 | 19.11 | 10.515 | 230 |
| | | January, 2025 | Inlet | 7.69 | 289 | 279 | 10 | 100 | 5 | 9.18 | 14.406 | 6.025 | 230 |
| | | | Outlet | 7.56 | 630 | 628 | 2 | 9 | 1 | 0.54 | 10.584 | 0.8526 | 92 |
| | | March, 2025 | Inlet | 7.25 | 1477 | 1387 | 90 | 166 | 19.0 | 24.8 | 24.108 | 17.346 | 43000 |
| | | | Outlet | 7.33 | 837 | 827 | 10 | 85.5 | 6.0 | 8.9 | 9.702 | 9.702 | 92 |
| | | | Mean inlet | 7.687 | 1136.3 | 1066.33 | 70 | 204 | 15.0 | 16.0 | 45.7 | 27.0 | 21410 |
| | | | Mean outlet | 7.623 | 962.33 | 957.667 | 4.667 | 85.5 | 3.0 | 7.3 | 13.1 | 7.0 | 138 |
| | | | Per cent removal | NA | 15.312 | 10.1907 | 93.33 | 58.088 | 80 | 54.69 | 71.245 | 73.953 | 99.36 |

| S. no. | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Jhansi (32 KLD) | December, 2024 | FS | 7.26 | 6957 | 5757 | 1200 | 25200 | 1560.0 | 109 | 296.94 | 15.915 | 930 |
| | | | Inlet | 7.59 | 37161 | 37141 | 20 | 34 | 2.0 | 1.1 | 17.934 | 0.9663 | 30 |
| | | | Outlet | 7.71 | 847 | 840 | 7 | 23 | 1.0 | 0.39 | 1.176 | 0.7389 | 36 |
| | | January, 2025 | FS | 7,67 | 63449 | 43449 | 20000 | 78400 | 6110 | 216 | 1631.7 | 110.84 | 1400000 |
| | | | Inlet | 7.72 | 990 | 790 | 200 | 424 | 38 | 23.52 | 168.46 | 124.31 | 240000 |
| | | | Outlet | 7.83 | 550 | 549 | 1 | 19 | 1 | 0.18 | 4.998 | 0.6821 | 30 |
| | | March, 2025 | FS | 6.29 | 40885 | 21885 | 19000 | 27750 | 3020.0 | 304.0 | 1737.5 | 1205.4 | 92000 |
| | | | Inlet | 7.33 | 20788 | 8188 | 12600 | 1192 | 1091.0 | 165.6 | 882.88 | 174.93 | 93000 |
| | | | Outlet | 7.42 | 568 | 555 | 13 | 21 | 1.5 | 2.0 | 8.82 | 4.7177 | 2300 |
| | | | Mean FS | 6.775 | 37097 | 23697 | 13400 | 43783 | 3563.3 | 209.7 | 1222.1 | 444.1 | 497643 |
| | | | Mean inlet | 7.547 | 19646 | 15373 | 4273 | 550 | 377.0 | 63.4 | 356.4 | 100.1 | 111010 |
| | | | Mean outlet | 7.653 | 655 | 648 | 7 | 21 | 1.0 | 0.9 | 5.0 | 2.0 | 789 |
| | | | Per cent removal | NA | 96.666 | 95.7848 | 99.84 | 96.182 | 99.726 | 98.65 | 98.598 | 97.955 | 99.29 |

# Annexure 2:

## Table 2: Consolidated data for STP co-treatment plants in Uttar Pradesh

| S. no. | STP co-treatment plant locations | 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/ 100ml) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Varanasi | November, 2024 | FS | 8.26 | 9589 | 4089 | 5500 | 36650 | 2250.0 | 45 | 441 | 81.85 | 93000 |
| | | | FSTP inlet | 7.82 | 3962 | 3842 | 120 | 6675 | 2147.0 | 15.3 | 326.34 | 126.47 | 92 |
| | | January, 2025 | FS | 7.55 | 46881 | 45981 | 900 | ... | .. | 39 | 2419.6 | 1532.4 | 3600 |
| | | | FSTP inlet | 7.36 | 5108 | 4948 | 160 | 1980 | 1750.0 | 25.1 | 226.38 | 163.42 | 4300 |
| | | | STP outlet | 7.97 | 617 | 612 | 5 | 27 | 2.0 | 0.43 | 5.586 | 4.3767 | 30 |
| | | March, 2025 | FS | 7.48 | 79833 | 57833 | 22000 | 66400 | 5860.0 | 69.5 | 764.4 | 690.9 | 4600000 |
| | | | FSTP inlet | 6.41 | 1146 | 404 | 742 | 652 | 123.0 | 18.7 | 118.78 | 99.96 | 240000 |
| | | | STP outlet | 7.36 | 590 | 587 | 3 | 27 | 8.4 | 1.68 | 16.464 | 10.878 | 30 |
| | | | Mean FS | 7.763 | 45434 | 35967.7 | 9466.67 | 51525 | 4055.0 | 51.2 | 1208.3 | 768.4 | 1565533 |
| | | | Mean inlet | 7.197 | 3405.3 | 3064.67 | 340.667 | 3102.3333 | 1340.0 | 19.7 | 223.8 | 129.9 | 81464 |
| | | | Mean STP outlet | 7.665 | 603.5 | 599.5 | 4 | 27 | 5.2 | 1.1 | 11.0 | 7.6 | 30 |
| | | | Per cent removal | NA | 82.278 | 80.4383 | 98.8258 | 99.129687 | 99.6119 | 94.64 | 95.074 | 94.13 | 99.96 |
| 2 | Prayagraj | November, 2024 | FS | 6.81 | 2458 | 1158 | 1300 | 32250 | 689.9 | 24 | 191.1 | 75.597 | 9300000 |
| | | | FSTP inlet | 7.11 | 2354 | 2094 | 260 | 1960 | 110.0 | 23 | 146.12 | 96.685 | 1100000 |
| | | | STP outlet | 7.26 | 667 | 662 | 5 | 9 | 3.6 | 1.07 | 17.052 | 10.686 | 230 |
| | | January, 2025 | FS | 7.26 | 1665 | 1565 | 100 | 21900 | 449.9 | 46 | 311.64 | 174.5 | 24000000 |
| | | | FSTP inlet | 7.61 | 1223 | 1183 | 40 | 320 | 100.0 | 20.64 | 129.07 | 84.351 | 4600000 |
| | | | STP outlet | 8.07 | 783 | 763 | 20 | 79 | 15.0 | 2.89 | 28.812 | 16.029 | 30 |
| | | March, 2025 | FS | 7.11 | 1612 | 312 | 1300 | 16600 | 390.0 | 59.5 | 308.7 | 299.88 | 1100000 |
| | | | FSTP inlet | 7.42 | 1247 | 1127 | 120 | 210 | 51.0 | 20.7 | 216.09 | 199.34 | 240000 |
| | | | STP outlet | 7.83 | 479 | 458 | 21 | 44 | 7.5 | 2.6 | 9.70 | 16.71 | 430 |
| | | | Mean FS | 7.06 | 1911.7 | 1011.67 | 900 | 23583.333 | 509.9 | 43.2 | 270.48 | 183.33 | 11466667 |
| | | | Mean inlet | 7.38 | 1608 | 1468 | 140 | 830 | 87.0 | 21.4 | 163.8 | 126.8 | 1980000 |
| | | | Mean STP outlet | 7.72 | 643 | 627.667 | 15.3333 | 44 | 8.7 | 2.2 | 18.5 | 14.5 | 230 |
| | | | Per cent removal | NA | 60.012 | 57.2434 | 89.0476 | 94.698795 | 90 | 89.882 | 88.69 | 88.584 | 99.99 |

| S. no. | STP co-treatment plant locations | 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/100ml) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Rampur | November, 2024 | FS | 6.91 | 1494 | 1294 | 200 | 19000 | 1469.7 | 18 | 155.82 | 42.062 | 9300000 |
| | | | FSTP inlet | 7.23 | 711 | 691 | 20 | 54 | 51.0 | 3.7 | 43.218 | 18.416 | 23000 |
| | | | STP outlet | 7.69 | 448 | 440 | 8 | 20 | 10.8 | 4.58 | 36.162 | 28.363 | 2300 |
| | | February, 2025 | FS | 7.12 | 5091 | 2291 | 2800 | 21850 | 2280.0 | 26 | 1484.7 | 90.944 | 24000 |
| | | | FSTP inlet | 7.31 | 902 | 722 | 180 | 380 | 89.0 | 13.28 | 86.73 | 56.385 | 24000000 |
| | | | STP outlet | 7.61 | 428 | 412 | 16 | 69 | 13.8 | 2.84 | 29.988 | 17.507 | 2300000 |
| | | March, 2025 | FS | 7.17 | 1545 | 145 | 1400 | 17250 | 80.0 | 1.37 | 97.02 | 83.555 | 46000 |
| | | | FSTP inlet | 7.43 | 677 | 637 | 40 | 40 | 21.0 | 4.49 | 67.032 | 35.98 | 1500000 |
| | | | STP outlet | 7.57 | 409 | 391 | 18 | 44.5 | 54.0 | 2.58 | 74.97 | 22.932 | 9300 |
| | | | Mean FS | 7.067 | 2710 | 1243.33 | 1466.67 | 19366.667 | 33.2 | 2.7 | 50.6 | 42.1 | 11600000 |
| | | | Mean inlet | 7.323 | 763.33 | 683.333 | 80 | 158 | 797.0 | 40.1 | 546.8 | 71.8 | 777433 |
| | | | Mean STP outlet | 7.623 | 428.33 | 414.333 | 14 | 44.5 | 26.2 | 11.9 | 103.2 | 44.8 | 23477 |
| | | | Per cent removal | NA | 43.886 | 39.3659 | 82.5 | 71.835443 | 96.7169 | 70.284 | 81.128 | 37.623 | 96.98 |

# Annexure 2

**Table 3: Consolidated data for biosolids collected from both FSTPs and co-treatment plants in Uttar Pradesh**

| Location | Month | pH | EC (ms/cm) | Moisture (per cent) | Helminths (no. egg/4g) | Organic Carbon (per cent by weight) | Total Nitrogen (per cent by weight) | FC (MPN /g) | EC (MPN /g) | Salmonella (MPN/4g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Varanasi | November, 2024 | 7.67 | 1.63 | 71.53255835 | 9189 | 22.6 | 52.136 | 1510 | 323 | 646352 |
| | January, 2025 | 7.74 | 1.4 | 34.59242779 | 1015 | 16.1 | Nil | 115 | 115 | 379161 |
| | March, 2025 | 6.84 | 1.485 | 11.92325899 | 518 | 25.8 | 0.720 | 26114 | 26114 | 408734 |
| Chunar | Mean | 7.4 | 1.51 | 39.34941504 | 3574 | 21.5 | 26.428 | 9246 | 8850 | 478083 |
| | November, 2024 | 6.81 | 0.99 | 50.68895504 | 1411 | 15 | 1.57 | 3042 | 73 | 332583 |
| | January, 2025 | 7.95 | 1.4 | 34.59242779 | 914 | 20.6 | 0.484 | 79228 | 42378 | 176881 |
| | March, 2025 | 7.22 | 0.609 | 45.16810815 | 394 | 10.8 | 0.373 | 7842 | 7842 | 240736 |
| Jaunpur | Mean | 7.3 | 1.00 | 43.48316366 | 906 | 15.5 | 0.809 | 30037 | 16764 | 250066 |
| | November, 2024 | 6.88 | 1.22 | 37.77569754 | 1543 | 28.1 | 2.66 | 17678 | 579 | 4500 |
| | January, 2025 | 7.68 | 1.61 | 17.25325968 | 232 | 15.1 | Nil | 278 | 112 | 24170 |
| | March, 2025 | 5.61 | 1.556 | 7.359234392 | 1062 | 27.9 | 1.520 | 4965 | 4965 | 5613080 |
| Raebareli | Mean | 6.7 | 1.46 | 20.79606387 | 946 | 23.7 | 2.090 | 7640 | 1885 | 1880583 |
| | November, 2024 | 7.15 | 0.54 | 54.08884328 | 366 | 28 | 2.71 | 327 | 7 | 20039 |
| | January, 2025 | 7.19 | 2.58 | 7.508695732 | 631 | 33.3 | 1.52 | 46491 | 24867 | 21624 |
| | March, 2025 | 6.46 | 1.149 | 11.51603634 | 1157 | 29.0 | 1.670 | 2599 | 2599 | 31644 |
| | Mean | 6.9 | 1.42 | 24.37119178 | 718 | 30.1 | 1.967 | 16472 | 9158 | 24436 |
| Prayagraj | November, 2024 | 7.13 | 1.32 | 66.25221175 | 2773 | 20 | 2.27 | 7112 | 7112 | 71116 |
| | January, 2025 | 7.53 | 1.21 | 65.44561865 | 2778 | 19.8 | 0.372 | 110 | 110 | 104184 |
| | March, 2025 | 8.02 | 2.81 | 56.64928928 | 1513 | 10.2 | 0.451 | 171 | 171 | 396764 |
| | Mean | 7.6 | 1.78 | 62.78237323 | 2355 | 16.7 | 1.031 | 2464 | 2464 | 190688 |
| Khurja | November, 2024 | 7.34 | 1.12 | 60.76057183 | 1774 | 32.5 | 3.2 | 3058 | 1911 | 479110 |
| | January, 2025 | 7.51 | 5.07 | 11.65923752 | 136 | 30.3 | 1.13 | 12452 | 5207 | 181117 |
| | March, 2025 | 6.51 | 1.683 | 10.21978962 | 142 | 27.2 | 1.260 | 2673 | 1036 | 129204 |
| | Mean | 7.1 | 2.62 | 27.54653299 | 684 | 30.0 | 1.863 | 6061 | 2718 | 263144 |
| Rampur | November, 2024 | 6.57 | 0.61 | 23.02198926 | 322 | 24.9 | 2.54 | 120814 | 55860 | 244226 |
| | January, 2025 | 6.71 | 4.04 | 76.44189218 | 3803 | 36 | 1.95 | 4669305 | 123100 | 899902 |
| | March, 2025 | 6.68 | 0.506 | 73.52800478 | 393 | 10.4 | 0.516 | 4155335 | 4155335 | 604412 |
| | Mean | 6.7 | 1.72 | 57.66396207 | 1506 | 23.8 | 1.669 | 2981818 | 1444765 | 582847 |
| Banda | December, 2024 | 6.40 | 1.67 | 37.56952607 | 192 | 37.7 | 3.88 | 69 | 5 | 57664 |
| | January, 2025 | 6.48 | 4.65 | 17.16360615 | 2965 | 34.5 | 1.81 | 2897 | 254 | 77261 |
| | March, 2025 | 6.51 | 1.081 | 7.373432311 | 345 | 22.0 | 1.970 | 1187564 | 1187564 | 371384 |
| | Mean | 6.5 | 2.47 | 20.70218817 | 1167 | 31.4 | 2.553 | 396843 | 395941 | 168770 |

| Location | Month | pH | EC (ms/cm) | Moisture (per cent) | Helminths (no. egg/4g) | Organic Carbon (per cent by weight) | Total Nitrogen (per cent by weight) | FC (MPN /g) | EC (MPN /g) | Salmonella (MPN/4g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Farrukhabad | December, 2024 | 6.56 | 1.28 | 13.8289702 | 3231 | 32.5 | 3.17 | 5338 | 5338 | 27852 |
| | January, 2025 | 6.83 | 2.34 | 32.43148062 | 2167 | 32.7 | 1.61 | 6364 | 1376 | 331515 |
| | March, 2025 | 6.78 | 1.364 | 11.20028395 | 1054 | 29.1 | 1.850 | 2590098 | 2590098 | 315316 |
| | Mean | 6.7 | 1.66 | 19.15357826 | 2151 | 31.4 | 2.210 | 867267 | 865604 | 224894 |
| Jhansi (6+12 KLD) | December, 2024 | 6.96 | 1.10 | 7.790232254 | 425 | 21.5 | 2.12 | 24943 | 24943 | 39041 |
| | January, 2025 | 7.14 | 4.06 | 11.60042243 | 190 | 22.7 | 0.173 | 486428 | 486428 | 85973 |
| | March, 2025 | 7.16 | 1.187 | 4.915897484 | 135 | 24.5 | 1.370 | 11568706 | ####### | 967564 |
| | Mean | 7.1 | 2.12 | 8.102184055 | 250 | 22.9 | 1.221 | 4026692 | 4026692 | 364193 |
| Jhansi (32 KLD) | January, 2025 | 6.84 | 1.62 | 36.06953612 | 138 | 30.8 | 1.16 | 3754 | 673 | 6882 |
| | March, 2025 | 5.89 | 1.327 | 4.107508549 | 1527 | 22.0 | 1.160 | 44842 | 44842 | 16685 |
| | Mean | 6.4 | 1.4735 | 20.08852233 | 833 | 26.4 | 1.160 | 24298 | 22757 | 11784 |
| Bakshi Ka Talab | March, 2025 | 5.59 | 0.54 | 5.523471191 | 25 | 20.8 | 0.909 | 45514 | 15877 | 338708 |
| | Mean | 5.6 | 0.54 | 5.523471191 | 25 | 20.8 | 0.909 | 45514 | 15877 | 338708 |
| Bahraich | January, 2025 | 7.57 | 2.88 | 30.51812711 | 1002 | 22.5 | Nil | 6620 | 619 | 443281 |
| | March, 2025 | 6.19 | 1.206 | 5.894466399 | 978 | 22.9 | 0.844 | 4569338 | 4569338 | 8161050 |
| | Mean | 6.9 | 2.043 | 18.20629675 | 990 | 22.7 | 0.844 | 2287979 | 2284978 | 4302166 |

# Annexure 2

## Table 4: Heavy metals in biosolids

| Locations | Sample collection | Heavy metals | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | As | Hg | Cd | Cr | Pb | Zn | Cu | Ni | Total phos-phates | Total potash (as K20), percent by weight, mini-mum | Ca | Mg per cent by weight | Mn per cent by weight | Na per cent weight |
| | | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (as P205), percent by weight, mini-mum | 0.4 | Per-cent by weight | | | |
| | | 10 | 0.15 | 5 | 50 | 100 | 1000 | 300 | 50 | 0.4 | | | | | |
| Varanasi | November, 2024 | 0.54 | 1.23 | 2.07 | 33.0 | 32.80 | 2050 | 187 | 18.6 | 2.34 | 0.78 | 3.17 | 0.74 | 0.040 | 0.141 |
| | January, 2025 | 0.355 | 0.653 | 2.02 | 24.1 | 26.60 | 870.0 | 151.0 | 18.2 | 2.634 | 0.438 | 3.440 | 0.776 | 0.044 | 0.132 |
| | March, 2025 | 0.672 | 1.730 | 3.190 | 102.0 | 66.90 | 2170.0 | 366.0 | 51.6 | 4.649 | 0.923 | 1.270 | 1.160 | 0.058 | 0.135 |
| | Mean value | 0.52 | 1.20 | 2.43 | 53.03 | 42.10 | 1696.67 | 234.67 | 29.47 | 3.21 | 0.72 | 2.63 | 0.89 | 0.05 | 0.14 |
| Chunar | November, 2024 | NIL | 0.13 | 0.96 | 25.1 | 40.90 | 1290 | 139 | 11.8 | 9.16 | 0.42 | 9.07 | 0.55 | 0.100 | 0.090 |
| | January, 2025 | 0.222 | 0.327 | 0.94 | 18.2 | 31.60 | 840.0 | 166.0 | 14.2 | 10.649 | 0.329 | 10.400 | 0.573 | 0.101 | 0.153 |
| | March, 2025 | 1.234 | 4.960 | 3.110 | 45.4 | 94.20 | 2250.0 | 320.0 | 29.3 | 5.175 | 0.624 | 4.000 | 1.020 | 0.059 | 0.469 |
| | Mean value | 0.73 | 1.81 | 1.67 | 29.57 | 55.57 | 1460.00 | 208.33 | 18.43 | 8.33 | 0.46 | 7.82 | 0.71 | 0.09 | 0.24 |
| Jaunpur | November, 2024 | 0.80 | 1.41 | 5.98 | 29.0 | 41.30 | 2300 | 291 | 19.0 | 2.24 | 0.57 | 2.96 | 0.62 | 0.034 | 0.186 |
| | January, 2025 | 0.762 | 1.320 | 2.77 | 32.7 | 47.10 | 1690.0 | 393.0 | 25.2 | 2.267 | 0.482 | 5.550 | 0.870 | 0.043 | 0.245 |
| | March, 2025 | 2.311 | 1.870 | 1.640 | 40.0 | 49.10 | 777.0 | 176.0 | 19.5 | 1.997 | 0.713 | 4.610 | 1.110 | 0.060 | 0.096 |
| | Mean value | 1.29 | 1.53 | 3.46 | 33.90 | 45.83 | 1589.00 | 286.67 | 21.23 | 2.17 | 0.59 | 4.37 | 0.87 | 0.05 | 0.18 |
| Raebareli | November, 2024 | 0.27 | 0.95 | 2.34 | 42.8 | 42.80 | 2770 | 253 | 23.1 | 2.14 | 0.69 | 4.11 | 0.74 | 0.038 | 0.033 |
| | January, 2025 | 0.305 | 1.390 | 3.56 | 29.0 | 33.90 | 804.0 | 160.0 | 17.6 | 4.053 | 0.553 | 6.430 | 1.020 | 0.053 | 0.099 |
| | March, 2025 | 1.107 | 3.760 | 3.310 | 106.0 | 70.10 | 2110.0 | 382.0 | 54.1 | 4.832 | 0.963 | 2.790 | 1.220 | 0.061 | 0.140 |
| | Mean value | 0.56 | 2.03 | 3.07 | 59.27 | 48.93 | 1894.67 | 265.00 | 31.60 | 3.68 | 0.74 | 4.44 | 0.99 | 0.05 | 0.09 |

| Locations | Sample collection | Heavy metals | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | As | Hg | Cd | Cr | Pb | Zn | Cu | Ni | Total phos-phates | Total potash (as K20), percent by weight, mini-mum | Ca | Mg per cent by weight | Mn per cent by weight | Na per cent weight |
| | | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (mg/kg) maxi-mum | (as P205), percent by weight, mini-mum | 0.4 | Per-cent by weight | | | |
| | | 10 | 0.15 | 5 | 50 | 100 | 1000 | 300 | 50 | 0.4 | | | | | |
| Khurja | November, 2024 | 0.47 | 1.36 | 2.38 | 39.1 | 76.10 | 3530 | 279 | 24.4 | 3.85 | 0.57 | 5.26 | 0.86 | 0.047 | 0.434 |
| | January, 2025 | 2.517 | 1.880 | 2.29 | 18.4 | 68.70 | 2120.0 | 307.0 | 20.7 | 4.282 | 0.196 | 5.050 | 0.841 | 0.050 | 0.175 |
| | March, 2025 | 1.063 | 4.640 | 3.330 | 49.6 | 102.00 | 2030.0 | 346.0 | 31.8 | 5.611 | 0.685 | 3.200 | 1.130 | 0.066 | 0.515 |
| | Mean value | 1.35 | 2.63 | 2.67 | 35.70 | 82.27 | 2560.00 | 310.67 | 25.63 | 4.58 | 0.48 | 4.50 | 0.94 | 0.05 | 0.37 |
| Banda | November, 2024 | 0.86 | 1.59 | 3.90 | 58.8 | 60.10 | 3990.0 | 420 | 36.8 | 3.69 | 0.83 | 5.21 | 1.20 | 0.059 | 0.425 |
| | January, 2025 | 1.589 | 1.600 | 1.34 | 11.7 | 17.80 | 992.0 | 157.0 | 13.4 | 1.516 | 0.144 | 2.130 | 0.470 | 0.025 | 0.136 |
| | March, 2025 | 1.039 | 2.760 | 2.380 | 47.8 | 33.00 | 913.0 | 202.0 | 19.9 | 7.397 | 1.139 | 4.290 | 1.130 | 0.086 | 0.192 |
| | Mean value | 1.16 | 1.98 | 2.54 | 39.43 | 36.97 | 1965.00 | 259.67 | 23.37 | 4.20 | 0.70 | 3.88 | 0.93 | 0.06 | 0.25 |
| Farrukhabad | November, 2024 | 0.95 | 2.04 | 2.62 | 102.0 | 62.00 | 3920.0 | 353 | 49.6 | 4.65 | 0.88 | 5.69 | 1.06 | 0.058 | 0.156 |
| | January, 2025 | 2.700 | 1.350 | 1.41 | 22.5 | 39.40 | 1360.0 | 207.0 | 17.9 | 2.382 | 0.189 | 4.210 | 0.589 | 0.044 | 0.069 |
| | March, 2025 | 1.267 | 3.410 | 2.720 | 55.1 | 37.70 | 1150.0 | 229.0 | 22.8 | 8.542 | 1.283 | 5.950 | 1.300 | 0.099 | 0.220 |
| | Mean value | 1.64 | 2.27 | 2.25 | 59.87 | 46.37 | 2143.33 | 263.00 | 30.10 | 5.19 | 0.78 | 5.28 | 0.98 | 0.07 | 0.15 |
| Bahraich | January, 2025 | 0.131 | 0.481 | 0.64 | 11.7 | 74.00 | 550.0 | 98.4 | 9.6 | 7.053 | 0.345 | 7.130 | 0.681 | 0.073 | 0.149 |
| | March, 2025 | 2.557 | 2.270 | 1.710 | 41.7 | 50.80 | 888.0 | 181.0 | 20.1 | 2.084 | 0.736 | 4.770 | 1.160 | 0.062 | 0.099 |
| | Mean value | 1.34 | 1.38 | 1.18 | 26.70 | 62.40 | 719.00 | 139.70 | 14.83 | 4.57 | 0.54 | 5.95 | 0.92 | 0.07 | 0.12 |
| Jhansi (6+12 KLD) | November, 2024 | 0.95 | 3.36 | 3.58 | 52.2 | 53.50 | 4010.0 | 400 | 28.6 | 6.09 | 0.62 | 7.37 | 0.77 | 0.077 | 0.091 |
| | January, 2025 | 1.761 | 1.940 | 2.43 | 19.3 | 39.90 | 1930.0 | 300.0 | 19.8 | 4.328 | 0.148 | 4.950 | 0.535 | 0.058 | 0.055 |
| | March, 2025 | NIL | 0.238 | 0.506 | 29.8 | 9.54 | 355.0 | 120.0 | 21.6 | 1.337 | 0.369 | 2.780 | 0.672 | 0.054 | 0.088 |
| | Mean value | 1.35 | 1.85 | 2.17 | 33.77 | 34.31 | 2098.33 | 273.33 | 23.33 | 3.92 | 0.38 | 5.03 | 0.66 | 0.06 | 0.08 |
| Jhansi (32 KLD) | January, 2025 | 1.684 | 2.490 | 1.90 | 24.5 | 37.90 | 1620.0 | 274.0 | 18.3 | 4.855 | 0.098 | 5.330 | 0.527 | 0.064 | 0.027 |
| | March, 2025 | 1.474 | 8.160 | 5.080 | 64.5 | 79.80 | 2110.0 | 461.0 | 39.5 | 3.847 | 1.392 | 3.140 | 1.470 | 0.059 | 0.264 |
| | Mean value | 1.50 | 4.17 | 3.05 | 40.92 | 50.67 | 1942.78 | 336.11 | 27.04 | 4.21 | 0.62 | 4.50 | 0.89 | 0.06 | 0.12 |

| Locations | Sample collection | Heavy metals | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | As | Hg | Cd | Cr | Pb | Zn | Cu | Ni | Total phosphates | Total potash (as K20), percent by weight, minimum | Ca | Mg per cent by weight | Mn per cent by weight | Na per cent weight |
| | | (mg/kg) maximum | (mg/kg) maximum | (mg/kg) maximum | (mg/kg) maximum | (mg/kg) maximum | (mg/kg) maximum | (mg/kg) maximum | (mg/kg) maximum | (as P205), percent by weight, minimum | 0.4 | Percent by weight | | | |
| | | 10 | 0.15 | 5 | 50 | 100 | 1000 | 300 | 50 | 0.4 | | | | | |
| Varanasi | November, 2024 | 0.54 | 1.23 | 2.07 | 33.0 | 32.80 | 2050 | 187 | 18.6 | 2.34 | 0.78 | 3.17 | 0.74 | 0.040 | 0.141 |
| | January, 2025 | 0.355 | 0.653 | 2.02 | 24.1 | 26.60 | 870.0 | 151.0 | 18.2 | 2.634 | 0.438 | 3.440 | 0.776 | 0.044 | 0.132 |
| | March, 2025 | 0.672 | 1.730 | 3.190 | 102.0 | 66.90 | 2170.0 | 366.0 | 51.6 | 4.649 | 0.923 | 1.270 | 1.160 | 0.058 | 0.135 |
| | Mean value | 0.52 | 1.20 | 2.43 | 53.03 | 42.10 | 1696.67 | 234.67 | 29.47 | 3.21 | 0.72 | 2.63 | 0.89 | 0.05 | 0.14 |
| Prayagraj | November, 2024 | 2.44 | 2.04 | 2.41 | 54.4 | 49.40 | 1720 | 220 | 28.0 | 2.07 | 1.43 | 5.01 | 1.36 | 0.035 | 0.133 |
| | January, 2025 | 0.352 | 0.626 | 1.65 | 32.1 | 38.80 | 800.0 | 158.0 | 22.0 | 2.111 | 0.525 | 4.630 | 1.030 | 0.029 | 0.082 |
| | March, 2025 | NIL | NIL | 0.908 | 43.6 | 11.80 | 222.0 | 87.4 | 21.9 | 4.397 | 2.190 | 8.230 | 1.040 | 0.043 | 0.473 |
| | Mean value | 1.39 | 1.33 | 1.66 | 43.37 | 33.33 | 914.00 | 155.13 | 23.97 | 2.86 | 1.38 | 5.96 | 1.14 | 0.04 | 0.23 |
| Rampur | November, 2024 | 0.96 | 0.46 | 2.77 | 499.0 | 59.40 | 2820 | 329 | 210.0 | 5.27 | 1.38 | 5.02 | 1.03 | 0.167 | 0.076 |
| | January, 2025 | 2.996 | 0.302 | 0.86 | 7.7 | 21.90 | 709.0 | 118.0 | 8.6 | 0.781 | 0.073 | 1.740 | 0.419 | 0.027 | 0.045 |
| | March, 2025 | 1.772 | 5.230 | 5.350 | 67.6 | 83.20 | 2130.0 | 482.0 | 41.7 | 4.030 | 1.440 | 3.340 | 1.570 | 0.062 | 0.272 |
| | Mean value | 1.91 | 2.00 | 2.99 | 191.42 | 54.83 | 1886.33 | 309.67 | 86.76 | 3.36 | 0.96 | 3.37 | 1.01 | 0.09 | 0.13 |

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The Centre for Science and Environment (CSE) has partnered with Uttar Pradesh state government to enhance the skills of its urban and sanitation planning and implementation.

This report assesses the effectiveness of 14 faecal sludge and co-treatment plants in the state. It includes the evaluation of 11 faecal sludge treatment plants (FSTPs) and three sewage treatment plants (STPs) that incorporate co-treatment.

The Environment Monitoring laboratory rigorously evaluated the treatment efficiency of these facilities. Based on its findings, the report offers recommendations to improve the performance and long-term sustainability of both FSTPs and co-treatment units. Furthermore, it highlights the potential for the safe reuse of treated effluent and outlines the restricted safe applications for the resulting biosolids.

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