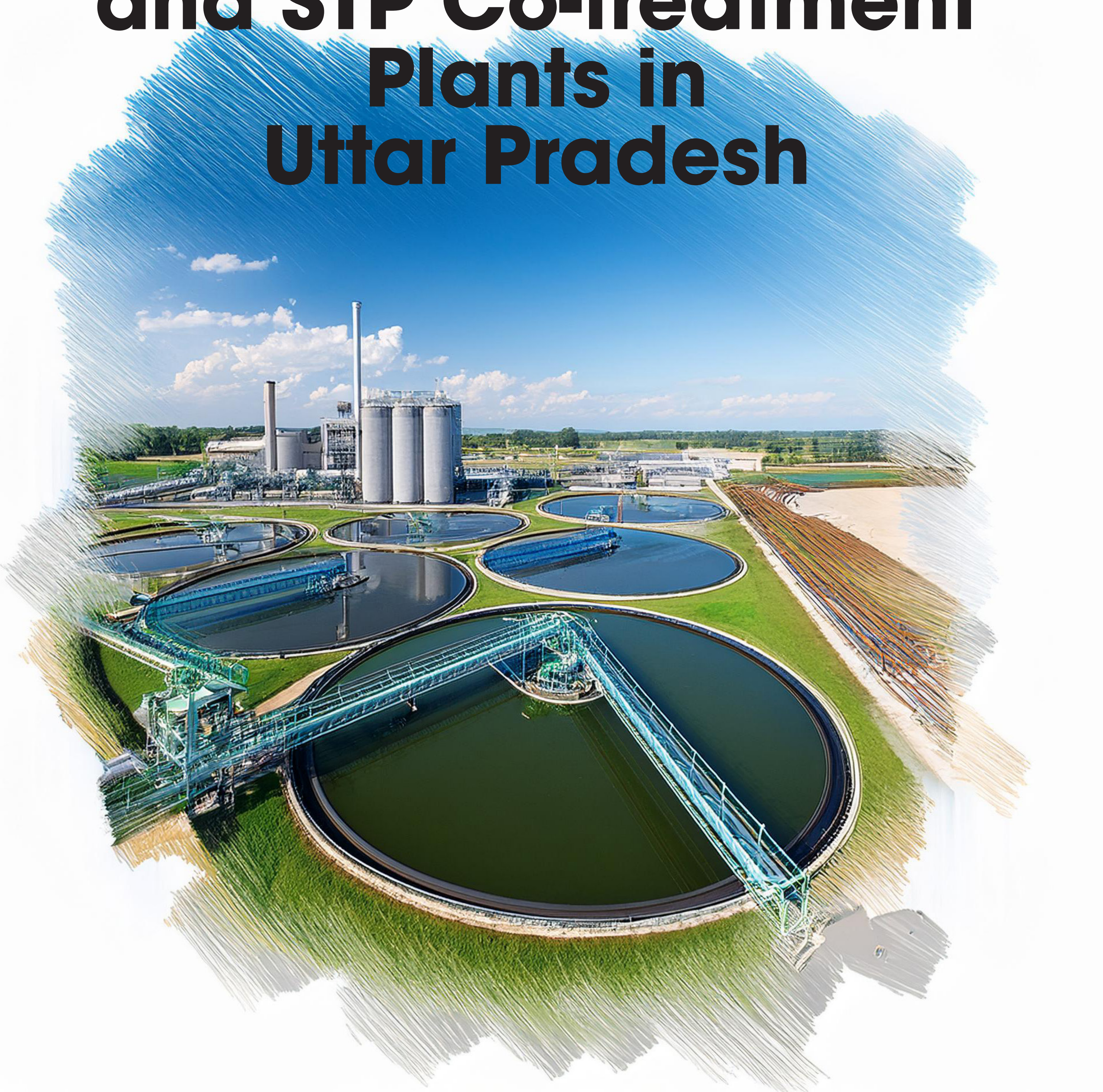
Monitoring and Evaluation of FSTPs and STP Co-treatment Plants in Uttar Pradesh



Monitoring and Evaluation of FSTPs and STP Co-treatment Plants in Uttar Pradesh

Research direction: Sunita Narain

Sampling, analysis, data curation and report writing: Ashitha Gopinath, Sama Kalyan Chakravarthy, Saumya and Arvind Singh Senger

Research support: Subrata Chakraborty, Hari Prakash Haihyvanshi, Harsh Yadav, Manish Mishra, Sarim A and Alka Kumari

Editor: Souparno Banerjee

Cover and design: Ajit Bajaj

Layouts: Kirpal Singh

Production: Rakesh Shrivastava and Gundhar Das

All photographs used in the pages that follow have been clicked by the CSE teams which have been involved in the preparation of this report.

The Centre for Science and Environment is grateful to the Swedish International Development Cooperation Agency (Sida) for their institutional support

BILL & MELINDA GATES foundation

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

CSE

Maps in this report are indicative and not to scale.

Citation: Sunita Narain, Ashitha Gopinath *et al*, 2024, *Monitoring and Evaluation of FSTPs and STP Co-treatment Plants in Uttar Pradesh*, Centre for Science and Environment, New Delhi

Published by
Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi 110 062
Phones: 91-11-40616000
E-mail: ashitha@cseindia.org, cse@cseindia.org
Website: www.cseindia.org

Contents

1. Introduction

Uttar Pradesh (UP) is one of India's biggest states. Its 75 districts hold a population of over 0.23 billion, making it the country's most populous state. For some years now, UP has been actively working towards improving its sanitation services. The state has made investments to safely manage faecal sludge (FS) and septage in its urban centres. This is a challenging task, as 95 per cent of UP's towns and cities are dependent on onsite sanitation systems.

As part of its initiatives in the state, Centre for Science and Environment (CSE) has been working closely with the state administration since 2017 to build capacity of its urban and sanitation planners. As of June 2022, 59 treatment plants have been built in UP under AMRUT and NMCG or through funding from urban local bodies (ULBs). These plants are spread across 56 cities. CSE has supported in the construction and commissioning of one FSTP (in Chunar) and one STP co-treatment plant (in Bijnor), both of which are fully operational.[1]

The treatment technologies being used in UP are either nature-based or hybrid. Within these two, the following variations exist among FSTPs:[1]

- Nature based I: Screening, planted drying beds, liquid collection tank, liquid treatment, secondary + tertiary, advanced treatment
- Nature based II: Screening, anaerobic stabilization reactor, tiger biofilter I, liquid storage tank, tiger biofilter II, horizontal planted gravel filter, polishing pond, vermicomposting yard
- Hybrid I: Screening, stabilization, mechanized solid-liquid separation, liquid collection tank, liquid treatment (secondary + tertiary + advanced treatment), sludge drying beds
- Hybrid II: Screening, bio-digester, lamella clarifier-1, aeration-1 and aeration 2, lamella clarifier-2, sludge drying beds

2. Objectives of this study

1) To understand the different kinds of FSTP technologies being used in Uttar Pradesh
2) To evaluate the treatment efficiency of the FSTPs/STP co-treatment processes
3) To check whether the treated water is within the limits set by the National Green Tribunal (NGT) and the Union Ministry of Environment, Forest and Climate Change (MoEF&CC)
4) To determine the potential of biosolids generated in the FSTPs/STP co-treatment plants for agriculture as well as a solid fuel.

3. Selection criteria for FSTPs

Most of the FSTPs in UP were commissioned in 2021-2023; their capacity utilization is not very high. CSE has, earlier, assessed and analysed the status of the 59 FSSM projects in UP.

In the current study:

- The selection for evaluation has been done on the basis of capacity utilization, generation and reuse of biosolids.
- FSTPs that utilize at least 20 to 40 per cent of their treatment capacities have been selected.[1]
- The locations from where the plants have been selected – four in eastern UP (Basti, Deoria, Gorakhpur and Chunar); seven in western UP (Loni, Modinagar, Aligarh, Amroha, Hapur, Shamli and Saharanpur); and two in southern UP (Etawah and Shahjahanpur).
- Out of these, 10 are FSTPs and three are STP co-treatment plants.

4. Significance of the study

This study is critical for its focus on two outcomes: one, it has assessed the performance of FSTPs and STP co-treatment plants in the state, and two, it has also assessed the biosolid resource recovery potential of the plants.

Assessment of the performance of FSTPs and STP co-treatment plants

Faecal sludge treatment plants and sewage treatment plants play a vital role in removing contaminants from faecal sludge (FS) and sewage, thereby protecting the environment and public health. Performance analysis of the plants involves monitoring key indicators such as chemical oxygen demand, biological oxygen demand, nutrients and pathogens. This evaluation helps identify the areas for improvement, enabling operators to optimize processes, reduce operating costs, and maintain regulatory compliance. By monitoring FSTP and STP co-treatment performance, treatment plant operators can ensure efficient and effective treatment of FS, ultimately protecting ecosystem health and ensuring human well-being.

The following parameters are most commonly adopted for monitoring of the plants; this study has used these parameters.[2]

- **pH**: pH (potential of hydrogen) is a measure of the acidity (<7) or alkalinity (>7) of sludge based on the chemical activity of hydrogen ions in solution. pH also has a strong influence on chemical and biological processes that occur in wastewater and FSTPs, such as precipitation, coagulation and disinfection.

- **Total solids**: Solids refer to matter suspended or dissolved in water/wastewater/FS. 'Total solids' is the term applied to the material residue left in the vessel after evaporation of a sample and its subsequent drying in an oven at a defined temperature. Total solids include 'total suspended solids', the portion of total solids retained by a filter, and 'total dissolved solids', the portion that passes through the filter.

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

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

- **Total Kjeldahl nitrogen (TKN):** Nitrogen is an important parameter to consider in faecal sludge treatment, as total nitrogen concentrations are typically quite high. Total Kjeldahl nitrogen (TKN) is the US EPA-approved parameter used to measure organic nitrogen and ammonia, which is the sum of organic nitrogen and ammoniacal nitrogen (NH_3-N)/ammonium (NH_4^+N). Excess nitrogen in the treated water discharged into waterbodies can cause eutrophication and depletion of dissolved oxygen which can lead to death of aquatic organisms.

- **Total phosphates (TP):** Phosphate concentration must be measured in order to ensure effective FS/sewage treatment in treatment plants. The discharges from these plants into rivers and lakes leading to a nutrient surplus is a significant concern. Excess nutrients, particularly phosphates, can stimulate unwanted algae growth, depleting oxygen levels in the water. This disruption in the ecological balance can cause long-term harm to the aquatic ecosystem. As a result, it is essential to implement measures to control nutrient runoff and promote sustainable water practices.

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

Assessment of biosolid resource recovery potential

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

The primary nutrients in biosolids are present in organic form; they are not as soluble as those in chemical fertilisers, and are released more slowly through decomposition by soil bacteria. Biosolids thus release nitrogen and other nutrients over several growing seasons. This allows the nutrients to nourish plants over a longer period of time; efficiency of use is higher and there is a lower likelihood of groundwater pollution when the application rate is appropriate. Using biosolids as soil amendments reduces the volume of waste that would otherwise require disposal in landfills. This practice promotes a closed-loop system, minimising waste and promoting ecological balance.

The following parameters need to be analysed to check the usability of biosolids as an alternative to chemical fertilisers:[3,4]

- **pH**: The pH of biosolids can vary depending on several factors, including the origin of the biosolids (such as sewage/FSTPs), the treatment processes they undergo, and any amendments or treatments applied to them before use.

- **Electrical conductivity**: Electrical conductivity (EC) is an important parameter in soil science for measuring dissolved salts, fertilizers and biosolids in the soil. It is typically measured in deciSiemens per meter (dS/m) and indicates the ability of the soil to conduct electricity. High EC values indicate high levels of dissolved salts such as sodium, calcium and magnesium, which can affect soil structure, fertility and plant growth. Understanding EC is crucial for farmers and researchers to optimise fertiliser/manure/biosolid application rates, ensuring efficient and effective nutrient delivery to crops.

- **Moisture content**: Moisture content or water content refers to the quantity of water present in a material, which is crucial in various fields. Accurate moisture content analysis helps in implementing efficient strategies for dryness control, quality assurance and environmental sustainability.

- **Carbon:nitrogen ratio**: The carbon-to-nitrogen (C:N) ratio is an important aspect in various biological and ecological processes. In soil science, it determines the nutrient availability for plants and microorganisms. These two elements are essential for microbial growth and activity. Nitrogen, in particular, supports the synthesis of important biological compounds such as amino acids, proteins and nucleic acids, while carbon serves as a structural component and energy source for microbes. Hence, the organic carbon and nitrogen have to be determined.[5] A balanced C:N ratio of 15:1 to 20:1 enables optimal decomposition, as bacteria and fungi work together to break down organic matter. An imbalance, however, can lead to inefficient decomposition and potential environmental issues.

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

- **Faecal coliform (FC) and *E. coli:*** Faecal sludge (FS) contains an enormous diversity of pathogenic microorganisms that fall into four major groups -- pathogenic bacteria, viruses, parasitic protozoa and helminths. These pathogens occur in raw FS and septage, and in liquid effluent and biosolids generated from FSTPs which require appropriate treatment before their discharge/disposal into the environment or before they are reused, particularly for agricultural purposes. When humans come in contact with water or food contaminated with improperly treated FS and/or its derivatives, the pathogenic organisms present in them can trigger diseases like diarrhoea, hepatitis, different types of fever etc. Coliforms are a group of bacteria that are predominantly found in the gastrointestinal tract of warm-blooded animals including humans, apart from a minor portion in soils and on plant surfaces. Faecal coliforms (FC), also known as thermotolerant coliforms, are a group of coliform bacteria that are exclusively found in the intestines and faeces of humans and other warm-blooded mammals and hence their presence specifically indicates faecal contamination. The predominant FC is *Escherichia coli*. Hence, the coliform bacteria, FC/*E. coli*, in addition to their habitat, their ease of cultivation and non-pathogenic nature, makes them the indicator of choice for pathogen determination in biosolids.[6]

- ***Salmonella***: *Salmonella* spp are resistant microorganisms that can readily adapt to and survive in extreme environmental conditions. They are frequently found in sewage and can grow actively within a wide temperature range (10-54°C). *Salmonella* serotypes cause life-threatening typhoid fever and salmonellosis, a major food-poisoning diarrhoeal disease in humans. There has been an increase across the world in the number of outbreaks involving *Salmonella* spp, especially in context to the fresh-cut produce industry and consumption of fresh-cut vegetables. Such outbreaks are caused by a few *Salmonella* serotypes which have the capability to resist environmental stresses, remaining viable for extended periods on field crops. It has been observed that *Salmonella* can regrow in the soil and remain viable for more than two years after soil inoculation. These characteristics make them the indicator of choice for monitoring the effectiveness of biosolid pathogen reduction. The overall burden caused by *Salmonella* spp on public health necessitates its monitoring and control in FS-derived biosolids that are reused, particularly for agricultural purposes.[7]

- **Helminth eggs**: Helminth eggs are the primary cause of helminthiases, a group of worm-induced diseases that affects people worldwide. Despite being part of multicellular animals, helminth eggs are incredibly small, measuring between 20-80 micrometer in diameter. These microscopic eggs are often found in wastewater, sludge and excreta, and can be present in varying amounts, particularly in areas with inadequate sanitation and waste management. They are the source of the larvae of intestinal worms like hookworm, roundworm and whipworm. These eggs can pose a risk of infection if ingested, causing several complications and diseases including intestinal obstructions, abdominal cramps, haemorrhagic colitis, schistosomiasis etc. Therefore, proper treatment and disposal of faecal sludge is crucial to prevent the spread of infections and maintain public health.[8]

- **Calorific value**: The calorific value of biomass or biosolids is a measure of the energy content of the sample, typically expressed in units of energy per unit mass, such as megajoules per kilogram (MJ/kg) or calories/gram. This value is essential for determining the potential energy output of biomass or biosolids as a solid fuel. A higher calorific value indicates a more energy-dense material, making it more suitable for combustion or other energy conversion processes. Accurate measurement of calorific value is crucial for optimising the energy production and utilisation of biomass or biosolids.[9]

5. Sample collection and testing parameters

Scientists from CSE's Environment Monitoring Lab visited each site, collected the samples, and preserved and transported them to the CSE lab; standard protocols for sampling, preservation and transportation were followed. Personal protective equipment like gloves, face masks, protective shoes and eyewear were used during the sampling. Sampling bottles were properly cleaned, sterilised, and attached with appropriate labelling stickers. Names of sampling locations with date and time were clearly stated on each bottle after sampling. Samples were finally transported in leak proof ice-boxes with frozen ice-gel packs.

Sampling interval and duration of the visit

Evaluation of the selected treatment plants was conducted for a period of six months from January to June 2024. Samples were collected in alternate months – thus, sample collection happened three times from each location.

Sampling point in FSTPs and STP co-treatment plants

Raw faecal sludge samples were collected from the tanker at the time when it unloaded the sludge into the receiving chamber of the plants.

Around one litre of the inlet and outlet contents of the FSTPs was collected to assess the performance of individual plants. 'Inlet' refers to the leachate entering into the treatment modules after the solid-liquid separation process, while 'outlet' is the final discharge water emerging from the last stage of the treatment process in the FSTPs.

Another litre each was collected from the FSTP inlet, FSTP outlet and the STP outlet to assess the performance of STP co-treatment plants. 'FSTP inlet' refers to the leachate entering into the treatment modules after the solid-liquid separation process in the FSTP segment located inside the STP. 'FSTP outlet' is the treated water from the final stage (PGF) of treatment process in the FSTP. 'STP outlet' refers to the final treated water from the STPs.

FS collection from the tanker

Testing parameters and methods

Physico-chemical parameters of the collected samples, such as pH, TS, TSS, TDS, COD, BOD, TKN, AN and TP, and microbial parameter FC were analysed using standard methods as mentioned in Table 1.

Table 1: 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

Biosolids

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

Testing parameters and methods

Physico-chemical parameters such as pH, electrical conductivity, moisture content, carbon and nitrogen and heavy metals were determined; microbiological parameters that were enumerated included faecal coliform, *E. coli*, *Salmonella* and helminth eggs. In addition to this, calorific value was determined to assess the fuel potential (*see Table 2*).

Collection of biosolids from drying bed and storage area

Table 2: Biosolid characterisation methods and equipment used

Parameters	Standard methods/equipment used
pH	APHA 4500-H^+B, 24^{th} Ed, 2023
Electrical conductivity (dS/m)	Conductivity meter (Cyberscan 200)
Carbon, nitrogen	CHN elemental analyser (LECO, USA, 828 series)
Heavy metals	ICP-OES (Perkin Elmer Avio® 200)
Faecal coliforms [11]	USEPA, Method 1680, 2014; USDA, MLG Appendix 2.05, 2014
E. coli	APHA 9221 B, 9221 F, 23^{rd} Ed., 2023; USDA, MLG Appendix 2.05, 2014
Salmonella	Pour plate method using HiCrome Salmonella agar
Helminth eggs	Ambic-$ZnSO_4$ method [12]
Calorific value	Bomb calorimeter (LECO AC 500)

6. FSTPs and STP co-treatment plants in UP

There are 59 treatment plants in Uttar Pradesh; 39 of these are FSTPs and 20 are STP co-treatment plants. In 2021-23, seven of these FSTPs and three STP co-treatment plants were monitored by CSE.[13] A list of these plants is provided in *Table 3*. In the present study, 10 FSTPs and three STP co-treatment plants have been selected (*see Table 4*). Of the 10 FSTPs, three plants – Loni, Modinagar and Chunar – have been re-evaluated to monitor the consistency in their performance. The technology description of all the selected treatment plants in the present study has been provided in this section.

Table 3: List of FSTPs and STP co-treatment systems evaluated in the year 2021-2023[13]

S no	FSTP/STP location	Commissioned year	Capacity	Solid liquid separation	Treatment technology	Tertiary treatment
Faecal sludge treatment plants						
1	Jhansi	2018	6 KLD	PDB	ABR and PGF	NA
2	Jhansi	2018	12 KLD	PDB	ABR and PGF	NA
3	Unnao	2018	32 KLD	Screw press	ABR and PGF	ACF & PSF followed by UV
4	Chunar	2021	10 KLD	PDB	ABR and PGF	UV disinfection
5	Modinagar	2021	32 KLD	-	Anaerobic digestion and MBBR	ACF, PSF followed by ozonation
6	Loni	2021	32 KLD	Screw press	MBBR, tube settler and clarifier	Sand & activated carbon filter followed by UV
7	Amethi	2021	3 KLD	PDB	ABR and PGF	NA
STP co-treatment plants						
8	Bharwara	2022	345 MLD		UASB	Chlorination, polishing pond
9	Bijnor	2018	20 KLD FSTP; 24 MLD STP	Unplanted drying bed	UASB	Chlorination, polishing pond
10	Bingawan	2022	210 MLD	-	UASB	Chlorination, polishing pond

ABR - Anaerobic baffled reactor; ACF- Activated carbon filtration; KLD - Kilo litres per day; MBBR - Moving bed biofilm reactor; MLD – Million litres per day; PDB- Planted drying bed; PGF- Planted gravel filter; PSF- Pressure sand filtration; UASB - Upflow anaerobic sludge blanket; UV - Ultra violet irradation

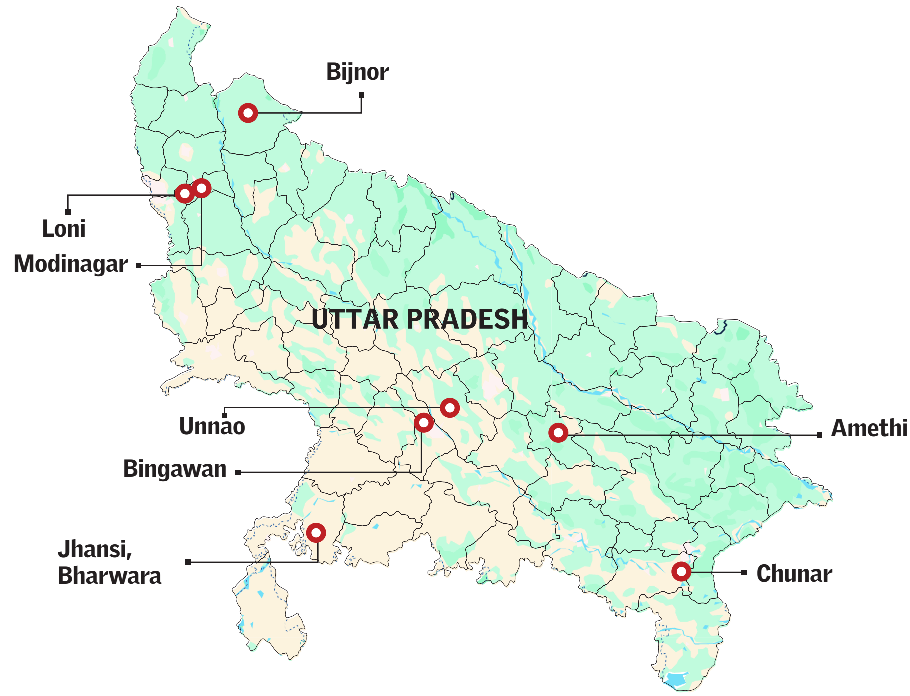
Table 4: List of FSTPs and STP co-treatment systems evaluated in the current study

S No	Location	Commissioned year	Operator	Design capacity	Capacity utilization *	Solid liquid separation	Treatment technology	Tertiary treatment	Treated water reuse
Faecal sludge treatment plants									
1	Chunar	2021	UP Nagar Nigam	10 KLD	90%	PDB	ABR and PGF	ACF, PSF followed by UV disinfection	Gardening
2	Deoria	2023	UP Nagar Nigam	32 KLD	10%	Screw Press	CWs	Hypochlorination	-
3	Basti	2023	UP Nagar Nigam	32 KLD	15%	Screw Press	CWs	Hypochlorination	-
4	Aligarh	2022	UP Nagar Nigam	32 KLD	30%	TBF	Anaerobic stabilization, TBF, HPGF	Polishing Pond	Gardening
5	Loni	2022	Private agency	32 KLD	65%	Screw Press	MBBR	ACF, DMF followed by UV disinfection	Gardening
6	Modinagar	2021	UP Nagar Nigam	32 KLD	20%	Nil	Anaerobic digestion, Anoxic process and aeration process	ACF, PSF followed by ozonation	Discharge into the Yamuna river
7	Shamli	2023	UP Nagar Nigam	32 KLD	25%	Screw Press	ABR and CWs	ACF, DMF followed by chlorination	Gardening
8	Amroha	2022	UP Nagar Nigam	32 KLD	35%	Screw Press	ABR and CWs	ACF, DMF followed by chlorination	-
9	Hapur	2022	UP Nagar Nigam	32 KLD	75%	Screw Press	ABR and CWs	ACF, DMF followed by chlorination	-
10	Shahjahanpur	2022	SS Engineering works	32 KLD	50%	Screw Press	ABR and SBR	Chlorination	Gardening
STP co-treatment plants									
11	Gorakhpur	2023	Jal Nigam	FSTP- 50 KLD, STP- 30 MLD	-	Screw Press	ABR and PGF in FSTP, SBR in STP	Chlorination	Discharge to Rapti River
12	Saharanpur	2022	UP Nagar Nigam	FSTP- 25 KLD, STP- 38 MLD	60%	Screw Press	Anaerobic tank and PGF in FSTP, UASB and aerated lagoons in STP	Polishing Pond	Discharge to Dhamola River
13	Etawah	2022	Rubicon	FSTP- 25 KLD, STP- 21 MLD	50%	Screw Press	ABR and PGF in FSTP, SBR in STP	Chlorination	Discharge to Yamuna River

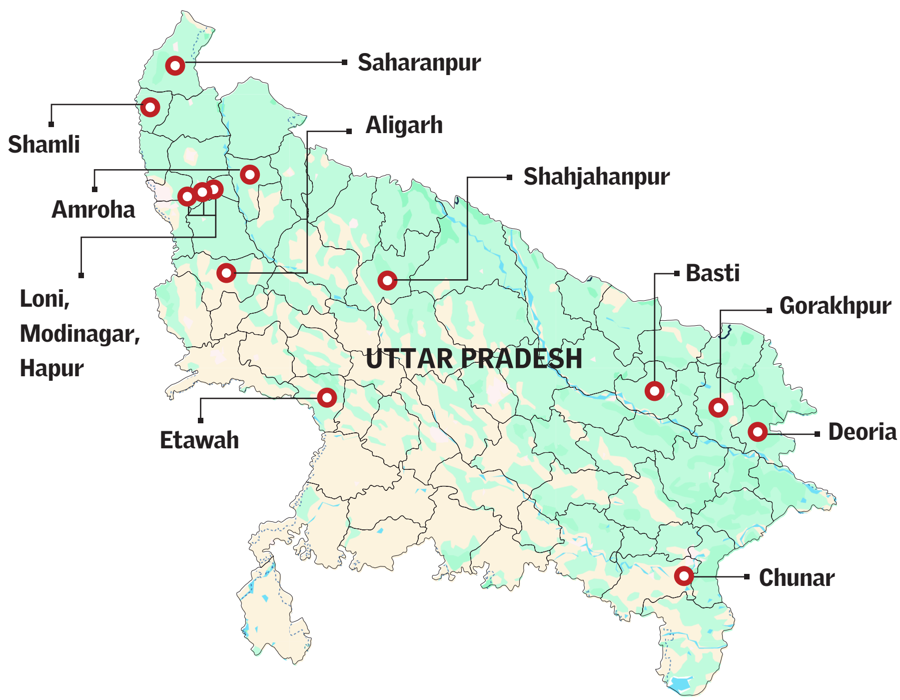
ABR - Anaerobic baffled reactor; ACF- Activated carbon filtration; CWs- Constructed wetlands; DMF -Dual media filtration; HPGF – Horizontal Planted gravel filter; KLD - Kilo litres per day; MBBR - Moving bed biofilm reactor; MLD – Million litres per day; PDB- Planted drying bed; PGF- Planted gravel filter; PSF- Pressure sand filtration; SBR-Sequential batch reactor; TBF-Tiger bio-filter;
UASB - Upflow anaerobic sludge blanket; UV - Ultra violet irradation

*Capacity utilization calculated based on the information collected during the 6-month study (January -June 2024).

Map 1: Locations of FSTPs and STP co-treatment plants monitored in the year 2021-2023



Map 2: Locations of FSTPs and STP co-treatment plants monitored in the present study



7. Faecal sludge treatment plants (FSTPs)

Chunar

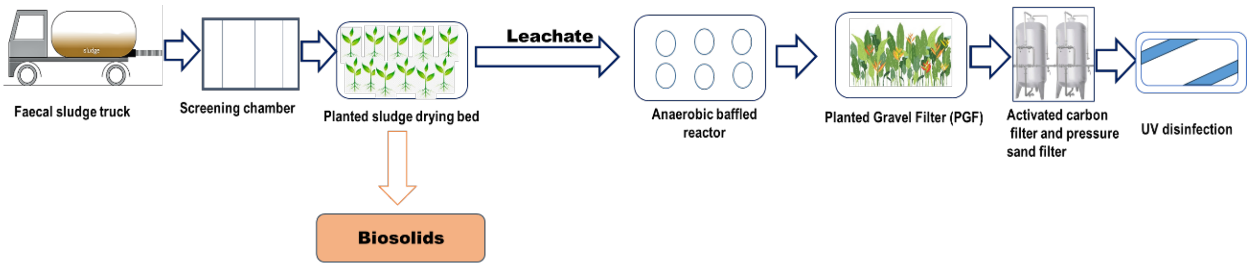
Chunar is a town located in Mirzapur district, which lies in the north and north-east of UP.

The first FSTP fully funded by the National Mission for Clean Ganga (NMCG) was constructed in Chunar and inaugurated in March 2023. The plant, with a capacity of 10 KLD, is fully operational now and receives faecal sludge (FS) on a regular basis. Every day, three tankers with a capacity of three kl per tanker empties FS into the receiving chamber of the plant. The FS received in the plant is mostly collected from public toilets, community toilets and household toilets.

Filtration module in the Chunar plant

In the chamber, the non-faecal matter is screened. Post-screening, the liquid sludge is conveyed to planted sludge drying beds, where it is allowed to degrade naturally with the help of specific varieties of plants known as Macrophytes such as *Typha*, *Canna indica* etc. Planted drying beds are structures with sloped base for holding graded filter media.

Figure 1: Chunar FSTP: A process flow diagram



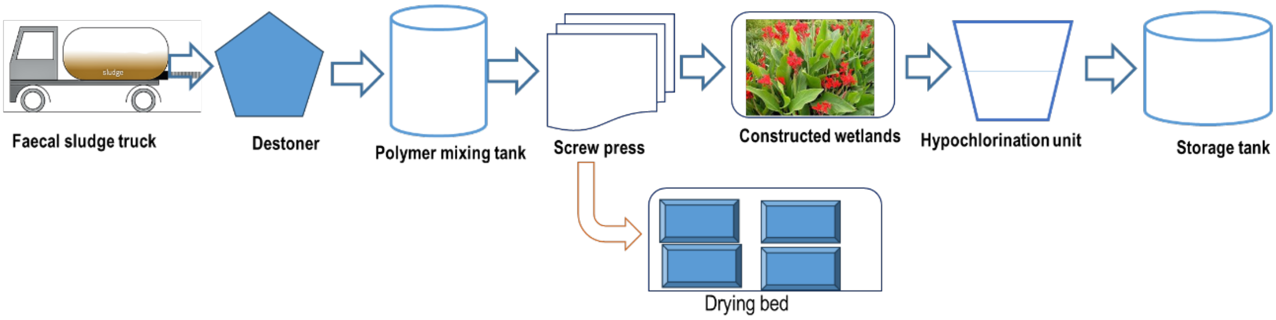
The sludge undergoes solid liquid separation and gets dried in the planted sludge drying beds (PDBs). The leachate from the PDBs enters the anaerobic baffled reactor (ABR), and flows into the planted gravel filter (PGF) system via gravity. The effluent from PGF is pumped to the filtration system (such as activated carbon and pressure sand filtration) and the filtered water is disinfected by UV irradiation. The final treated water is stored in the collection tank and reused in the FSTP premises for gardening.

Deoria

Deoria is one of the five tehsils of Deoria district in UP. An FSTP with a capacity of 32 KLD was commissioned in the town in 2023. The FSTP is located in Chakbhandhan Urf Singhpur village, eight km from the city. The plant is functional, but it barely receives 15 tanker-loads of sludge a month (tanker capacity: 1-4 kl). The FS received in the plant is collected from household, community and public toilets.

Preliminary stage of the treatment module in Deoria

Figure 2: Deoria FSTP: A process flow diagram



The treatment technology consists of a de-stoner where the stones and gravel get removed. From here, the sludge is passed to the polymer mixing unit where it is mixed with a cationic polymer. The sludge agglomerates in the presence of the polymer and this agglomerated form goes into the screw press. In the screw press, dewatering of the sludge occurs and this is then conveyed to the drying bed. The liquid part which is separated in the screw press flows into the constructed wetlands where it undergoes treatment. The treated water is passed to the hypochlorination tank for disinfection. Post disinfection, the water is stored in the storage tank.

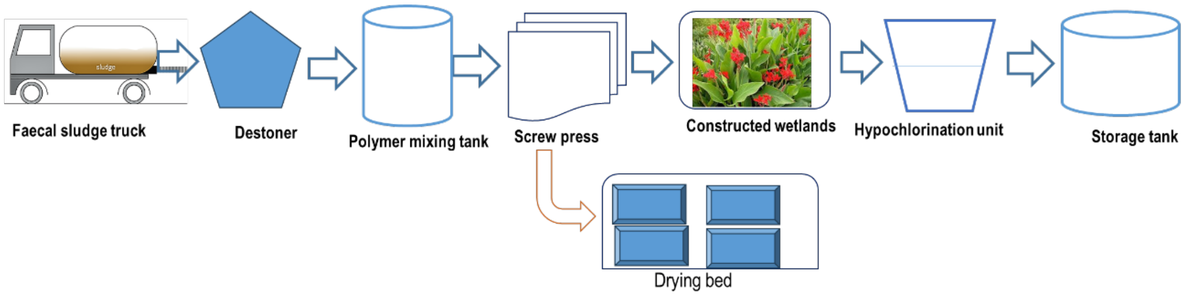
Basti

Basti is a city in eastern Uttar Pradesh, about 55 km east of Faizabad on the Kuwana river, a tributary of the Ghaghara.

In Basti, a 32-KLD plant is located in Amhut village, three km away from the city. The average capacity of the truck which empties sludge in the plant is four kl. The plant receives sludge once in three days (three-four trucks) from various sources, including public toilets and community toilets.

Preliminary stage of the treatment module in Basti

Figure 3: Basti FSTP: A process flow diagram



The treatment technology consists of a destoner where the stones and gravels get removed. 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 agglomerated form goes into the screw press. In the screw press, dewatering of the sludge occurs and the dewatered sludge is conveyed to the drying bed.

The liquid part which is separated in the screw press flows to the constructed wetlands where it undergoes treatment. The treated water is passed to the hypochlorination tank for disinfection purpose. Post disinfection, the water is stored in the storage tank.

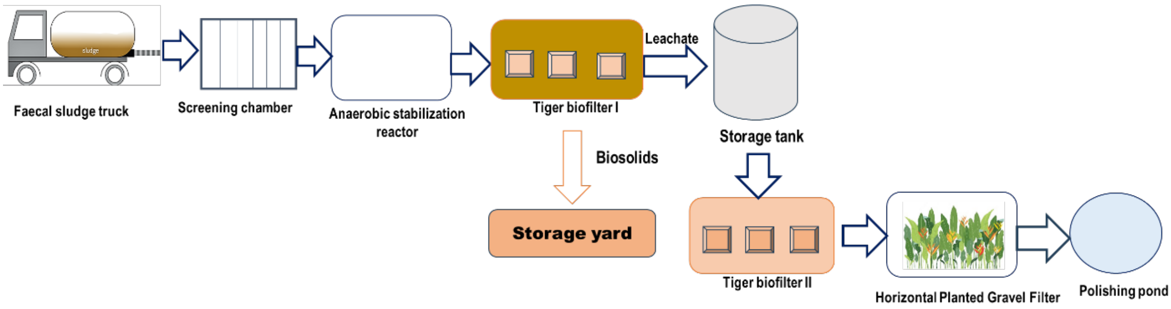
Aligarh

Aligarh city, located upstream of the Ganga-Yamuna Doab region, is the administrative capital of Aligarh district in western Uttar Pradesh.

A 32-KLD FSTP was commissioned in 2022 in the Barola Jaffarbad area of Aligarh. On an average, the plant receives 63 kl faecal sludge every week. The average capacity of the truck used for collection and transportation of the sludge is four kld. The plant receives the FS from various sources, including public, community, household and hospital toilets.

Preliminary stage of the treatment module in Aligarh

Figure 4: Aligarh FSTP: A process flow diagram



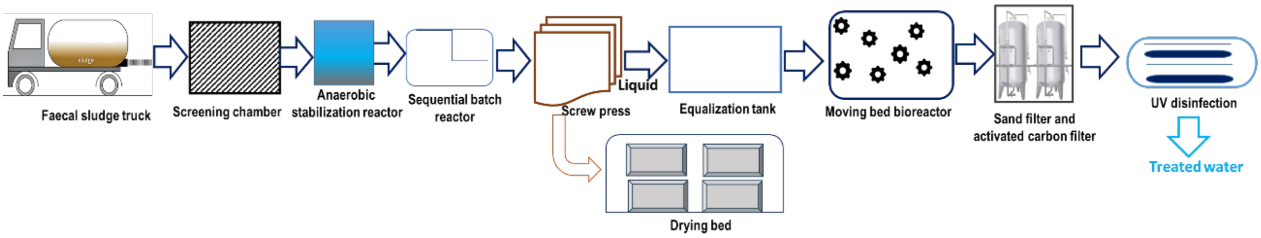
After screening, the sludge enters the anaerobic stabilization tank where its stabilization occurs and the organic matter gets degraded. The resulting supernatant of this reactor moves to the tiger biofilter (TBF I) system. The TBF bed consists of a mixture of earthworms, cocopeat and coir. The organic matter in the supernatant and the little amount of sludge that may pass along with the supernatant settles in the TBF system. This settled organic matter is degraded by the action of earthworms. The effluent from TBF I system flows into the storage tank and then to TBF II, horizontal planted gravel system and polishing pond. The solid part, which is settled in TBF I, is removed and dried separately and stored in the storage yard.

Loni

Loni is a town in Ghaziabad district, located near the Yamuna river. It has a 32-kld FSTP located in a residential area near the sewage treatment plant neighbouring Ved Vihar. Commissioned in 2022, the plant is well-maintained and managed. It receives four-five truck-loads of sludge per day; the average capacity of each truck is four kl. The sludge is received from household, hospital, community and public toilets.

Primary and secondary stages of treatment in Loni

Figure 5: Loni FSTP: A process flow diagram



The treatment process begins with screening to remove non-faecal matter, followed by stabilization in an anaerobic stabilization reactor. The sludge is then moved to the sequential batch reactor (SBR) and screw press. Separation of solids and liquid occurs in the screw press, and the liquid moves to the equalization tank whereas the solid part is sun-dried in the drying bed.

After equalization, the liquid part goes to the moving bed biofilm reactor (MBBR) where it is treated by using biofilm attached onto plastic carriers. After treatment, the water undergoes filtration in dual media filter and disinfection by an UV process.

Finally, the treated water is used for horticulture in the FSTP premises. In a day, around 3.5 liter of water and 10-15 kg of dried sludge are generated after treatment. Apart from horticultural usage in the plant, the dried sludge is also sent to the Nagar Nigam for use in gardening.

Modinagar

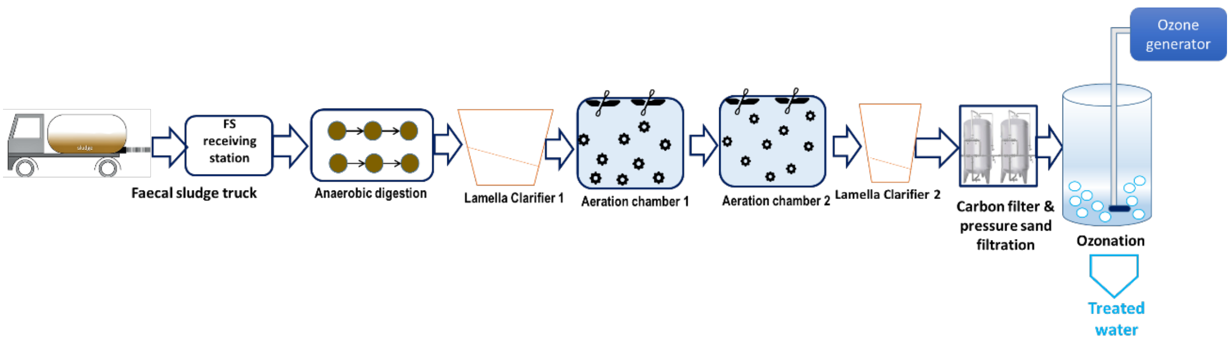
Modinagar, in Ghaziabad district, has a 32-KLD FSTP commissioned in 2021; the plant is located within the premises of a 20-MLD STP in Jagatpuri Colony near Shani Mandir. The plant receives one-two truck-loads of faecal sludge every day. The average capacity of the trucks is three kl. The sludge is collected from household, community, hospital and public toilets.

The treatment technology involves a series of processes including screening, anaerobic digestion, anoxic and aerobic digestion. In the screening process, non-faecal matter is removed from the sludge. The anaerobic chamber degrades the sludge in the presence of anaerobic bacteria. The treated sludge is then pumped to the anoxic chamber, where bacteria degrade the waste under oxygen-limited conditions. The effluent from the anoxic chamber moves through two mud chambers where the mud-like material settles down.


Primary and secondary stages of treatment in Modinagar

The effluent passes to lamella clarifier 1 where oil and grease removal occurs, after which it flows into two aeration chambers where MBBR media of 2-3 mm is employed to trap and adsorb the organic matter. After treatment, it moves to lamella clarifier 2 which removes suspended solids. The treated water from lamella clarifier 2 undergoes processes such as ozonation to remove odour, activated carbon filtration, sand filtration and micron filtration to remove the remaining small suspended solids. The final treated water is stored in the collection tank. The volume of water generated per day is 2-3 kl.

Figure 6: Modinagar FSTP: A process flow diagram



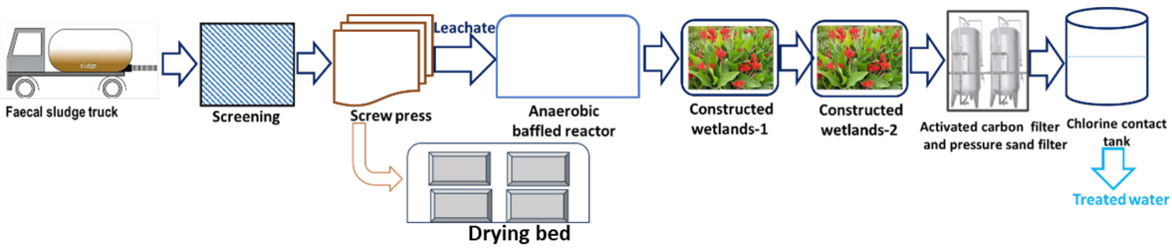
Shamli

Shamli is a district located in western Uttar Pradesh's Doab region. The district has a 32-KLD plant commissioned in 2023 in Lilaun village of Shamli block. The plant receives two truckloads of sludge per day; the capacity of the trucks is one kl and three kl, respectively. The sources of the faecal sludge are household, community, public and hospital toilets.

Primary stage treatment facility in Shamli

The treatment technology consists of a sequence of stages starting from screening to removal of non-faecal matter, equalization to bring the incoming sludge to a constant flow and dewatering in the screw press. After dewatering, the liquid part is pumped to ABR where degradation of organic matter occurs. The effluent from ABR passes through two stages of wetland systems. Finally, the effluent undergoes filtration in a dual media filter system and disinfection in the chlorination tank. The solid part separated in the dewatering stage goes to the drying bed where it is dried in the sun. The dried sludge is given to local farmers free of cost. The treated water is used for gardening the plants in the FSTP and discharged into the *nallah* located near the plant.

Figure 7: Shamli FSTP: A process flow diagram



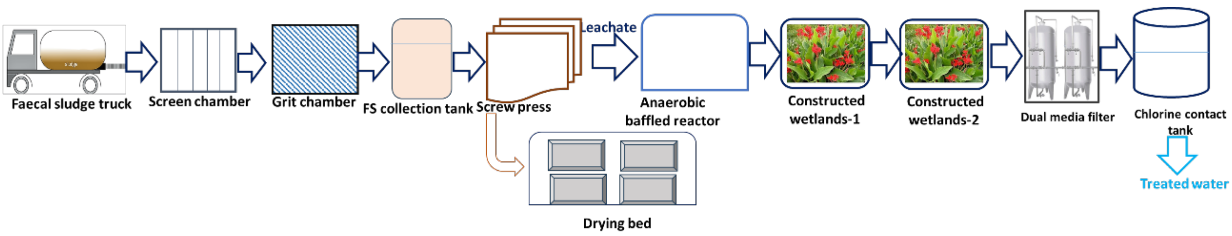
Amroha

Amroha is located on the banks of the Ganga in western Uttar Pradesh. In 2022, the town commissioned a 32-KLD FSTP; the plant was set up far away from the town. It receives three trucks of FS every day; the capacity of the trucks is three-four kl. The plant receives FS from various sources including public, community, household and hospital toilets. The power required for running the FSTP is generated through solar panels.

The treatment technology consists of a sequence of stages starting from screening to removal of non-faecal matter, equalization to bring the incoming sludge to a constant flow and dewatering in a screw press. But before dewatering, the sludge is mixed with polymer to agglomerate it to enable separation of solids and liquids. After dewatering, the liquid part is pumped to ABR where degradation of organic matter occurs. The effluent from ABR passes through two stages of wetland systems. After this, the effluent enters the filtration set-up and undergoes filtration in dual media filter system to remove small suspended solids. Finally, the treated water is disinfected in the chlorination tank. The solid part separated in the dewatering stage goes to the drying bed where it is dried in the sun-drying process. The dried sludge is used in gardening and also given to local farmers.

Sludge being received at the Amroha plant

Figure 8: Amroha FSTP: A process flow diagram



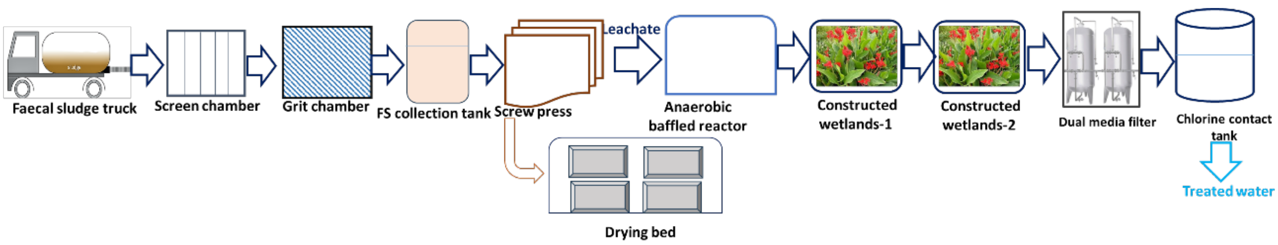
Hapur

Hapur city, the headquarters of the district with the same name, has a 32-KLD FSTP in Paidhampur near Dheerkheda. The plant which is treating seven-eight truckloads of FS in a day. Each truck has a capacity of three kl, and the plant receives sludge from various sources including public, community, household and hospital toilets. Hapur FSTP uses solar panels to power itself.

Primary and secondary stage treatment in Hapur

The treatment technology begins with screening to remove non-faecal matter and equalization to retain the FS in a basin to control the hydraulic flow rate, followed by dewatering using a screw press. Before dewatering, the sludge is mixed with polymer to agglomerate it for ensuring proper separation of solids and liquids. After dewatering, the liquid part is pumped to the ABR where degradation of organic matter occurs. The effluent from ABR passes through two stages of wetland systems. After this, the effluent enters the filtration set-up and undergoes filtration in dual media to remove small suspended solids. Finally, the treated water enters the chlorination tank for tertiary treatment. The solid part separated in the dewatering stage goes to the drying bed where it is dried in the sun.

Figure 9: Hapur FSTP: A process flow diagram



Shahjahanpur

Shahjahanpur town, in the district with the same name in Uttar Pradesh has a 32-kld FSTP in Kakra; the FSTP was commissioned in 2022.

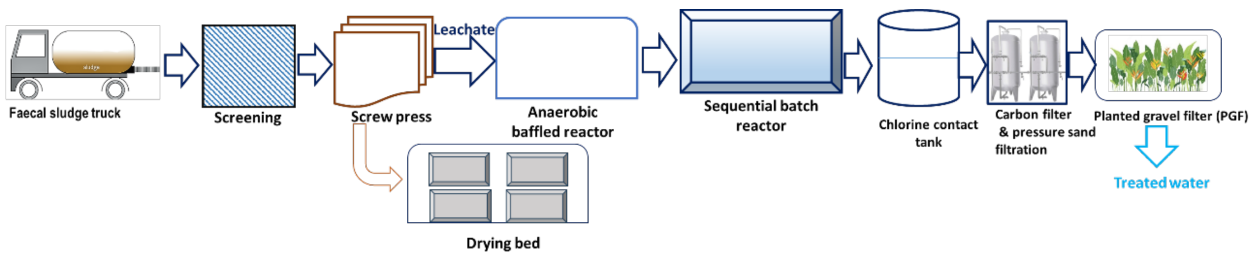
The plant receives four-five truckloads of FS on a daily basis; the average capacity of a truck is three kl. Toilets – in households, communities and hospitals – are the sources of the sludge.

Primary and secondary stage treatment in Shahjahanpur

The treatment technology consists of several stages, beginning with screening to remove non-faecal matter, equalization process to retain FS in a basin to control the hydraulic flow rate, and dewatering using a screw press. Before dewatering, the sludge is mixed with polymer to agglomerate it so that proper separation of solid and liquid can occur. After dewatering, the liquid part moves to ABR where the organic matter gets degraded. The effluent from ABR passes to two sequential batch reactors and the treated water is disinfected in the chlorine contact tank.

After disinfection, it undergoes filtration in activated carbon filter and pressure sand filtration system to remove small suspended solids. Post filtration, it enters the PGF system. The final treated water which emerges from PGF is used for gardening in the FSTP campus. The solid part separated in the dewatering stage goes to a storage room covered by a metallic sheet.

Figure 10: Shahjahanpur FSTP: A process flow diagram



8. STP Co-treatment Plants

The treatment process that takes place in an STP co-treatment plant evaluated in this study is as follows:

- Faecal sludge received through tankers undergoes screening to remove non-faecal matter or inert materials, followed by dewatering in a screw press.
- The separated solids are dried in drying beds, whereas the liquid undergoes treatment in anaerobic chambers or ABR and PGF. Since faecal sludge is treated through the aforementioned modules, this particular segment is referred to as FSTP in the current study.
- The treated liquid emerging from the FSTP enters the inlet of the STP for further treatment. Hence, the entire process is referred to as STP co-treatment.

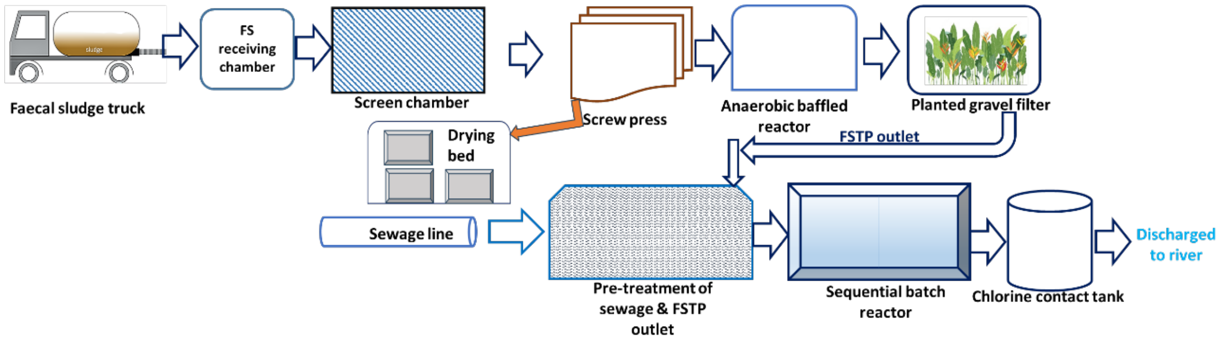
Gorakhpur

Gorakhpur, in the north-eastern part of Uttar Pradesh, is bounded by the Rapti river.

Faecal sludge collected from different onsite sanitation systems is transported and emptied into a 50-KLD FSTP located on the premises of a 30-MLD STP, where it undergoes initial treatment. The effluent from the FSTP is pumped into the inlet of the STP for further treatment. This co-treatment process was initiated in 2023.

The Gorakhpur plant's primary treatment facility

Figure 11: Gorakhpur plant: A process flow diagram



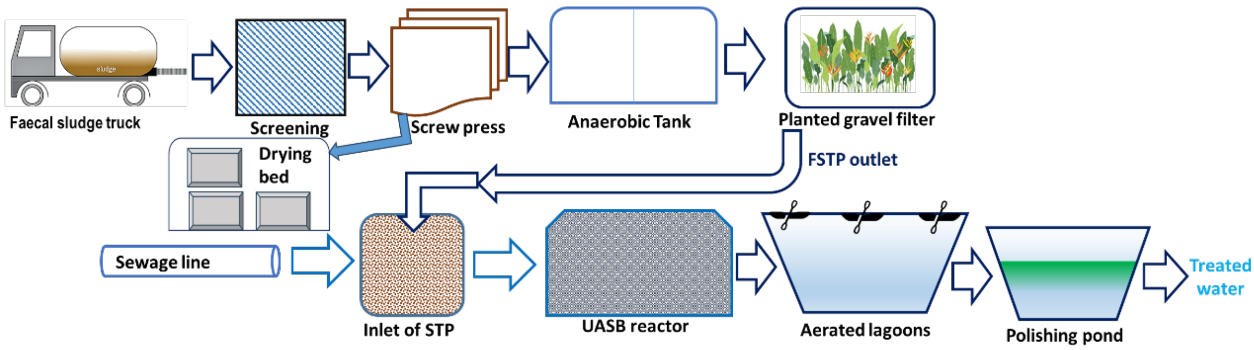
Faecal sludge received in the plant is mixed with a cationic polymer which aids in agglomeration of the sludge. The agglomerated sludge is dewatered in a screw press and the separated sludge (solid part) is transferred to the drying bed. The liquid part moves to the ABR where it undergoes degradation by anaerobic bacteria. It is then moved to the PGF system where major nutrients like nitrogen and phosphate get removed through the uptake by plants. The effluent from PGF is pumped to the STP where it gets treated by sequential batch reactor process. The treated water undergoes disinfection process via chlorination and is discharged into the Rapti river.

Saharanpur

Saharanpur, UP's northernmost district, is a town that has the Yamuna river flowing by its west.

The primary treatment stage and drying bed in Saharanpur

Figure 12: Saharanpur plant: A process flow diagram



Faecal sludge collected from different onsite sanitation systems in Saharanpur is transported and discharged into a 25-KLD FSTP located inside the premises of a 38-MLD STP. The sludge undergoes partial treatment in the FSTP, and is then sent out from the PGF to the inlet of the STP for further treatment.

The plant receives around three-four truckloads of FS from household, community and public toilets. The capacities of the desludging vehicles are four and six kl.

The treatment process begins with screening in the screen chamber to eliminate non-faecal matter. After screening, the faecal sludge mixed with a polymer is conveyed to a screw press where the sludge is squeezed to separate the solid and liquid parts. The separated liquid passes into an anaerobic tank with two chambers where it undergoes anaerobic digestion. The effluent from the anaerobic tank passes to a planted gravel filter system and is pumped thereafter to the STP, where it is treated by the upflow anaerobic sludge blanket (UASB) system. The effluent from UASB is treated in aerated lagoons and extended aeration systems. The final treated water is discharged into the nearby Dhamola river.

Etawah

The district of Etawah lies in the southwestern part of Uttar Pradesh and forms a part of the Kanpur division.

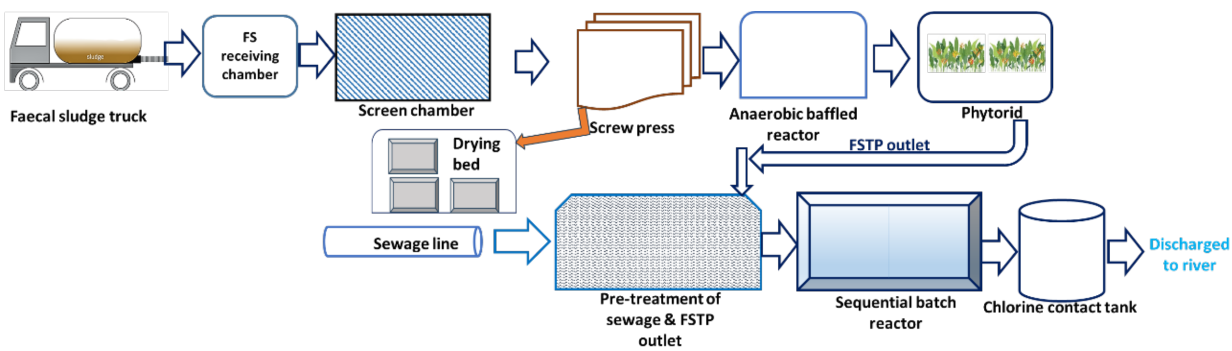
Faecal sludge collected from different onsite sanitation systems in the district is transported and discharged into a 25-KLD FSTP located near a 21-MLD STP. The sludge undergoes partial treatment in the FSTP; the liquid that emerges from the phytorid beds moves to the inlet of the STP for further treatment. The plant

Preliminary and primary treatment stages in Etawah

receives around three-four truckloads of FS daily from household, community and public toilets. The average capacity of the desludging vehicle is 3.5 kl.

In the FSTP, the tankers discharge the sludge into a screen chamber where the non-faecal matter is removed. Subsequently, it passes to the FS collection tank where the flow is equalized, and then to the sludge dewatering machine (screw press). The dewatered sludge falls directly into the drying bed where it gets dried by sun drying process. The liquid which is separated flows into the ABR and phytorid beds. The effluent from these beds moves to the inlet STP, where it undergoes further treatment along with sewage by the SBR process. The effluent from the SBR is disinfected in the chlorine contact tank, and the final treated water is discharged into the Yamuna.

Figure 13: Etawah plant: A process flow diagram



9. The results of the study

Notes on the study

- The CSE study team visited 10 FSTPs and three STP co-treatment plants in Uttar Pradesh. Three visits were carried out in January, March and May 2024 to collect samples for analysis. The faecal sludge samples collected from the plants were characterized on 10 parameters, while the biosolid samples were analyzed for nine parameters.

- The term '% removal' here implies 'removal that has occurred from inlet to final outlet'. The graphs in this chapter are based on the average data of the three months mentioned above.

- The regulatory standards available for discharge of treated effluents from STPs has been presented in Annexure 1.

- The physico-chemical parameters of biosolids have been compared against the Fertilizer Control Order (FCO), 2023 standards for analyzing their nutrient value for agricultural applications (*see Annexure 1*). To assess the pathogen level in biosolids, the regulatory limit set by the USEPA/WHO for class A biosolids has been followed (*see Annexure 1*).

- The consolidated data of all the results has been tabulated and presented in *Annexure 2*.

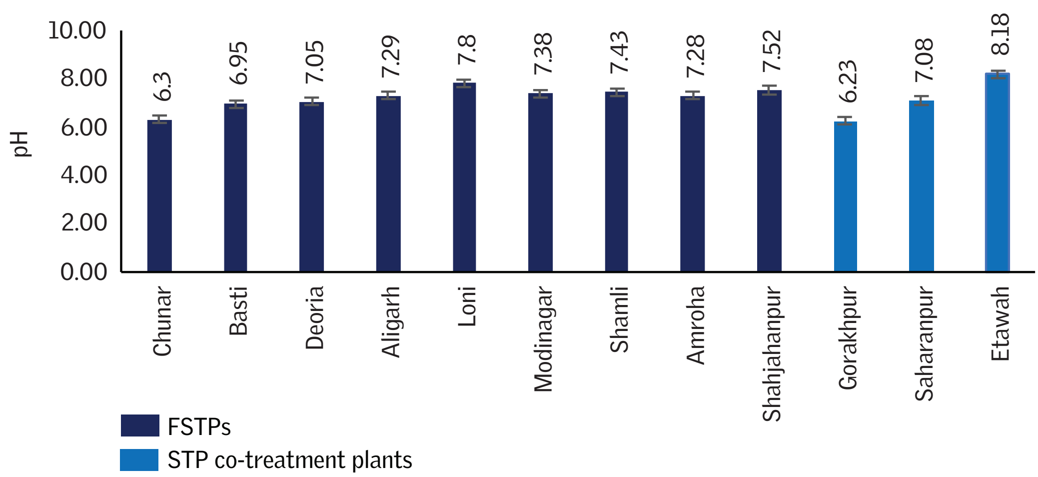
Faecal sludge characterization

The faecal sludge (FS) samples collected from discharge vehicles at the FSTPs were analyzed for various important parameters. The data presented here is the average value of the FS samples collected over three months (January, March and May 2024). The CSE team was unable to collect tanker samples from the Hapur FSTP. This is why the data represented in Graphs 1-7 relate to only 12 of the 13 plants studied by CSE.

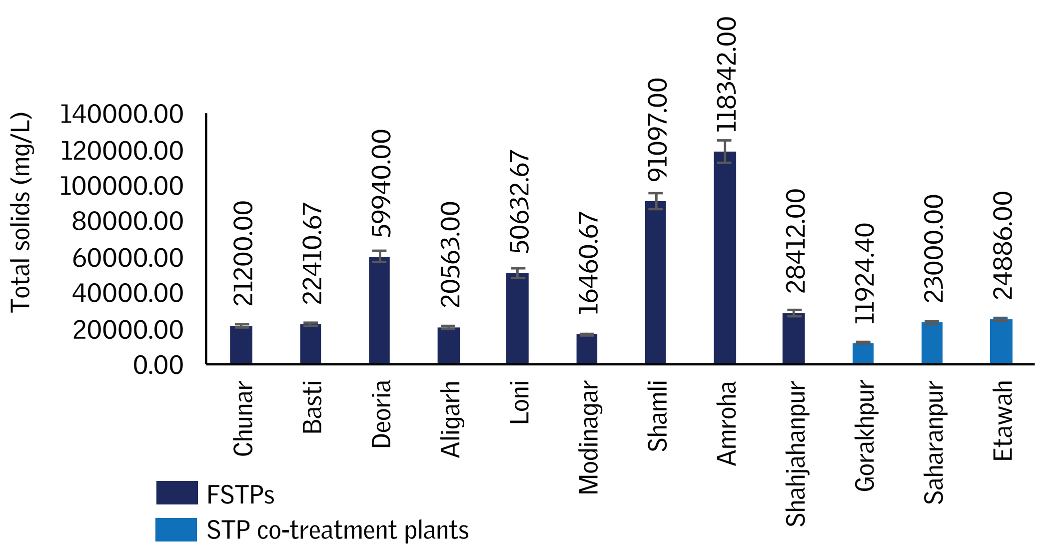
The pH of the sludge ranged between 6.23 and 8.18. Both total solids and total suspended solids were found to be the highest in Amroha FSTP and lowest in Gorakhpur STP co-treatment plant. Total solids in Amroha and Gorakhpur were

118,342 and 11,924 mg/L, respectively whereas total suspended solids in these locations were 116,949 and 10,484 mg/L, respectively. The COD of FS ranged from 46,325 to 88,233 mg/L, whereas BOD was between 5,745 to 13,346 mg/L. The lowest COD and BOD were observed for Aligarh and the highest for the Loni FSTP. TKN varied from 497 mg/L in Shamli to 6,700 mg/L in the Chunar FSTP. Faecal coliforms were in the range of 92 (log 1.96) to 24,000,000 MPN/100 ml (log 7.38).

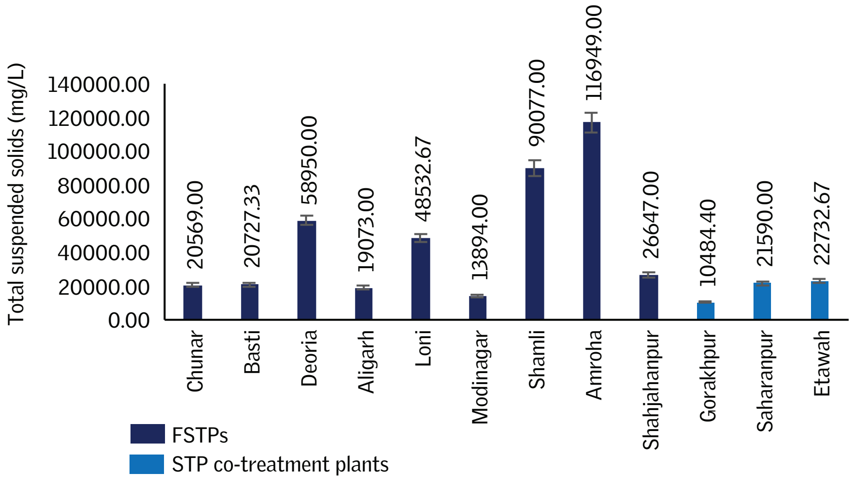
Graph 1: pH value of faecal sludge



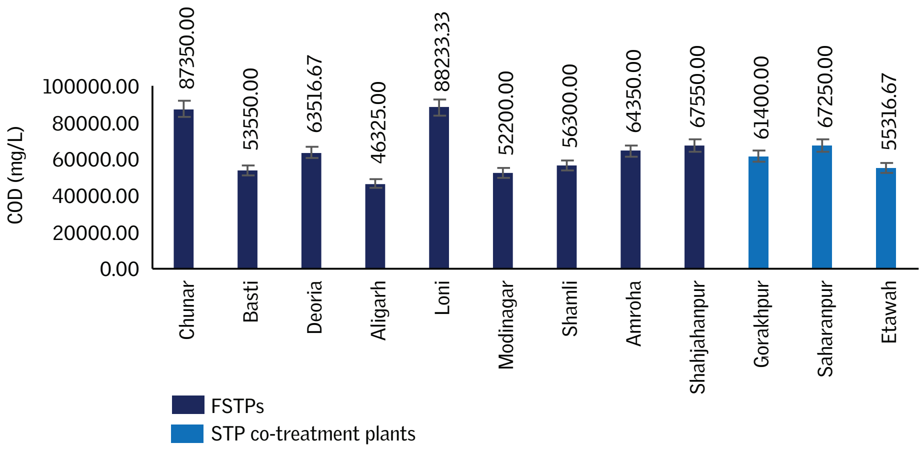
Graph 2: Total solids in the faecal sludge



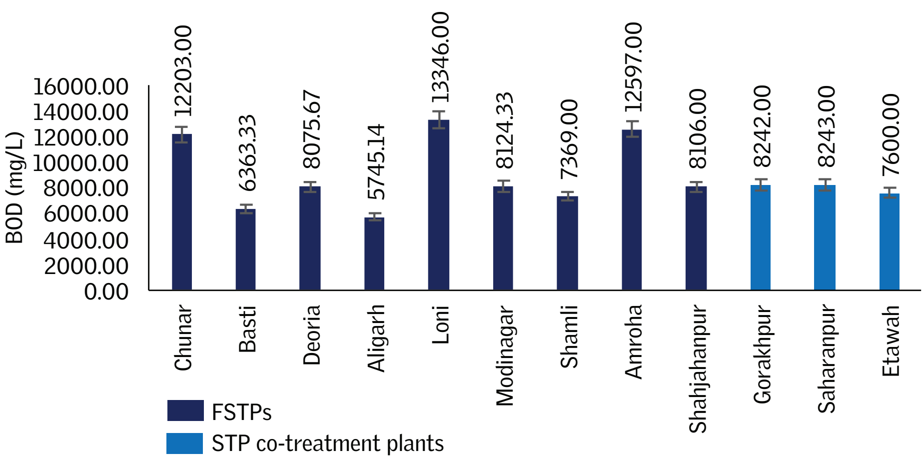
Graph 3: Total suspended solids in the faecal sludge



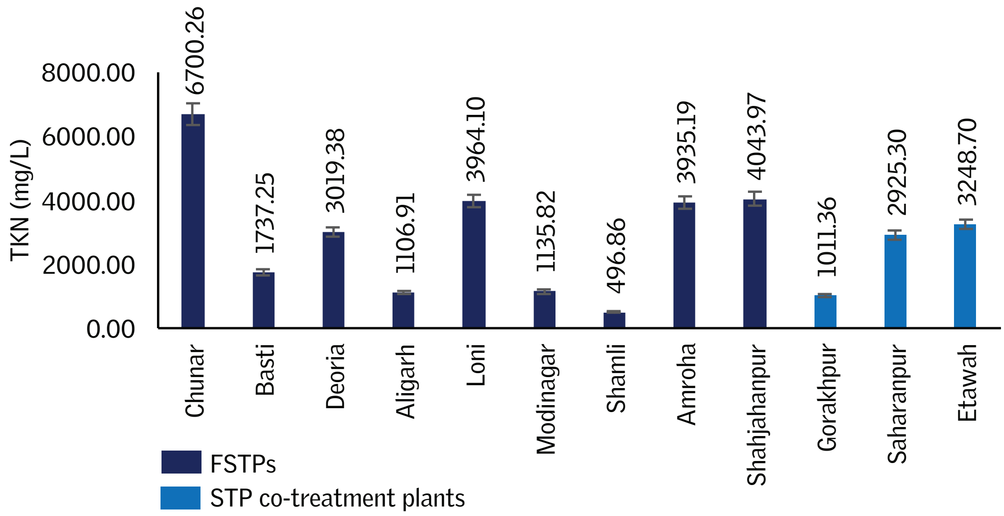
Graph 4: Chemical oxygen demand (COD) of the faecal sludge



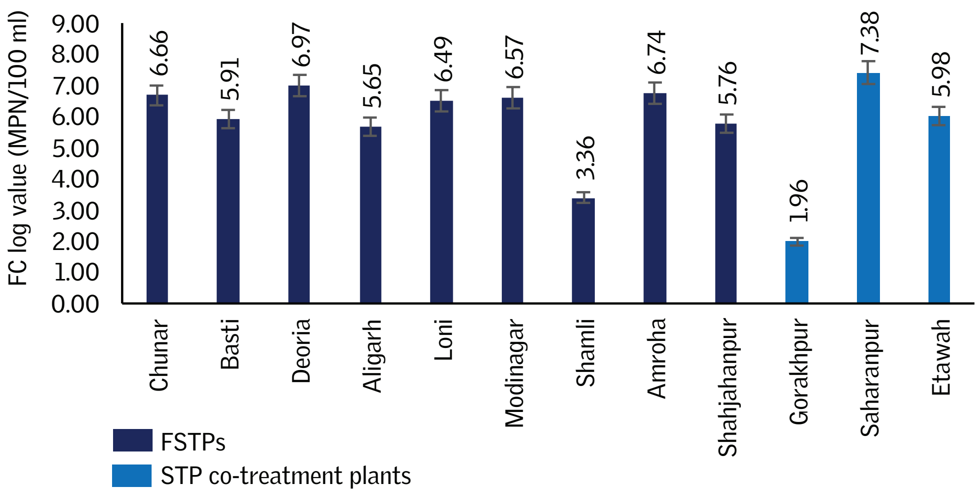
Graph 5: Biochemical oxygen demand of the faecal sludge



Graph 6: Total Kjeldahl nitrogen of the faecal sludge



Graph 7: Faecal coliform in the sludge

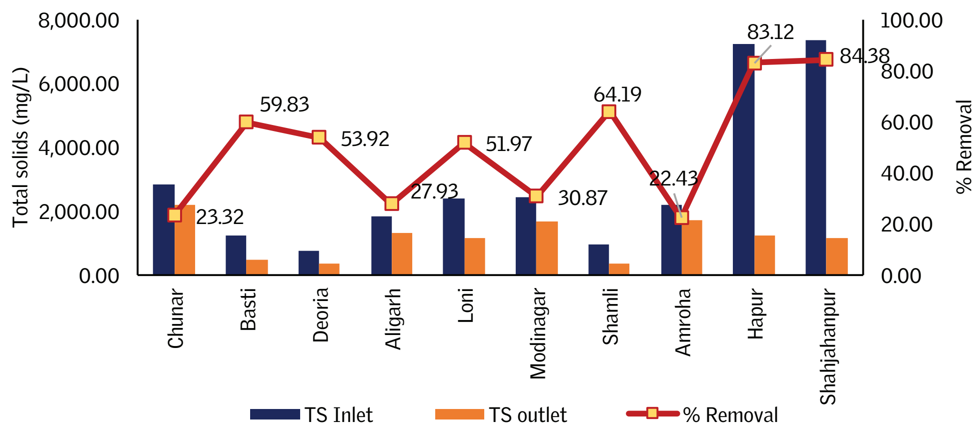


Performance of FSTPs

Ten different parameters were selected for the evaluation -- including pH, total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total Kjeldahl nitrogen (TKN), ammoniacal nitrogen (AN), total phosphate (TP) and faecal coliform (FC). Seven of those parameters have been represented here.

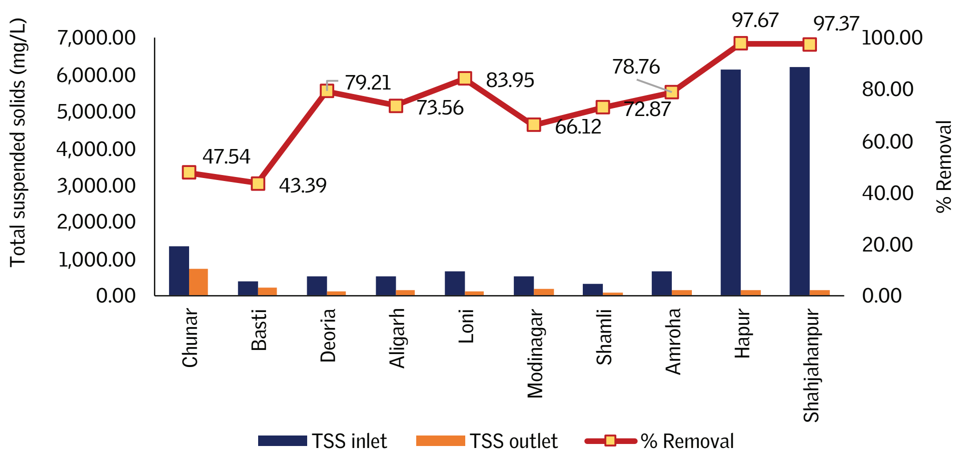
Total solids (TS): The inlet TS, outlet TS and % removal of TS from the FSTPs have been shown in *Graph 8*. The average value of TS in the inlet ranged from 769 mg/L in Deoria to 7,358 mg/L in Shahjahanpur, whereas the TS in the outlet was found to be in the range of 346 mg/L (Chunar) to 2,180 mg/L (Shamli). The removal percentage of TS varied from 22.43 per cent to 84.38 per cent. The lowest % removal of TS was observed in the Amroha FSTP, whereas the highest was in the Shahjahanpur FSTP.

Graph 8: Total solids in inlet and outlet of FSTP and % removal from inlet to outlet



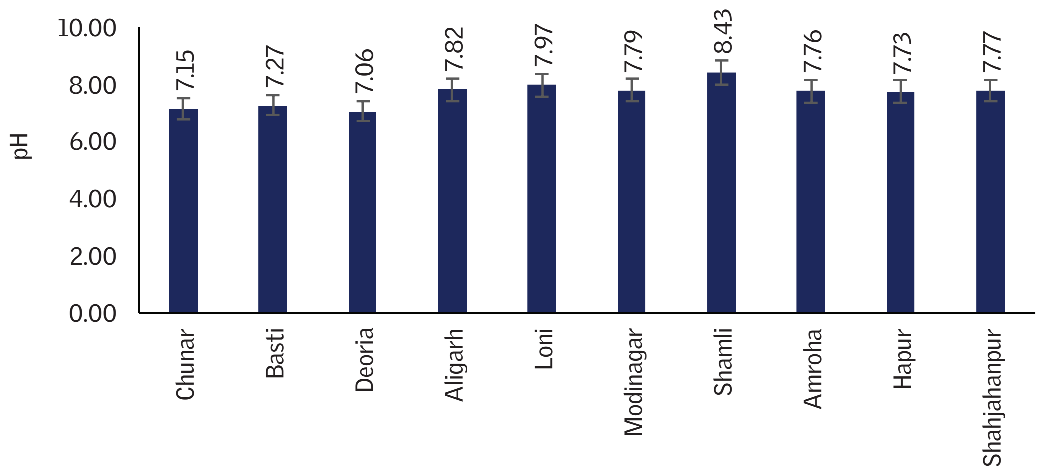
Total suspended solids (TSS): The inlet and outlet TSS and % removal of TSS from the FSTPs is represented in *Graph 9*. The average inlet TSS varies from 309 mg/L in Shamli to 6,202 mg/L in Shahjahanpur FSTP. The range of TSS in the outlet or discharge water from the FSTPs was observed to be 84 mg/L in Shamli to 710 mg/L in Chunar. The % removal of TSS varied from 43.39 per cent to 97.67 per cent. The lowest % removal of TSS was observed for Basti; the highest, for Hapur.

Graph 9: Total suspended solids in inlet and outlet of FSTP and % removal from inlet to outlet



pH: The pH of the outlet water from the FSTPs ranged between 7.06 and 8.43. There is not much difference in the pH of this water with respect to different locations. According to the NGT, the discharge limit of pH should be 5.5-9, whereas according to the MoEF&CC, the discharge limit must be 6.5-9. The outlet water from all the evaluated FSTPs in the current study has pH value within both these limits.

Graph 10: pH of FSTP outlet water



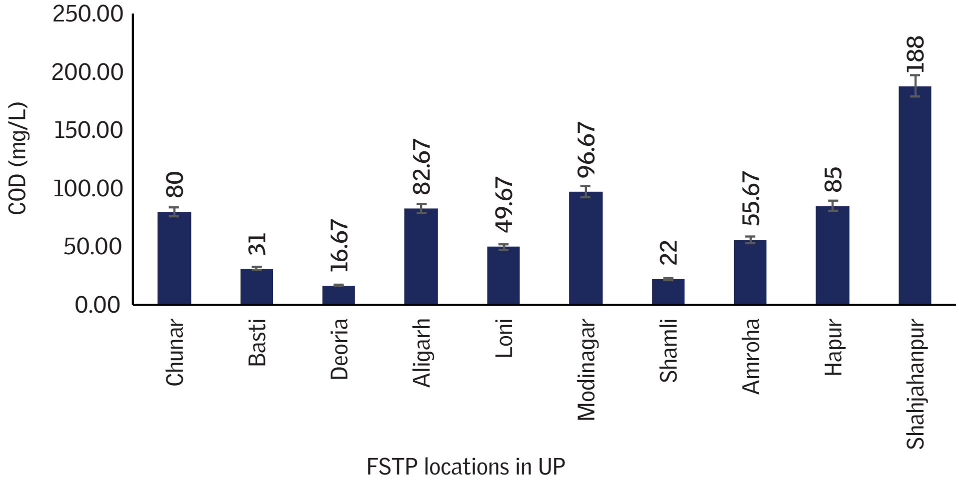
Chemical oxygen demand (COD): *Graph 11* represents the values of COD of outlet water from the FSTPs. The COD value varies from 16.67 mg/L to 188 mg/L. The lowest value of 16.67 mg/L was observed in the outlet of the Deoria FSTP; the highest was for Shahjahanpur.

According to NGT standards for effluent discharge from an STP, the regulatory limit for COD is 50 mg/L. Out of the evaluated 10 FSTPs, four had a COD value within the 50 mg/L range in their outlet water.

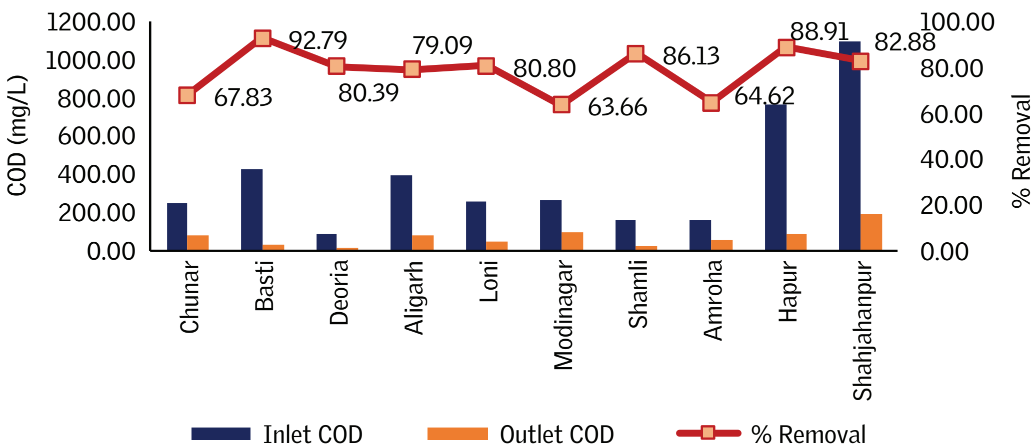
Graph 12 provides the inlet and outlet values of COD as well as the % removal of COD from each FSTPs. As far as % removal is concerned, the highest removal efficiency of 92.79 per cent was achieved by the Basti FSTP; the lowest of 63.66 per cent was attributed to the Modinagar FSTP.

The COD removal efficiency of all the evaluated 10 FSTPs in UP is above 60 per cent. The performance of FSTPs in Chunar, Loni and Modinagar, evaluated in 2021-2023 had shown that outlet COD values were 71 mg/L, 231 mg/L and 44.5 mg/L for the three towns, respectively; in the current study, the COD values have been 80 mg/L, 49.67 mg/L and 96.67 mg/L, respectively. These values indicate that the Loni FSTP has improved its performance by bringing the COD value below the regulatory limit.

Graph 11: COD of outlet water from the FSTPs



Graph 12: Inlet and outlet COD and % removal of COD from FSTPs



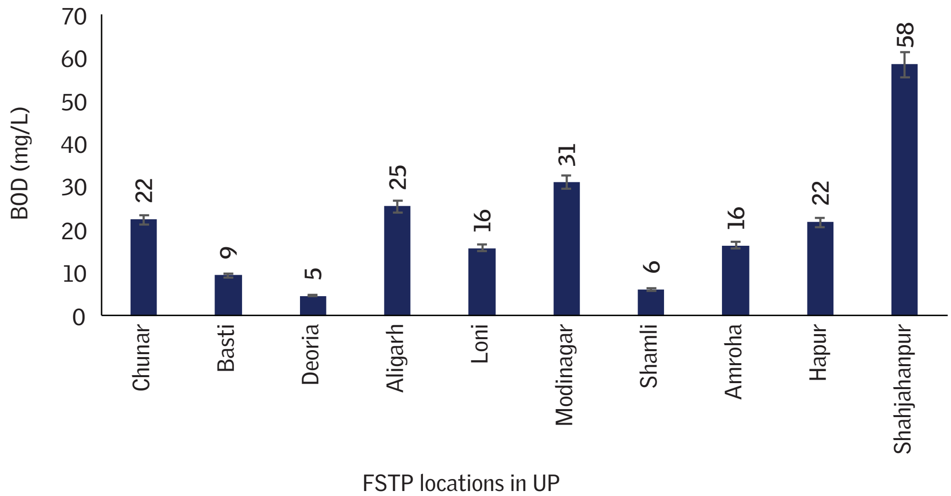
Biochemical oxygen demand (BOD): The BOD of the outlet from FSTP is provided in *Graph 13*; % removal of BOD is represented in *Graph 14*.

The outlet BOD from FSTPs was in the range of 5 to 58 mg/L. According to the NGT, the BOD norm is 10 mg/L for all cities; the MoEF&CC standards put the BOD at 20 mg/L for metros and state capitals and 30 mg/L for other cities (Annexure 1). All the 10 FSTPs in this study come under the category of 'other cities'. Out of the 10, three FSTPs had BOD values within the 10 mg/L (NGT) limit, whereas eight had values within 30 mg/L (MoEF&CC).

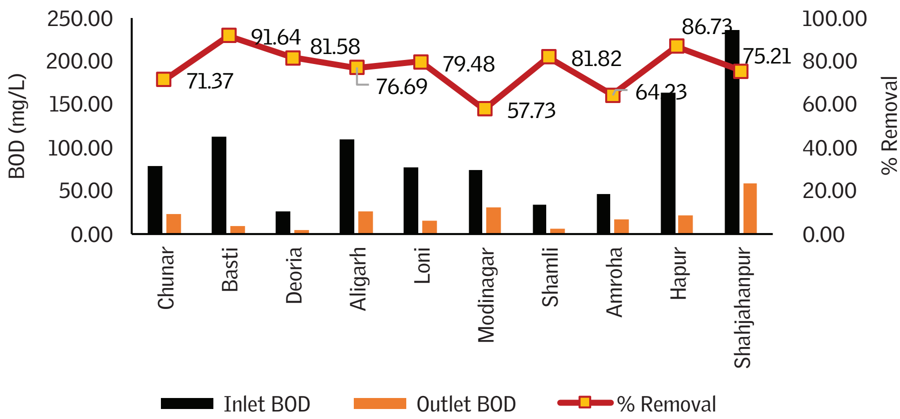
The % removal of BOD from FSTPs varied from 57.73 to 91.64 per cent. The lowest removal was observed in Modinagar; the highest in Basti. The Chunar FSTP's outlet BOD in the previous and present study were 20 and 22 mg/L, respectively, both of which are within the discharge limit of 30 mg/L. Similarly, for Modinagar, the BOD for the previous and current study were 11.5 and 31 mg/L.

A comparative performance analysis indicates that the Modinagar FSTP has demonstrated a lower performance than during the previous study. The BOD value of the Loni FSTP was above the regulatory limits in the previous study, but it is within the limits in the current study, indicating its performance improvement.

Graph 13: BOD of outlet water from the FSTPs

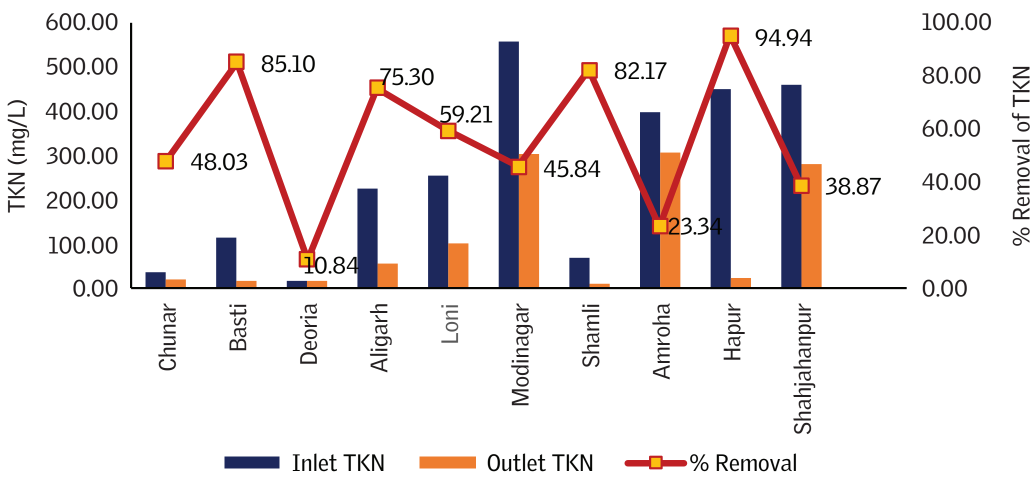


Graph 14: Inlet and outlet BOD and % removal of BOD from FSTPs



Kjeldahl nitrogen (TKN): The TKN present in the inlet and outlet of a treatment plant is represented in *Graph 15*. Inlet TKN varied from 19.01 mg/L in Deoria to 557.33 mg/L in Modinagar, and outlet TKN varied from 12.44 mg/L in Shamli to 305.86 mg/L in Amroha. The lowest % removal was observed for the Deoria FSTP (10.84 per cent); the highest, in Hapur FSTP (94.94 per cent). Out of the 10 FSTPs evaluated, five have demonstrated more than 50 per cent TKN removal.

Graph 15: Inlet and outlet TKN and % removal of TKN from FSTPs



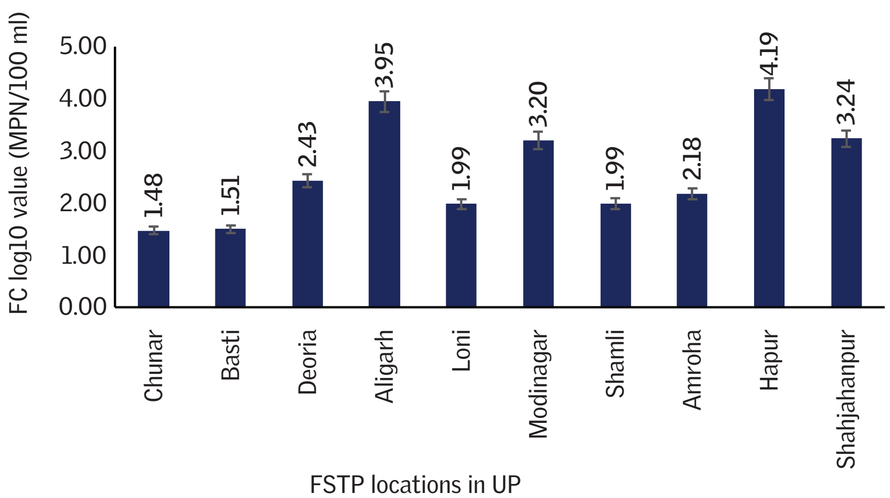
Faecal coliforms present in outlet water has been shown in *Graph 16*. According to the MoEF&CC standards, faecal coliforms must be below 1,000 MPN/100 ml (log10 1,000=3). As per the NGT, the desirable limit is 100 MPN/100 ml (log10 100=2) and the permissible limit is 230 MPN/100 ml (log10 230=2.36). Of the 10 FSTPs evalauted, five are meeting the permissible limit set by the NGT. MoEF&CC standards are being met by six plants.

The highest faecal coliform value was observed in the Hapur FSTP, with MPN of 15,374 (log 15,374=4.19). The high number of faecal coliforms might be due to the inefficiency of the disinfection process. In Hapur FSTP, disinfection in done by hypochlorination. Chlorine dosage must be optimized according to the fluctuating incoming sludge and sufficient contact time must be given for ensuring a proper disinfection process.

The Chunar FSTP was observed to have the lowest number of faecal coliforms with a MPN of 30 (log 30=1.48). This indicates that the tertiary treatment stages in Chunar are very efficient. A filtration step followed by disinfection via UV light is the final treatment stage in Chunar. However, in the previous study of Chunar's FSTP, it was noticed that FC was higher than the regulatory limit.[5] In the current study, Chunar shows the least FC value, indicating substantive imrpovement in the maintanence of tertiary treatment stages.

Both Loni and Modinagar FSTPs have shown values within the regulatory limits in the previous study; but in the current study, Loni is meeting the limits set by both NGT and the ministry, while Modinagar is not meeting either.

Graph 16: Faecal coliforms in the outlet water from the FSTPs



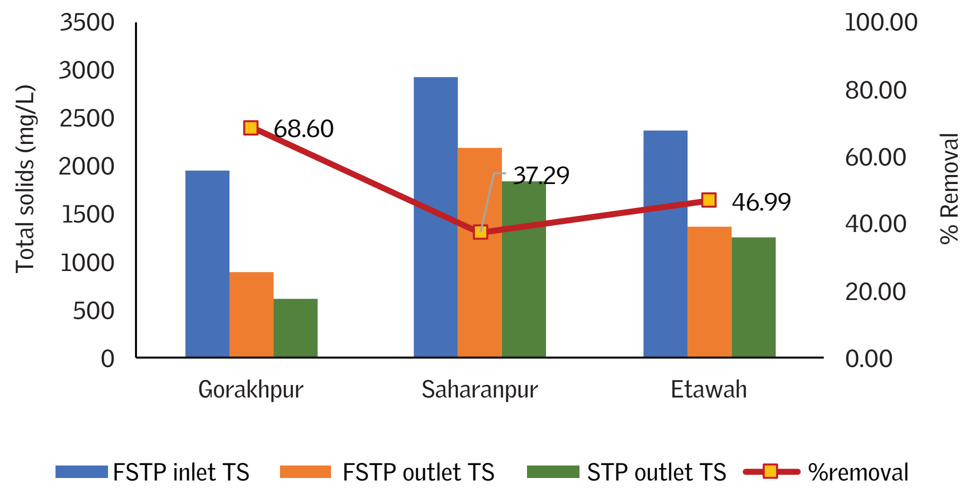
Performance of STP co-treatment plants

For the evaluation of STP co-treatment systems, samples were collected from the inlets and outlets of FSTPs, and the STP outlets (as the STP outlet discharges the final treated water).

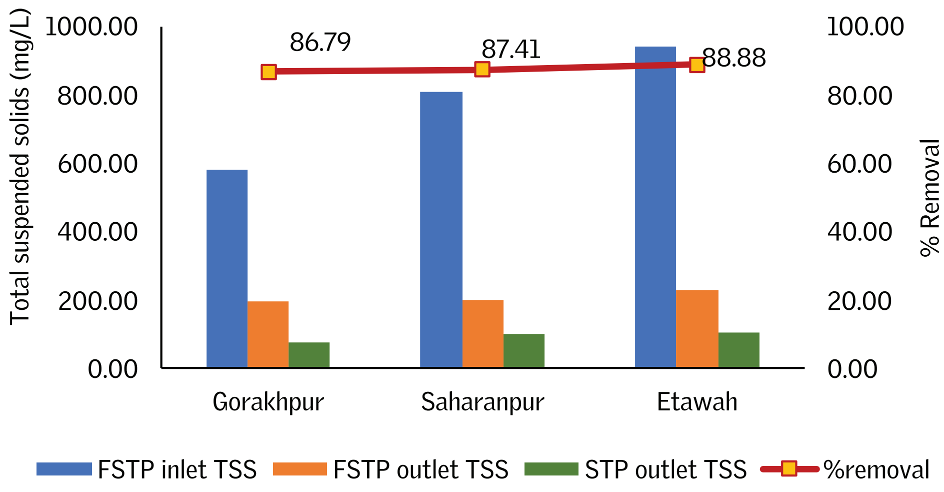
Total solids (TS): *Graph 17* represents the data on FSTP inlet TS, FSTP outlet TS, STP outlet TS and % removal of TS. The highest % removal was achieved in Gorakhpur (68.60 per cent) followed by Etawah (46.99 per cent) and Saharanpur (37.29 per cent). Removal efficiency of Etawah and Saharanpur plants was less than 50 per cent, which is very less. Apart from this, it can be observed that there was not much difference between FSTP outlet TS and STP outlet TS – this means there was little TS removal in the STP treatment stages.

Total suspended solids (TSS): FSTP inlet TSS, FSTP outlet TSS, STP outlet TSS and % removal of TSS has been represented in *Graph 18*. The % removal of TSS is more or less same in all the treatment plants. More than 85 per cent removal has been achieved in all the three evaluated locations. There is considerable reduction of TSS in the FSTP itself in all the locations, which is evident from the results of the FSTP inlet and outlet TSS graph. Further reduction of TSS has occurred in STPs.

Graph 17: FSTP inlet and outlet TS, STP outlet TS, and % removal

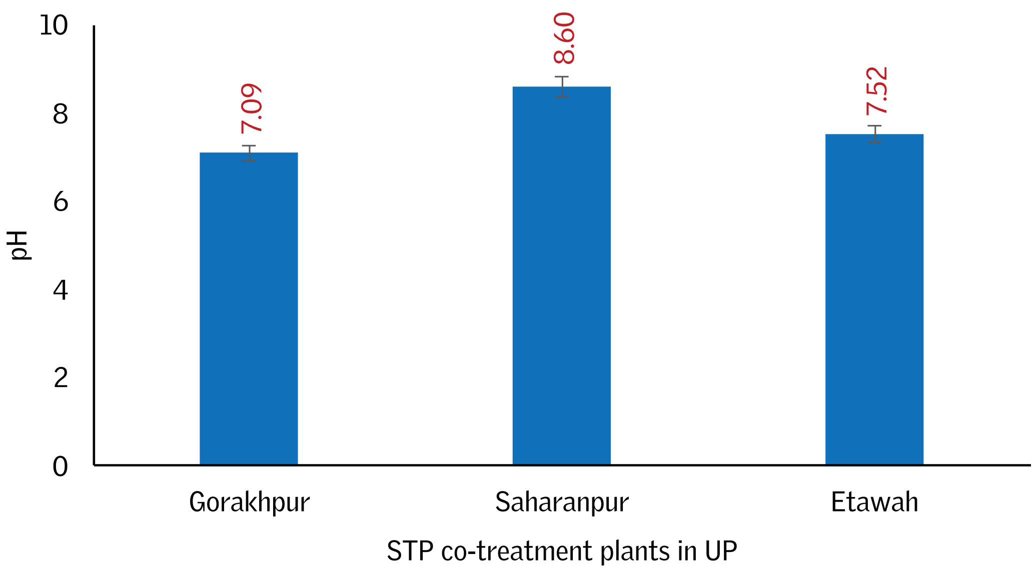


Graph 18: FSTP inlet and outlet TSS, STP outlet TSS, and % removal



pH: The average pH of treated water from STP co-treatment plants is in the range of 7.09 to 8.60 (*Graph 19*)**.** All the three evaluated STP co-treatment systems had pH value within the discharge limit (pH 5.5-9) set by both NGT and the MoEF&CC.

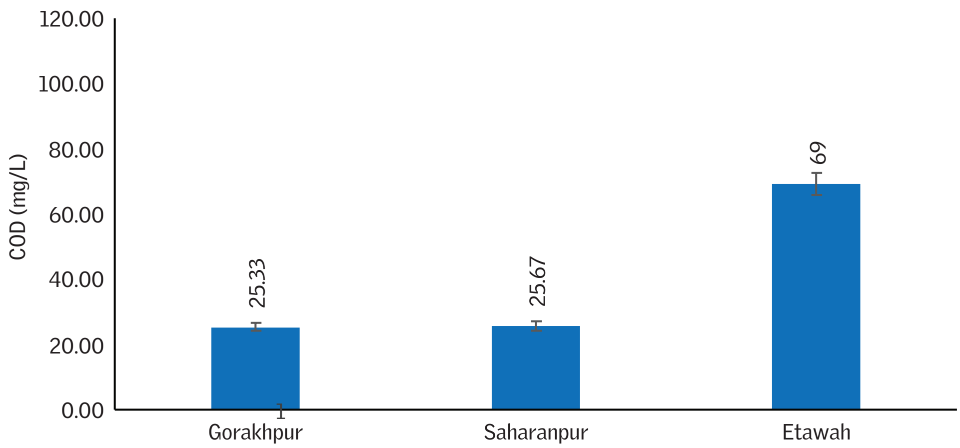
Graph 19: pH of STP outlet water



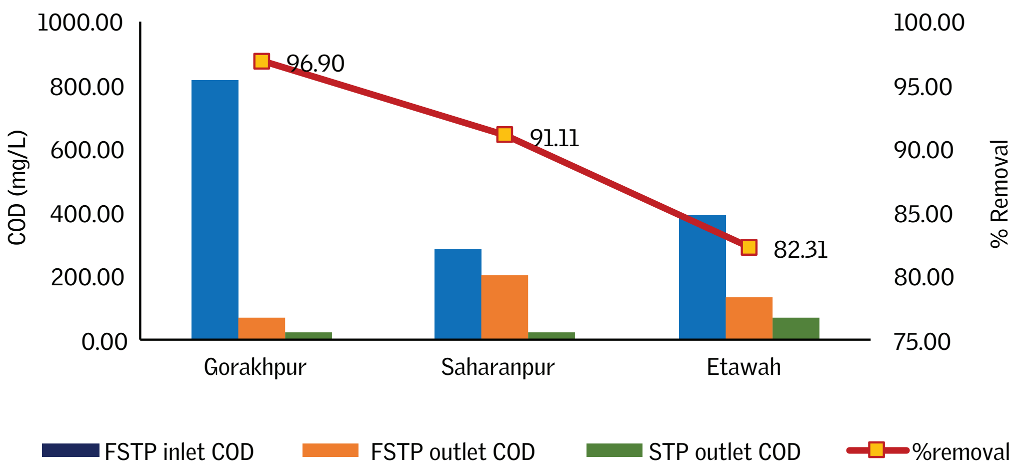
Chemical oxygen demand (COD): *Graph 20* represents the values of COD of the outlet water from STP co-treatment plants. The COD of outlet has varied from 25.33 to 69 mg/L. The lowest value of 25.33 mg/L was observed in the Gorakhpur co-treatment plant, whereas the highest was observed for the Etawah co-treatment plant.

Graph 21 indicates that there is a significant reduction of COD in the STP outlet water when compared to the inlet. This can be due to primary treatment in the FSTP to reduce the COD to a certain level, followed by further treatment in the STP. The % removal varied from 82.31 per cent to 96.90 per cent – this indicates that STP co-treatment plants can achieve more than 80 per cent removal of COD.

Graph 20: COD of outlet water from the STP co-treatment plants



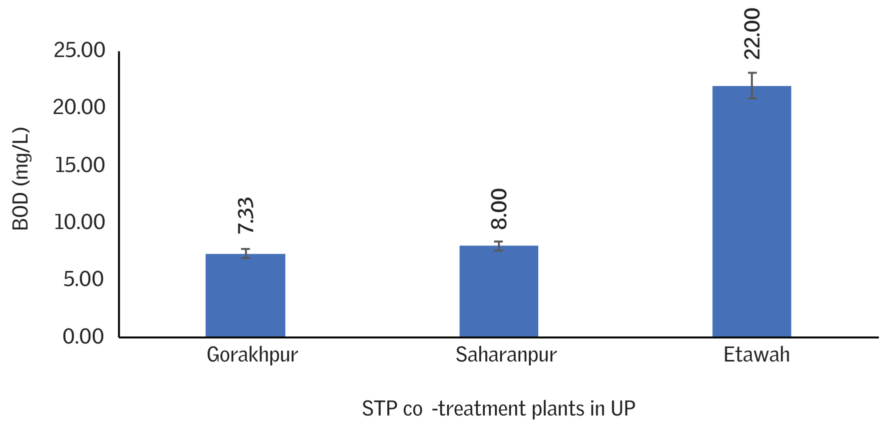
Graph 21: FSTP inlet and outlet COD, STP outlet COD, and % removal



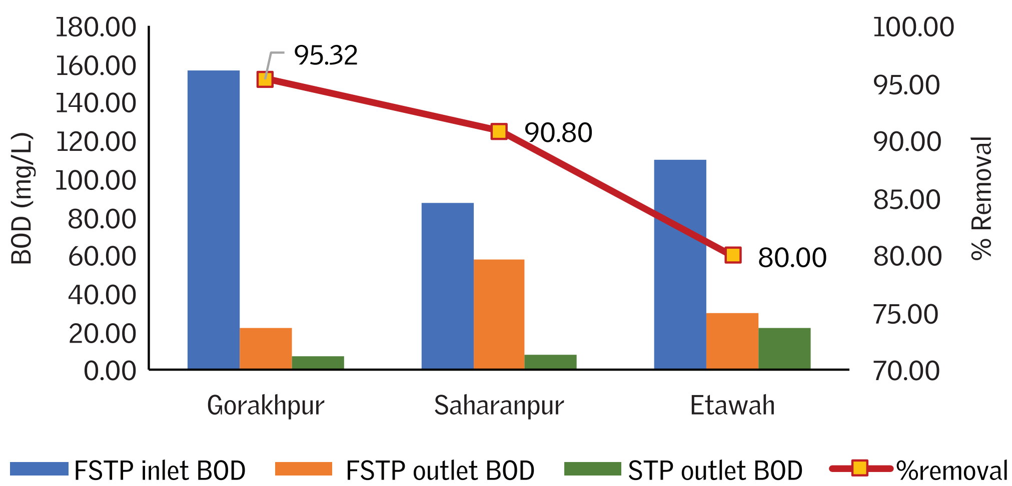
Biochemical oxygen demand (BOD): *Graph 22* represents the outlet BOD of STP co-treatment plants in UP; *Graph 23* points to % removal of BOD. The BOD of outlets has been in the range of 7.33 to 22 mg/L. The lowest was observed for Gorakhpur and the highest for Etawah. Removal of 95.32 per cent has been observed for the Gorakhpur plant; the Etawah plant managed to remove 80 per cent. The Gorakhpur and Saharanpur plants discharged outlet water with BOD value of less than 10 mg/L (limit set by the NGT). All the three STP co-treatment plants demonstrated outlet BOD values within the limit of 30 mg/L (limit set by the MoEF&CC).

The Gorakhpur and Saharanpur plants discharge outlet water with BOD value well below the standards; however, the Etawah plant had an outlet BOD value that is slightly higher than the regulatory limits.

Graph 22: BOD of STP outlet water



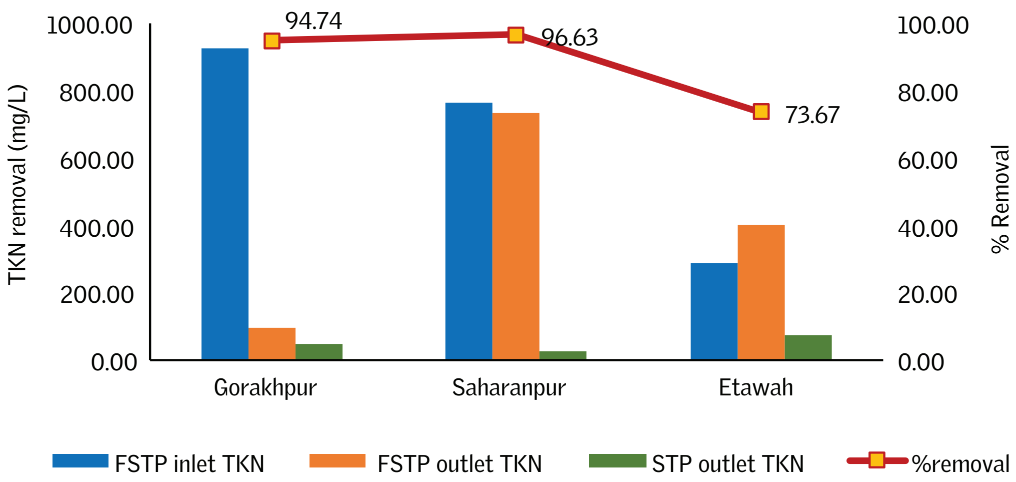
Graph 23: FSTP inlet and outlet BOD, STP outlet BOD, and % removal



Total Kjeldahl nitrogen (TKN): *Graph 24* represents the data on FSTP inlet and outlet TKN, STP outlet TKN and % removal of TKN.

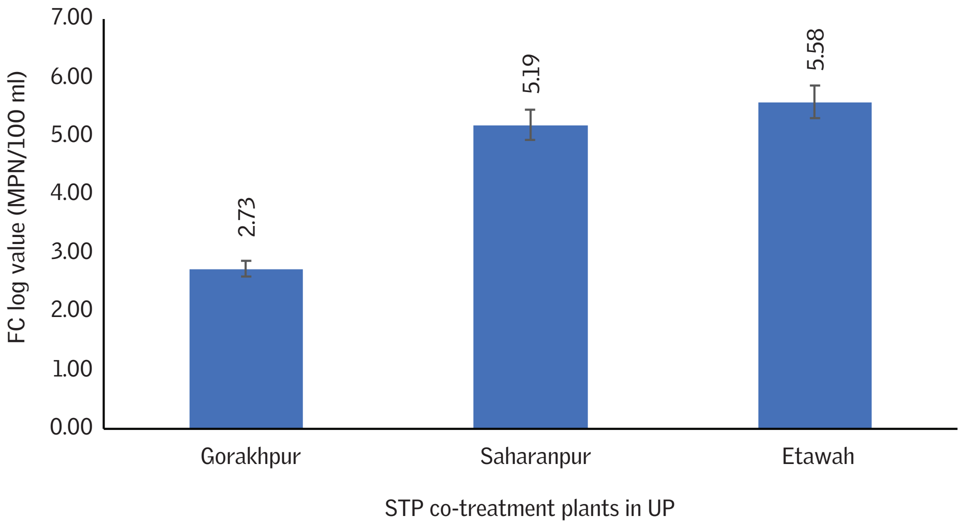
Outlet TKN has been observed to be in the range of 48.71 to 75.75 mg/L. The highest % removal was achieved in Saharanpur (96.63 per cent), followed by Gorakhpur (94.74 per cent) and Etawah (73.67 per cent). This indicates that TKN removal is very efficient in STP co-treatment plants as more than 70 per cent reduction has been achieved. The high removal efficiency of the Saharanpur co-treatment plant points to the fact that aerated lagoons and the extended aeration system in the plant is effective. The other two treatment plants, which have adopted the sequential batch reactor process, have also succeeded in TKN removal.

Graph 24: FSTP inlet and outlet TKN, STP outlet TKN, and % removal



Faecal coliforms (FC): The log values of faecal coliforms are depicted in *Graph 25*. All the three evaluated STP co-treatment plants were unable to achieve the permissible limit set by the NGT for faecal coliforms in outlet water. If we consider the MoEF&CC norms, only the Gorakhpur plant with a value of 534 MPN/100 ml came within the limit of 1,000 MPN/100 ml (log10 1000=3); the Saharanpur and Etawah plants had values higher than the limit. This is an indication of the poor disinfection technology and lack of proper optimization of disinfection process parameters.

Graph 25: Faecal coliforms in the STP outlet water



Biosolids evaluation

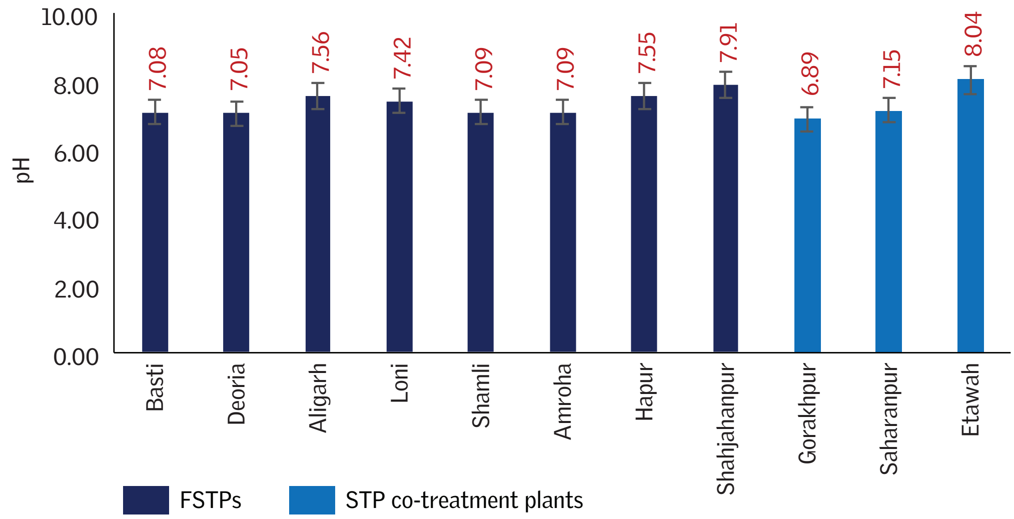
Biosolids were collected from eight FSTPs (Basti, Deoria, Aligarh, Loni, Shamli, Amroha, Hapur and Shahjahanpur) and three STP co-treatment plants (Gorakhpur, Saharanpur and Etawah).

In Aligarh, vermi-composted sun-dried biosolids were collected from the storage yard; from all the other locations, the biosolids were collected from the drying beds. Biosolids were not collected from the Chunar and Modinagar FSTPs as they (biosolids) had not been removed during the sampling period from January to May 2024. This is because biosolids (dried sludge) are removed from the planted drying beds (solid liquid separation stage in Chunar) only once in one or two years.

In the Modinagar FSTP, the sludge accumulation rate is very less as sludge degradation occurs in the anaerobic chamber. Hence, the sludge is removed once in a year during cleaning and maintenance of the chamber.

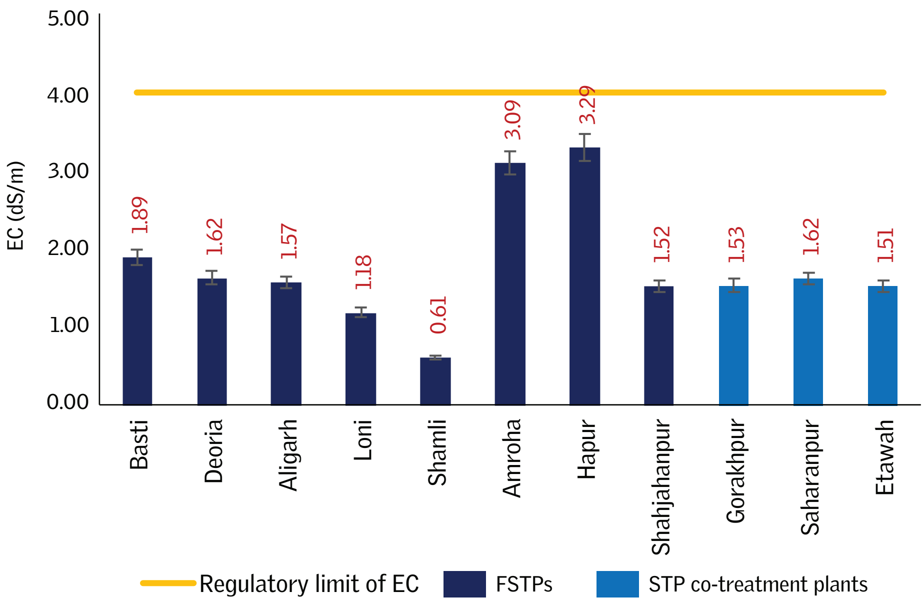
pH: According to FCO 2023, the pH of organic manure has to be between 6 and 8.5. *Graph 26* shows that pH of the biosolids collected from FSTPs and STP co-treatment plants fell between 6.89 and 8.04. From this, it can be inferred that the pH is within the range of the FCO standards.

Graph 26: pH of biosolids from FSTPs and STP co-treatment plants



Electrical conductivity (EC): Electrical conductivity of biosolids is shown in *Graph 27***.** The recommended value for EC is below 4 dS/m. The EC value of biosolids collected from different locations in UP ranged from 0.61 to 3.29 ds/m. From the results, it is inferred that the EC value of biosolid samples collected from all the locations was below the recommended value.

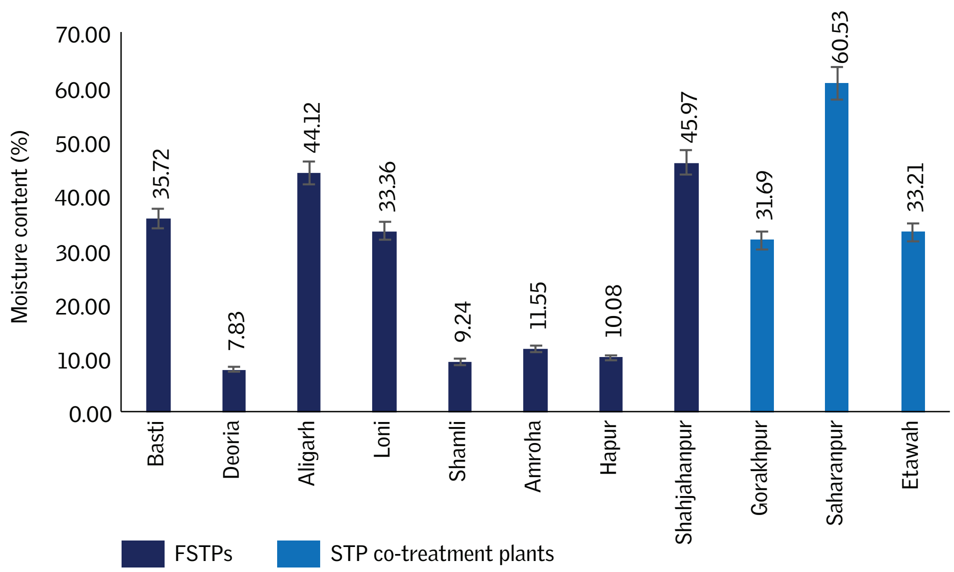
Graph 27: EC of biosolids from FSTPs and STP co-treatment plants



Moisture content: Moisture content of biosolids is a critical parameter as it influences microbial growth. Moisture content measured in terms of % by weight is represented in *Graph 28***.** The value has varied from 7.83 per cent in Deoria to 60.53 per cent in Saharanpur. Moisture content depends upon the drying time and drying conditions. In all the evaluated FSTPs, sun drying was adopted for removing the moisture content.

To use biosolids as organic manure, it is recommended to have a moisture content below 25 per cent. From the results, it can be observed that only four locations had moisture content below this figure. It is important to provide sufficient time for sun drying to reduce the moisture content.

Graph 28: Moisture content of biosolids from FSTPs and STP co-treatment plants

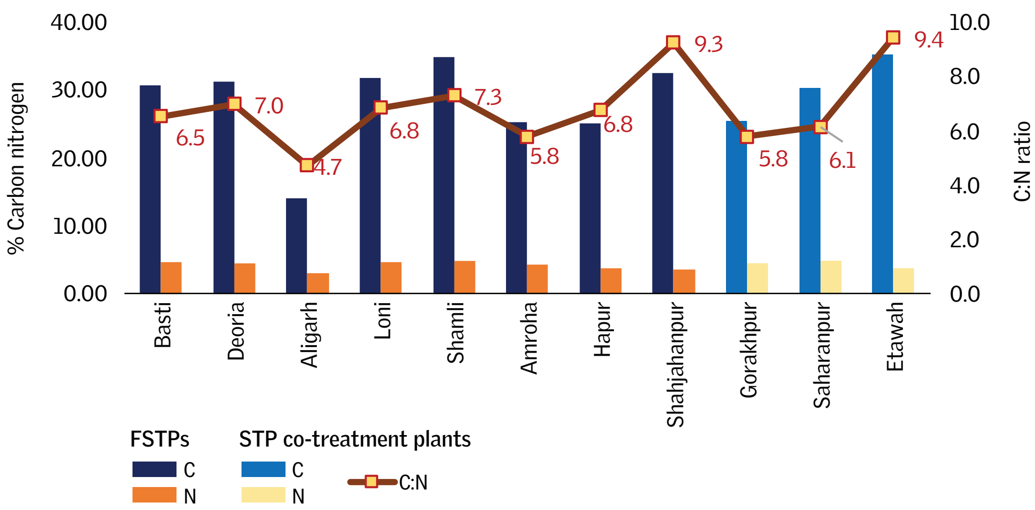


Carbon nitrogen (C:N) ratio: The organic matter or content of biosolids is one of the important parameters that needs to be considered when applied to soil for agricultural applications. This organic content influences the diversity of soil biota and can affect crop yield.

The total organic carbon of biosolids was observed to be in the range of 14 per cent to 35.25 per cent by weight (*Graph 29*). The total nitrogen was in the range of 2.96 per cent to 4.92 per cent by weight. The C:N ratio of the evaluated biosolids was in the range of 4.7 to 9.4. According to the FCO limit, C:N ratio must be below 20.

A higher C:N ratio (>20) indicates high amount of carbon in biosolids, which promotes immobilization of nitrogen; low C:N ratio indicates higher mineralization of nitrogen for plant uptake. There should be an equilibrium between the mineralization and immobilization processes for proper utilization of carbon and nitrogen by plants and microbes. Hence, to maintain an equilibrium between these processes, the C:N ratio should be between 15:1 to 20:1.

Graph 29: Carbon and nitrogen of biosolids from FSTPs and STP co-treatment plants



Heavy metals: The application of sewage sludge or biosolids on soil has been widespread in agriculture – but this use should not increase the heavy metal content in the soil. The CSE study analyzed biosolids for arsenic, mercury, cadmium, chromium, lead, zinc, copper and nickel – as indicated in *Table 5*. Arsenic, cadmium, lead and nickel were found to be within limits (FCO, 2023) in all the locations. But in a majority of the locations, mercury, chromium, zinc and copper were observed to be above the limits. The source of heavy metals in biosolids can be from toilet cleaners, detergents and non-faecal matter disposed of in toilets.

Table 5: Heavy metal content in biosolids collected from FSTPs and STP co-treatment plants

Locations	Arsenic (mg/kg) max. 10.001	Mercury (mg/kg) max 0.15	Cadmium (mg/kg) max. 5	Chromium (mg/kg) max. 50	Lead (mg/kg) max. 100	Zinc (mg/kg) max. 1000	Copper (mg/kg) max. 300	Nickel (mg/kg) max. 50
Basti	0.71	0.46	1.68	34.57	33.30	1512.67	254.33	22.37
Deoria	0.67	0.68	2.65	43.00	41.73	1853.33	308.67	28.03
Aligarh	1.61	0.22	0.92	51.20	26.03	487.67	87.57	21.73
Loni	0.20	0.42	1.51	28.75	34.55	871.00	191.50	17.10
Shamli	1.85	4.51	2.57	53.17	62.43	3220.00	522.67	40.30
Amroha	1.17	0.29	1.92	42.63	66.57	1955.67	225.33	23.57
Hapur	0.60	0.35	3.62	99.80	91.47	1503.67	830.67	28.50
Shahjahanpur	1.18	1.40	1.72	25.30	30.47	1770.00	217.67	21.97
Gorakhpur	1.10	1.35	2.23	40.15	41.35	1205.00	210.00	23.70
Saharanpur	1.95	1.17	1.72	34.43	39.17	1456.00	183.33	20.97
Etawah	1.54	1.99	1.82	37.00	28.20	1862.33	190.67	23.60

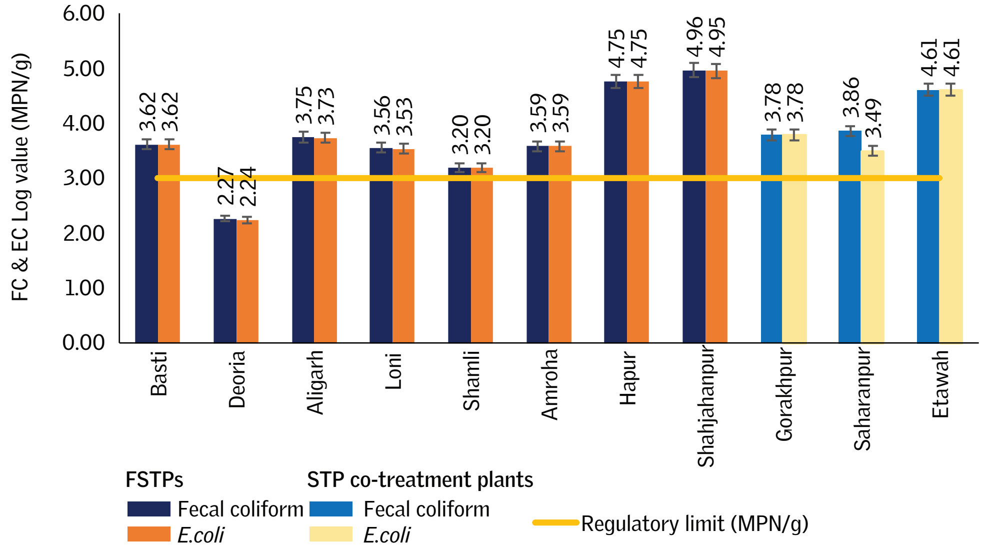
Faecal coliform and *E. coli*: To assess the pathogen content of biosolids, indicator microorganisms were enumerated. Faecal coliforms and *E. coli* are the microbial indicators which point to the presence of other pathogens. The most probable number of microbes per gram of biosolids was enumerated: their log value has been presented in *Graph 30*.

According to the US EPA/WHO standards for land application of biosolids, the number of faecal coliforms and *E. coli* must be below 1,000 MPN/g (log 1,000=3). Except Deoria, biosolids collected from all the other locations in UP showed values above the regulatory limit. This indicates that adequate drying and storage is not happening. Moisture content and the number of microbes is correlated as moisture content accelerates the growth of microbes; sufficient drying should be provided to biosolids to reduce the growth of microbes.

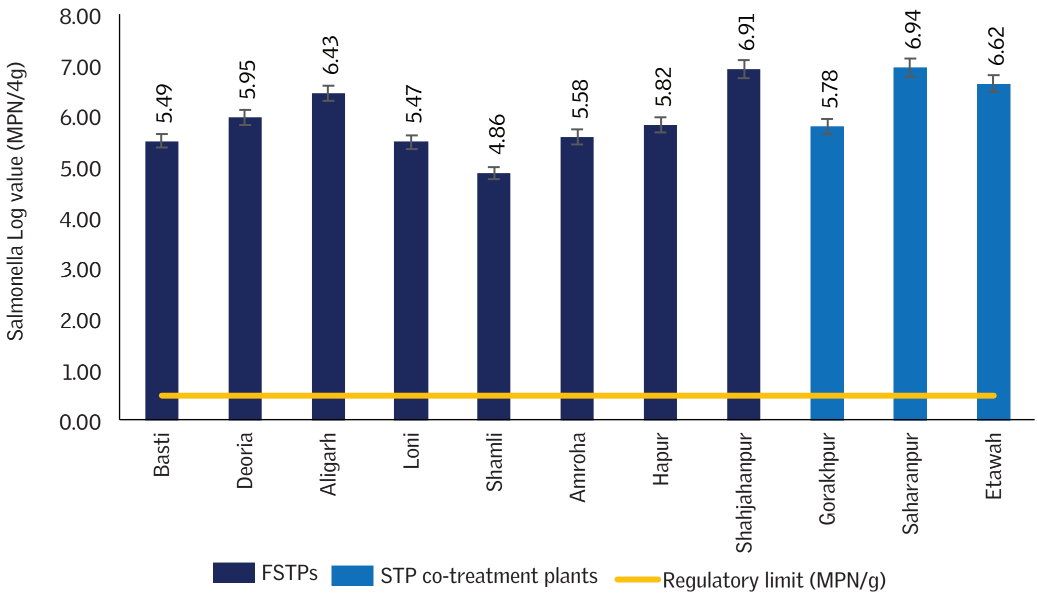
Salmonella: *Salmonella* is another group of bacteria that can cause salmonellosis. For land application of Class A biosolids, *salmonella* must be below 3 MPN/4g (log 3=0.48). *Graph 31* shows the *salmonella* in biosolids collected from all the locations – the number was significantly above the USEPA standard.

Salmonella can be reduced in biosolids by adequate heat treatment or by adopting any disinfection techniques such as lime treatment, and pasteurization.[14]

Graph 30: Faecal coliforms and *E. coli* in biosolids from FSTPs and STP co-treatment plants



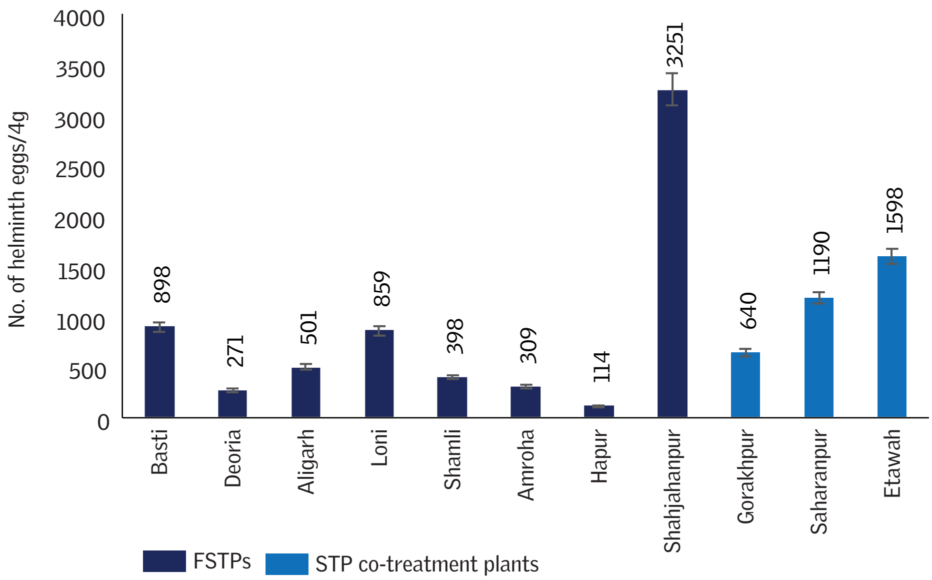
Graph 31: *Salmonella* in biosolids from FSTPs and STP co-treatment plants



Helminth eggs: The concentration of helminth ova in raw septage (1 litre) and sludge (4 gram dry weight) can be as high as 10^3–10^4 depending upon the rate of infection in the community. Due to the high settling velocity of helminth ova, their concentration in sludge should be higher than in wastewater.

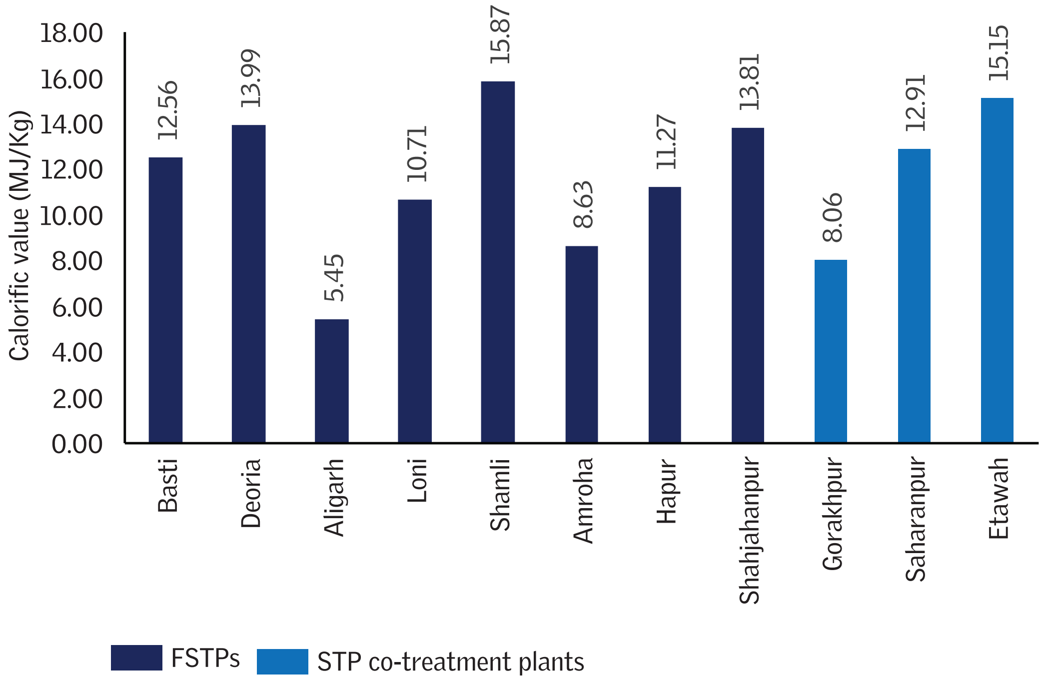
Helminth eggs were detected in most of the dried biosolid samples from FSTPs and co-STPs (*Graph 32*). According to USEPA, the regulatory limit for helminth eggs in biosolids is <1egg/4 g. Helminth eggs were present in significant numbers in the samples collected by CSE. The range varied from 114 eggs/4 g in Hapur to 3,251 eggs/4 g in Shahjahanpur. Helminth eggs are difficult to elminiate from sludge, but the number can be reduced to a great extent when they are subjected to sun drying for long periods. It is advisable to crush the biosolid sample collected from the drying bed to reduce the size of particles. This will ensure adequate and sufficient drying when exposed to sunlight as smaller particles have higher surface area than bulk materials. Apart from that, lime treatment and pasteurization techniques are known to reduce helminth eggs in biosolids.[15]

Graph 32: Helminth eggs in biosolids from FSTPs and STP co-treatment plants



Calorific value: Calorific value of the biosolids was determined to understand the energy content contained within the biosolid (*Graph 33*). The calorific value of the biosolids collected from UP ranged from 5.45 to 15.87 MJ/kg. Calorific value of wood pellets was reported to be 15-19 MJ/kg, whereas that of non-renewable sources such as coal and kerosene were 20 and 40 MJ/kg, respectively.[16] This indicates that biosolids with calorific value lower than 15 MJ/kg cannot be directly used as a solid fuel; rather, they can be co-processed with other biomass-based fuel for application in industries.

Graph 33: Calorific value of biosolids from FSTPs and STP co-treatment plants



The findings: A summary

FSTPs

Among the 10 FSTPs, all except the Chunar and Aligarh plants adopted the screw press system for solid-liquid separation and the drying bed for drying biosolid samples. Chunar adopted planted drying bed for solid-liquid separation and drying, whereas Aligarh adopted the tiger biofilter technology for solid-liquid separation and sun drying.

For treatment of leachates after solid-liquid separation, Basti and Deoria adopted constructed wetlands; Shamli, Amroha and Hapur went for anaerobic baffled reactor and constructed wetlands; Loni and Shahjahanpur opted for sequential batch reactor.

The faecal sludge collected from tankers at all the locations was characterized. The pH was found to be in the range of 6.23 to 8.18; TS varied from 11,924 to 1,18,342 mg/L; TSS ranged from 10,484 to 1,16,949 mg/L; COD was in the range of 46,325 to 88,233 mg/L; BOD varied from 5,745 to 13,346 mg/L; TKN was in the range of 496.86 to 6,700.26 mg/L; and FC was in the range of 92 to 24,000,000 MPN/100 ml.

In the evaluated FSTPs, pH of outlet water was in the range of 7.06-8.43. The % removal of TS varied from 22.43 to 84.38 per cent, whereas TSS removal % was in the range of 43.39 to 97.67 per cent.

The COD of outlet water ranged from 16.67 to 188 mg/L. Out of the evaluated 10 FSTPs, four had COD values within 50 mg/L (regulatory limit set by NGT) in the outlet water. COD removal efficiency of all FSTPs has been observed to be above 60 per cent.

The outlet BOD was in the range of 5-58 mg/L. Out of the 10 FSTPs evalauted, three had BOD values within 10 mg/L (NGT), while eight FSTPs had BOD values within 30 mg/L (MoEF&CC) in the outlet water. The % removal of BOD was in the range of 57.73 to 91.64 per cent.

The TKN of outlet from the FTSPs varied from 12.44 to 305.86 mg/L. More than 50 per cent TKN removal was achieved for five out of the 10 plants.

Faecal coliforms in the outlet water from the FTSPs varied from 30 in Chunar to 15,374 MPN/100 ml in Hapur. Amongst the 10 FSTPs evaluated, five were meeting the permissible limit set by the NGT. If the MoEF&CC standards are compared, six out of the 10 met the standard limits.

STP co-treatment plants

All the three STP co-treatment plants – in Gorakhpur, Saharanpur and Etawah – have adopted screw press for solid-liquid separation and drying bed for drying the sludge. A small capacity FSTP equipped with anaerobic baffled reactor and planted gravel filter has been adopted for the initial treatment of leachate in all the three locations. The outlet from the planted gravel filter is pumped to the STP; in Gorakhpur and Etawah, further treatment is done using sequential batch reactor, while Saharanpur uses the up flow anaerobic sludge blanket process.

In the three plants, pH of outlet water has been in the range of 7.09-8.60. The % removal of TS varied from 37.29 to 68.60 per cent, whereas TSS removal % was in the range of 86.79 to 88.88 per cent.

The COD of the outlet water ranged from 25.33 to 69 mg/L. Of the three evaluated STP co-treatment plants, two have shown outlet COD value below 50 mg/L, which is the limit set by the NGT. BOD of outlet water from the plants ranges from 7.33 to 22 mg/L. Of the three plants, two have outlet BOD values less than 10 mg/L (limit set by the NGT). All the three STP co-treatment plants have outlet BOD values within the limit of 30 mg/L (as set by MoEFF&CC for other cities).

The outlet TKN was in the range of 48.71 to 75.75 mg/L. More than 60 per cent TKN reduction was achieved in all the plants.

If the MoEF&CC norms are considered, faecal coliforms in the outlet water have been found to be higher than the regulatory limit (1,000 MPN/100 ml) in Saharanpur and Etawah; it was within the limit in Gorakhpur. However, if the NGT norms (230 MPN/100 ml) are considered, none of the evaluated STP co-treatment plants adhere to the limits set for faecal coliforms.

Performance on other parameters

pH of the biosolids collected from FSTPs and STP co-treatment plants was between 6.89 and 8.04; the EC value ranged from 0.61 to 3.29 ds/m. pH and EC of the biosolids collected from all the evaluated locations was found to be within the limit set by FCO, 2023. The moisture content of biosolids ranged from 7.83 to 60.53 per cent. Only four of the locations met the FCO moisture content norm of less than 25 per cent.

The C:N ratio of the evaluated biosolids was in the range of 4.7 to 9.4. However, for use in agricultural applications, the ratio needs to be between 15:1 and 20:1.

In all the evaluated locations, arsenic, cadmium, lead and nickel were found to be below the recommended value set by FCO, 2023 – but levels of mercury, chromium, zinc and copper were above the recommended limits in many of the locations.

Biosolids collected from all the locations except Deoria showed faecal coliforms above the regulatory limit set by the USEPA. This is an indication of inadequate drying of biosolids.

Both *salmonella* and helminth eggs numbers were significantly higher than the regulatory limit set by the USEPA for class A biosolids. This shows that post-disinfection treatment is essential for eliminating the pathogens from biosolids.

Calorific value of the analyzed biosolids ranged from 5.45 to 15.87 MJ/kg.

Recommendations

- **Monitor incoming sludge:** Amount of polymers added to the sludge, pH of the sludge, and mixing ratio must be optimized based on the incoming sludge load and its pH. Solid-liquid separation is a critical step in FS treatment. Effective sludge agglomeration has an optimum pH window. If the pH swings to either side of this window, polymer will be wasted or would become ineffective. Failure in proper mixing can lead to higher amounts of total solids and total suspended solids in the leachate. Hence, the incoming sludge load and its pH has to be regularly monitored.

- **Take steps to reduce TSS:** Total suspended solids can be reduced by increasing the retention time of the leachate in each of the treatment stages; TSS removal occurs in the filtration step as well. Hence, the filtration set-up needs to be checked regularly for any clogging in the filters. Based on the condition of the filters, their cleaning and replacement must be carried out once in three months.

- **Reduce BOD levels:** The first step in reducing BOD is to bring down the TSS levels as they are closely related. Another way to reduce BOD is to increase aeration as the microbes depend on oxygen for the consumption of organic matter.

- **Monitor tertiary treatment:** The tertiary treatment sytem must be monitored routinely to check the disinfection efficiency in all the FSTPs and STP co-treatment plants in order to maintain the faecal coliform value within the regulatory limit. Chlorine dosing must be optimized if hypochlorination is the tertiary treatment. Ozone generator must be checked for its ozone generating efficiency and the ozone dosage required for treatment must be optimized.

- **Ensure proper drying of biosolids:** Inadequate drying of biosolids was found to be one of the critical concerns. In the FSTPs, the biosolids or dry sludge were lying in the drying bed as an aggregated mass of solids or hard rock material. This is due to the mixing of the polymer in the initial stage for agglomeration of sludge for proper solid-liquid separation in the screw press. This consequently puts the biosolids in that aggregated form when it is taken from screw press and placed in the drying bed. It is recommended to pulverize the aggregated mass of solids in order to reduce the size before putting it in the drying bed. This ensures proper and uniform drying of the biosolids. This will help in reducing the moisture content and microbial growth.

- **Treat the biosolids to reduce pathogens:** Biosolid treatment using lime can effectively reduce *Salmonella* and total coliforms. Lime treatment increases pH; a pH of above 12 can disrupt the cell membranes of harmful pathogens, supply high levels of ammonia, and contribute to the removal of hazardous pathogens by functioning as a biocide. The pH and temperature are important parameters when it comes to the efficiency of the urea treatment. Some bacterial pathogens such as *Salmonella* spp. and *E. coli* might only need 1 per cent urea and temperatures in the range 14–34°C for reduction. The reduction time can take just a couple of days up to months, depending on the specific conditions for bacteria. The BSF larval activity sanitises the sludge which is evident from the inactivation of bacteria such as *Salmonella* spp. and *E. coli.*

- **Reduce the helminth load in biosolids:** For reducing the helminth load from biosolids, certain techniques can be adopted. These include:

  Heat treatment: Sun drying followed by pasteurization of the biosolid at (150-160ºC) with the retention time of six hours

  Lime stabilization: Widely used in treatment of sludge when a large amount of helminth ova is involved. By adding lime (or any other alkaline material) to dewatered sludge, pH can be raised above 12 for at least two hours. Lime dose of 20-40 per cent dry weight can inactivate the helminth ova.

- **Keep heavy metals in safe limits:** Biosolids that meet regulatory standards can be beneficially used as fertilizers or soil conditioners in agriculture and land reclamation projects, as they contain valuable nutrients and organic matter. Proper management practices ensure that heavy metal concentrations remain within safe limits. To reduce the heavy metal concentration in biosolids some treatment strategies can be adopted which are commonly adopted by wastewater treatment plants. Techniques such as stabilization, extraction, and thermal treatment can help mitigate heavy metal content in biosolids.

ANNEXURES

Annexure 1

Table 1: Effluent Discharge standards for treated effluent of Sewage Treatment Plants[17]

Sl.No.	Parameters	Norms as per NGT direction dated 30/04/2019 in the matter of OA No 1069 of 2018	MoEF&CC Notification dated October, 2017	
			Cities (more than 10 lakh population)	Areas / regions other than mentioned above
1	pH	5.5-9.0	6.5-9.0	
2	BOD, mg/L	10	20	30
3	COD, mg/L	50	-	-
4	TSS, mg/L	20	50	100
5	NH4-N, mg/L	-	-	-
6	N-Total, mg/L	10	-	-
7	Faecal coliforms, MPN/100 ml	100 - Desirable 230 - Permissible	1000	

Note: Metro Cities*, all State Capitals except in the State of Arunachal Pradesh, Assam, Manipur, Meghalaya Mizoram, Nagaland, Tripura Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Union territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep

*Metro Cities are Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune

Table 2: Fertilizer Control Order standards for organic manure, 2023

S.No	Parameters	Standard
1	Moisture per cent by weight, maximum	25
2	Particle size	Minimum 90% material should pass through 4.0 mm IS sieve
3	Bulk density (g/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

continued...

Table 2: ... continued

S.No	Parameters	Standard
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.

Table 3: Global standards for pathogens in biosolids

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	WHO	Faecal sludge reuse in agriculture

Annexure 2

Table 1: Consolidated three-month data of FSTPs in UP

FSTP location	Month	Type of sample	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)
Chunar	Jan-24	FS	21200	631	20569	87350	12203	476	6700.26	1010.62	4600000
		Inlet	4000	1900	2100	254	80	10.36	51.744	2.05	230000
		Outlet	2400	1300	1100	39	12	0.58	21.168	1.31	30
	Mar-24	Inlet	1700	1270	430	214	62	6.52	45.276	0.74	230
		Outlet	1944	1820	124	70	21	0.42	26.46	0.51	30
	May-24	Inlet	2844	1310	1534	278	92	13.2	14.994	2.16	2300
		Outlet	2198	1290	908	131	34	1.24	10.584	1.59	30
		Mean FS	21200	631	20569	87350	12203	476	6700.26	1010.62	4600000
		Mean Inlet	2844.00	1493.33	1354.67	248.67	78	10.03	37.338	1.65	77510
		Mean Outlet	2180.67	1470.00	710.67	80	22	0.75	19.404	1.14	30
		% removal	23.32	1.56	47.54	67.83	71.37	92.55	48.03	31.03	NA
Basti	Jan-24	FS	7900	2050	5850	49050	6013	476	1669.92	570.11	2400000
		Inlet	500	428	72	358	113	10.36	19.992	5.63	30
		Outlet	400	353	47	28	9	0.58	16.17	3.47	36
	Mar-24	FS	28081	1320	26761	67100	7357	315	3063.48	178.48	23000
		Inlet	406	389	17	99	25	1.11	46.158	2.44	30
		Outlet	241	227	14	56	17	0.08	24.99	2.39	30
	May-24	FS	31251	1680	29571	44500	5720	85	478.338	218.83	9200
		Inlet	2761	1730	1031	832	197	21.12	283.122	213.15	23000
		Outlet	832	259	573	9	2	0.02	10.878	1.99	30
		Mean FS	22410.67	1683.33	20727.33	53550.00	6363.33	292.00	1737.25	322.47	810733
		Mean Inlet	1222.33	849.00	373.33	429.67	111.67	10.86	116.42	73.74	7687
		Mean Outlet	491.00	259.00	211.33	31.00	9.33	0.23	17.35	2.61	32
		% removal	59.83	69.49	43.39	92.79	91.64	97.91	85.10	96.45	NA
Deoria	Jan-24	FS	97700	835	96865	58850	6426	90	2234.4	195.53	24000000
		Inlet	350	249	101	34	11	0.08	19.4	2.79	360
		Outlet	300	255	45	32	10	0.05	19.1	3.87	36
	Mar-24	FS	69355	1450	67905	86800	12616	332	6479.76	323.42	2400000
		Inlet	417	243	174	99	30	0.1	23.52	2.10	30
		Outlet	327	248	79	9	2	0.08	22.932	1.36	30
	May-24	FS	12765	685	12080	44900	5185	32	343.98	30.13	1500000
		Inlet	1542	297	1245	122	35	0.56	14.112	4.72	1400
		Outlet	437	245	192	9	2	0.09	8.82	3.75	750
		Mean FS	59940	990	58950	63516.67	8075.67	151.33	3019.38	183.02	9300000
		Mean Inlet	769.67	263.00	506.67	85.00	25.33	0.25	19.01	3.20	597
		Mean Outlet	354.67	249.33	105.33	16.67	4.67	0.07	16.95	2.99	272
		% removal	53.92	5.20	79.21	80.39	81.58	70.27	10.84	6.51	NA
Aligarh	Jan-24	FS	13200	1490	11710	43850	5375	36	1202.46	1084.5072	430000
		Inlet	1100	900	200	304	96	8.94	137.886	61.61456	23000
		Outlet	1000	870	130	123	39	6.86	109.662	78.60972	24000
	Mar-24	FS	27926	1490	26436	48800	6115	108	1011.36	178.4776	460000
		Inlet	1838	1600	238	266	80	13.88	478.338	142.78208	93000
		Outlet	1187	1100	87	93	28	7.86	46.452	10.34488	2400
	May-24	Inlet	2618	1490	1128	616	150	26.88	62.328	59.3978	15000
		Outlet	1817	1620	197	32	9	6.44	11.466	4.77456	430
		Mean FS	20563	1490	19073	46325.00	5745	72	1106.91	631.49	445000
		Mean Inlet	1852	1330	522	395.33	109	16.57	226.18	87.93	43667
		Mean Outlet	1334.67	1620	138	82.67	25	7.05	55.86	31.24	8943
		% removal	27.93	NA	73.56	79.09	76.69	57.42	75.30	64.47	NA

continued...

Table 1: ... continued

FSTP location	Month	Type of sample	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)
Loni	Jan-24	FS	14100	1630	12470	84450	11798	588	5718.3	404.7008	4600000
		Inlet	1300	1020	280	396	125	9	303.702	49.28028	360
		Outlet	800	700	100	100	32	6.9	259.602	230.202	230
	Mar-24	FS	51117	1430	49687	86150	13398	426	5641.86	534.296	4600000
		Inlet	1553	1250	303	80	19	11.24	99.372	28.07896	36
		Outlet	1291	1210	81	40	14	6.46	40.866	6.76396	30
	May-24	FS	86681	3240	83441	94100	14842	402	532.14	475.1824	23000
		Inlet	4351	2940	1411	300	85	13.32	359.562	2.842	2300
		Outlet	1369	1230	139	9	1	4.93	10.584	1.421	30
		Mean FS	50632.67	2100.00	48532.67	88233.33	13346.00	472.00	3964.10	471.39	3074333
		Mean Inlet	2401.33	1736.67	664.67	258.67	76.33	11.19	254.21	26.73	899
		Mean Outlet	1153.33	1046.67	106.67	49.67	15.67	6.10	103.68	79.46	97
		%removal	51.97	39.73	83.95	80.80	79.48	45.50	59.21	NA	NA
Modinagar	Jan-24	FS	13800	3050	10750	48600	7892	83	1893.36	1552.8688	11000000
		Inlet	1000	860	140	102	32	9.14	594.174	84.23688	4300
		Outlet	800	720	80	73	23	6.84	191.394	157.27628	430
	Mar-24	FS	9880	2290	7590	41600	6968	45	1008.42	245.5488	210000
		Inlet	2503	2250	253	330	80	14.32	724.71	232.7598	460000
		Outlet	2070	1980	90	133	41	7.46	541.548	181.71748	4300
	May-24	FS	25702	2360	23342	66400	9513	200	505.68	338.198	2300
		Inlet	3850	2670	1180	366	108	11.92	353.094	168.2464	15000
		Outlet	2213	1850	363	84	29	6.92	172.578	84.6916	30
		Mean FS	16460.67	2566.67	13894.00	52200.00	8124.33	109.33	1135.82	712.21	3737433
		Mean Inlet	2451.00	1926.67	524.33	266.00	73.33	11.79	557.33	161.75	159767
		Mean Outlet	1694.33	1516.67	177.67	96.67	31.00	7.07	301.84	141.23	1587
		% removal	30.87	21.28	66.12	63.66	57.73	40.02	45.84	12.69	NA
Shamli	Jan-24	Inlet	500	452	48	30	9	1.9	13.2	3.8	360
		Outlet	200	160	40	25	8	1.2	13.5	1.8	230
	Mar-24	Inlet	588	443	145	64	15	1.52	16.758	6.36608	360
		Outlet	326	278	48	32	8	0.95	14.406	1.87572	36
	May-24	FS	91097	1020	90077	56300	7369	184	496.86	158.5836	2300
		Inlet	1816	1080	736	382	75	11.48	179.34	103.05092	9300
		Outlet	514	350	164	9	2	0.79	9.408	1.59152	30
		Mean FS	91097	1020	90077	56300.00	7369.00	184.00	496.86	158.58	2300
		Mean Inlet	968.00	658.33	309.67	158.67	33.00	4.97	69.77	37.74	3340
		Mean Outlet	346.67	262.67	84.00	22.00	6.00	0.98	12.44	1.76	99
		% removal	64.19	60.10	72.87	86.13	81.82	80.27	82.17	95.35	NA
Amroha	Jan-24	Inlet	1100	910	190	72.00	23.00	7.20	395.72	350.48	4300
		Outlet	900	825	75	48	15	7.3	204.036	194.33596	150
	Mar-24	FS	167740	1820	165920	105000	16330	932	7220.64	525.77	11000000
		Inlet	2956	2650	306	174	52	15.16	704.424	217.18564	240000
		Outlet	2475	2370	105	83	23	7.48	635.04	251.40332	150
	May-24	FS	68944	966	67978	64350	8864	236	649.74	125.6164	38000
		Inlet	2541	1050	1491	226	62	6	96.726	51.83808	7500
		Outlet	1742	1500	242	36	11	9.94	78.498	75.99508	150
		Mean FS	118342	1393	116949	64350.00	12597.00	584.00	3935.19	325.69	5519000
		Mean Inlet	2199.00	1536.67	662.33	157.33	45.67	9.45	398.96	206.50	83933
		Mean Outlet	1705.67	1565.00	140.67	55.67	16.33	8.24	305.86	173.91	150
		% removal	22.43	NA	78.76	64.62	64.23	12.83	23.34	15.78	NA

continued...

Table 1: ... continued

FSTP location	Month	Type of sample	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)
Hapur	Jan-24	Inlet	1000	841	159	200	63	9.1	206.388	133.80	920
		Outlet	800	740	60	58	18	4.38	16.464	3.01	92
	Mar-24	Inlet	1620.4	1390	230.4	254	74	11.56	306.348	75.82	360
		Outlet	1261	1180	81	193	46	5.18	33.81	3.75	46000
	May-24	Inlet	19111	1150	17961	1845	353	77.4	834.666	161.48	240000
		Outlet	1607	1320	287	4	1	2.42	17.934	4.49	30
		Mean Inlet	7243.8	1127	6116.8	766.33	163.33	32.69	449.13	123.70	80427
		Mean Outlet	1222.67	1080.00	142.67	85.00	21.67	3.99	22.74	3.75	15374
		%removal	83.12	4.17	97.67	88.91	86.73	87.78	94.94	96.97	NA
Shahjahanpur	Jan-24	FS	12300	2220	10080	50100	6141	129	2834.16	283.63	930000
		Inlet	800	680	120	368	117	17.72	715.302	176.60	430000
		Outlet	300	210	90	165	52	8.64	393.372	114.36	4300
	Mar-24	FS	44524	1310	43214	85000	10071	438	5253.78	262.60	230000
		Inlet	2165	1640	525	1052	205	30.72	272.244	165.97	240000
		Outlet	1542	1430	112	128	38	4.83	383.082	121.98	750
	May-24	Inlet	19111	1150	17961	1874	384	14.72	391.314	252.20	93000
		Outlet	1607	1320	287	271	85	9.34	66.444	35.41	150
		Mean FS	28412	1765	26647	67550	8106	283.5	4043.97	273.12	580000
		Mean Inlet	7358.67	1156.67	6202	1098	235	21.05	459.62	198.26	254333
		Mean Outlet	1149.67	986.67	163	188	58	7.60	280.97	90.58	1733
		% removal	84.38	14.70	97.37	82.88	75.21	63.89	38.87	54.31	NA

Table 2: Consolidated three-month data of STP co-treatment plants in UP

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)
Gorakhpur	Jan-24	FSTP inlet	6.31	1500	1390	110	216	68	12.92	1891.01	445.40	3600
		FSTP outlet	6.37	700	613	87	115	36	4.79	154.94	135.90	150
		STP outlet	6.65	400	340	60	50	16	1.48	41.75	25.58	1500
	Mar-24	FS	6.23	11924.4	1440	10484.4	61400	8242	26	1011.36	160.86	92
		FSTP inlet	6.49	1760	1250	510	1616	259	19.16	644.74	112.32	1500
		FSTP outlet	6.56	683	627	56	77	22	2.63	119.66	29.44	150
		STP outlet	6.29	885	787	98	17	4	0.52	85.55	20.12	30
	May-24	FSTP inlet	8.06	2581	1460	1121	618	143	16.32	241.37	164.49	23000
		FSTP outlet	8.09	1102	706	396	19	7	4.88	21.76	7.84	430
		STP outlet	8.33	751	637	114	9	2	4.27	18.82	10.91	74
		Mean FS	6.23	11924.4	1440	10484.4	61400	8242	26	1011.36	160.86	92
		Mean inlet	6.95	1947	1366.67	580.33	816.67	156.67	16.13	925.71	240.74	9366.67
		Mean FSTP outlet	7.01	895.67	702	193.67	70.33	21.67	4.1	98.78	57.73	243.33
		Mean STP outlet	7.09	611.33	534.67	76.67	25.33	7.33	2.09	48.71	18.87	534.67
		% removal	NA	68.60	60.88	86.79	96.90	95.32	87.05	94.74	92.16	NA

continued...

Table 2: ... continued

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)
Saharanpur	Jan-24	FS	7.08	23000	1410	21590	67250	8243	219	2925.30	538.27	24000000
		FSTP inlet	8.13	1600	1330	270	394	125	12.56	938.74	467.28	460000
		FSTP outlet	7.85	1300	1190	110	297	94	9.28	875.83	682.14	110000
		STP outlet	9.54	3000	2870	130	15	5	2.72	27.05	9.78	230
	Mar-24	FSTP inlet	6.69	3512	3160	352	274	78	15.32	1103.68	359.57	460000
		FSTP outlet	7.01	3115	2980	135	168	45	7.9	1096.33	373.04	93000
		STP outlet	8.78	1854	1780	74	41	13	2.97	20.29	3.07	30
	May-24	FSTP inlet	7.83	3671	1870	1801	198	58	11.56	254.60	203.37	4300
		FSTP outlet	7.76	2134	1780	354	149	35	7.34	229.32	197.46	15000
		STP outlet	7.49	654	553	101	21	6	2.88	29.99	20.41	460000
		Mean FS	7.08	23000	1410	21590	67250	8243	219	2925.30	538.27	24000000
		Mean inlet	7.55	2927.67	2120.00	807.67	288.67	87.00	13.15	765.67	343.41	308100
		Mean FSTP outlet	7.54	2183.00	1983.33	199.67	204.67	58.00	8.17	733.82	417.55	72666.67
		Mean STP outlet	8.60	1836.00	1734.33	101.67	25.67	8.00	2.86	25.77	11.08	153420
		% removal	NA	37.29	18.19	87.41	91.11	90.80	78.27	96.63	96.77	NA
Etawah	Jan-24	FS	9.44	13000	3190	9810	56150	7844	122	5656.56	810.54	230000
		FSTP inlet	8.27	1700	1040	660	712	225	9.16	200.80	42.63	36000
		STP outlet	7.67	1000	870	130	86	27	4.91	105.84	25.86	1100000
	Mar-24	FS	7.61	21009	2080	18929	59400	8071	160	2099.16	201.78	2400000
		FSTP inlet	7.29	2170	1600	570	230	50	16.88	464.81	134.14	92
		FSTP outlet	7.33	1346	1230	116	138	31	6.78	684.43	77.30	36
		STP outlet	7.02	1240	1180	60	52	16	2.6	77.32	26.83	4300
	May-24	FS	7.5	40649	1190	39459	50400	6885	392	1990.38	175.07	230000
		FSTP inlet	8.1	3230	1640	1590	228	54	7.4	197.57	138.23	230
		FSTP outlet	8.28	1775	1330	445	132	29	6.04	120.83	81.51	1500
		STP outlet	7.87	1269	1120	149	69	22	3.95	44.10	27.40	29000
		Mean FS	8.18	24886.00	2153.33	22732.67	55316.67	7600.00	224.67	3248.70	395.80	953333.33
		Mean inlet	7.89	2366.67	1426.67	940	390	110.00	11.15	287.73	105.00	12107.33
		Mean FSTP outlet	7.81	1373.67	1143.33	230.33	135	30	6.41	402.63	79.41	768
		Mean STP outlet	7.52	1254.50	1150.00	104.50	69	22.00	3.82	75.75	26.70	377766.67
		% removal	NA	46.99	19.39	88.88	82.31	80.00	65.73	73.67	74.58	NA

Table 3: Consolidated three-month data on bio-solids collected from UP

Location	Month	pH	EC (ms/cm)	Moisture (%)	Helminths (no. egg/4g)	Organic Carbon (% by weight)	Total Nitrogen (% by weight)	FC (MPN/g)	FC_Log value	EC (MPN/g)	EC_Log value	Salmonella (MPN/4g)	Salmonella Log value
Basti	Jan-24	6.53	1.52	56.22	438	32.3	3.87	7	0.84	7	0.84	109627	5.04
	Mar-24	6.82	2.70	39.88		28.9	3.76	5	0.70	5	0.70	13307	4.12
	May-24	7.88	1.44	11.05	1358	31	6.48	12367	4.09	12367	4.09	809481	5.91
	Mean	7.08	1.89	35.72	898.00	30.73	4.70	4126	3.62	4126	3.62	310805	5.49
Deoria	Jan-24	6.81	1.68	9.35	106	30.5	3.71	32	1.51	23	1.36	21179	4.33
	Mar-24	7.12	1.82	9.68		31.2	3.73	476	2.68	476	2.68	2427019	6.39
	May-24	7.22	1.37	4.46	435	31.8	5.95	45	1.65	24	1.38	234461	5.37
	Mean	7.05	1.624	7.83036455	270.5	31.17	4.46	184	2.27	174	2.24	894220	5.95
Aligarh	Jan-24	7.14	1.45	31.87	305	12.7	1.81	3523	3.55	3523	3.55	29361	4.47
	Mar-24	8.22	1.68	37.21		13.9	2.04	685	2.84	239	2.38	286660	5.46
	May-24	7.33	1.59	63.29	697	15.4	5.04	12530	4.10	12530	4.10	7845017	6.89
	Mean	7.56	1.57	44.12	501.00	14	2.96	5579	3.75	5431	3.73	2720346	6.43
Loni	Mar-24	6.81	1.72	64.48		30	3.47	6757	3.83	6757	3.83	585602	5.77
	May-24	8.03	0.64	2.24	859	33.5	5.81	471	2.67	24	1.37	8184	3.91
	Mean	7.42	1.18	33.36	859.00	31.75	4.64	3614	3.56	3390	3.53	296893	5.47
Shamli	Jan-24	6.01	0.29	15.89	285	34.3	3.9	4	0.63	4	0.63	33292	4.52
	Mar-24	7.13	0.81	9.17		34.4	3.81	10	1.01	10	1.01	162934	5.21
	May-24	8.12	0.72	2.67	510	35.7	6.59	4726	3.67	4726	3.67	20549	4.31
	Mean	7.09	0.61	9.24	397.50	34.8	4.77	1580	3.20	1580	3.20	72258	4.86
Amroha	Jan-24	5.64	2.84	20.43	231	23.3	3.51	5	0.66	4	0.58	25134	4.40
	Mar-24	7.44	5.39	9.25		24.9	3.51	3	0.52	3	0.52	925658	5.97
	May-24	8.19	1.03	4.98	387	27.5	6.07	11577	4.06	11577	4.06	189441	5.28
	Mean	7.09	3.09	11.55	309.00	25.23	4.36	3862	3.59	3861	3.59	380078	5.58
Hapur	Jan-24	6.94	6.65	12.73	119	25.7	2.81	52712	4.72	52712	4.72	595874	5.78
	Mar-24	8.01	1.82	6.52		25.4	2.87	117676	5.07	117676	5.07	1112570	6.05
	May-24	7.71	1.41	11.00	108	24.1	5.46	258	2.41	103	2.01	287625	5.46
	Mean	7.55	3.29	10.08	113.50	25.07	3.71	56882	4.75	56830	4.75	665356	5.82
Shahjanpur	Jan-24	7.73	2.12	23.33	1116	35.7	3.88	27391	4.44	19565	4.29	3078261	6.49
	Mar-24	7.51	1.39	58.84		29.7	3.45	7	0.86	7	0.86	10008773	7.00
	May-24	8.48	1.05	55.73	5385	32.2	3.22	248489	5.40	248489	5.40	11204615	7.05
	Mean	7.91	1.52	45.97	3250.50	32.53	3.52	91963	4.96	89354	4.95	8097216	6.91
Gorakhpur	Mar-24	6.67	1.78	55.93		20.8	2.85	211	2.32	211	2.32	853146	5.93
	May-24	7.11	1.27	7.46	640	30.2	5.95	11886	4.08	11886	4.08	345788	5.54
	Mean	6.89	1.53	31.69	640	25.5	4.4	6049	3.78	6049	3.78	599467	5.78
Saharanpur	Jan-24	6.51	2.12	61.99	842	31.8	3.57	245	2.39	245	2.39	21467664	7.33
	Mar-24	7.29	0.88	71.64		30.1	3.56	264	2.42	264	2.42	2397612	6.38
	May-24	7.65	1.88	47.95	1537	28.7	6.27	21133	4.32	8837	3.95	2305424	6.36
	Mean	7.15	1.62	60.53	1189.5	30.25	4.92	7214	3.86	3116	3.49	8723566	6.94
Etawah	Jan-24	7.89	0.71	68.73	2379	35.8	4.05	92745	4.97	92745	4.97	11896981	7.08
	Mar-24	8.01	2.55	18.02		34.4	3.85	29277	4.47	29277	4.47	258612	5.41
	May-24	8.23	1.27	12.89	817	34.7	3.42	26	1.42	26	1.42	293870	5.47
	Mean	8.04	1.51	33.21	1598	35.25	3.735	40683	4.61	40683	4.61	4149821	6.62

Table 4: Heavy metals in bio-solids

Locations	Replicate	Heavy Metals													
		As (mg/kg) max. 10.00	Hg (mg/kg) max 0.15	Cd (mg/kg) max. 5	Cr (mg/kg) max. 50	Pb (mg/kg) max. 100	Zn (mg/kg) max. 1000	Cu (mg/kg) max. 300	Ni (mg/kg) max. 50	Total Phosphates (asP205), percent by weight, min. 0.4	Total Potash (as K20), percent by weight, min. 0.4	Ca % by weight	Mg % by weight	Mn % by weight	Na % weight
Deoria	Jan-24	0.824	0.068	2.28	37.4	38.7	2340	283	24.8	2.75	0.934	3.10	0.674	0.046	0.069
	Mar-24	0.674	1.370	3.86	57.7	57.8	1980	439	37.5	4.12	1.319	4.60	1.00	0.068	0.081
	May-24	0.511	0.589	1.81	33.9	28.7	1240	204	21.8	2.162	0.685	2.91	0.576	0.032	0.088
	Mean value	0.670	0.676	2.650	43.000	41.733	1853.333	308.667	28.033	3.011	0.979	3.537	0.750	0.049	0.079
Basti	Jan-24	0.512	0.112	1.57	30.2	30.1	1960	240	20.3	2.95	0.620	2.84	0.693	0.047	0.044
	Mar-24	0.143	0.675	1.35	35.0	30.2	998	226	20.8	3.37	0.768	3.24	0.849	0.044	0.123
	May-24	1.489	0.597	2.12	38.5	39.6	1580	297	26.0	3.78	0.760	3.99	0.904	0.059	0.067
	Mean value	0.715	0.461	1.680	34.567	33.300	1512.667	254.333	22.367	3.366	0.716	3.357	0.815	0.050	0.078
Aligarh	Jan-24	4.448	0.024	1.12	54.1	36.3	528	51.5	28.4	1.665	1.525	3.65	1.800	0.088	0.216
	Mar-24	0.142	0.585	0.97	71.0	25.7	793	179	20.2	3.46	1.68	4.97	0.828	0.041	0.738
	May-24	0.226	0.047	0.68	28.5	16.1	142	32.2	16.6	0.918	0.757	2.42	1.04	0.050	0.235
	Mean value	1.605	0.219	0.921	51.200	26.033	487.667	87.567	21.733	2.014	1.321	3.680	1.223	0.060	0.396
Loni	Mar-24	0.118	0.507	1.16	27.4	29.1	742	160	15.7	3.25	0.432	3.60	0.689	0.040	0.222
	May-24	0.272	0.331	1.85	30.1	40.0	1000	223	18.5	3.34	0.394	3.73	0.776	0.041	0.158
	Mean value	0.195	0.419	1.505	28.750	34.550	871.000	191.500	17.100	3.298	0.413	3.665	0.733	0.041	0.190
Shamli	Jan-24	4.024	2.110	2.82	61.3	71.8	5450	652	43.5	6.18	0.805	6.51	1.06	0.081	0.053
	Mar-24	0.694	8.640	2.46	49.3	61.0	2160	551	40.0	5.50	0.651	5.77	0.864	0.070	0.045
	May-24	0.843	2.770	2.42	48.9	54.5	2050	365	37.4	4.76	0.864	5.71	1.040	0.069	0.152
	Mean value	1.854	4.507	2.567	53.167	62.433	3220.000	522.667	40.300	5.481	0.773	5.997	0.988	0.073	0.083
Shahjahan-pur	Jan-24	4.501	0.463	1.35	26.7	26.7	2030	148	16.9	2.050	0.415	3.05	0.576	0.029	0.089
	Mar-24	0.204	1.990	1.14	25.0	27.3	878	142	16.1	2.203	0.358	2.97	0.508	0.032	0.066
	May-24	1.158	1.060	2.67	51.6	63.5	1460	260	29.9	4.53	1.049	5.78	1.160	0.058	0.233
	Mean value	1.954	1.171	1.720	34.433	39.167	1456.000	183.333	20.967	2.929	0.607	3.933	0.748	0.040	0.129
Amroha	Jan-24	2.548	0.089	2.24	51.6	82.5	3590	296	27.7	9.37	1.081	6.56	1.870	0.096	0.127
	Mar-24	0.171	0.387	1.74	39.6	80.4	1450	241	22.5	6.41	0.728	4.91	1.33	0.064	0.092
	May-24	0.787	0.387	1.79	36.7	36.8	827	139	20.5	3.57	2.021	4.20	1.00	0.048	0.489
	Mean value	1.169	0.288	1.923	42.633	66.567	1955.667	225.333	23.567	6.450	1.277	5.223	1.400	0.069	0.236
Hapur	Jan-24	1.141	0.365	1.38	34.7	36.0	2650	207	19.1	7.31	0.570	7.22	0.899	0.066	0.140
	Mar-24	0.408	0.142	8.19	234	209	711	2110	46.7	1.042	1.59	7.78	1.31	0.056	0.456
	May-24	0.260	0.550	1.28	30.7	29.4	1150	175.0	19.7	4.672	0.515	5.14	0.706	0.047	0.114
	Mean value	0.603	0.352	3.617	99.800	91.467	1503.667	830.667	28.500	4.340	0.890	6.713	0.972	0.056	0.237
Etawah	Jan-24	2.746	0.266	2.40	46.6	36.8	3410	235	26.0	3.32	0.620	4.45	1.040	0.039	0.253
	Mar-24	Nil	5.03	1.24	28.8	15.0	837	146	23.5	1.99	0.160	2.50	0.257	0.047	0.087
	May-24	0.332	0.686	1.82	35.6	32.8	1340	191.0	21.3	2.290	0.530	3.43	0.859	0.030	0.244
	Mean value	1.539	1.994	1.820	37.000	28.200	1862.333	190.667	23.600	2.534	0.436	3.460	0.719	0.039	0.195

continued...

Table 4: ... continued

Locations	Replicate	Heavy Metals													
		As (mg/kg) max. 10.00	Hg (mg/kg) max 0.15	Cd (mg/kg) max. 5	Cr (mg/kg) max. 50	Pb (mg/kg) max. 100	Zn (mg/kg) max. 1000	Cu (mg/kg) max. 300	Ni (mg/kg) max. 50	Total Phosphates (asP205), percent by weight, min. 0.4	Total Potash (as K20), percent by weight, min. 0.4	Ca % by weight	Mg % by weight	Mn % by weight	Na % weight
Saharan-pur	Jan-24	2.747	0.287	1.46	21.80	31.4	2740	200	16.1	3.27	0.491	3.65	0.751	0.040	0.128
	Mar-24	0.254	3.16	2.24	31.0	20.1	1370	265	32.9	2.68	0.224	2.93	0.363	0.043	0.086
	May-24	0.533	0.761	1.45	23.1	39.9	1200	188.0	16.9	3.366	0.509	3.64	0.695	0.043	0.142
	Mean value	1.178	1.403	1.717	25.300	30.467	1770.000	217.667	21.967	3.107	0.408	3.407	0.603	0.042	0.119
Gorakhpur	Mar-24	0.374	1.970	1.67	32.5	33.6	1160	206	19.7	3.32	0.564	4.74	0.621	0.048	0.099
	May-24	1.820	0.721	2.79	47.8	49.1	1250	214	27.7	2.38	0.744	4.51	0.839	0.039	0.165
	Mean value	1.097	1.346	2.230	40.150	41.350	1205.000	210.000	23.700	2.851	0.654	4.625	0.730	0.044	0.132

References

1. Septage management for city-wide inclusive sanitation in Uttar Pradesh https://www.cseindia.org/septage-management-for-city-wide-inclusive-sanitation-in-uttar-pradesh-11364

2. https://www.cseindia.org/content/downloadreports/11712

3. Lu, Qin, Zhenli L. He, and Peter J. Stoffella. "Land application of biosolids in the USA: a review." Applied and Environmental Soil Science 2012, no. 1 (2012): 201462.

4. https://www.cseindia.org/biosolids-11713.

5. Brust, Gerald E. "Management strategies for organic vegetable fertility." In Safety and practice for organic food, pp. 193-212. Academic Press, (2019).

6. Fane, S., Andreas Nocker, Peter Vale, M. Rivas Casado, Elise Cartmell, J. Harris, Y. Bajón Fernández, and S. Tyrrel. "Characterisation and control of the biosolids storage environment: Implications for E. coli dynamics." Science of The Total Environment 752 (2021): 141705.

7. Krzyzanowski, F., Zappelini, L., Martone-Rocha, S. et al. Quantification and characterization of Salmonella spp. isolates in sewage sludge with potential usage in agriculture. BMC Microbiol 14, 263 (2014).

8. https://www.cseindia.org/biosolids-11713.

9. S. Diener, S. Semiyaga, C.B. Niwagaba, A.M. Muspratt, J.B. Gning, M. Mbéguéré, J.E. Ennin, C. Zurbrugg, L. Strande, A value proposition: Resource recovery from faecal sludge—Can it be the driver for improved sanitation?, Resour. Conserv. Recycl. 88 (2014) 32–38.

10. A.P.H. Association, A.P.H. Association, Standard methods for the examination of water and wastewater. APHA, Am. Water Work. Assoc. Water Environ. Fed. 24th Ed.; Am. Public Heal. Assoc. Washington, DC, USA (2023).

11. USEPA, Method 1680: Faecal coliforms in sewage sludge (biosolids) by multiple tube fermentation using Lauryl Tryptose Broth (LTB) and EC Medium, Environ. Regul. Technol. United States Environ. Prot. Agency (2010).

12. P. Moodley, C. Archer, D. Hawksworth, L. Leibach, Standard methods for the recovery and enumeration of helminth ova in wastewater, sludge, compost and urine-diversion waste in South Africa: report to the Water Research Commission, Water Research Commission, (2008).

13. https://www.cseindia.org/content/downloadreports/11712

14. Emma Lindberg Anna Rost, Treatment of faecal sludge from pit latrines and septic tanks using lime and urea: Pathogen die-off with respect to time of storage. Natural Resources Engineering, Master's, Luleå University of Technology Department of Civil, Environmental and Natural Resources Engineering, (2018).

15. Keller, R., R. F. Passamani-Franca, S. T. Cassini, and F. R. Goncalves. "Disinfection of sludge using lime stabilisation and pasteurisation in a small wastewater treatment plant." Water science and technology 50, no. 1 (2004): 13-17.

16. https://www.pellet-making.com/blog/wood-pellets-calorific-value.html

17. CPCB 2024, Guidelines for reuse of treated sewage in reference to item of Circular economy.

Centre for Science and Environment (CSE) has been working closely with the government of Uttar Pradesh to build capacity of the state's sanitation and urban planners, with the aim of improving UP's overall sanitation services and systems. This exhaustive study of 13 plants in the state by CSE's Environment Monitoring Laboratory is an effort towards strengthening this collaboration by evaluating the performance of the state's existing infrastructure, and deriving some guidelines on how UP can move forward.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phone: 91-11-40616000 Fax: 91-11-29955879
E-mail: cse@cseindia.org Website: www.cseindia.org