EVALUATION OF FSTPs AND STP CO-TREATMENT SYSTEMS ACROSS INDIA

AN INSIGHT INTO TECHNOLOGY AND PERFORMANCE

PHASE II STUDY

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Executive summary

FSTP technologies are being adopted in many states in India. It is important to understand the different aspects of effluent management in these plants, the efficacy of the technologies, and the variations in them. This study report by CSE's Environment Monitoring Laboratory is a step in that direction.

The key highlights of this report

1. A total of **69 treatment plants** were evaluated in **eight states**, over a period of **two years**, starting in 2021. These include Telangana (10 FSTPs, two STPs); Tamil Nadu (five FSTPs, four STPs); Odisha (16 FSTPs, one STP); Rajasthan (three FSTPs); Uttar Pradesh (seven FSTPs, three STPs); Uttarakhand (12 STPs); Madhya Pradesh (four FSTPs); and Chhattisgarh (two FSTPs). Of these, 47 plants are FSTPs, with an approximate combined installed capacity of 1.6 million litre per day (MLD).

2. The performance of different faecal sludge treatment technologies have been tested: DEWATs with or without tertiary treatment, geotube technology, moving bed bioreactor (MBBR), pyrolysis with packaged treatment module, Mizuchi and electrocoagulation. In the case of co-treatment, technologies like moving bed bioreactor (MBBR), sequencing batch reactor (SBR), waste stabilisation pond, activated sludge process (ASP) and upflow anaerobic sludge blanket (UASB) have been assessed for their performance.

3. In terms of adoption of technologies, it is found that Telangana has adopted many more diverse technologies for the treatment of faecal sludge compared to other states – these other states have mostly adopted DWWTS technology, with minor changes in the operating modules.

4. The key problem noted is that most of the FSTPs are working below their designed treatment capacities; they are facing difficulties in getting faecal sludge daily or even weekly (for some plants). This is affecting performance. In some plants that were surveyed, the situation is so dire that the process of treatment remains incomplete and there is no outlet effluent available for testing.

5. In most plants, the BOD values are within the limit (30 mg/L), which is the standard prescribed for treated effluents by the CPCB. Only six FSTPs did not meet the BOD standard. The raw faecal sludge had an average BOD of 8,143 mg/L,

but the BOD levels could go as high as 28,357 mg/L sometimes. After solid-liquid separation, the BOD level goes down to an average of 127 mg/L, which is then treated to bring it within the standard.

6. Most plants were not meeting the COD limit for discharge water (50 mg/L). Most non-compliant plants were found to be within the COD range of 50-200 mg/L. The average value of COD in the faecal sludge received for treatment was 50,421 mg/L – but COD level was found to be as high as 164,500 mg/L (Unnao). After solid-liquid separation, the COD goes down to an average of 510 mg/L, which is then sent for treatment.

7. The mean COD and BOD of pan-India faecal sludge is 50,421 and 8,143 mg/L, respectively, in which only about 510 mg/L of COD and 127 mg/L of BOD is entering into the treatment module. That means an average of 97.6 per cent COD and 95.9 per cent BOD is removed in solids during the initial stages of solid-liquid separation.

8. Faecal coliform is an issue of concern as it could add to contamination in the environment because of discharge of effluents carrying pathogens. FSTPs in Telangana and Rajasthan were found to be under the limit set by MoEF&CC (1,000 MPN/100 mL). In the other states, one out of five FSTPs in Tamil Nadu, two out of 16 in Odisha, four out of seven in Uttar Pradesh, one out of two in Chhattisgarh and two out of four in Madhya Pradesh were not meeting the faecal coliform norm in the treated effluent. This is even though many of the plants have post-treatment technologies to eliminate the bacterial load. Also, it is clear that the count of faecal coliform is technology-agnostic, and therefore, this suggests that it has to do with the internal management of the plant. For instance, a plant using DEWATS in one location was within the limit of faecal coliform, while another plant using the same technology was not compliant.

9. Faecal coliform is also an issue in STPs; most plant samples analysed for this report are not within the discharge limit for faecal coliform value, even though many have a chlorination unit to remove the bacterial load. Tamil Nadu STPs showed better performance in controlling microbial load in the discharge water, which was close to or below the discharge limit.

10. Testing of faecal coliform in the treated effluent is not being done in most FSTPs/STPs, in spite of the limit being set by the CPCB.

11. Among the evaluated treatment technologies, the DWWTS systems showed

high variability in the treatment efficacy followed by MBBR technologies, which may be due to the inconsistency in the availability of the faecal sludge and improper operation and maintenance.

12. After solid-liquid separation, the solids are dried and stored in the treatment site without further treatment or reuse (some cases do reuse for compost). Therefore, complete pathogen removal along with resource recovery from the dry sludge is very important for sustainable faecal sludge management.

13. The dried sludge samples are tested for nutrients (carbon/nitrogen/phosphorus/potassium) and for contaminants (heavy metals and pathogens).

14. The overall performance of FSTPs in all the states was observed to be satisfactory in terms of removing organics and pathogens provided the operation and maintenance is carried out properly. Selection of treatment technologies is, therefore, also dependent on other issues including land availability, CAPEX, humanpower and availability of technical expertise.

Introduction

In an effort to eradicate open defecation from both rural and urban India, Swachh Bharat Mission was launched by the Government of India (GOI) in October 2014. The focus of the mission was to construct toilets for the safe containment of faecal sludge (FS) and subsequent treatment of the sludge through treatment plants to protect human health and environment. The mission was intended to promote cleanliness, hygiene and better management of solid and liquid waste to eliminate unhealthy practices of open defecation.

In the event of septic tanks or pit latrines becoming full, the sludge collected from them is largely discharged untreated into open drains, irrigation fields, open lands or surface waters. Untreated FS discharge in open environment poses serious public health related risks. To address this issue, the Ministry of Housing and Urban Affairs (MoHUA) promulgated the National Faecal Sludge and Septage Management Policy in 2017 to achieve the goal of making all Indian cities and towns totally sanitised, healthy and livable.

With an estimated 40 per cent of households in urban India connected to sewer networks, a pertinent question that arises is about how to handle the waste generated by the remaining 60 per cent of the households which are connected with onsite sanitation systems (OSS) like septic tanks, twin pits and single pits. In order to handle the waste accumulated in these OSS, a common practice is to desludge the septic tank/pit latrine in the open environment, mostly into surface water bodies, fields or vacant lands leading to contamination of the surrounding environment.

To mitigate the latter scenario, a number of FSTPs were built in the last couple of years in several states under Swachh Bharat Mission and Atal Mission for Rejuvenation & Urban Transformation (AMRUT) for FS treatment and management. At present, more than 130 FSTPs are operational in India and at least 300 more are under various stages of construction. In a number of locations, co-treatment of FS through STP has also been initiated.

It is now quite relevant to study the performance efficiency of FSTPs and STPs to observe how the FS is being managed and whether the level of management is enough to protect the land and water bodies. It is also pertinent to understand which technologies are most effective and economically sustainable. This study was undertaken to achieve these goals.

Further, with nearly 70 per cent of water sources contaminated, India is placed at the 120th position (among 122 countries) in water quality index, according to a study conducted by NITI Aayog in 2018. The Government of India has taken up the challenging task of preventing pollution of fresh water sources and providing piped water connection to the entire population through the 'Nal se Jal' initiative under its flagship programme 'JalJeevan Mission'. Therefore, it is equally important to conduct a study to see if there are any adverse effects on natural waterbodies due to discharge of effluent water from co-treatment in STPs.

The FSTPs set up to address these challenges have been designed by adopting diverse technologies depending on the end use or disposal options of the sludge and liquid streams. The extent of pathogen reduction in outlet of effluent water and level of sludge dryness requirements depend on their application on food crops or combustion in industrial processes. Simultaneously, extensive efforts have also been initiated to investigate the co-treatment of faecal sludge through existing sewage treatment plants (STPs) with various technologies in several municipalities and urban local bodies (ULBs). To understand the efficacy or effectiveness of above FSTPs/STPs for treatment of FS, a phase II study has been initiated on diverse technologies used in the treatment process and the impact of the discharged effluent on the environment and surface waterbodies has been investigated.

Objectives of the study

The Environment Monitoring Laboratory of CSE has set out the following objectives for the study to delineate the performance effectiveness of FSTP/ STP co-treatment in India:

- Evaluate the treatment efficiency of FSTPs in India on the basis of commissioned technologies, existing capacity utilisation, and prevailing operation and maintenance scenario.
- Establish the co-treatment competence of faecal sludge in STPs of India with prevailing technologies.
- Spread awareness about the importance of co-treatment/treatment of FS through STP/FSTP to avoid environment pollution in surrounding ecosystems.

Sampling strategy

A total of 69 treatment technologies were evaluated across the six states:

- Telangana (10 FSTPs and two STPs)
- Tamil Nadu (five FSTPs and four STPs)
- Odisha (16 FSTPs and one STP)
- Rajasthan (three FSTPs)

- Uttar Pradesh (seven FSTPs and three STPs)
- Madhya Pradesh (four FSTPs)
- Chhattisgarh (two FSTPs)
- Uttarakhand (12 STPs)

Any study that involves field sampling entails requisite planning, which includes site selection, purchase of sampling equipment and personal protective equipment, and coordination with local facilitators. Since sampling is the starting point for many other sequential actions, a plan must be devised for its flawless execution as well as the extraction of useful data for subsequent work. Hence adequate attention was given to the representative sample collection in FSTP performance evaluation.

The phase II study covers six states — Telangana, Tamil Nadu, Odisha, Uttar Pradesh, Rajasthan and Uttarakhand — for a period of minimum three months. Lab Scientists visited each site, collected, properly preserved and transported the samples at the earliest possible time to the lab by adopting standard protocols for sampling, preservation and transportation.

The faecal sludge was collected from the tankers at the FSTP discharge points. In all the FSTPs, the leachate entering into the treatment modules (inlet water) and the final discharge output after the solid–liquid separation was also collected and tested to establish the performance of the leachate treatment efficiency of individual FSTPs. A plastic bucket and a ladle was used to collect composite samples from the sludge tankers.

Wastewater (leachate) was collected from a certain depth of the chamber by using cylindrical stainless steel wastewater sampler attached with a rope. For precise measurement of pH, portable pH meter was also carried to the field. PPE like overalls, gloves, face masks, protective eyewear, gumboots and hand sanitizers were taken in the sampling kit. Sampling bottles were properly cleaned, sterilized, and attached with appropriate labelling stickers. Sampling location with date and time was clearly stated on each bottle after sampling. Samples were finally transported in leak proof ice-boxes with frozen ice-gel packs.

Testing methodologies and data analysis

Analyses was conducted according to standardised and well-documented methods and protocols:

- pH—APHA 4500-H+B, 23rd Ed, 2017
- Total Suspended Solids—APHA 2540-D, 23rd Ed, 2017

- Total Dissolved Solids - APHA 2540-C, 23rd Ed, 2017
- Chemical Oxygen Demand (COD)—APHA 5220-D, 23rd Ed, 2017
- Biological Oxygen Demand (BOD)—Automated BOD Analyzer & APHA 5210-B, 23rd Ed, 2017
- Total Kjeldahl Nitrogen—APHA 4500-Norg C
- Ammoniacal Nitrogen—APHA 4500-NH_3 C
- Total Phosphorus - APHA 4500-P E
- Faecal Coliform—APHA 9221 E, 21st Ed., 2005; USDA, MLG Appendix 2.05

The treatment efficiency was calculated by comparing the parameters with the leachate to the final discharge water. Means and standard deviations were calculated, using Microsoft® Excel 2013, for all the results.

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). Five of the more important of these parameters are represented here to evaluate the performance.

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 biological processes, including pathogen inactivation. Measurement of pH is essential for the understanding of water chemistry processes, such as acid-base chemistry, alkalinity, neutralisation, biological stabilisation, precipitation, coagulation, disinfection, and corrosion control.

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 water bodies, resulting in the possible death of aquatic fauna. The oxygen demand is reduced through stabilization, and can be achieved by aerobic or anaerobic treatment.

Total Kjeldahl Nitrogen (TKN): Nitrogen is an important parameter to consider in faecal sludge treatment, as the total nitrogen concentrations are typically quite high. Total Kjeldahl Nitrogen (TKN) is the USEPA-approved parameter used to measure organic nitrogen and ammonia, which is the sum of organic nitrogen and ammonia (NH3-N)/ammonium ($NH4^{+}N$).

Faecal Coliform (FC): Faecal sludge contains large amounts of microorganisms, mainly originating from the faeces. These microorganisms can be pathogenic, and exposure to untreated faecal sludge constitutes a significant health risk to humans, either through direct contact, or through indirect exposure. Faecal sludge needs to be treated to an adequate hygienic level based on the end use or disposal option. Indicator organisms are used as a metric of pathogen concentrations. Coliform bacteria are bacteria that populate the intestinal tract, and are pervasive in faeces. Their presence in the environment is therefore used as an indicator of faecal contamination.

Faecal sludge treatment Plants (FSTPs)

The technologies adopted by the FSTPs included DEWATs with or without tertiary treatment, geotube technology, moving bed bioreactor (MBBR), pyrolysis with packaged treatment module and electrocoagulation. The STP co-treatment systems adopted moving bed bioreactor (MBBR), sequencing batch reactor (SBR), waste stabilisation pond, activated sludge process (ASP) and upflow anaerobic sludge blanket (UASB).

Decentralised wastewater treatment system (DWWTs/DEWATS)

DEWATS is a technical approach to decentralized, community-level wastewater treatment in developing communities. The passive design uses physical and biological treatment mechanisms such as sedimentation, floatation, aerobic and anaerobic treatment to treat both domestic and industrial wastewater sources. DEWATS is designed to be affordable, low maintenance, use local materials, and meet environmental laws and regulations. DEWATS has service packages available for the sanitation needs of small and medium-sized enterprises including communities, schools, municipalities, agro-industry, emergency settlements, hospitals, hotels, and prisons. DEWATS technology is also commonly used for the treatment of liquid effluent/leachate after solid-liquid separation in a FS treatment plant.

In a typical DWWTs technology, the treatment takes place in three units — Settler, Anaerobic Baffled Reactor (ABR)/Anaerobic Filter (AF) and Planted Gravel Filter (PGF) bed. The settler and ABR/AF are underground units, while the PGF is constructed over the surface.

Settler: A settler is usually two-chambered and helps in the sedimentation of solids present in the wastewater (primary treatment). Wastewater enters a settler that offers enough time for the solids to settle down due to gravity.

Anaerobic Baffled Reactor (ABR): The ABR provides secondary treatment for the effluent from the settler. ABR is typically five-chambered and contains filter materials (gravels and pebbles) in the last two chambers. Wastewater flows from one chamber to the other while suspended organic matter settles down in each chamber forming a sludge blanket at the bottom where they undergo anaerobic degradation with the help of inherent microorganisms. The filter present in the last two chambers prevent the sludge from leaving the ABR. As time passes, this settled sludge gets activated and helps in further bio-degradation.

Planted Gravel Filter Bed (PGF): The partially treated wastewater passes through the PGF for secondary/tertiary treatment. The PGF consists of crushed stones, pebbles and wetland plants—*Canna indica, Typha*. These wetland plants offer further treatment by removing nutrients like phosphates and nitrates from the wastewater.

Storage Tank: The treated wastewater is stored in a storage tank from where it is used for horticulture purposes within the premises of the plant. Sometimes, the wastewater from PGF enters a polishing pond for further treatment where removal of odours and pathogens takes place by aeration and sunlight.

Geotubes and geobags

This technology is based on the use of geotextiles — permeable fabrics made of fibre woven polypropylene that have the potential to dewater sludge more efficiently than drying beds. Geotextiles are commercially available in a tube or bag form known as 'Geotube' or 'Geobag' and have been used in many parts of the world for dewatering of sludge from various sources (such as in wastewater treatment and aquaculture) at different scales.

The operation is as follows

1. The faecal sludge is flocculated by adding polymers; the flocculated sludge is filled in geobags for treatment.
2. The free water gets drained through the permeable geotextile material within hours or days, leaving behind the dewatered sludge, which is later removed by cutting open the geobag and dried.
3. After solid-liquid separation, the solids are allowed to stay in the geobag for a few weeks for stabilisation as well as moisture and pathogen reduction, which are achieved during the composting process inside the geobag.
4. Tertiary treatment like pressure sand filter, activated carbon filter and UV treatment are generally applied to the geobag effluent for final treatment before reuse/disposal.

The operation of these bags is based on gravity, and requires no mechanical units. The system is modular in operation, therefore making the bags potentially suitable for decentralised faecal sludge treatment. Geobags are claimed to remove TSS by >99 per cent after solid-liquid separation; TS of up to 25-30 per cent remains in the dewatered sludge. The major disadvantage of geobags is its non-reusability. These bags have to be usually discarded once the entire volume is occupied by solids.

Moving bed biofilm reactor (MBBR)

The MBBR technology was developed in Norway at the Norwegian University of Science and Technology in cooperation with a Norwegian company, Kaldnes Miljøteknologi (now Anox Kaldnes AS) in late 1980s. Since then, it is widely used, with more than 700 installations throughout the world. Like SBR, MBBR technology is an advanced variation of the AS process that combines the benefits of two technologies, the activated sludge (suspended biomass) process and conventional fixed film/trickling filters (attached biomass) systems for improved treatment. These systems can be used for municipal and industrial wastewater treatment, aquaculture, potable water denitrification, and in roughing, secondary, tertiary, and side stream applications.

Technology description

The MBBR process typically includes a submerged biofilm reactor and liquid-solid separation unit. It can be operated as a2- (anoxic) or 3- (aerobic) phase system with buoyant free-moving plastic biofilm carriers (media) that require energy (aeration or mechanical mixing) for uniform distribution throughout the bulk phase.

The media used in MBBR provides increased surface area for the biological microorganisms to attach to and grow in the reactors/tanks thereby increasing the amount of microorganisms available to treat the wastewater (organic material). The increased surface area of media also reduces the footprint of the tanks required to treat the wastewater.

The biomass in the MBBR exists in two forms: suspended flocs and a biofilm attached to carriers thus providing dual treatment. A biofilm reactor with a length-to-width ratio (L: W) in the range of 0.5:1 to 1.5:1 is optimum for an MBBR operation. An MBBR may be a single reactor or configured as several reactors-in-series. The media volume is up to 67 per cent of the empty bed liquid volume (or carrier fill) of an MBBR reactor. Media retaining screens are installed with one MBBR wall which retain media and allow treated effluent to flow through to the next treatment step.

Two variants exist in MBBRs depending on function/energy generation: Aerobic and Denitrification. In Aerobic MBBRs, diffused aeration system is used to uniformly distribute the media and meet process oxygen requirements. In Denitrification MBBRs, media are distributed by mechanical mixers. Biofilm thickness on the media is controlled by air flow or mechanical mixing energy.

Advantages

- Ability to meet treatment objectives similar to activated sludge, with respect to 5-day biochemical oxygen demand (BOD_5) and nitrogen removal, in a smaller tank volume.
- Compact units with small size
- Increased treatment capacity
- Complete solids removal
- Improved settling characteristics
- Operation at higher suspended biomass
- Concentrations resulting in long sludge retention times.
- Enhanced process stability.
- Low head loss.
- No filter channelling.
- No need of periodic backwashing.
- Reduced sludge production
- No problems with sludge bulking.
- Can be operated at high organic loads.
- Less sensitive to hydraulic overloading.
- Well-suited for retrofit installation.
- Biomass retention is clarifier-independent.
- It is a continuous-flow process that does not require a special operational cycle for biofilm thickness control.
- Liquid-solid separation can be achieved with a wide variety of technologies including sedimentation basins, dissolved air flotation, ballasted flocculation, granular media filtration, cloth-disc filtration, and membrane (UF/MF) filtration.

Electrocoagulation-flotation (ECF)

Electrocoagulation-flotation (ECF) is a type of treatment technology in which electrical current is applied to flocculate and treat contaminants. Hence, addition of flocculating agents/ coagulants is not required. Direct current is applied due to which smaller particles start moving forming aggregates which gets either settled or floated and later removed. The apparatus consists of a series of electrodes in the form of metal sheets arranged in pairs (positively charged anode and negatively charged cathode).

Electric current is applied as a result of which cathode loses electrons and becomes oxidized while water gains electrons and becomes reduced. When wastewater comes in contact with cathode electrode, metal is released and neutralizes the particulates by forming hydroxide complexes. The neutralized particles agglomerates and settles to the bottom of the tank which can be removed by filtration. In an electrocoagulation-flotation apparatus, the particulates will float to the top of the tank by means of hydrogen bubbles created at the anode. The floated particulates can be skimmed from the top of the tank.

Several factors affect the removal efficiency, kinetics and overall treatment time of the electrocoagulation process which include wastewater type, pH, current density, type (aluminum, steel, and iron), number and size of electrodes, and configuration of metals.

Advantages

- Alternative to classical chemical coagulation — thus reduces the usage of expensive chemical coagulants and also their safe disposal.
- Capable of reducing waste production from wastewater treatment.
- Reduces the time necessary for treatment.

Packaged sewage treatment plant (PSTP)

Packaged sewage treatment plant (PSTP) is housed in specially designed and highly durable fiber glass reinforced plastic (FRP) tank. These tanks are compact which can be utilized in a decentralized manner at any location, either it is underground or above the ground. Moving bed biofilm reactor (MBBR) technology is used in this system. This technology is designed to treat municipal sewage water, but, is also used to treat leachate water after solid-liquid separation in a FSTP.

Technology description

The treatment in this system takes place in three stages — preliminary, secondary and tertiary treatments.

Preliminary treatment: A bar screen is placed to remove large inert solids like plastic, cloth etc. from the water stream.

Secondary treatment: It happens in four distinct zones which are arranged sequentially each with a unique environment and function.

- Anaerobic Zone: This is the first oxygen-depleted anaerobic zone in the PSTP in which the solids in raw sewage gets settled while allowing the scum to float on the surface. In this zone, the settled sludge is stabilized by anaerobic digestion.

- Anoxic Zone: The second zone is the anoxic zone with low oxygen concentration (0.2 to 0.5 mg/l) which is accomplished by returning the activated sludge from the final sedimentation zone. The low oxygen conditions prevailing in this zone favours the denitrification process to occur in the wastewater stream. Denitrification is carried out by anoxic microbes which break down the existing nitrates into nitrogen gas which is released into the atmosphere.
- Aeration Zone: The third zone is the aeration zone where aerobic degradation of organic matter takes place with the help of aerobic microorganisms. In this zone, aeration is provided with the help of air blowers which accelerates the growth and activity of microbes present throughout the surface of floating plastic media (as a biofilm) added in the aeration zone. The MBBR media provides the extended surface area for the growth of microorganisms.
- Sedimentation Zone: The final step in the secondary treatment is the settling of organic waste which occurs in the sedimentation zone. The settled waste in the bottom of the tank is pumped back to the anoxic zone for further treatment.

Tertiary treatment: The treated sewage from secondary treatment is passed through the pressure sand filter and activated carbon filter for the removal of suspended solids (TSS), colour, and odour. The treated water is then disinfected using sodium hypochlorite before it is reused.

STP co-treatment systems

Sequencing batch reactor (SBR)

The SBR process basically incorporates a fill-and-draw type biological wastewater treatment process, functionally resembling to an AS process, but is an advanced variation of the AS process. In the SBR process, all the unit processes take place within a single tank for their specific duration and intervals, sequentially spaced over a span of time. Depending on the scale of operation, the SBR system, along with its variants and hybrids, may involve single or multiple tanks, each of which features five basic operating modes, namely, Fill, React, Settle, Draw, and Idle. Being a batch process, the time duration of each mode within a tank can be adjusted to meet the different treatment needs, such as low COD in the effluent, biological nutrient removal, etc.

Fill Phase: During the Fill Phase, the tank receives the raw wastewater that comes in contact with the active biomass left inside the tank at the end of the previous cycle. Three variations may be operated singly or combined, depending on the wastewater characteristics, the target organics and biological nutrient removal: Static Fill, Aerated Fill and Mixed Fill. During Static fill, influent wastewater is added to the biomass already present in the SBR without mixing. This creates a high food to microorganisms (F/M) ratio which favors the growth of floc-forming bacteria over filamentous ones thus providing good settling characteristics to the sludge. In addition, Static Fill conditions also create a "feast"-like situation in which phosphate accumulating organisms (PAO) are favoured which are responsible for biological phosphorus removal. Aerated Fill operates under aerobic conditions. During Mixed Fill, wastewater is added to the biomass under a combination of aerobic, anaerobic or anoxic conditions.

React Phase: This phase is primarily meant for the complete degradation of organics by microbial actions thereby also promoting a high degree of nutrient removal. The treatment is controlled by air and creates anaerobic, anoxic, or aerobic conditions. This phase may be operated under two modes: Aerated React and Mixed React. During Aerated React mode which operates under aerobic condition, the aerobic reactions initialized during Aerated Fill are completed. Nitrification, the conversion of ammonia-nitrogen to nitrite-nitrogen and ultimately to nitrate-nitrogen occurs in this phase. In Mixed React mode, combinations of anoxic (limited oxygen) and anaerobic (absence of oxygen) conditions are created apart from aerobic conditions in the reactor. Anoxic conditions promote denitrification, a process in which nitrate-nitrogen is converted into nitrogen gas. Anaerobic conditions create a “famine” phase that promotes phosphorus removal.

Settle Phase: During the Settle phase, the entire reactor tank acts as a batch clarifier, without any inflow or outflow allowing time for the biomass or AS (floc-forming bacteria and sludge) to settle.

Draw Phase: In the Draw phase, a fixed or floating decanter is used to decant the treated supernatant after the settlement of the biomass generated after the React phase.

Idle Phase: This is the time interval between the Draw and Fill phases. This phase is often required as a buffering time when several reactors are operating in parallel. During this phase, mixing of the biomass to condition the reactive contents, and wasting of excess sludge, may be taken up, depending on the operating strategy.

Single tank SBR system: In a single tank SBR system, the duration between beginning of Fill phase and end of Idle phase spans one complete cycle time. The frequency of wasting of microorganisms (removal of excess microorganisms) may be as low as once every 2 weeks. As the yield is low, the Single tank operation is suitable for low population localities or in industries with variable flow conditions.

Multiple tank SBR system: The multiple tank SBR system consists of tanks in series where it is ensured that the Draw of a tank is completed by the time another tank completes Fill. The wasting of microorganisms is done once per cycle during the react phase in high yielding multiple tank system. The simultaneous aeration, mixing, reaction, and settling occurring within the SBR tank obviate the requirement of a separate clarifier unit.

Advantages

- The duration of Fill and React phases can be adjusted to impart the SBR system a CSTR-like (Continuous Stirred-Tank Reactor-like) or ideal PFR-like (Plug Flow Reactor-like) treatment characteristics.
- The SBR system provides major operational flexibilities like internal equalization and control of biological reactions through regulation of aeration.
- The presence of microorganisms in high concentrations right from the Fill phase reduces the treatment duration significantly.
- The ability to control the substrate availability by varying the aeration duration during Fill provides a high degree of flexibility in controlling the filamentous organism population and concentration of nitrogen.

- Anoxic period during the React phase is useful in nitrogen removal from the system.
- Reactor operating conditions such as low dissolved oxygen (DO), low F/M ratio, and completely mixed operation favours the growth of filamentous bacteria that have poor settling characteristic. It causes the effluent to have high suspended solids content (TSS), known as "sludge bulking" that result in poor efficiency of the treatment plant. To overcome this, a Bio-selector is used in SBR system which favors the growth of floc-forming heterotrophic bacteria (that have good settling characteristic) over filamentous bacteria.
- The selectors can be made either anoxic or anaerobic, by varying the degree of mixing at low or no oxygen supply, depending on whether denitrification and biological phosphorus removal are targeted in the SBR.

Upflow Anaerobic Sludge Blanket (UASB)

UASB technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used for wastewater treatment. The bottom of the UASB reactor contains a high concentration of microbial biomass which is formed by a complex aggregation of anaerobic bacteria. The wide-variety of anaerobic bacteria attach to one another into multiple layers forming dense granules which settles along with the accumulated sludge to the bottom of the reactor. Hence, a sludge blanket composed of bacterial granules and sludge is formed at the bottom.

The unit consists of a sludge bed at the bottom and solid-liquid-gas separator at the top. Wastewater with the help of peristaltic pump flows upwards through the blanket and is degraded by the anaerobic microorganisms. Biogas with a high concentration of methane is produced which is collected and can be harnessed for energy. Hence, the upward flow of wastewater and generated biogas combined with the settling action of gravity with the help of flocculants makes the microbial sludge blanket to remain in suspension thereby enabling the degradation of sludge and wastewater. The blanketing of the sludge enables a dual solid and hydraulic (liquid) retention time in the digesters.

Solids requiring a high degree of digestion can remain in the reactors for periods up to 90 days. The treated wastewater comes out of the UASB reactor through effluent outlet for further treatment whereas the unused granules containing smaller sludge particles and microbes are recycled back to the reactor for reuse and treatment.

Advantages

- Supportive media is not required for the growth of microbes due to the availability of granular sludge.
- Excess biomass enhances the COD removal efficiency for high strength wastewater.
- The sludge blanket facilitates the lower hydraulic retention time (HRT) and higher solid retention time.
- Gas bubble formation helps in the mixing of the effluent, which eliminates the need to introduce external energy for mixing purposes.
- The treatment efficiency of the technology is good even at a higher organic loading rate (OLR) and low temperature.
- Construction, maintenance, and operation of the technology are simple due to the wide availability of the accessories required.
- The capital cost of the technology is low because the land required for the technology is less, even for a higher loading rate.
- Energy consumption of the technology is low; moreover, some energy is also produced in the form of methane.
- As compared to aerobic processes, much less sludge is produced, which is significantly stabilized and can be used as fertilizer.

Activated Sludge Process (ASP)

The activated sludge (AS) process is one of the most widely used biological wastewater treatment processes in the developed world. The basic process of this flexible ASP has been widely adopted world-wide with further modifications for use in various applications. In majority of AS processes, settled sewage is used as the feedstock. The AS process consists of two separate phases: aeration and sludge settlement.

Aeration: This is the first phase in the AS process. In this phase, wastewater (from the primary settlement tanks) is added to the reactor/aeration tank containing a mixed microbial population comprising of bacteria and other microfauna (protozoa) and microflora involved in the biodegradation process. These microbes remain as clumps (by forming flocs) inside the reactor. Flocs are aggregates of different groups of microorganisms forming a compact structure. Air or sometimes pure oxygen is added into the aeration tank either by surface agitation or through diffusers using compressed air.

The aeration (and mixing) has two important functions: 1. It provides oxygen to the aerobic microorganisms inside the reactor for their growth and respiration; and 2. It maintains the microbial flocs in a continuous state of agitated suspension which provides maximum contact between the surface of the flocs and the wastewater to ensure sufficient degradation. Continuous mixing through aeration not only provides microbes with adequate food but also helps to disperse the metabolic waste products from within the flocs. The sludge present in the aeration tank is a flocculant suspension of microbial biomass and often referred to as the mixed liquor. As the sludge is in continuous contact with the flocculant microbes actively involved in degradation process, it is referred to as activated sludge (AS) and hence the name activated sludge process (ASP). Usually sludge is not allowed to settle in the aeration tank.

Sludge settlement: This is the second stage in the AS process which occurs in a separate tank called sedimentation tank. After sufficient degradation of wastewater in the aeration tank, new wastewater is allowed to enter the aeration tank. This causes in the displacement of treated wastewater with microbial biomass (mixed liquor/AS) from aeration tank into the sedimentation tank. Settling of flocculated microbial biomass out of sludge suspension/treated effluent occurs in the sedimentation tank. The leftover water is a clarified effluent free from solids and microbes which is discharged for further treatment.

As the wastewater gets clarified (free from solids) in the sedimentation tank, this process is often called as clarification and the tank as clarifier/secondary settling tank. Part of the settled AS in the sedimentation tank is recycled back to the aeration tank to maintain adequate concentration of the microbial population to ensure complete and continuous treatment of wastewater during its retention period within the aeration tank. Poor settlement (bulking) of microbial flocs can result in turbid effluents and the loss of microbial biomass.

The properties of microbial flocs like adsorption, absorption of organic matter and separation from treated effluent is dependent on the optimum conditions existing in the aeration tank. Under normal operating conditions with high nutrient content in the AS process, there is an increase in biomass (AS) due to the growth of the microbial population and the accumulation of non-biodegradable solids. Hence, AS process should be aimed at operating close to a food-limited condition which encourages endogenous respiration and utilization of own microbial cellular components thereby causing reduction in the biomass production.

The AS process has two principle removal mechanisms each with different function, and AS plants can be operated to favour either of these two processes.

Assimilation: During this process, waste (colloidal and soluble BOD) is utilized by microbes to create new biomass which is then settled out. In the plants dominated by assimilation, there is rapid removal of the BOD with a correspondingly high production of sludge, with concomitant increase in sludge treatment costs.

Mineralization: Mineralization is the oxidation (degradation) of waste to inert end products, which are either released to the atmosphere or are left in solution in the effluent. Plants that favours mineralization require long aeration times and hence are high in operating costs required for aeration. However, this is balanced by the reduced production of sludge and correspondingly low sludge treatment costs.

MBBR

(*Mentioned above in the FSTP technology section*)

Waste stabilisation ponds

Waste stabilisation ponds (WSPs) are widely used for the treatment of municipal wastewater. Co-treatment of wastewater with faecal sludge (FS) was tested in WSPs, nevertheless, certain limitations were observed. Direct application of FS was unsuccessful due to high organic, solid and ammonia content in FS, and hence not recommended. However, WSPs can be used for co-treatment of liquid part alone of FS which contain less organic/solid content. Hence, WSP can be used to treat liquid effluent/leachate after initial solid-liquid separation in other FS treatment technologies like 1. Unplanted and planted sludge drying beds, and 2. Settling-thickening tanks. High concentration of ammonia in liquid effluent can still cause problem by inhibiting the growth of algae and methanogenic bacteria in the ponds, but, it can be overcome by using mechanical aeration which lowers the ammonia concentration.

The mechanisms for stabilisation in WSPs are based on natural processes that occur in aquatic ecosystems. WSPs consist of several ponds having different depths and retention times. A combination of three types of ponds in series is frequently implemented in wastewater treatment. 1. Anaerobic ponds that are 2 to 4 m deep are used for settling of suspended solids and subsequent anaerobic digestion. The effluent flows to the facultative pond. 2 Facultative ponds that are 1 to 1.8 m deep allow for remaining suspended solids to settle. In the top layer of the pond dissolved organic pollution is aerobically digested, while anaerobic conditions are prevalent at the bottom. 3 Maturation ponds that are 1 to 1.5 m deep allow for pathogen reduction and stabilisation. The ponds are mainly aerobic. Oxygen is supplied through algae and diffusion from the air. Pathogen reduction occurs via UV rays from the sun.

Advantages

- Simple to build and require relatively low O&M requirements, hence suitable for low-income countries with adequate land
- Appropriate for tropical climates, and achieves relatively high pathogen removal in the effluent

Constraints

- Land availability
- High rate of solids accumulation if preliminary solids separation is not performed
- Potential inhibition of microbes due to high salt and ammonia concentrations
- Heavy mechanical equipment may be required for the removal of sludge that accumulates in the anaerobic ponds.

Table 1: List of treatment technologies evaluated in Telangana

S No	FSTP location	Capacity	Technology	Description	Post-treatment	Capex (Rs/ annum)	Opex (Rs/ annum)
1	Boduppal	15 KLD	Geotube Technology	Screening Chamber, Sludge holding tank, Polymer tank, Geotube dewatering system, aeration system	Pressure Sand filter and activated carbon filter	-	-
2	Uppal	40 KLD	Combined Biological Treatment with solar sludge drying and decontamination	Bar Screen, Collection pit, dewatering unit, moving bed bioreactor; Sludge dried by paddle dryer followed by IR decontamination	Membrane filter and activated carbon filter, photocatalytic oxidation reactor	-	-
3	Khajaguda	7 MLD	Moving Bed Bioreactor	*STP Co-treatment* Sewage sump, rake classifier, moving bed bioreactor, clarifier, centrifugal separation of solids	Chlorination	-	-
4	Nanakramguda	4.5 MLD	Moving Bed Bioreactor	*STP Co-treatment* Grit chamber, moving bed bioreactor, clarifier, centrifugal separation of solids	Chlorination	-	-
5	Bhongir	15 KLD	Geotube Technology	Screening Chamber, Sludge holding tank, Polymer tank, Geotube dewatering system, aeration system	Sand filter and activated carbon filter	-	-

S No	FSTP location	Capacity	Technology	Description	Post-treatment	Capex (Rs/annum)	Opex (Rs/annum)
6	Shadnagar	25 KLD	Geotube Technology	Screening Chamber, Sludge holding tank, Polymer tank, Geotube dewatering system, aeration system	Sand filter and activated carbon filter	-	-
7	Siddipet	20 KLD	DEWATs	Anaerobic stabilization reactor, sludge drying bed, balancing tank, integrated settler with anaerobic filter, Planted gravel filter	Polishing pond	-	-
8	Sircilla	18 KLD	DEWATs	Screening chamber, stabilization reactor, unplanted sludge drying bed, integrated settler with anaerobic filter	Sand and carbon filter, polishing pond	1.6 Cr.	11 lakhs.
9	Nirmal	30 KLD	Moving Bed Bioreactor	Receiving sump, grit removal, equalization tank, clarifier, settling tank, moving bed bioreactor, clarified water tank	Pressure sand and carbon filter, Chlorination	2.19 Cr.	7.5 lakhs.
10	Kamareddy	30 KLD	Moving Bed Bioreactor, Paddle drying and IR radiation of sludge	Main screen, bar screen, solid liquid separator, moving bed bioreactor, tube settler,	Chlorination, sand and carbon filter	2.25 Cr.	7 lakhs
11	Warangal	15 KLD	Packaged STP, Sludge processing by pyrolysis	Dewatering unit, moving bed bioreactor, Sludge processing by two ways: aerobic biodegradation of sludge and compost preparation, sludge drying by pyrolysis and preparation of biochar	Pressure sand filter, activated carbon filter and chlorination	1.1 Cr.	18 lakhs
12	Nalgonda	75 KLD	Electrocoagulation	Screen chamber, equalization tank, electrocoagulation, aeration tank	Sand Filter, activated carbon filter and UV disinfection	4 Cr.	8.3 lakhs

Table 2: List of treatment technologies evaluated in Tamil Nadu

S No	FSTP location	Capacity	Technology	Description	Post-treatment	Capex (Rs/ annum)	Opex (Rs/ annum)
1	Ukkadam, Coimbatore	70 MLD	SBR	*STP Co-treatment:* Screening, Grit chamber followed by SBR system and chlorination	Chlorination	0.22 Cr. for co-treatment	-
2	PNP, Coimbatore	30 KLD	MBBR	*FSTP:*Polymer based dewatering machine followed by MBBR and tertiary treatment by sand & carbon filter and UV treatment; co-composting of dry sludge	Carbon filter, sand filter, UV treatment	2.48 Cr	-
3	Erode	50 MLD	MBBR	*STP Co-treatment:* Grit chamber, Equalization tank, Anoxic tank, MBBR tank, aeration tank and tertiary treatment by disc filter and chlorination	Chlorination	18 Cr.	-
4	Thuraiyur, Tiruchirapalli	20 KLD	DWWT	*FSTP:* Stabilization tank followed by Unplanted drying beds, anaerobic filter, and planted gravel filter.	Absent	3.2 Cr.	-
5	Tiruchirapalli	58 MLD	Waste stabilization pond	*STP Co-treatment:* Anaerobic treatment followed by Facultative pond and polishing pond	Absent	116 Cr.	-
6	Madurai	125 MLD	SBR	*STP Co-treatment:* Screening and grit removal followed by SBR system and chlorination	Chlorination	72 Cr.	-
-7	Tirumangalam Madurai	40 KLD	DWWT	*FSTP:* Stabilization reactor followed by gravity based settling on drying beds, anaerobic filter, planted gravel filter and polishing pond	Absent	-	-
8	VK puram, Tirunelveli	30 KLD	DWWT	*FSTP:* Stabilization reactor followed by gravity based settling on drying beds, anaerobic filter, planted gravel filter and polishing pond	Polishing pond	3 Cr.	7.2 lakhs
9	Shenkottai, Thenkasi	20 KLD	DWWT	*FSTP:* Stabilization reactor followed by gravity based settling on drying beds, anaerobic filter, planted gravel filter and polishing pond	Polishing pond	2.6 Cr	10 lakhs

Table 3: List of treatment technologies evaluated in Odisha

S No	FSTP location	Capacity	Capex (Rs)	Opex (Rs/annum)	Technology	Description	Post-treatment
1	Puri	50 KLD	1.75 Cr	17.5 Lakhs	*STP Co-treatment*: Waste stabilization pond	Settler cum Thickener, Unplanted Sludge Drying Bed (USDB); Supernatant & Leachate diverted to STP	Without tertiary treatment
2	Balasore	60 KLD	2.55 Cr	18.8 Lakhs	DEWATS	Settler cum Thickener, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF	Polishing Pond
3	Baripada	50 KLD	2.41 Cr		DEWATS	Settler cum Thickener, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF Polishing Pond	Polishing Pond
4	Bhubaneswar	75 KLD	3.54 Cr	19.5 Lakhs	DEWATS	Settler cum Thickener, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF	Polishing Pond
5	Dhenkanal	27 KLD	2.85 Cr	10.5 Lakhs	DEWATS	Stabilization Reactor, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF & Collection Tank	Tertiary treatment with sand & activated carbon filter followed by UV irradiation
6	Berhampur	40 KLD	2.48 Cr	-	DEWATS	Settler cum Thickener, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF	Polishing Pond
7	Angul	18 KLD	2.53 Cr	-	DEWATS	Stabilization Reactor, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF & Collection Tank	Tertiary treatment with sand & activated carbon filter followed by UV irradiation
8	Sambalpur	20 KLD	1.92 Cr	-	DEWATS	Settler cum Thickener, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF	Polishing Pond
9	Rourkela	40 KLD	2.15 Cr	-	DEWATS	Settler cum Thickener, Unplanted Sludge Drying Bed (USDB), ABR with AF, PGF	Polishing Pond
10	Asika	10 KLD	1.5 Cr	3.6 Lakhs	DEWATS	Settling-thickening tank (STT) and unplanted sludge drying beds (USDB, ABR, horizontal planted gravel filter (PGF)	Polishing pond

S No	FSTP location	Capacity	Capex (Rs)	Opex (Rs/annum)	Technology	Description	Post-treatment
11	Bhadrak	30 KLD	-	11 Lakhs	DEWATS	Settling-thickening tank (STT) unplanted sludge drying beds (USDB), ABR, planted gravel filter	Polishing pond
12	Choudwar	12 KLD	2.3 Cr	6.96 Lakhs	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, planted gravel filter (PGF)	Activated carbon filter (ACF) and UV
13	Jagatsinghpur	20 KLD	3.5 Cr	9.6 Lakhs	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, horizontal planted gravel filter (PGF)	Polishing pond
14	Jatni	20 KLD	-	-	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, horizontal planted gravel filter (PGF)	Polishing pond
15	Khordha	20 KLD	-	-	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, horizontal planted gravel filter (PGF)	Polishing pond
16	Nimapada	10 KLD	-	-	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, planted gravel filter (PGF)	Polishing pond
17	Paralakhemundi	20 KLD	3.0 Cr	9.12 Lakhs	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, horizontal planted gravel filter (PGF)	Polishing pond
18	Surada**	10 KLD	3.0 Cr	12 Lakhs	DEWATS	Settling-thickening tank (STT) and unplanted sludge drying beds (USDB), ABR, horizontal planted gravel filter (PGF)	Polishing pond
19	Kashinagar**	10 KLD	3.0 Cr	9.12 Lakhs	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, planted gravel filter (PGF)	Polishing pond
20	Hinjilicut**	10 KLD	3.0 Cr	9.6 Lakhs	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, planted gravel filter (PGF)	Polishing pond
21	Talcher**	20 KLD	2.75 Cr	9.12 Lakhs	DEWATS	Settling-thickening tank (STT), unplanted sludge drying beds (USDB), ABR, planted gravel filter (PGF)	Polishing pond

**Water samples could not be collected due to non-availability of outlet water.

Table 4: List of treatment technologies evaluated in Rajasthan

S No	FSTP location	Capacity	Capex (Rs)	Opex (Rs/annum)	Technology	Description	Post-treatment
1	Phulera	20 KLD	2.8 Cr.	8.6 Lakhs	DEWATS	Stabilization Reactor, Unplanted Sludge Drying Bed (USDB), Integrated Settler with AF, PGF & Collection Tank	Without tertiary treatment
2	Lalsot	20 KLD	3.85 Cr.	8.4 Lakhs	DEWATS	Stabilization Reactor, Unplanted Sludge Drying Bed (USDB), Integrated Settler with AF, PGF & Collection Tank	Without tertiary treatment
3	Khandela	10 KLD	2.08 Cr.	6.5 Lakhs	DEWATS	Planted Sludge Drying Bed (PSDB), Integrated Settler with AF, PGF & Polishing Pond	Without tertiary treatment

Table 5: List of treatment technologies evaluated in Uttar Pradesh

S No	FSTP location	Capacity	Capex (Rs)	Opex (Rs/annum)	Technology	Description	Post-treatment
1	Unnao	32 KLD	4.93 Cr.	21.5 Lakhs	DEWATS	Stabilization Reactor, Screw Press, USDB, Settler–ABR-AF, PGF & Polishing Pond	Tertiary treatment with sand & activated carbon filter followed by UV irradiation
2	Jhansi	6 KLD	-	-	DEWATS	Planted sludge drying bed, ABR and PGF	Polishing pond
3	Jhansi	12 KLD	-	-	DEWATS	Planted sludge drying bed, ABR and PGF	Polishing pond
4	Chunar	10 KLD	-	-	DEWATS	Planted sludge drying bed, ABR and PGF	Tertiary treatment with sand & activated carbon filter followed by UV irradiation
5	Modinagar	32 KLD	-	-	Hyper core (LAMELLA)*	The hyper-core system in which faecal sludge undergoes the baffled anaerobic digestion and then clarifier-led aeration followed by tertiary treatment equipped with carbon filter, sand filter and ozonation	Sand & activated carbon filter followed by Ozone
6	Loni	32 KLD	-	-	MBBR	MBBR, tube settler and clarifier	Sand & activated carbon filter followed by UV

S No	FSTP location	Capacity	Capex (Rs)	Opex (Rs/annum)	Technology	Description	Post-treatment
7	Amethi	3 KLD	-	-	DEWATS	Planted sludge drying bed, ABR and PGF	NA
8	Bharwara	345 MLD	-	-	*STP Co-treatment* UASB	Up flow anaerobic Sludge blanket (UASB), pre-aeration tank, polishing pond	Chlorination
9	Bijnor	24 MLD	-	-	*STP Co-treatment* UASB	UASB, pre-aeration tank & polishing pond; solid sludge from Reactor diverted to the filter press and finally to the sludge drying bed	Chlorination
10	Bingawan	210 MLD	-	-	*STP Co-treatment* UASB	UASB, pre-aeration tank & polishing pond; solid sludge from Reactor diverted to the filter press and finally to the sludge drying bed	Chlorination

Table 6: List of treatment technologies evaluated in Madhya Pradesh

S No	FSTP location	Capacity	Capex (Rs)	Opex (Rs/annum)	Technology	Description	Post-treatment
1	Indore	3 KLD	-	-	DEWATS	Stabilization tank followed by planted sludge drying beds, (PDB) integrated settler and anaerobic filter (ISAF), and planted gravel filter (PGF)	Polishing pond
2	Elanza, Jabalpur	50 KLD	-	-	Mizuchi	Settling tank, trickling filtration, vermicomposting (MIZUCHI), Filtration through pebble layers (TERRA)	NA
3	Ojus, Jabalpur	100 KLD	-	-	Mizuchi	Settling tank, trickling filtration, vermicomposting, Multigrade sand filter and activated carbon filter	Multigrade sand filter and activated carbon filter
4	St.Alosius, Jabalpur	100 KLD	-	-	Mizuchi	Settling tank, trickling filtration, vermicomposting, water filtration through pebbles	NA

Table 7: List of treatment technologies evaluated in Chhattisgarh

S No	FSTP location	Capacity	Capex (Rs)	Opex (Rs/annum)	Technology	Description	Post-treatment
1	Kumhari	6 KLD	-	3.84 Lakhs	DEWATS	Planted sludge drying beds (PDB), integrated settler and anaerobic filter (ISAF), planted gravel filter (PGF)	Polishing pond
2	Patora	9 KLW	0.36 Cr.	1.47 lakhs	DEWATS	Planted sludge drying beds (PDB), integrated settler and anaerobic filter (ISAF),planted gravel filter (PGF)	Polishing Pond

Table 8: List of sewage treatment technologies evaluated in Uttarakhand

S No	STP location	Capacity	Technology	Description	Post-treatment
1	Lakkarghat, Rishikesh	26 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Sand filter & chlorination
2	Chorpani, Rishikesh	5 MLD	MBBR	MBBR technology followed by Secondary Clarifier and finally chlorination; Centrifugation of sediment to separate solid sludge	Sand filter &chlorination
3	Chandreswar, Rishikesh	7.5 MLD	MBBR	MBBR technology followed by Secondary Clarifier and finally chlorination; Centrifugation of sediment to separate solid sludge	Dish filter & chlorination
4	Tapovan, Rishikesh	3.5 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Chlorination
5	Mothrowala-I, Dehradun	20 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Chlorination
6	Mothrowala-II, Dehradun	20 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Chlorination
7	Indira Nagar, Dehradun	5 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Chlorination
8	Jagjeetpur, Haridwar	68 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Chlorination
9	Jagjeetpur, Haridwar	27 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Dual medial filter & chlorination
10	Jagjeetpur, Haridwar	18 MLD	ASP	ASP followed by Secondary Settling Tank and finally chlorination; solid sludge treated trough sludge digester &sludge drying bed	Chlorination
11	Sarai, Haridwar	18 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Chlorination
12	Sarai, Haridwar	14 MLD	SBR	SBR chamber followed by chlorination; Centrifugation of sediment to separate solid sludge	Chlorination

Results and Discussion

Performance evaluation of FSTPs

The technologies adopted by the FSTPs included DEWATS with or without tertiary treatment, geotube technology, moving bed bioreactor (MBBR), pyrolysis with packaged treatment module, Mizuchi and electrocoagulation.

Table 9: Representation of significant parameters of FSTPs equipped with various technologies (*Each value in the table represents the average of multiple samples*)

S No		Average values of the multiple sampling						
	FSTP locations based on treatment technology	Per cent removal COD	Per cent removal BOD	Per cent removal TKN	pH	Faecal coliform (MPN/100mL)	Discharge COD (mg/L)	Discharge BOD (mg/L)
	Decentralized wastewater treatment system (DWWTs/DEWATS)							
1	Siddipet	97.9	98.3	95.4	6.8	6	24.3	6.3
2	Sircilla	58.9	62.7	46.1	7.8	549	124.7	24
3	Thirumangalam	67.5	66.9	95.4	8.7	14	66.3	16.3
4	Thuraiyur	82.5	81.7	98	10.2	30	58.3	15
5	Vickramasingapuram	83.8	77.9	83.8	9.2	251	54.7	14.7
6	Shenkottai	31.7	32.6	82.9	8.9	296	172	42.7
7	Jhansi 12KLD	59.4	58	55.9	8.5	2165	75	20
8	Jhansi 6KLD	48.3	59	72.6	7.7	16593	144.4	16.7
9	Unnao	89	90.5	82.8	8	69	53.6	8.4
10	Chunar	33.8	48.3	72.6	7.4	3820	71	20
11	Amethi	1.2	1.2	66.8	8.7	2400	168	48.3
12	Phulera	60.3	70.5	60.9	8.5	173	148.2	23.2
13	Lalsot	67.1	71.3	47.6	8	622	121	19.4
14	Khandela	61.7	65.9	53.6	9.1	35	124.2	22.4
15	Balasore	91.4	73.5	77.6	7.5	72	146.3	50
16	Baripada	79.1	62.2	49.9	7.6	5838	367.3	90
17	Bhubaneswar	83.7	69.2	64.2	7.1	314	74.5	25.7
18	Dhenkanal	51.1	46.3	80.7	7.7	61	56	30.6
19	Berhampur	80.3	87.3	82	7.7	300	153.3	27.6
20	Angul	49.8	60.4	68.5	7.6	16947	162	26.7
21	Sambalpur	49.6	32.8	89.8	7.8	9	76.3	14.1
22	Rourkela	68.9	55.6	89.8	7.7	5	89.3	18.2
23	Asika	95.2	94.6	93.1	6.6	30	17.0	6.1
24	Bhadrak	83.7	83.2	92.2	8.1	32	105.0	32.1
25	Chodwar	77.4	76.0	92.7	8.3	30	43.0	13.5
26	Jagatsinghpur	97.9	98.0	95.4	7.3	320	24.7	7.5
27	Jatni	73.3	71.9	76.0	7.0	32	91.3	28.5
28	Khordha	83.6	82.7	83.4	6.6	200	65.7	20.6

S No		Average values of the multiple sampling						
	FSTP locations based on treatment technology	Per cent removal COD	Per cent removal BOD	Per cent removal TKN	pH	Faecal coliform (MPN/100mL)	Discharge COD (mg/L)	Discharge BOD (mg/L)
29	Nimapada	50.0	48.6	67.1	8.0	30	31.5	9.0
30	Paralakhemundi	95.5	95.0	95.2	7.1	33	36.0	10.5
31	Patora, Raipur	53.3	58.5	78.4	8.4	117	89.0	22.0
32	Kumhari, Raipur	59.7	52.3	75.2	8.2	2310	68.7	17.0
33	Kalibilod, Indore	60.9	60.1	62.3	8.0	4026	119.0	27.7
	Moving Bed Biofilm Reactor (MBBR)							
1	Kamareddy	97.6	96.9	96.3	7.3	34	40.33	11
2	Nirmal	73.8	67.4	82.8	7.6	235	27	7.5
3	Uppal	54.8	69.3	94.5	7.7	55	82	14.33
4	Periyanaickenpalayam	35.9	41.7	20.5	8.6	1330	163.3	37.3
5	Loni	58.6	60.9	74.2	7.9	765	231	48
6	Modinagar*	71.7	71	49.9	8.2	30	44.5	11
	Geotube Technology							
1	Boduppal	91	90.1	91.3	8.2	14	57.33	13.33
2	Bongir	78.3	77.7	96.2	8.6	29	49	11
3	Shandnagar	95.8	95.5	92.9	8.1	46	54.67	13
	Mizuchi treatment technology							
1	Ojus, Jabalpur	94.4	93.7	83.5	7.105	233	19.5	6.5
2	Elanza, Jabalpur	94.7	94.7	87.3	7.225	14299	38.5	11.5
3	St.Alosius, Jabalpur	80.6	79.3	72.2	7.745	133	28	8.6
	Electrocoagulation-Flotation (ECF)							
1	Nalgonda	92.6		97.8	8.2	20	41	10.67
	Packaged sewage treatment plant (P-STP)							
1	Warangal	86.9	85.1	87.1	8.3	13	46	11.33

pH

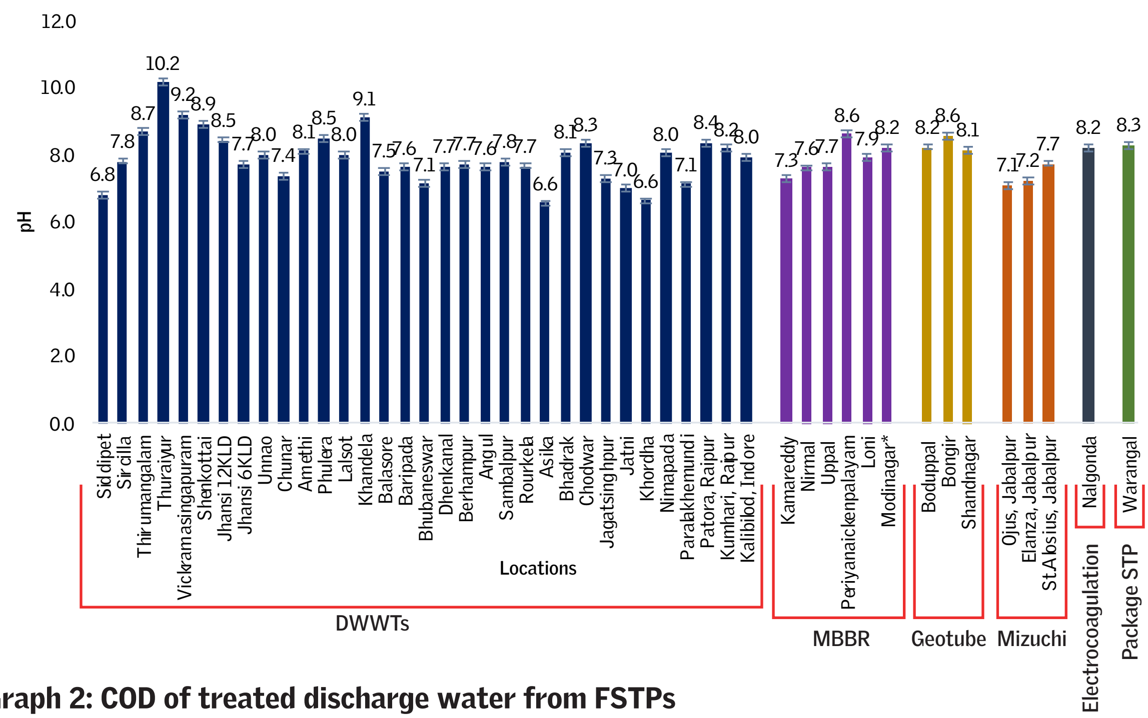
pH of the discharge water from different treatment systems ranges from 6.8 to 10.2. There is not much difference in the pH of the discharge water with respect to the treatment technology. All the pH values are under the discharge limit by MoEF&CC except in Thuraiyur (DWWT system).

Chemical Oxygen Demand (COD)

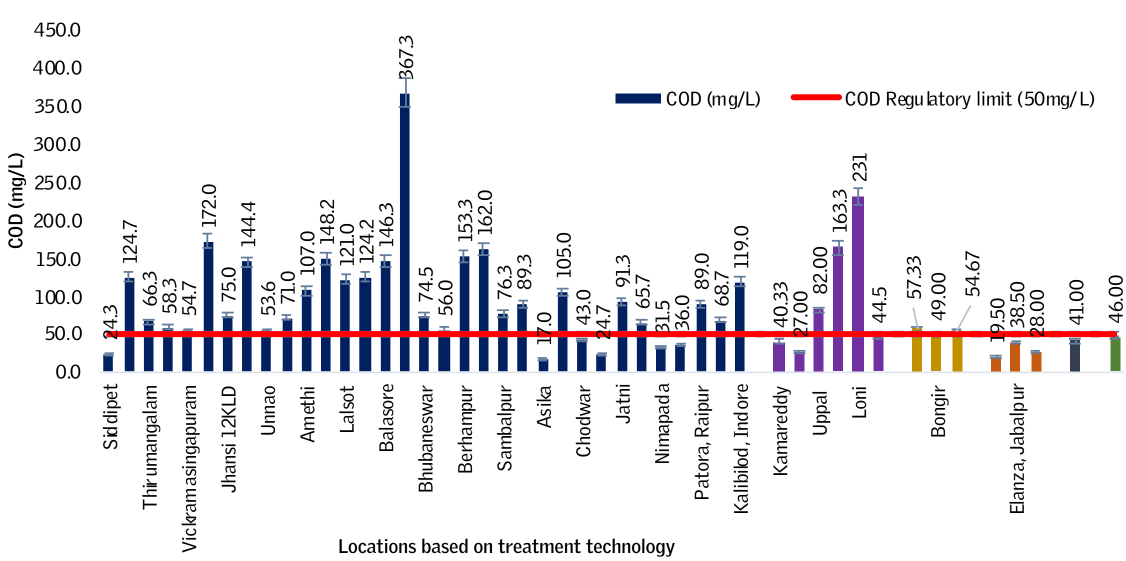
The average COD value of the treated discharge water ranges from 24.3 mg/L to 367.3 mg/L. According to MoEF&CC, the discharge standard for COD is 50 mg/L. Among the 47 FSTPs evaluated, only 15 FSTPs showed the discharge water COD below the standard limit.32 FSTPs showed high level COD in discharge water, which is above 50 mg/L.

Among the different treatment systems, the per cent removal of COD from inlet to outlet ranges from 29.1 to 97.9 per cent. The FSTPs, with DWWTs and MBBR treatment system showed high variability in the per cent reduction of COD. Other treatment systems showed a stable per cent reduction of 78 to 95 per cent.

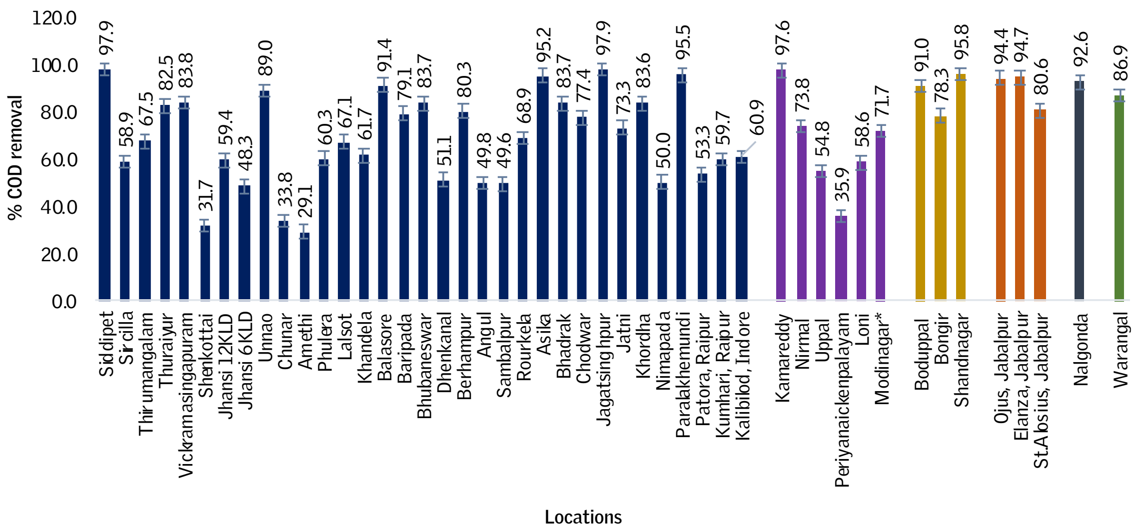
Graph 1: pH of treated discharge water from FSTPs



Graph 2: COD of treated discharge water from FSTPs



Graph 3: Per cent COD removal of FSTPs



Biochemical Oxygen Demand (BOD)

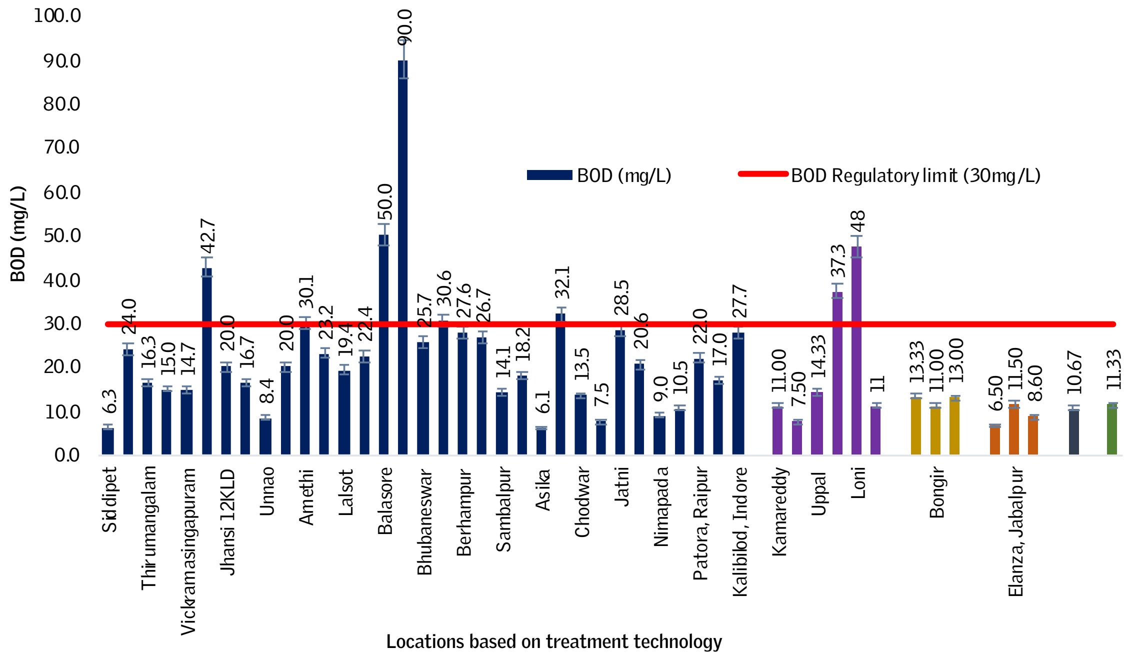
Among the evaluated faecal sludge treatment systems, the average BOD value of the treated discharge water ranges from 6.3 mg/L to 90.0 mg/L. According to the MoEF&CC, the discharge standard for BOD in metro cities is 20mg/L and non-metro cities is 30 mg/L. Except six FSTPs (four DWWTs and two MBBRs), all the locations show BOD values as below 30mg/L i.e. within the permissible level.

The per cent removal of BOD from inlet to outlet ranges from 29.0 to 98.3 per cent, that depicts the BOD removal efficacy of the systems. Variability in the per cent removal of BOD was observed in the DWWTs systems and MBBR treatment modules.

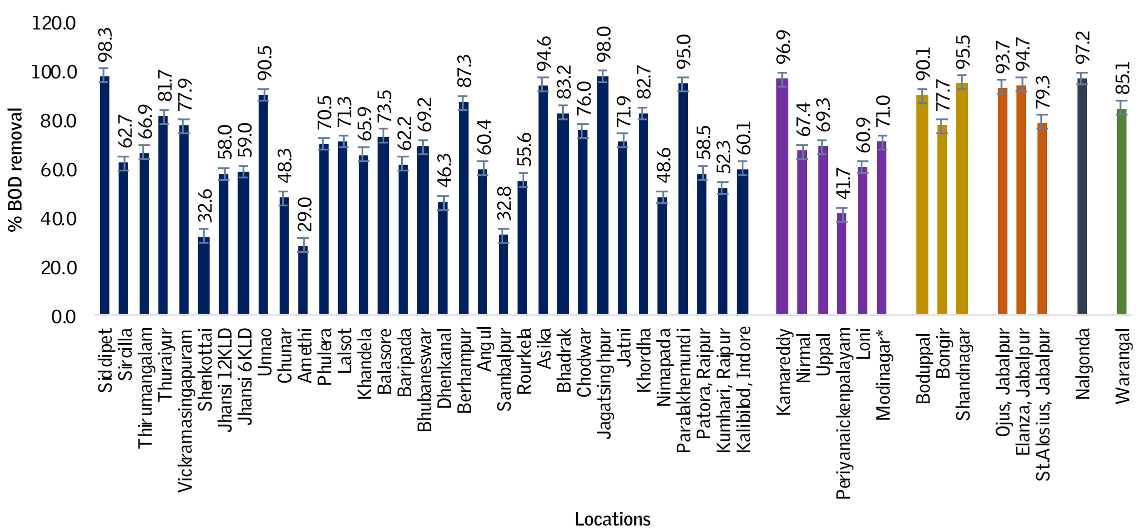
Total Kjeldahl Nitrogen (TKN)

The removal of TKN was observed in the evaluated FSTPs in the range of 20.5 to 98.0 per cent. Lowest removal efficacy is observed for Periyanaickenpalayam FSTP (20.5 per cent) that is equipped with MBBR technology. The highest removal efficacy was observed for Thuraiyur FSTP (98 per cent) with DWWTs technology.

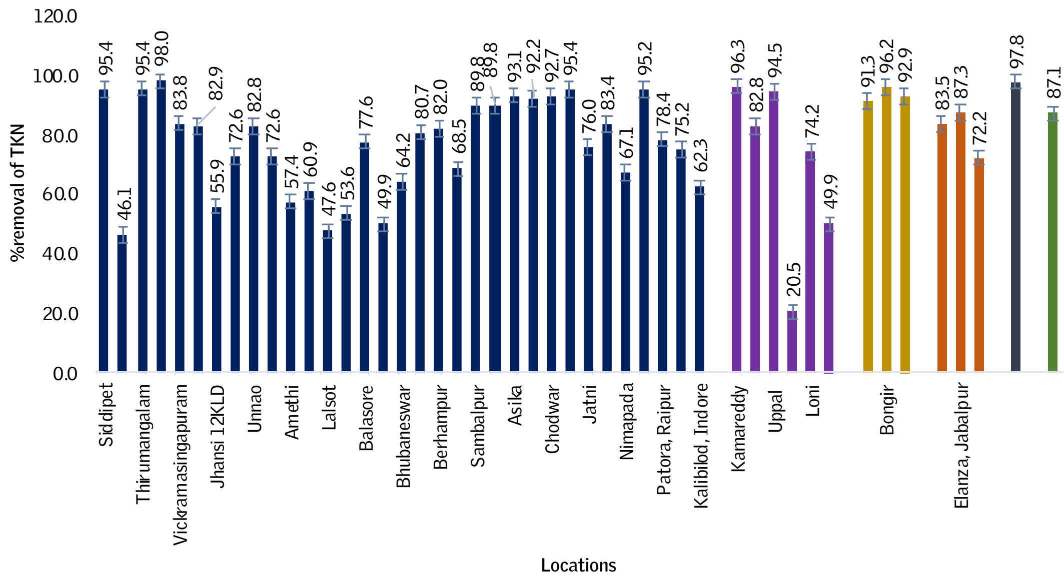
Graph 4: BOD of treated discharge water from FSTPs



Graph 5: Per cent BOD removal of FSTPs



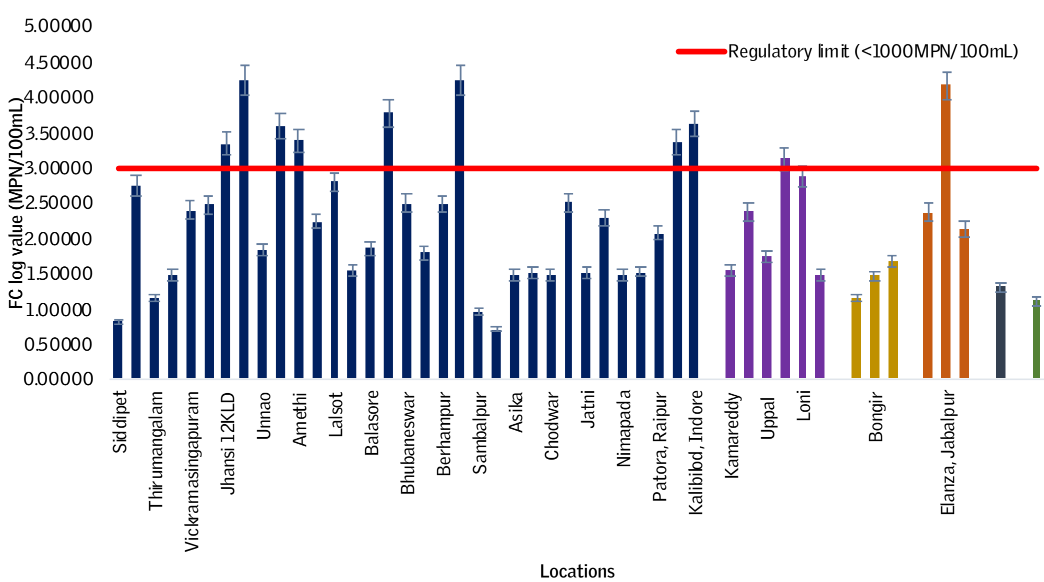
Graph 6: Per cent removal of TKN in FSTPs



Faecal coliform (FC)

The discharge limit of faecal coliform for unrestricted irrigation is R1000 MPN/100 ml. Out of all the evaluated systems, most of the FSTP outlet water came below the prescribed limit set by MoEF&CC regulations (R1000 MPN/100mL). Out of 47, outlet water of 10 sites showed higher FC value than the standard. Among these, some of the FSTPs (PNP, Angul, Chunar etc) showed a little higher FC value than the standard limit in spite of having a tertiary treatment i.e. sand filter, activated carbon filter and UV disinfection.

Graph 7: Faecal coliform in the discharge water of FSTPs



Performance evaluation of STP co-treatment

The STP co-treatment systems evaluated are adopted moving bed biofilm reactor (MBBR), sequencing batch reactor (SBR), waste stabilization pond, activated sludge process (ASP) and Upflow Anaerobic Sludge Blanket (UASB).

Table 10: Important parameters of evaluated STPs with different treatment technologies

STP Locations based on treatment technology	Per cent removal COD	Per cent removal BOD	Per cent removal TKN	Outlet pH	Faecal coliform (MPN/100mL)	Discharge COD (mg/L)	Discharge BOD (mg/L)
Sequential batch reactors (SBR)							
Lakkarghat	90.8	90.5	64.9	7.8	561.0	48.0	7.5
Tapovan	89.6	98.5	88.6	7.8	5767.0	78.0	2.8
Mothrowala -I	89.8	92.8	72.1	7.9	25833.0	39.7	4.3
Mothrowala -II	80.8	77.7	88.6	7.6	3151.0	57.3	13.3
Indranagar	92.5	88.9	55.1	7.8	36678.0	30.3	7.9
Jagjeetpur-I	93.6	96.3	81.1	7.7	117.0	23.5	3.8
Jagjeetpur- II	75.8	85.6	79.6	7.8	16.0	103.0	13.0
Sarai -I	89.7	88.9	94.3	7.9	13.0	62.5	12.0
Sarai -II	86.5	87.3	55.1	7.3	460000.0	86.0	19.0
Madurai	90.5	90.1	45.7	8.3	1193.3	69.3	17.3
Ukkadam	89.3	87.5	69.6	8.1	4476.7	82.0	23.3
Moving Bed Biofilm Reactor (MBBR)							
Erode	82.3	81.9	89.1	8.3	886.7	53.3	13.7
Khajaguda	93.6	92.6	44.9	7.2	125500.0	88.00	20.50
Nanakramkuda	97.2	95.3	40.2	8.0	37434.3	74.67	21.33
Chorpani	88.9	90.9	51.1	7.4	374433.0	77.7	11.9
Chandreswar	84.4	88.4	83.4	7.6	11933.0	46.3	7.0
Up Flow - Anaerobic Sludge Blanket Reactor (UASB)							
Bingwan	81.1	89.8	51.8	7.7	100666.7	94	13
Bharwara	69.0	79.9	56.5	7.8	54600.0	78.4	12
Bijnor	61.0	61.0	29.0	8.4	30.0	64	16
Waste Stabilization Pond (WSP)							
Trichy	78.0	76.9	43.9	8.1	1710.0	74.3	19.3
Puri	52.8	55.9	62.6	7.2	177.0	90.0	23.9
Activated Sludge Process (ASP)							
Jagjeetpur-III	88.3	89.3	91.0	7.7	2302.0	37.5	10.0

pH

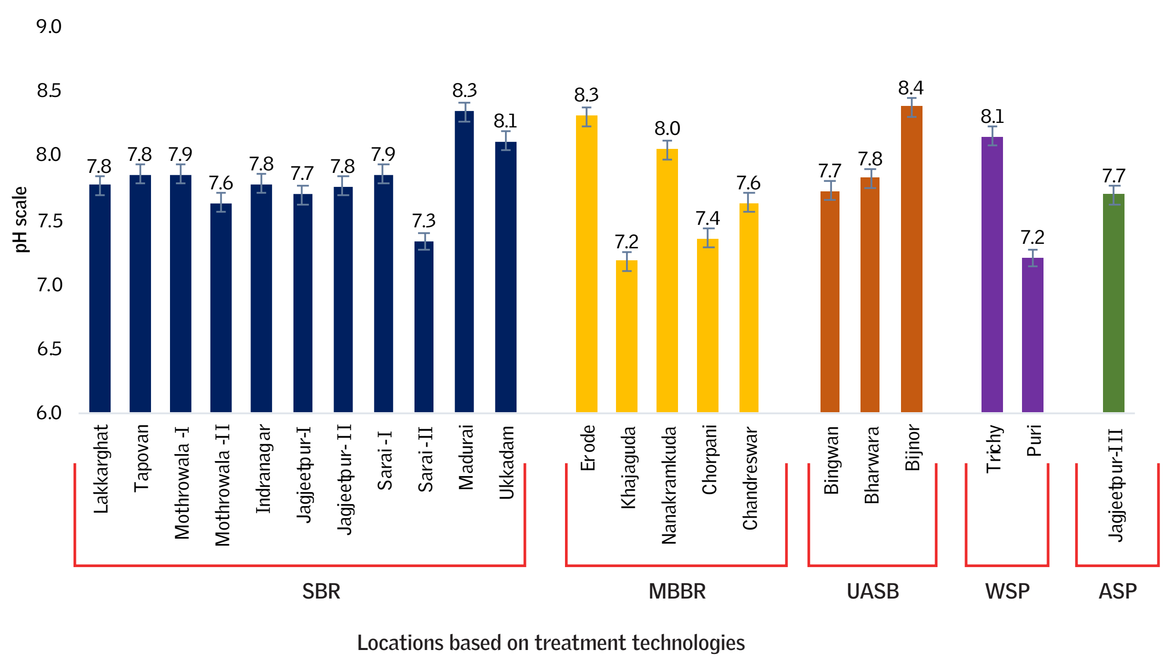
The pH of the discharge water from the different treatment systems ranges from 7.2 to 8.3. There is not much difference in the pH of the discharge water with respect to the treatment technology. All the STP co-treatment systems showed the pH values under the discharge limit by MoEF&CC.

Chemical Oxygen Demand (COD)

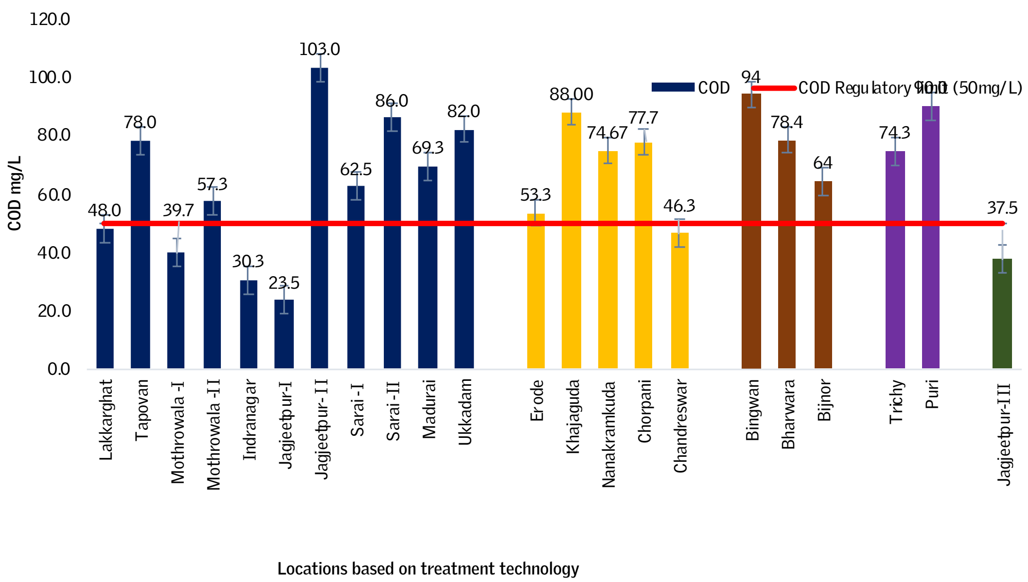
The average COD value of the treated discharge water ranges from 24.3 mg/L to 367.3 mg/L. According to MoEF&CC, the discharge standard for COD is 50 mg/L. Among the 22 STPs evaluated, only six showed the discharge water COD below the standard limit. The SBR technologies showed a better removal of COD from the effluent.

In the treatment efficacy of the systems, the per cent removal of COD from inlet to outlet ranges from 52.8 to 97.2 per cent. The STPs with SBR and MBBR treatment system showed a steady and high per cent reduction in COD.

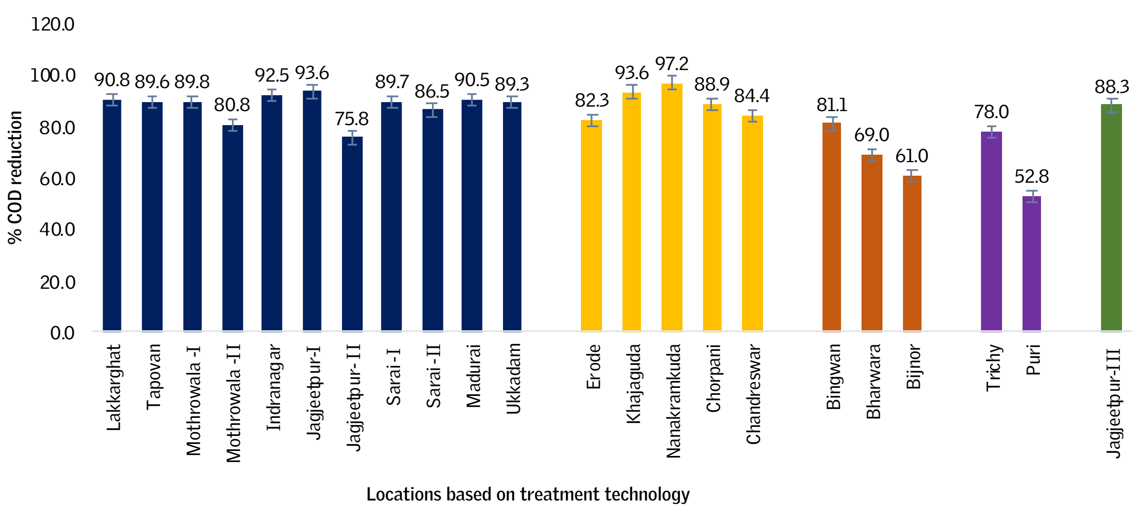
Graph 8: pH of treated discharge water of STPs



Graph 9: COD of treated discharge water of STPs



Graph 10: Per cent COD removal of STPs



Biochemical Oxygen Demand (BOD)

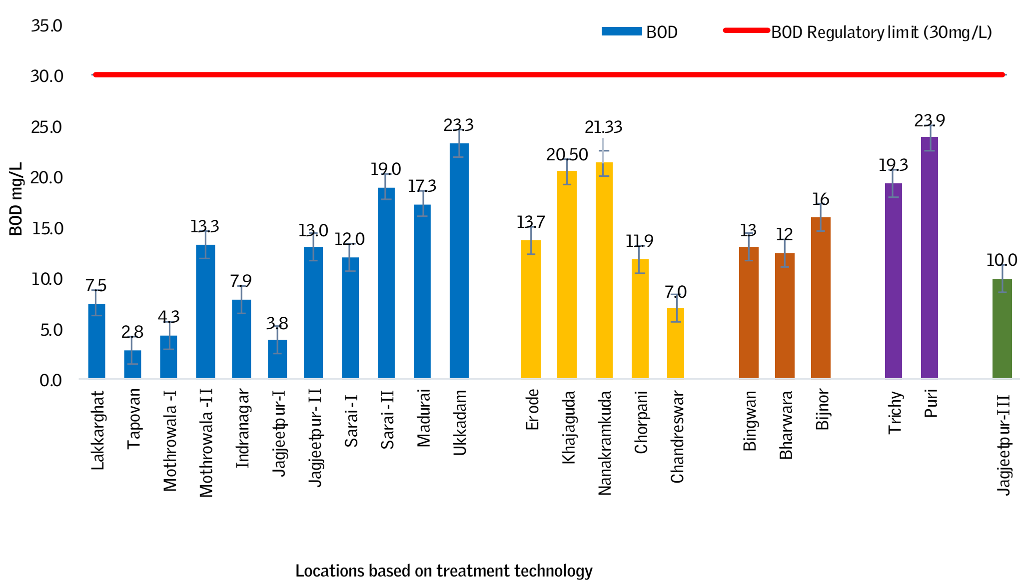
Among the evaluated sewage treatment systems, the average BOD value of the treated discharge water ranges from 2.8 mg/L to 23.9 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20mg/L and non-metro cities is 30 mg/L. All the locations showed BOD values below 30mg/L i.e. within the permissible level.

The per cent removal of BOD from inlet to outlet ranges from 55.9 to 98.5 per cent that depicts the BOD removal efficacy of the systems. High per cent removal efficacy of BOD was observed in the SBR systems and MBBR treatment modules. The waste stabilization pond showed a lesser removal which is below 75 per cent.

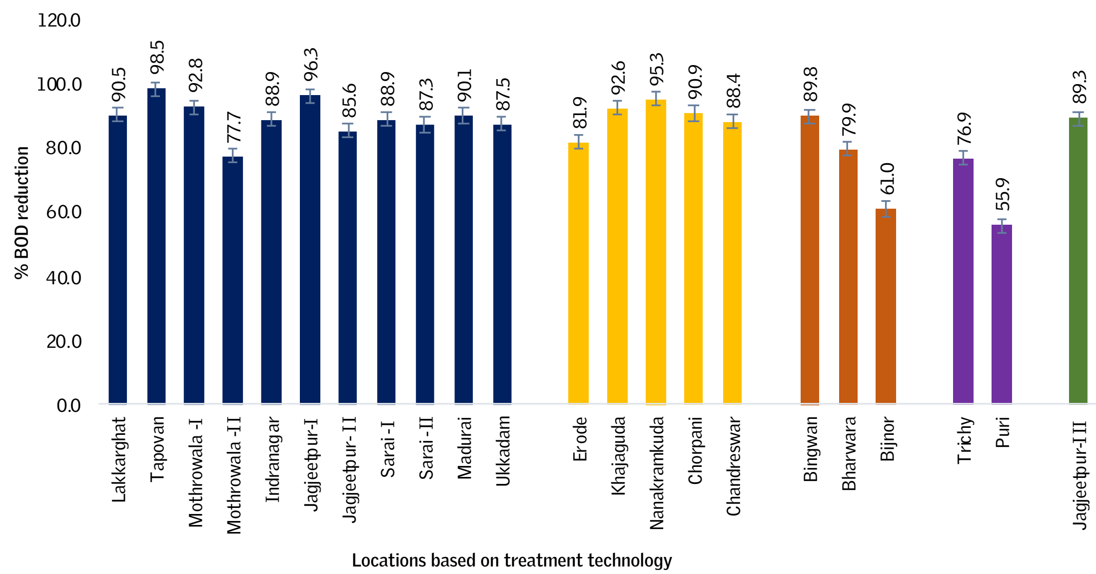
Total Kjeldahl Nitrogen (TKN)

The removal of nitrogen observed in the evaluated STPs was in the range of 29 to 94.3 per cent. Lowest removal efficacy is observed in Bijnor STP (29 per cent) with UASB technology and the highest removal efficacy was showed for Sarai (94.3 per cent) with SBR technology.

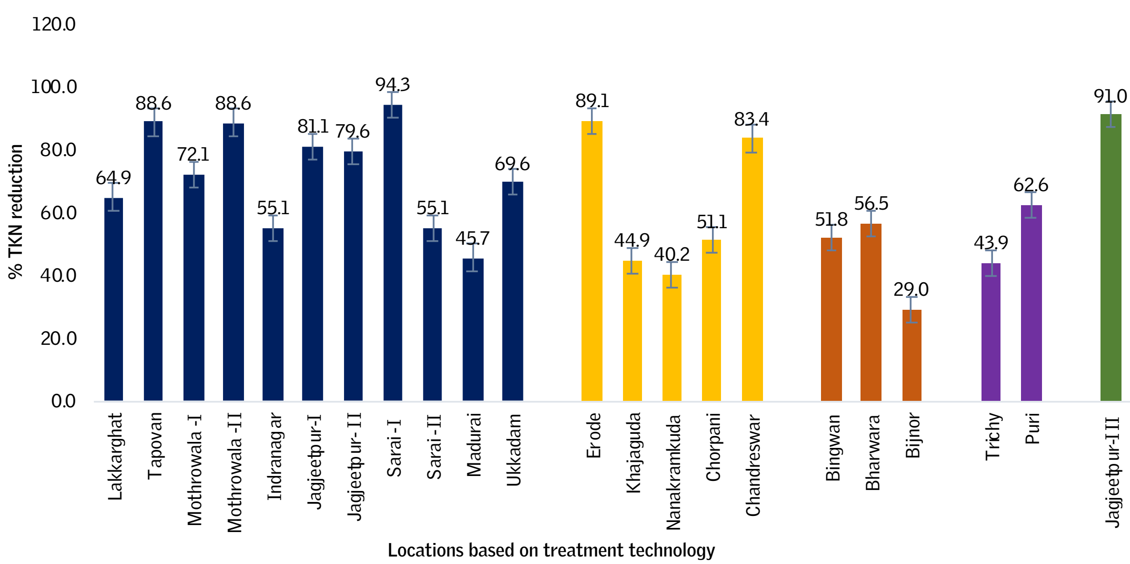
Graph 11: BOD of treated discharge water of STPs



Graph 12: Per cent BOD removal of STPs



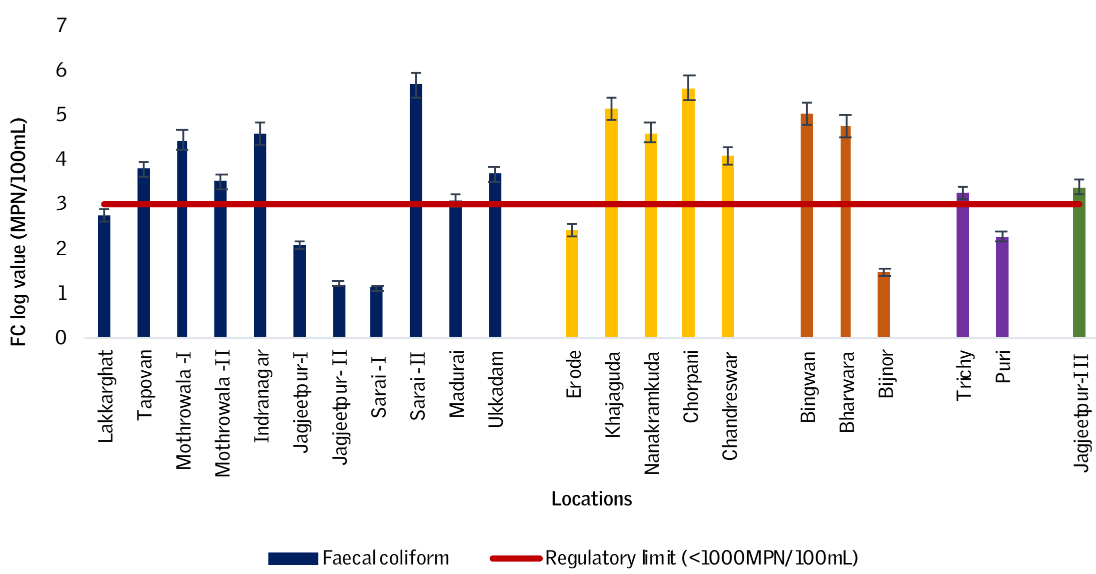
Graph 13: Per cent TKN reduction



Faecal coliform (FC)

The discharge limit of faecal coliform for unrestricted irrigation is R1000 MPN/100 ml. Out of the 22 evaluated sewage treatment systems, outlet water of 15 STPs came below the prescribed limit set by MoEF&CC regulations (R1000 MPN/100mL). In spite of having a tertiary treatment in all the STPs i.e. chlorination, >68% of the evaluated STPs are above the standard discharge limit. The microbial load in outlet water couldn't be controlled with predefined chlorine doses since the microbial load in in-fluent water varies in wide range. The microbial discharge quality in STPs is completely dependent on the tertiary treatment and how effectively chlorination (chlorine dosing) is used to treat the final discharge water, and not dependent on which technology is used in that STP for the treatment of wastewater

Graph 14: Faecal coliform in the discharge water



Characterisation of faecal sludge

The faecal sludge samples collected from the cesspool vehicle at the FSTPs were analysed for different parameters and the important parameters are provided in Table 11.

Table 11: Physico-chemical and biological parameters of the faecal sludge collected from the treatment plant discharge points

Locations	pH	Total solids (mg/L)	COD (mg/L)	BOD (mg/L)	Faecal coliform (MPN/100ml)	TS/COD ratio	COD/BOD ratio
Telangana							
Boduppal	7.1	11085	12750	2550	430000	0.87	5.00
Bongir	7.1	9569	9400	1880	9300	1.02	5.00
Kamareddy	7.9	30378	41767	11328	886667	0.73	3.69
Nalgonda	7.9	48884	48905	12644	1365000	1.00	3.87
Nanakramguda	3.8	4847	4553	921	120018	1.06	4.94
Nirmal	8.6	22000	54350	8750	110000	0.40	6.21
Siddipet	7.4	52923	67400	17594	11000000	0.79	3.83
Sircilla	8.9	25261	75375	17116	1570000	0.34	4.40
Uppal	7.9	2644	13410	420	380000	0.20	31.93
Warangal	8.0	27756	65950	10691	6700000	0.42	6.17
Tamil Nadu							
Ukkadam	7.7	2462	30090	6912	403333	0.08	4.35
PNP	7.9	3402	31000	8859	150000	0.11	3.50
Erode	8.0	12094	33043	7285	620800	0.37	4.54
Thurayiur	5.0	4783	37900	9828	30	0.13	3.86
Trichy	8.0	4059	25473	6715	2176667	0.16	3.79
Thirumangalam	7.6	6596	36225	7382	226500	0.18	4.91
Vickramasingapuram	7.9	83389	95600	28357	43000	0.87	3.37
Uttar Pradesh							
Modinagar	7.0	58892	101700	18340	46000000	0.58	5.55
Loni	7.8	15245	64700	10463	2154600	0.24	6.18
Jhansi	7.8	37347	75167	9775	5114333	0.50	7.69
Bijnor	8.2	47684	79750	11575	230000	0.60	6.89
Unnao	7.4	63807	164500	10700	304080	0.39	15.37
Bharwara	7.5	51328	70575	3513	1365000	0.73	20.09

Locations	pH	Total solids (mg/L)	COD (mg/L)	BOD (mg/L)	Faecal coliform (MPN/100ml)	TS/COD ratio	COD/BOD ratio
Chunar	7.1	79352	95367	11286	4866667	0.83	8.45
Bingawan	7.4	27580	27149	2648	3171000	1.02	10.25
Rajasthan							
Phulera	8.5	43537	52434	5083	2580000	0.83	10.32
Lalsot	8.0	48797	67838	6928	3018250	0.72	9.79
Khandela	9.1	23706	59667	5902	234333	0.40	10.11
Odisha							
Puri	7.2	29717	20637	3730	670000	1.44	5.53
Balasore	7.5	57619	74900	4655	21100000	0.77	16.09
Baripada	7.6	46736	57880	6230	38103100	0.81	9.29
Bhubaneswar	7.1	7817	20524	3760	141500	0.38	5.46
Dhenkanal	7.7	4485	3104	299	1380000	1.45	10.38
Berhampur	7.7	46486	54632	2018	5200000	0.85	27.07
Angul	7.6	30658	61533	6313	1250000	0.50	9.75
Sambalpur	7.8	31578	41562	6565	8300000	0.76	6.33
Rourkela	7.7	37469	42177	5635	545333	0.89	7.48
Bhadrak	6.9	11836	52625	10475	1275000	0.22	5.02
Chodwar	6.9	4089	6040	1518	430000	0.68	3.98
Jagatsinghpur	7.2	905	21740	6428	2515000	0.04	3.38
Khordha	6.9	9627	43700	13003	930000	0.22	3.36
Paralakhemundi	7.4	11064	3290	827	230000	3.36	3.98
Madhya Pradesh and Chhattisgarh							
Indore	7.97	54263	107550	14340	2400000	0.50	7.50
Patora	8.0	82593	79475	16917	2765000	1.04	4.70
Kumhari	7.4	18615	35543	8267	5965000	0.52	4.30
Mean	7.5	29665.8	50421.0	8142.7	4187322.5	0.7	7.7
Median	7.7	27580.0	48905.0	6928.0	1275000.0	0.6	5.5

Table 12: Consolidated data of per cent removal of COD in two important stages of faecal sludge treatment (solid-liquid separation and leachate treatment)

Locations	Faecal sludge (FS)	Leachate Inlet	Treated Outlet	FS to leachate Inlet (% removal)	FS to Outlet (% removal)	Leachate Inlet to Outlet (% removal)
Telangana						
Boduppal	12750	636	57.3	95	99.6	91
Bongir	9400	226	49	97.6	99.5	78.3
Kamareddy	41767	1713	40.3	95.9	99.9	97.6
Nalgonda	48905	1441	41	97.1	99.9	97.2
Nanakramguda	4553	1242.7	74.7	72.7	98.4	94
Nirmal	54350	103	27	99.8	99.95	73.8
Siddipet	67400	1163	24.3	98.3	99.96	97.9
Sircilla	75375	303.3	124.7	99.6	99.8	58.9
Uppal	13410	181.3	82	98.6	99.4	54.8
Warangal	65950	351.3	46	99.5	99.9	86.9
Tamil Nadu						
Ukkadam	30090	768.7	82	97.4	99.7	89.3
PNP	31000	254.7	163.3	99.2	99.5	35.9
Erode	33043	301.3	53.3	99.1	99.8	82.3
Thurayiur	37900	334	58.3	99.1	99.8	82.5
Trichy	25473	337.3	74.3	98.7	99.7	78
Thirumangalam	36225	204	66.3	99.4	99.8	67.5
Vickramasingapuram	95600	338	54.7	99.6	99.9	83.8
Uttar Pradesh						
Modinagar	101700	157	45	99.8	99.96	71.7
Loni	64700	558	231	99.1	99.6	58.6
Jhansi	75167	185	75	99.8	99.9	59.4
Bijnor	79750	164	64	99.8	99.9	61
Unnao	164500	487	54	99.7	99.97	89
Bharwara	70575	253	78	99.6	99.9	69
Chunar	95367	91	60	99.9	99.9	33.8
Bingawan	27149	495	94	98.2	99.7	81.1
Rajasthan						
Phulera	52434	373.2	78.6	99.3	99.9	78.9
Lalsot	67838	368	67.6	99.5	99.9	81.6

Locations	Faecal sludge (FS)	Leachate Inlet	Treated Outlet	FS to leachate Inlet (% removal)	FS to Outlet (% removal)	Leachate Inlet to Outlet (% removal)
Khandela	59667	324	65.6	99.5	99.9	79.8
Odisha						
Puri	20637	190.7	54	99.1	99.7	71.7
Balasore	74900	1695	188.5	97.7	99.7	88.9
Baripada	57880	1758.7	238	97	99.6	86.5
Bhubaneswar	20524	458	83.5	97.8	99.6	81.8
Dhenkanal	3104	114.5	57	96.3	98.2	50.2
Berhampur	54632	780	217.7	98.6	99.6	72.1
Angul	61533	322.7	67.3	99.5	99.9	79.1
Sambalpur	41562	151.3	21	99.6	99.9	86.1
Rourkela	42177	287.3	41	99.3	99.9	85.7
Bhadrak	52625	643.3	105	98.7	99.8	83.6
Chodwar	6040	190.6	43	96.8	99.2	77.4
Jagatsinghpur	21740	1168.6	24.6	94.6	99.8	97.8
Khordha	43700	400.6	65.6	99.0	99.8	83.6
Paralakhemundi	3290	798.5	36	75.7	98.9	95.4
Madhya Pradesh and Chhattisgarh						
Indore	107550	304	119	99.7	99.8	60.8
Patora	79475	220.6	89	99.7	99.8	59.6
Kumhari	35542	146.6	68.6	99.5	99.8	53.1
Mean	50421	510.8	78.9	97.6	99.7	76.2

Table 13: Consolidated data of per cent removal of BOD in two important stages of faecal sludge treatment (solid-liquid separation and leachate treatment)

Locations	Faecal sludge (FS)	Leachate Inlet	Treated Outlet	FS to leachate Inlet (% removal)	FS to Outlet (%removal)	leachate Inlet to Outlet (% removal)
Telangana						
Boduppal	2550	135	13.3	94.7	99.48	90.1
Bongir	1880	49.3	11	97.4	99.41	77.7
Kamareddy	11328	350.7	11	96.9	99.9	96.9
Nalgonda	12644	227.3	10.7	98.2	99.92	95.3
Nanakramguda	921	259	21.3	71.9	97.68	91.8
Nirmal	8750	23	7.5	99.7	99.91	67.4
Siddipet	17594	380	6.3	97.8	99.96	98.3
Sircilla	17116	64.3	24	99.6	99.86	62.7
Uppal	420	46.7	14.3	88.9	96.59	69.3
Warangal	10691	76	11.3	99.3	99.89	85.1
Tamil Nadu						
Ukkadam	6912	186	23.3	97.3	99.66	87.5
PNP	8859	64	37.3	99.3	99.58	41.7
Erode	7285	75.7	13.7	99	99.81	81.9
Thurayiur	9828	82	15	99.2	99.85	81.7
Trichy	6715	83.7	19.3	98.8	99.71	76.9
Thirumangalam	7382	49.3	16.3	99.3	99.78	66.9
Vickramasingapuram	28357	66.3	14.7	99.8	99.95	77.9
Utter Pradesh						
Modinagar	18340	40	11	99.8	99.94	71
Loni	10463	121	48	98.8	99.55	60.9
Jhansi	9775	47	20	99.5	99.8	58
Bijnor	11575	40	16	99.7	99.87	61
Unnao	10700	89	8	99.2	99.92	90.5
Bharwara	3513	62	12	98.2	99.65	79.9
Chunar	11286	29	15	99.7	99.87	48.3
Bingawan	2648	130	13	95.1	99.5	89.8
Rajasthan						
Phulera	5083	148.2	23.2	97.1	99.54	84.3
Lalsot	6928	121	19.4	98.3	99.72	84

Locations	Faecal sludge (FS)	Leachate Inlet	Treated Outlet	FS to leachate Inlet (% removal)	FS to Outlet (%removal)	leachate Inlet to Outlet (% removal)
Khandela	5902	124.2	22.4	97.9	99.62	82
Odisha						
Puri	3730	90	23.9	97.6	99.36	73.5
Balasore	4655	146.3	50	96.9	98.93	65.8
Baripada	6230	367.3	90	94.1	98.56	75.5
Bhubaneswar	3760	74.5	25.7	98	99.32	65.5
Dhenkanal	299	56	30.6	81.3	89.76	45.3
Berhampur	2018	153.3	27.6	92.4	98.63	82
Angul	6313	162	26.7	97.4	99.58	83.5
Sambalpur	6565	76.3	14.1	98.8	99.79	81.5
Rourkela	5635	89.3	18.2	98.4	99.68	79.6
Bhadrak	10475	282.4	22.1	97.3	99.8	92.2
Chodwar	1518	166.1	12.1	89.1	99.2	92.7
Jagatsinghpur	6428	259.0	11.9	96.0	99.8	95.4
Khordha	13003	148.2	24.6	98.9	99.8	83.4
Paralakhemundi	827	323.0	15.6	60.9	98.1	95.2
Madhya Pradesh and Chhattisgarh						
Indore	14340	69.3	27.7	99.5	99.8	60.1
Patora	16917	53.0	35.7	99.7	99.8	32.7
Kumhari	8267	22.0	17.0	99.7	99.8	22.7
Mean value	8143	126.8	21.1	95.9	99.3	75.2

The pH of the faecal sludge ranges from 3.8 to 8.2 with an average value of 7.7, which indicate that the sludge can be biologically treated by aerobic or anaerobic processes. The mean COD and BOD values of faecal sludge from all the locations are 51864.4 mg/L and 7963.5 mg/L with COD/BOD ratio of 8.42. The average total solid (TS) value of all the locations is 29717.0 mg/L with TS/COD ratio of 0.63. The faecal coliform ranges from 10^3 to 10^7 with a mean of 10^6 MPN/100mL.

The average COD of the fecal sludge reaching to the FSTPs in all the evaluated locations is 50421.0 mg/L. After the solid liquid separation, the leachate entering in to the treatment modules of the FSTPs have the average COD of 510.8 mg/L, with an average per cent reduction of 97.6 per cent. This COD load is further reduced in the treatment system and discharged with an average COD of 78.9 mg/L, with an average per cent reduction of 76.2 per cent. The average BOD of the fecal sludge reaching to the FSTPs in all the evaluated locations is 8143.0 mg/L.

Subsequent to the solid liquid separation, the leachate is entering in to the treatment modules of the FSTPs with an average BOD of 126.8 mg/L, and an average per cent reduction of 95.9 per cent. This BOD load is further reduced in the treatment system and finally discharged with an average BOD of 21.1 mg/L and an average per cent reduction of 75.2 per cent.

Summary and recommendations

- A total of 69 treatment plants were evaluated in the eight states, which included Telangana (10 FSTPs and 2 STPs), Tamil Nadu (5 FSTPs and 4 STPs), Odisha (16 FSTPs and 1 STP) Rajasthan (3 FSTPs) Uttar Pradesh (7 FSTPs and 3 STPs) Uttarakhand (12 STPs), Madhya Pradesh (4 FSTPs) and Chhattisgarh (2 FSTPs) with different treatment technologies.
- The technologies adopted by the FSTPs included DEWATs with or without tertiary treatment, geotube technology, moving bed bioreactor (MBBR), pyrolysis with packaged treatment module, mizuchi and electrocoagulation.
- The STP co-treatment systems adopted moving bed bioreactor (MBBR), sequencing batch reactor (SBR), waste stabilization pond, Activated sludge process (ASP) and Upflow Anaerobic Sludge Blanket (UASB).
- Telangana has adopted diverse technologies for the treatment of faecal sludge in comparison to other states.
- Most of the treatment plants in other states have adopted DWWTs technologies, with minor changes in the operating modules.
- Most of the FSTPs are working below their designed treatment capacity and facing difficulty in getting faecal sludge daily or even weekly for some plants.
- The COD value of the discharge water in most of the FSTPs in all the states is not within the regulatory limit (50 mg/L) of MoEF&CC, whereas the BOD values are within the limit (30 mg/L).
- The per cent removal of nitrogen (TKN) in most of the treatment systems is more than 60 per cent except in few locations.
- All the FSTPs in Telangana and Rajasthan are well maintaining the count of faecal coliform in the treated discharge water under the limit set by MoEF&CC (1000MPN/100mL).
- One out of five FSTPs in Tamil Nadu, two out of 16 FSTPs in Odisha, four out of seven FSTPs in Uttar Pradesh, one out of two in Chhattisgarh and two out of four in Madhya Pradesh are not maintaining the faecal coliform count under the discharge limit, even though many of the treatment system has post-treatment technologies to eliminate the bacterial load.
- Among the evaluated treatment technologies, the DWWTS systems showed high variability in the treatment efficacy followed by MBBR technologies, which may be due to the inconsistency in the availability of faecal sludge and improper operation and maintenance.
- The technologies other than DWWTS and MBBR technologies showed

consistent performance during the study period. However, less number of FSTPs were evaluated in other technologies.

- The faecal sludge received at the treatment systems is highly variable in its chemical characteristics, and most of the treatment systems treat the leachate water only after solid-liquid separation. The mean COD and BOD of the Pan-India faecal sludge are approximately 50,000 mg/L and 8,000 mg/L respectively, in which only approx. 500 mg/L of COD and 120 mg/L of BOD is entering into the treatment module. That means an average of 97.6 percent COD and 95.9 per cent BOD is removed in solids during the initial stages of solid-liquid separation.
- These solids are dried and stored in the treatment site without further treatment or reuse. Therefore, complete pathogens removal along with resource recovery from the dry sludge is very important for sustainable faecal sludge management.
- Most of the STPs in the states are not maintaining the discharge limit for faecal coliform value, even though all the system has a chlorination unit to remove the bacterial load.
- Among STPs of all the states, Tamil Nadu STPs showed better performance in controlling the microbial load in the discharge water, which is close to or below the discharge limit.
- The STP co-treatment facilities can be used to treat faecal sludge along with sewage as the evaluated facilities are removing organic matter in a high percentage, but the faecal coliform load is a matter of concern
- The overall performance of FSTPs in all the states was observed to be satisfactory in terms of removing organics and pathogens provided the operation and maintenance is carried out properly.
- Selection of treatment technologies are depending on the land availability, CAPEX and man power availability and the technical expertise

Recommendations (operation and maintenance guidelines)

- Most of the FSTPs are running under capacity due to several factors, such as location in the interior, narrow and broken roads, unavailability of vehicles etc. Operators should ensure a continuous supply of faecal sludge to the site for the smooth functioning of the FSTP.
- Many FSTPs are dependent on private operators for desludging, that sometimes leads to delays in routine collection and desludging process. There is a need to address this issue.
- There should be regular training programmes for FSTP operators about all the safety measures and operational guidelines.

- Awareness events should be conducted in rural areas to educate people about the importance of sustainable faecal sludge management and regular desludging of onsite sanitation systems.
- It should be ensured that the pumps are powerful enough to drive the sludge to the sludge drying beds, and are not frequently choking. Recurrent monitoring of pumps and pipeline is essential in order to avoid pump failure and any leakage or clogs in the pipeline. This enables smooth and continuous operation of FSTPs.
- Many sites showed high microbial load even when they are equipped with tertiary treatment systems. Therefore, regular monitoring and maintenance is required such as changing of filters, testing of UV light intensity and ozone generator.
- In many FSTPs, there is loss of sand from the upper layer of the sludge drying bed at the time of sludge removal. Instead of placing perforated tiles at the topmost layer, a synthetic net can be included in order to avoid mixing of sand with the sludge and prevent loss of sand.
- A lab facility for testing the basic physical, chemical and microbial parameters of the inlet (fresh sludge) and outlet (treated water) of FSTPs must be ensured. Testing should be carried out routinely to certify the proper performance of FSTPs.
- In most of the STPs, the BOD value in effluent water was within the regulatory limit but the microbial load in effluent water was determined to be high. Since microbial load in influent water was varying in a wide range, faecal coliform concentration in effluent water couldn't be controlled with a predefined chlorine dose applied in the treatment process. Residual chlorine should be regularly monitored and maintained.
- It is necessary to optimise and maintain a mixing ratio of faecal sludge to sewage water in STP co-treatment systems, for the smooth functioning and to avoid clogging of the treatment system.

Annexure I

State-wise performance analysis of FSTPs and STP co-treatment

Telangana

Telangana, the youngest state in the country, is rapidly urbanizing with close to 40 per cent of its population living in urban areas. The state has taken several path-breaking initiatives towards enhancing sanitation service delivery, and it is committed to providing high quality public sanitation facilities and services in all its 142 towns. The Government of Telangana (GoT) has prioritized sanitation and the health of its citizens through the provision of toilets in households and in public places.

In a scenario where the larger part of the country is dependent upon on-site sanitation systems, FSSM is essential to ensure city-wide inclusive sanitation. The safe management and treatment of faecal sludge goes a long way in securing public health and environment. Proper and timely de-sludging, along with safe disposal and treatment are of prime importance. Judicious de-sludging of septic tanks will improve its treatment efficiency. The Administrative Staff College of India (ASCI) is collaborating with the Telangana government to support implementation of scheduled de-sludging in 142 Urban Local Bodies (ULBs) across the state. The ASCI is providing support to the Telangana government for training and to ensure proper planning, implementation, and monitoring the scheduled de-sludging.

FSTPs have been designed by adopting diverse technologies depending on final end uses or disposal options of sludge and liquid streams. Simultaneously, extensive efforts have also been initiated to investigate the co-treatment of faecal sludge through existing sewage treatment plants. However, due to limited operating experience on specific design, there is inadequate treatment performance and thus failure of technologies. Therefore, monitoring the performance of different technologies of FSTP operation was required

Faecal sludge treatment systems evaluated for the current study

For faecal sludge management in Telangana, different technologies have been adopted in various locations of the state. The types of the technologies is as follows:

- **FSTP based on geotube technology** is operated by Banka Bioloo, is located in three different places including Boduppal, Bhongir and Shadnagar.

- **FSTP based on moving bed bioreactor and sludge drying by paddle dryer and IR decontamination technology** is operated by Meliorate Engineers Pvt Ltd in Uppal and Kamareddy.
- **FSTP based on integrated settler with anaerobic filter and planted gravel filter** has been constructed by the Priyadhar Group and is located in Siddipet and Sircilla.
- **FSTPs based on moving bed bioreactors and sludge management by composting and pyrolysis,** located in Warangal, are operated by Tide Technocrats.
- **FSTPs based on electrocoagulation technique** are located in Nalgonda.

Apart from the above FSTPs, co-treatment of faecal sludge with sewage is also implemented by the Hyderabad Metropolitan Water Supply & Sewerage Board in Hyderabad in two locations — Khajaguda and Nanakramguda — with plant capacities being 7 MLD and 4.5 MLD, respectively.

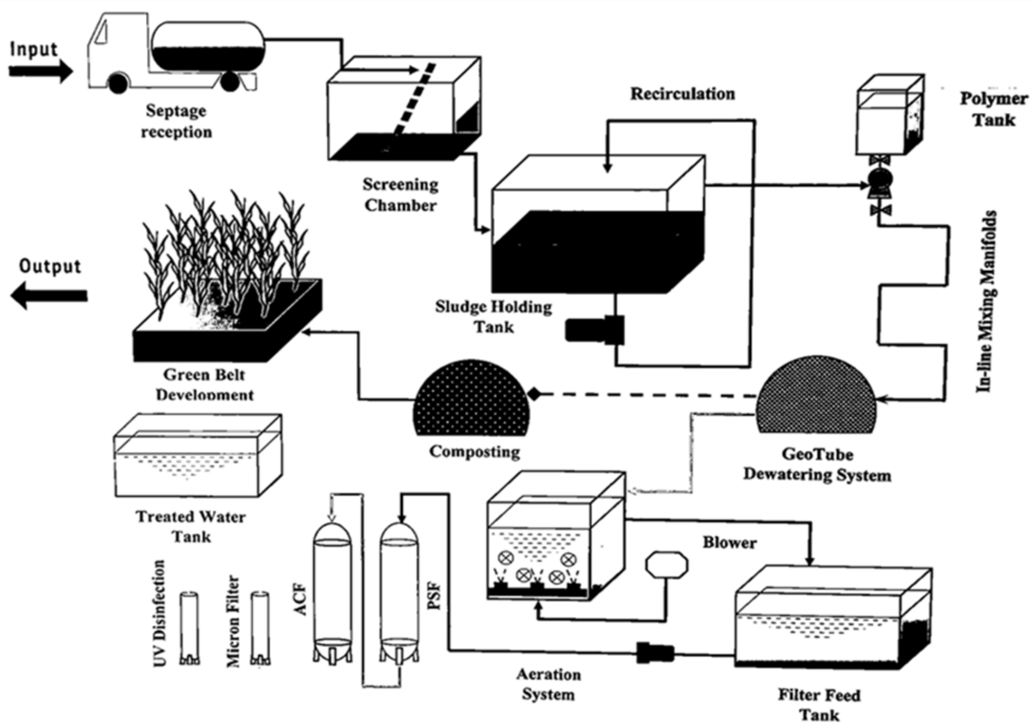
Boddupal FSTP

Boddupal FSTP is located in Medchal–Malkajgiri district of Telangana state. The FSTP was started in 2020 with a capacity to treat 15 KLD of faecal sludge. The plant is running at full capacity and receives faecal sludge every day with a frequency of one truck per day. Each truck has a capacity to hold 5,000 L of faecal sludge. The source of the sludge are household toilets, community toilets and public toilets.

The key treatment technology used in this site is Geotube. The whole treatment system can be divided into three parts — primary, secondary and tertiary. Primary treatment starts with the screening chamber with an 8 mm screen that leads to the removal of solid waste such as napkins and plastics. After this, the sludge undergoes the solid-liquid separation process—this process is composed of a sludge holding tank, polymer tank and geotube bags. The sludge is kept for 40 minutes in the sludge holding tank, followed by the polymer tank. Inside the polymer tank, a colloidal solution of cationic polymer is added in a proportion of 2 per cent of 5 KL of faecal sludge. Coagulation-flocculation process happens.

After this, the sludge is filled into 7-m size geotube bags where dewatering takes place. One geotube bag costs around Rs 30,000-50,000—a 7-m bag can accommodate 70-80 truckloads of faecal sludge. The water that comes out of the geotube bags is treated by aeration process (secondary treatment) resulting in reduction of BOD and COD. Finally, the water is also treated by a tertiary process that is a combination of activated carbon filter, pressure sand filter, micron filter and UV disinfection—this leads to removal of colour and particles. The treated

Figure 1: Schematic representation of the process flow in Boddupal FSTP



water quality is checked by a multi-parameter kit and samples are sent to labs at various time intervals for detailed analysis.

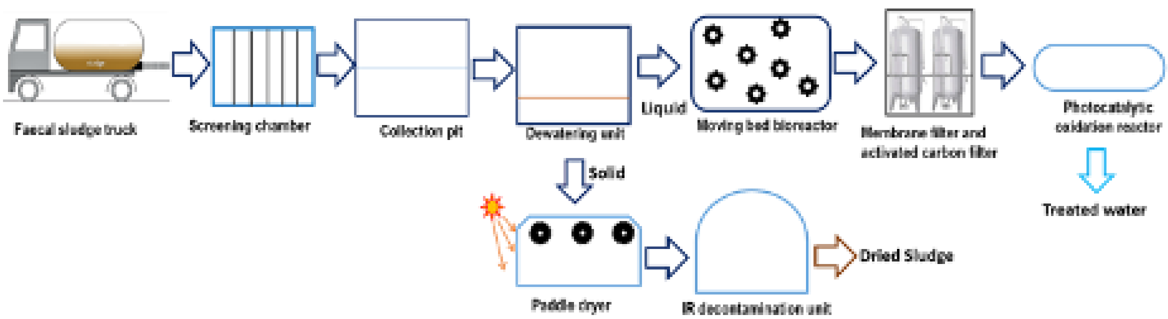
Solids filled in the bags are generally kept still for four weeks and moisture analysis is carried out periodically. After getting the optimum moisture conditions, the bag is cut down, sundried and the dry sludge is used for gardening purposes. The site has well maintained ornamental plants and a green belt that has been developed by using treated water and dry sludge as compost.

Uppal FSTP

Uppal is a suburban region in eastern Hyderabad, in Ranga Reddy district of Telangana. A 40-KLD FSTP was set up in 2021 here, with a technology called combined biological treatment with solar sludge drying and decontamination. The technology has been set up in such a way that it can be controlled by using a mobile app. This allows the operators to control the functioning of the FSTP from their homes.

The plant receives faecal sludge from household and public toilets. It is running at its full capacity as seven-eight trucks (capacity of 6 KL each) unload the sludge

Figure 2: Schematic representation of the process flow in Uppal FSTP



on a daily basis. The plant is maintained and managed well by the operators. The faecal sludge from the tankers is discharged into the bar screen where the coarse particles are eliminated and subsequently, it moves to the collection pit where the scum is removed. After this process, the solid and liquid contents are separated using the dewatering unit where the liquid moves to the moving bed bioreactor (MBBR) and the solid part moves to the drying unit. In the MBBR, the floating biofilm media consumes the organic content and reduces the organic load of the received liquid content. Further, the colour and odour are removed from the wastewater by activated carbon filter (ACF) and activated media filter (AMF). For the purpose of deactivating microorganisms, photo catalytic oxidation reactor-based decontamination unit is installed at the end of the treatment system.

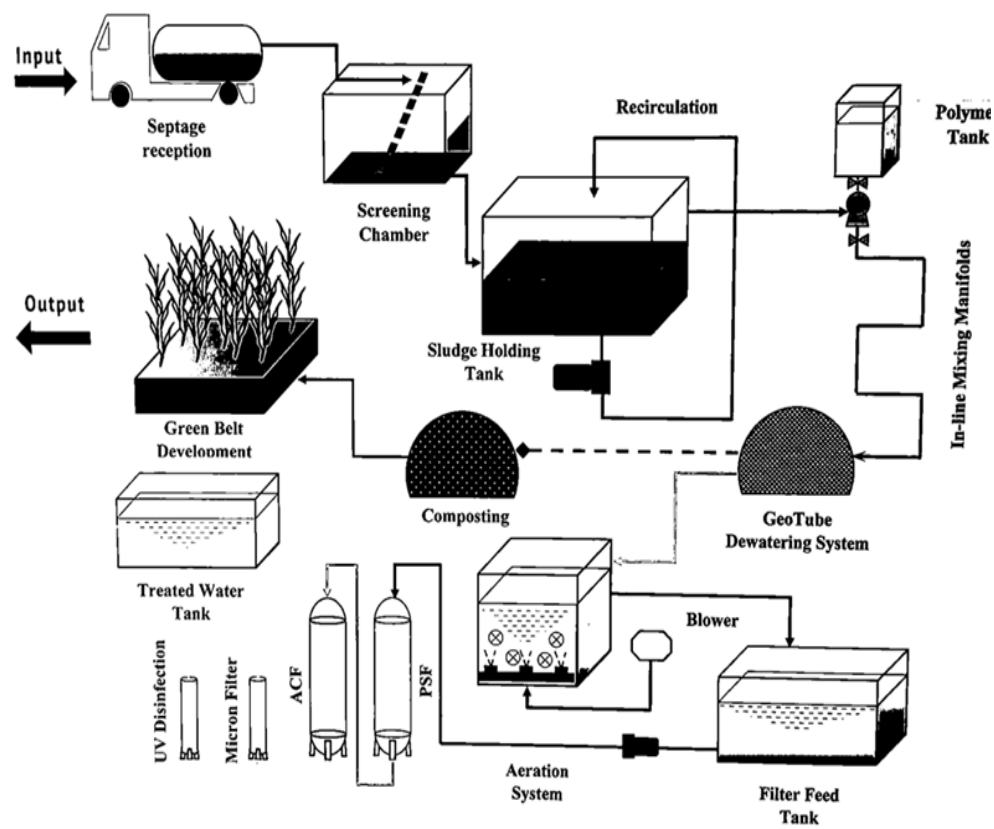
Around 35 KL of water is generated after treatment which is used for gardening purposes in and around the FSTP site. The solid part in the drying unit is conveyed to a paddle dryer and finally to an Infra-red radiation unit where decontamination (1-5 min of irradiation) of dried sludge is done. The dried sludge is stored until usage.

Bhongir FSTP

Bhongir, officially known as, Bhuvanagiri, is located in Yadadri district of Telangana. The FSTP here was started in 2020 with a capacity to treat 15 KLD of faecal sludge. The plant is not running to its full capacity and receives a maximum of only four truckloads of faecal sludge in a week—with each truck having a capacity to hold 3-5 KL of faecal sludge. This is because the area is sparsely populated and the FSTP itself is built at an interior location. The source of the sludge are household, community and public toilets.

The key treatment technology used in this site is Geotube. The whole treatment system can be divided into three parts — primary, secondary and tertiary. Primary

Figure 3: Schematic representation of the process flow in Bhongir FSTP



treatment starts with the screening chamber with an 8 mm screen that leads to the removal of solid waste such as napkins and plastics. After this, the sludge undergoes the solid-liquid separation process—this process is composed of a sludge holding tank, polymer tank and geotube bags. The sludge is kept for 40 minutes in the sludge holding tank, followed by the polymer tank. Inside the polymer tank, a colloidal solution of cationic polymer is added in a proportion of 2 per cent of 5 KL of faecal sludge. Coagulation-flocculation process happens.

After this, the sludge is filled into 7-m size geotube bags where dewatering takes place. One geotube bag costs around Rs 30,000-50,000—a 7-m bag can accommodate 70-80 truckloads of faecal sludge. The water that comes out of the geotube bags is treated by aeration process (secondary treatment) resulting in reduction of BOD and COD. Finally, the water is also treated by a tertiary process that is a combination of activated carbon filter, pressure sand filter, micron filter and UV disinfection—this leads to removal of colour and particles. The basic parameters of the treated water such as dissolved oxygen, pH, TDS, conductivity and temperature are checked by a multi-parameter kit and samples are sent to labs at various time intervals for detailed analysis.

Solids filled in the bags are generally kept still for four weeks and moisture analysis is carried out periodically. After getting the optimum moisture conditions, the bag is cut down, sundried and the dry sludge is used for gardening purposes.

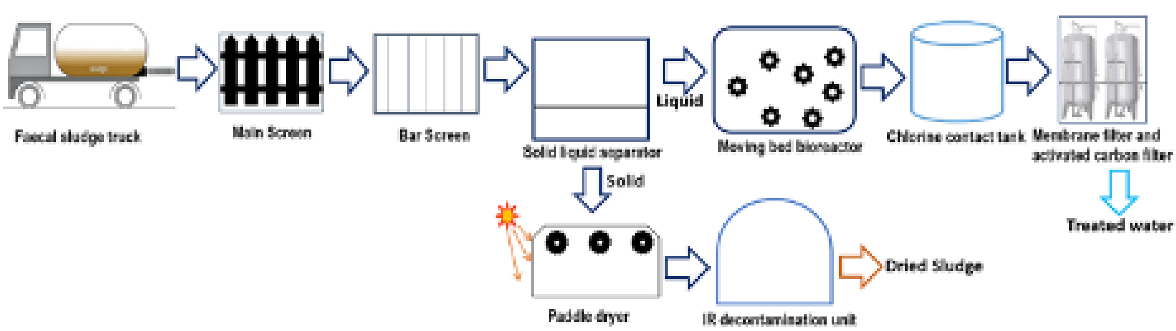
Kamareddy FSTP

Kamareddy district is located in the northern part of Telangana. A 30-KLD FSTP was commissioned here in 2020 with the technology based on MBBR for organic load reduction and paddle drying for sludge drying process. Similar to the FSTP in Uppal, the operation and control of this FSTP can be done by a mobile app.

Although the plant uses good technology, its operations are affected due to the very little load it receives—this is because the FSTP is located in a very remote area. The plant receives faecal sludge from public toilets, hospitals, community toilets and household toilets. The sludge is discharged initially into the main screen from the tanker, where sand and grit get separated. A bar screen placed adjacent to this removes coarse particles from the sludge, after which the the sludge is pumped into the solid-liquid separator. The liquid portion moves to the MBBR where a suspended biofilm media is present, whereas the solid part moves to the drying unit.

From the MBBR, the treated water moves to the tube settler and chlorine contact tank, the disinfection process occurs following which it is pumped to membrane filter and activated carbon filter. Around 28 KL of treated water generated every day is used for irrigating the crops planted in the FSTP site. In the drying unit, the sludge is conveyed through a paddle dryer, where sludge gets dried by solar radiation. The dried sludge is conveyed to theinfra-red radiation unit for decontamination of the dried sludge.

Figure 4: Schematic representation of the process flow in Kamareddy



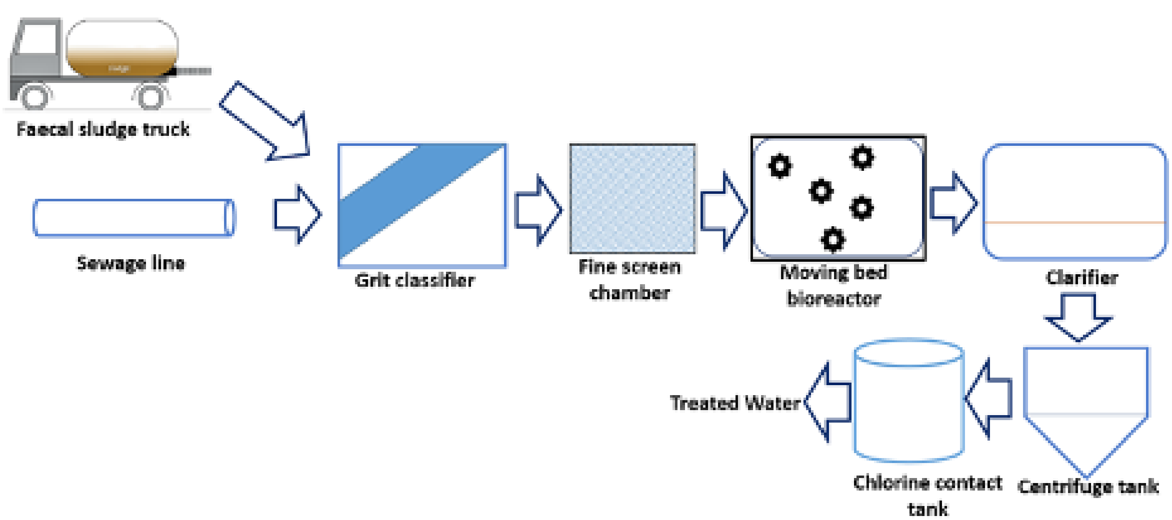
Khajaguda co-treatment STP

Khajaguda is located in the suburban region of Gachibowli, Hyderabad, in Telangana. In this region, faecal sludge is co-treated with sewage in a sewage treatment plant (STP) of 7 MLD capacity. This co-treatment system was commissioned in 2012. The treatment plant receives faecal sludge from household toilets, hospitals, public toilets and community toilets, delivered by 10 trucks of 15-20 KL capacity each, every day.

The sewerage and septage management system receives the sewage and septage in the sump tank where it is mixed together. The mixed sewage is pumped to the rake classifier where the coarse materials are eliminated. The grit chamber which follows it aids in the removal of suspended inorganic matter such as sand, silt and grit. After the screening process, it flows to the aeration tank where it is treated by MBBR technology, following which it moves to the clarifier where sludge settles at the bottom.

The effluent is pumped to the centrifuge tank for the complete separation of solids and liquid. The suspended and floatable matter which were not removed in the clarifier are eliminated in the centrifugal dewatering unit. Further, the treated water flows to the chlorination tank for disinfection purposes. To check the quality of the treated water, an online continuous monitoring scanner is installed. The treated water is discharged into Nanakramguda lake.

Figure 5: Schematic representation of the process flow in Khajaguda STP



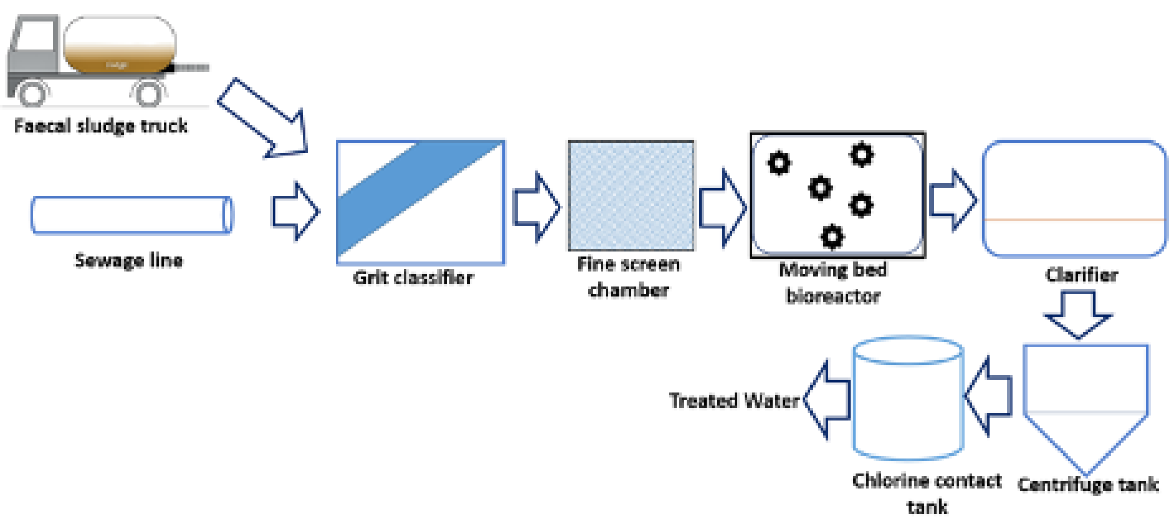
Nanakramguda co-treatment STP

Nanakramguda is situated in the west zone of Hyderabad, in Serlingampally mandal. Since this municipality has an STP, a provision was made in 2012 to co-treat the faecal sludge with the sewage in the STP, which has a capacity of 4.5 MLD. The co-treatment plant is located near Bhageeratham lake. Faecal sludge is received on a daily basis through three-four trucks, each having a capacity of five-seven KL. Sources of the sludge include household, community and public toilets.

The preliminary unit of the treatment plant consists of a grit chamber and fine screen chamber to remove coarse and fine particles (<6 mm) respectively. The next step is the separation of grit from the sewage and fecal sludge which is done by a grit classifier. This is followed by MBBR where polypropylene and polyethylene-based biofilm media is used for the reduction of organics and a clarifier for the settlement of sludge. The effluent from the clarifier flows to the centrifugal dewatering unit and to chlorine contact tank for disinfection of microbes present in the treated water.

The amount of treated water generated per day is 20-30 KL—this is sent to the nearby horticultural land for reuse. In addition to this, the treated water is re-used for gardening onsite.

Figure 6: Schematic representation of the process flow in Nanakramguda STP



Nalgonda FSTP

Nalgonda FSTP was started in the year 2020 with a capacity to treat 75 KLD of faecal sludge. Currently, the plant is not running at its full capacity and receives only 20 KLD of sludge daily. The source of faecal sludge is household, community and public toilets and hospitals. The main treatment technology used is electrocoagulation process.

Treatment starts with screen of faecal sludge in screen chambers where solid waste such as plastics etc gets eliminated. Then it is received and processed in an equalisation tank and further goes for electrocoagulation process. Electrocoagulation process is employed with electrode chambers line with 3 cathode and three anode plate. Subsequently, the water is separated through dewatering machine (separation chamber) and solids are collected through conveyer belt. Treated water is then undergoes the aeration process in the presence of bacteria where BOD and COD removal takes place. Finally the tertiary treatment is carried out through activated carbon filter and sand filter. Moreover, dry sludge is exposed to sunlight in the sun drying chamber.

Dry sludge and treated water are used for gardening purposes. Basic parameters such as pH, TDS and dissolved oxygen of the treated water are tested using multi-parameter kits.

Nirmal FSTP

Nirmal FSTP was commissioned in Telangana in the year 2020, with a capacity to treat 30 KLD of faecal sludge. The plant is running at its full capacity and receiving two truck-loads of sludge every two days. Each truck has a capacity to hold 4 KL of faecal sludge. The source of faecal sludge is household, community and public toilets and hospitals.

Figure 7: Schematic representation of the process flow in Nalgonda FSTP

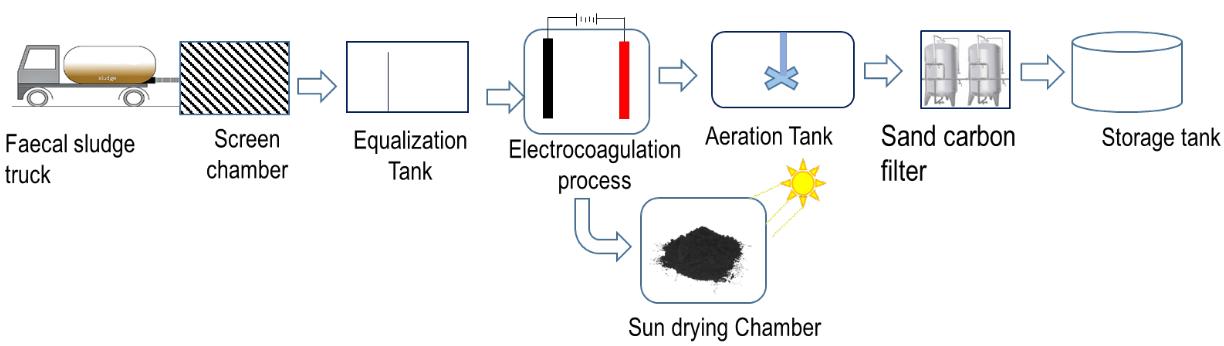
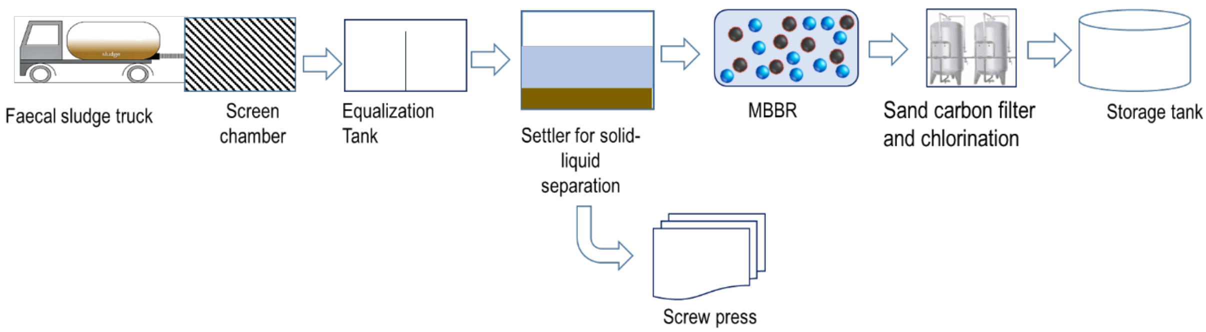


Figure 8: Schematic representation of the process flow in Nirmal FSTP



The MBBR treatment technology is employed for treatment of faecal sludge. Treatment process starts with two consecutive screen chambers for removal of solid waste such as tissues and plastics. Then the sludge goes to the equalisation tank and further pumped to the first settler for solid-liquid separation. After 90 per cent of the sludge gets settled in the first settler, it is pumped to the secondary settler where polymer-based solid-liquid separation is carried out. The liquid part is treated by MBBR process in two MBBR tanks. In this process, treatment occurs by addition of media chips and surface beads leading to biofilm formation for removal of BOD and COD.

The water is then treated in secondary clarifier or tube settler and further goes to clear water tank or filter feed tank. The tertiary treatment is carried out by activated carbon filter, sand filter and chlorination. Moreover, dry sludge coming out of the second settling tank undergoes a thermal treatment process where it is heated at 600°C in screw press resulting in the removal of all kinds of microbes. At the same time, this reduces the nutrient composition.

Every day, 300 kg of dry sludge and 20 KLD of treated water is produced and consumed for gardening purposes. The site has a small lab with a BOD incubator and can analyse the parameters of treated water.

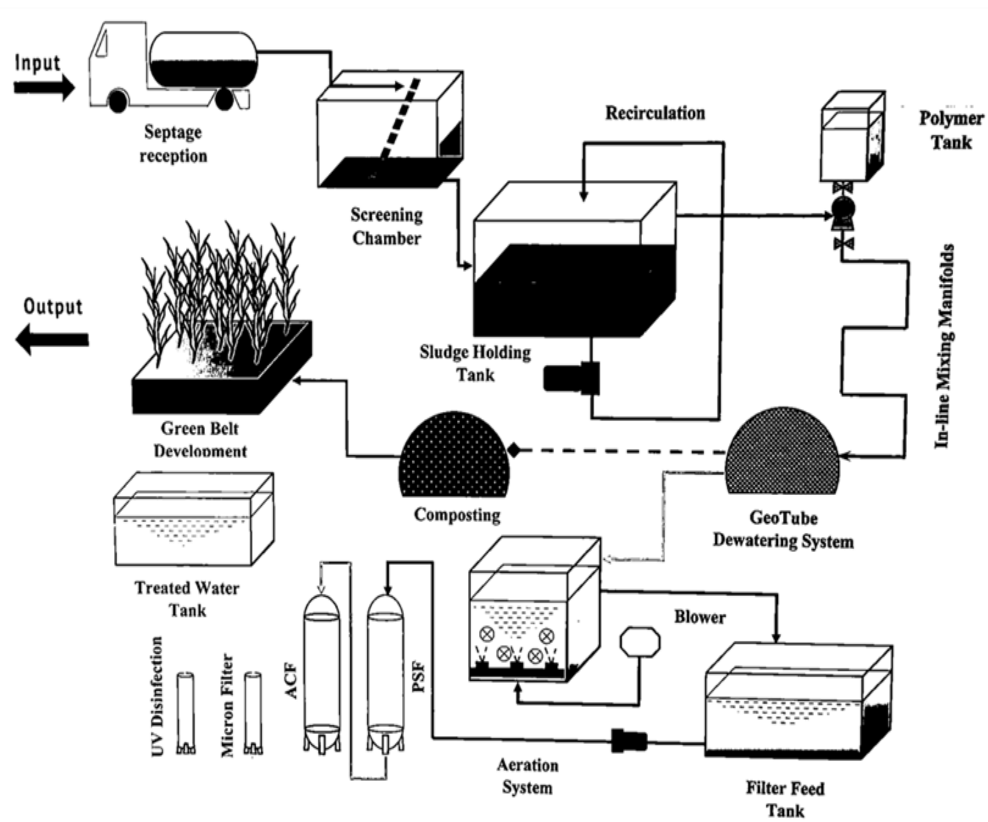
Shadnagar FSTP

Shadnagar is located in Mahabubnagar district in Telangana. The FSTP here was started in 2021 with a capacity to treat 25 KLD of faecal sludge. The plant is not running to its full capacity—it receives a mere one truckload of faecal sludge in two weeks—with each truck having a capacity of 3-5KL. This is because of the interior location of the plant and inhospitable roads that lead to it, that makes it difficult for vehicles to reach the site. The source of the sludge is household and public toilets.

The key treatment technology used in this site is the geotube technology. The whole treatment system can be divided into three parts — primary, secondary and tertiary. Primary treatment starts with the screening chamber with a 8 mm screen that leads to the removal of solids such as napkins, plastics etc. Then the faecal sludge undergoes the solid-liquid separation process, which is carried out in a sludge holding tank, a polymer tank and geotube bags. Sludge is kept for 40 minutes in the sludge holding tank, followed by the polymer tank. In the polymer tank, colloidal solution of cationic polymer is added and coagulation-flocculation process is carried out.

After this, the sludge is filled into geotube bags where dewatering takes place. Unlike the Boddupal and Bhongiri FSTPs, this site uses bigger (13 m) geotube bags having a capacity of 25 m^3 — one bag can accommodate the 150-170 truckloads of faecal sludge. Moreover, the water that comes out of the geotube bags is treated by aeration process (secondary treatment) resulting in reduction of BOD and COD. It is finally treated in a tertiary process that is a combination of activated carbon filter and pressure sand filter, which leads to the removal of colour and particles.

Figure 9: Schematic representation of the process flow of Shadnagar FSTP



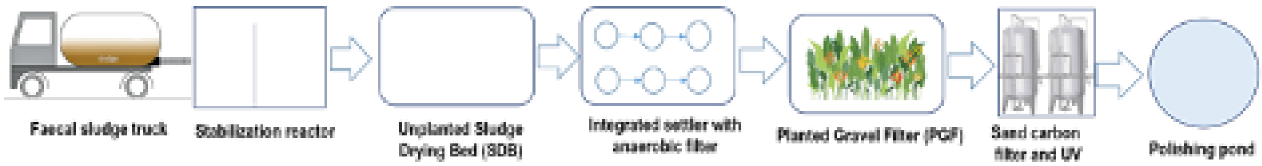
Solids filled in the bags are generally kept still for four weeks and moisture analysis is carried out periodically. After getting the proper moisture conditions, bag is cut down, sun dried and used as compost.

Siddipet FSTP

Siddipet is a town located in Siddipet district of Telangana. An FSTP with a capacity of 20 KLD was commissioned in the year 2021 in Basapur village. The plant is not working at its full capacity as the load received is very little, the plant being located in a very remote area. The load received is on a weekly basis, in two-three trucks with a capacity of 2.5-3 KL each.

The treatment plant consists of an anaerobic stabilisation reactor where the tanker discharges the faecal load. After a certain period of holding time, the sludge moves to the sludge drying bed where the solids are separated and the liquid flows to the balancing tank. The separated solids are placed in the sludge drying bed for a period of 18 days to completely drain out the liquid content. After this, the retained solids are kept for sun drying until usage. The liquid part of the faecal sludge passes to an integrated settler with anaerobic filter, planted gravel filter,

Figure 10: Schematic representation of the process flow in Siddipet FSTP



sand and carbon filter and finally, to the polishing pond. The end use of the treated water is for gardening the plants in the FSTP site.

Sircilla FSTP

Sircilla is a town located in Rajanna Sircilla district in Telangana. An 18-KLD FSTP was commissioned here in 2019. The plant receives faecal sludge daily from various sources including community toilets, household toilets, public toilets, and hospitals.

Desludging of the vehicles occurs into the screening chamber, where the floating materials are removed. The next unit in the FSTP is the stabilization reactor where homogenization and stabilization of faecal sludge takes place. This is followed by

Figure 11: Schematic representation of the process flow in Sircilla FSTP

unplanted sludge drying beds, where the liquid and solid portion are separated. The solid part of the faecal sludge gets deposited in the drying bed and the percolate from the sludge drying bed moves to the integrated ABR with filter chambers, where secondary treatment of the percolate occurs.

Subsequent to this, percolate moves to the planted gravel filter where some of the nutrients of percolate are absorbed by the plants. Further, it moves to sand and carbon filter for the removal of colour and odour and finally to the polishing pond. The solid part is removed from the sludge drying bed after 24 days of drying and mixed with vegetable waste to prepare co-compost.

The dried sludge and vegetable waste is mixed in the ratio of 2:3. The co-compost prepared is used for agriculture around the FSTP site.

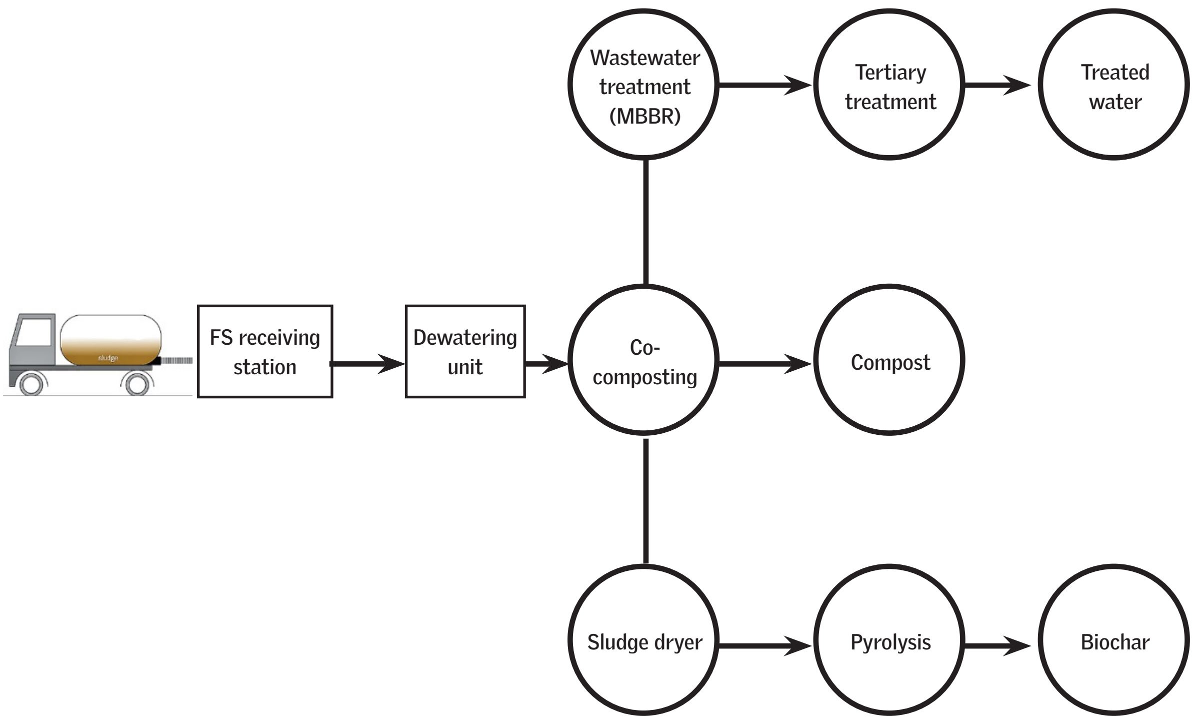
Warangal FSTP

The Warangal FSTP in Telangana has a capacity to treat 15 KLD of faecal sludge. The system is running to its full capacity and receives three truckloads a day of faecal for five days in a week, with each truck having a capacity to hold 3 KLD of sludge. The sources of faecal sludge are household toilets, community toilets, hospital sludge and public toilets.

The treatment system is composed of screening chamber, polymer-based dewatering system, MBBR (moving bed bioreactor) technology and tertiary treatment by pressure sand filter, activated carbon filter and chlorination. Treatment process starts by addition of 0.2 per cent polymer in the dewatering unit for separation of solids and liquid from the faecal sludge. Subsequently, the liquid part (water) undergoes the MBBR process that is divided into four zones — sedimentation, aeration, anoxic (denitrification process) and anaerobic (solids removal process).

On completion of the MBBR process, water is stored in a pre-tertiary storage tank and taken out at required intervals for further treatment. Finally the water portion is treated by pressure sand filter and activated carbon filter followed by chlorination. On the other hand, dry sludge is dried in sludge dryer, mixed with

Figure 12: Schematic representation of the process flow in Warangal FSTP



biomass (wood pellets) and subsequently filled into pyrolyzer where it is treated by pyrolysis process in anoxic conditions at the temperature of 500° C to 800°C for 8hr. Although, pyrolysis process leads to complete removal of every kind of microbe but at the same time lowers the nutrient composition of dry sludge. However, the excess amount of dry sludge is treated by composting process and used for gardening purpose. There is no lab facility present in this FSTP but samples send twice in a month to nearby labs to examine the quality of treated water.

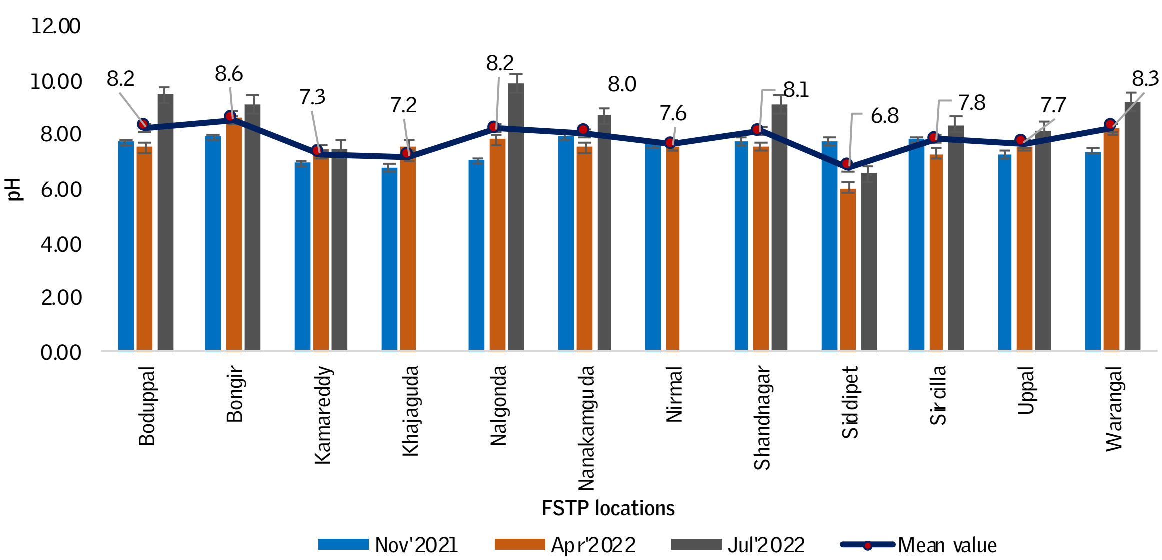
Performance evaluation of FSTPs in Telangana

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). Of these, five important parameters are represented here to evaluate the performance.

pH

The average pH of the treated discharge water from all the FSTP locations are ranges from pH-6.8 to 8.3, which is near neutral to slightly basic. The discharge standard for the pH is ranging from 6.0-9.0. A pH outside the range of 6 to 9 indicates an upset in the biological process that will inhibit anaerobic digestion of organic material. The pH of the discharge water from all the locations was observed to be within the limit of the discharge standard.

Graph 15: Average pH value of the treated discharge water



Chemical Oxygen Demand (COD)

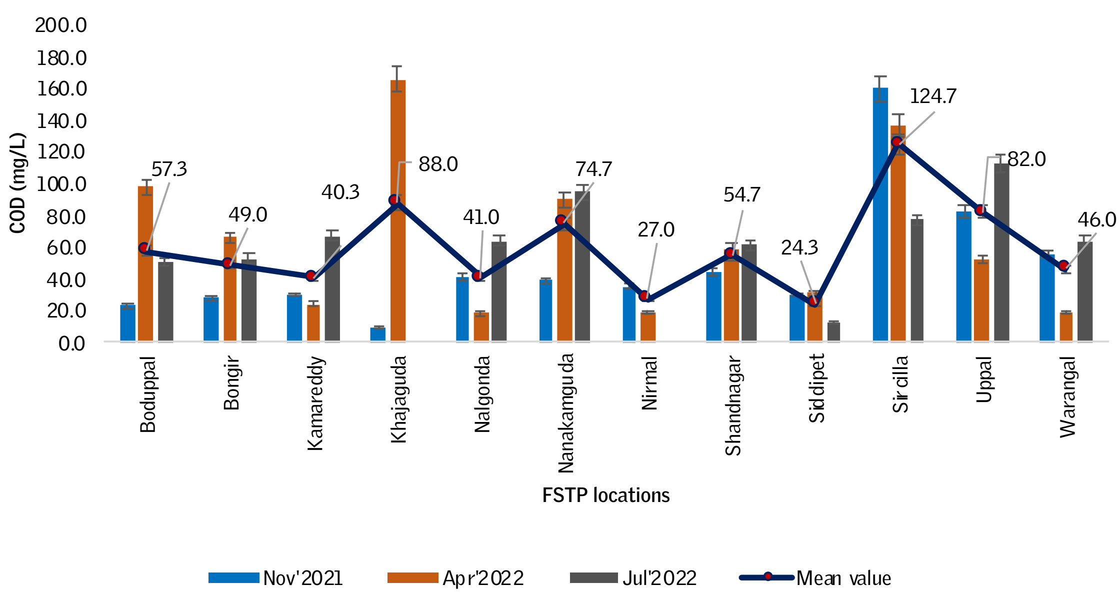
The average COD value of the treated discharge water ranges from 24.3 mg/L to 124.7 mg/L. According to MoEF&CC, the discharge standard for COD is 50 mg/L. FSTP sites, Siddipet, Nirmal, Kamareddy, Nalgonda, Warangal and Bongir showed the COD values below the discharge standard limit. However, Sircilla (124.7mg/L), Uppal (82 mg/L), Boduppal (57.3mg/L) Shandnagar (54.7mg/L) FSTPs and Kajaguda (88 mg/L), Nanakramguda (74.7mg/L) STP co-treatment systems showed a little higher COD values in the outlet water.

In the treatment efficacy of the systems, the per cent removal of COD from inlet to outlet ranges from 54.8 to 97.6 per cent. The FSTPs, Nalgonda, Kamareddy, Siddipet, Shandnagar and Boduppal showed high COD removal (>90 per cent). The STP co-treatment systems, Khajaguda and Nanakramguda also showed high per cent removal of COD (93.6 to 94 per cent). Sircilla and Uppal FSTPs showed less than 60% removal efficacy of COD.

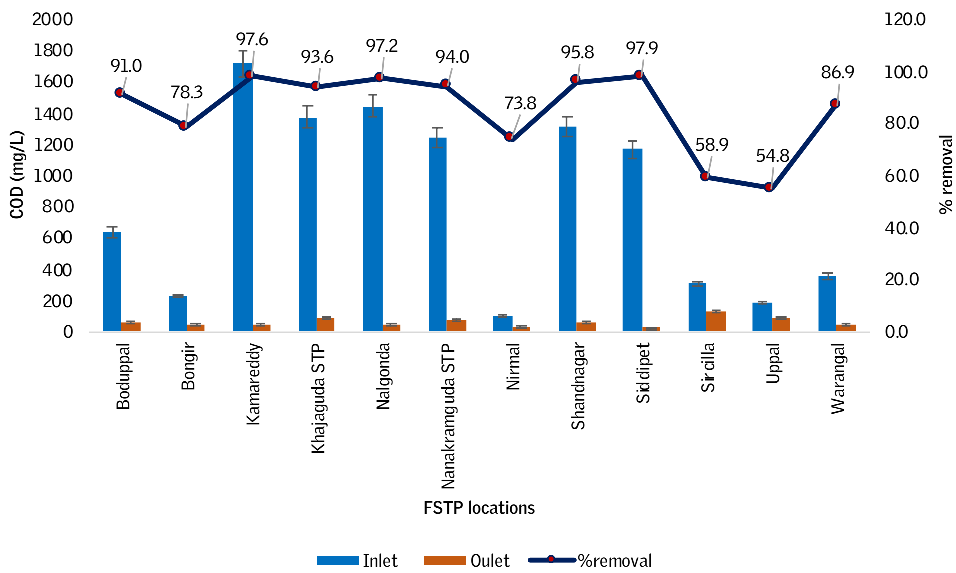
Biological Oxygen Demand (BOD)

Amongst the evaluated treatment systems, the average BOD value of treated discharge water ranges from 6.3 mg/L to 24 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20mg/L and non-metro cities 30 mg/L. The Khajaguda and Nanakramguda STP co-treatment systems are in metro city and the BOD of the discharge water is 20.5 mg/L and 21.3 mg/L respectively

Graph 16: Average three month COD value of the treated water



Graph 17: Per cent removal of COD by the treatment systems



and just above the discharge limit. In all FSTPs, the BOD is under the discharge limit. Although, the BOD value of Sircilla FSTP is observed to be above 20 mg/L, the FSTP is located in a non-metro city where the standard limit is 30mg/L.

The BOD removal efficiency of treatment systems ranges from 62.7 to 96.9 per cent. The STP co-treatment systems (Khajaguda-92.6 per cent and Nanakramguda-91.8 per cent) showed high per cent removal of BOD. Sircilla, Uppal and Nirmal FSTPs showed less than 75 per cent removal efficiency of BOD.

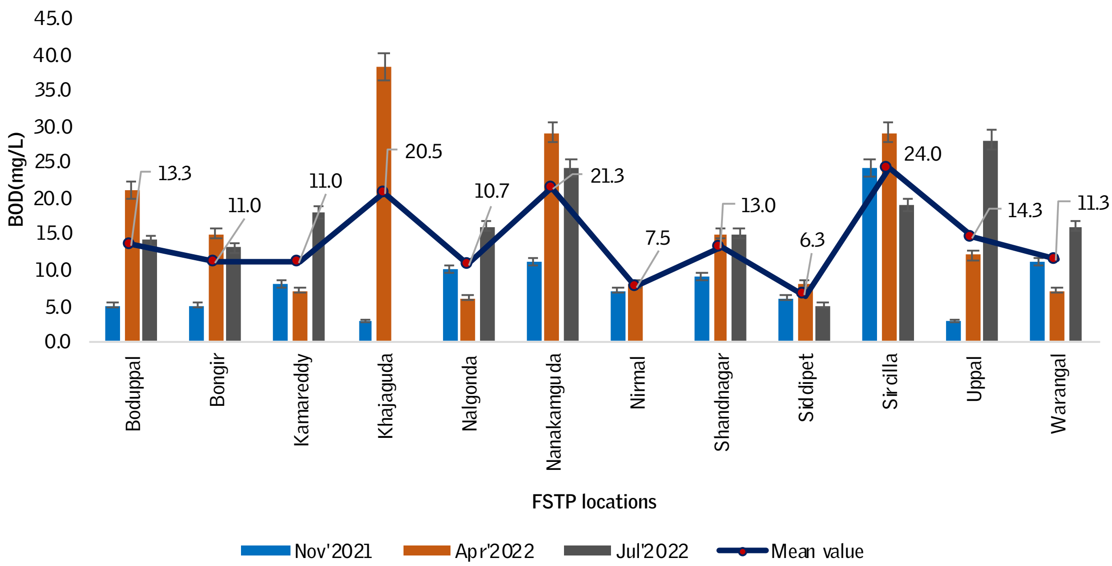
Total Kjeldahl Nitrogen (TKN)

The removal of TKN observed in the evaluated FSTPs was in the range of 40.2 to 97.8 per cent. Less removal efficacy is observed in the STP co-treatment systems (40-45 per cent). The Sircilla FSTP also showed less removal efficacy of nitrogen. All other FSTPs showed more than 80% removal efficacy. The highest removal efficacy was observed in the Nalgonada plant, which is using electrocoagulation for the treatment of the faecal sludge.

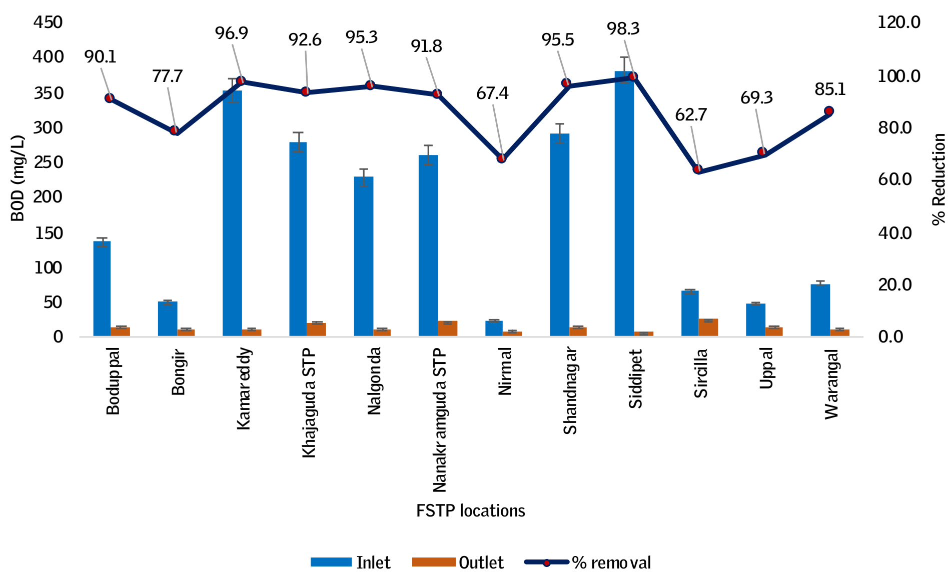
Faecal coliform

The guideline limit for faecal coliform bacteria in unrestricted irrigation is R1000 MPN/100 ml. In the treatment systems evaluated, all the FSTP outlet water came below the prescribed limit set by MoEF&CC regulations (R1000 (log 3.0) MPN/100mL) except for the two STP co-treatment systems, Khajaguda and

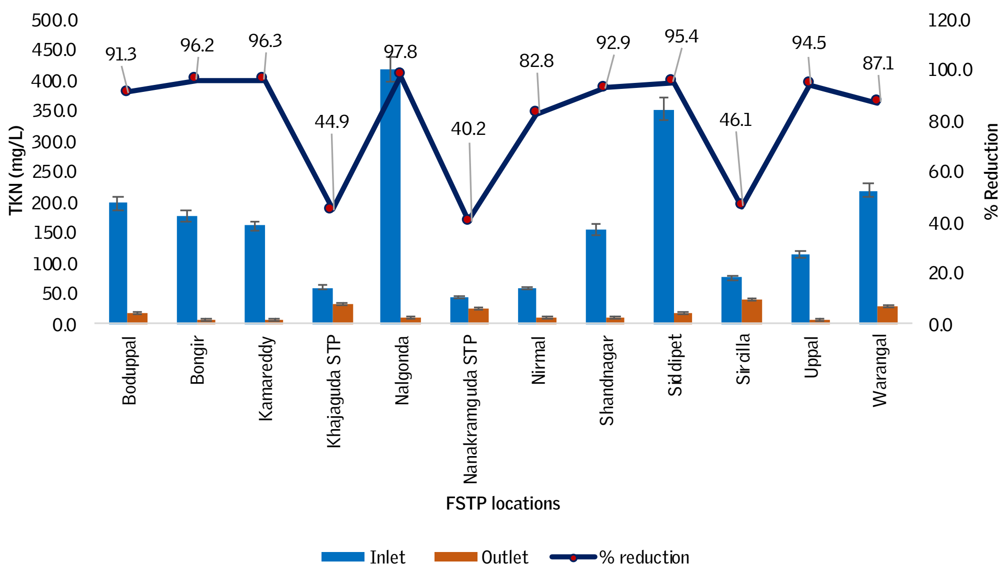
Graph 18: Average three month BOD value of the treated water



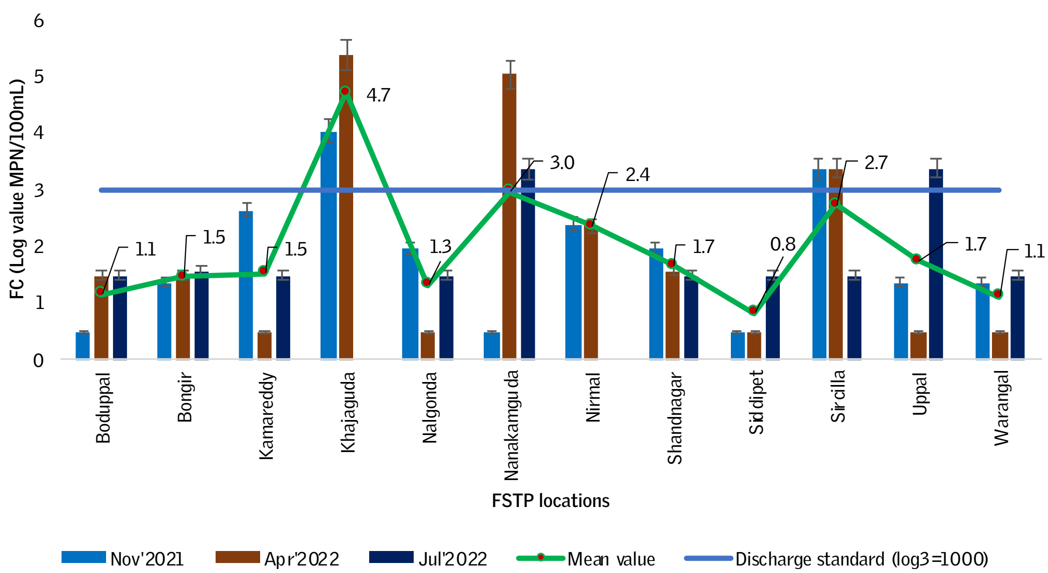
Graph 19: Per cent removal of BOD by the treatment systems



Graph 20: Per cent removal of Total Kjeldahl Nitrogen by the treatment systems



Graph 21: Faecal coliform count in the treated discharge water from the treatment systems



Nanakramguda. Like most of the STPs in India, these two STPs are also not maintaining the faecal coliform count under the standard limit, in spite of the post treatment systems like chlorine dosing. The microbial load in outlet water

SUMMARY

- Telangana FSTPs have adopted diverse technologies to treat faecal sludge, which includes geotube technology, pyrolysis with packaged water treatment module, MBBR, electrocoagulation and DEWATS.
- The pH of the discharge water (6.8 to 8.3) from all the treatment locations is found to be within the limit of the discharge standard.
- COD removal by all the treatment technologies attain more than 70 per cent, except in two FSTPs (Sircilla and Uppal).
- BOD removal by all the treatment technologies attain more than 75 per cent, except in three FSTPs — Nirmal, Sircilla and Uppal.
- Amongst all the evaluated FSTPs, the outlet BOD is under the discharge limit. For the STP co-treatment systems, BOD was observed to be a little higher than the discharge limit for metro cities (20 mg/L).
- Nitrogen removal in FSTPs showed more than 80 per cent efficacy except in Sircilla. The highest removal efficacy was observed in Nalgonda plant, which is using electrocoagulation technology.
- STP co-treatment systems had less nitrogen removal efficiency at lower than 45 per cent.
- Faecal coliform in the outlet water of the treatment plants came below the prescribed limit set by MoEF&CC regulations (≤1000 MPN/100 mL), except in the two STP co-treatment systems.

couldn't be controlled with predefined chlorine doses since the microbial load in influent water was varying in wide range. The microbial discharge quality in STPs is completely dependent on the tertiary treatment and how effectively chlorination (chlorine dosing) is used to treat the final discharge water, and not dependent on which technology is used in that STP for the treatment of wastewater.

Tamil Nadu

The Tamil Nadu Urban Sanitation Support Programme (TNUSSP), launched in November 2015, supports the state government in making improvements along the entire urban sanitation chain in cities. TNUSSP aims to scale safe and inclusive sanitation across the state by providing technical support to the state government and by working with the private sector, urban local bodies (ULB), sanitation workers, masons, schools, students, urban poor communities, desludging operators, and contractors, among others. FSTPs have been designed by adopting diverse technologies depending on final end uses or disposal options of sludge and liquid streams. The second phase of the Indian Institute for Human Settlements (IIHS) led- Tamil Nadu Urban Sanitation Support Programme (TNUSSP) is focused on the scale up Fecal Sludge Management (FSM) solutions across Tamil Nadu covering 663 Urban Local Bodies (ULBs) and a population of 25 million people. The Bill and Melinda Gates Foundation (BMGF) issupporting GoTN to achieve the Sanitation Mission of Tamil Nadu

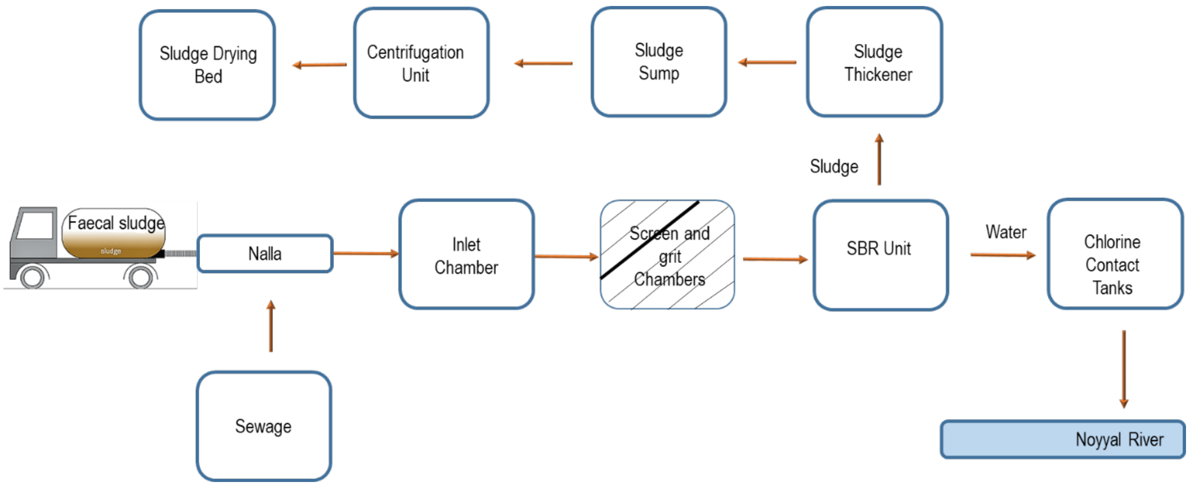
The TNUSSP is supporting improvements along the entire urban sanitation chain in the State with the aim to strengthen and sustain safe sanitation services for all. The key activities in this phase of the programme include technical assistance to the local, regional and state entities for implementation and operationalisation of sanitation treatment facilities; streamlining of desludging services; capacity building of multiple stakeholders; strengthening inclusivity of service delivery; improving livelihoods, health and welfare of sanitation workers; and Behaviour Change and Communication, among others. Simultaneously, extensive efforts have also been initiated to investigate the co-treatment of faecal sludge through existing sewage treatment plants. However, due to limited operating experience on specific design, there is inadequate treatment performance and thus failure of technologies. Therefore, monitoring the performance evaluation of different technologies of FSTP operation was required.

Ukkadam STP

The 70 MLD STP has been set up in Ukkadam located in the western part of Coimbatore city along with STPs in Ondipudur and Nanjundapura localities by Coimbatore City Municipal Corporation (CCMC). They were constructed to serve a population of 1.61 million from respective areas in the city which are covered with Underground Sewerage System (UGSS) covering a total area of approximately 23 km^2. However, only Ukkadam STP which was commissioned in January 2011 became operational.

Co-treatment of FS with sewage was started soon after commissioning of the STP with an aim to eliminate the unauthorized discharge of untreated FS in to open areas and water bodies in the city thereby preventing pollution. Thus, the un-sewered areas covering an area of 82.06 km^2 of the erstwhile CCMC and later added un-sewered areas covering an area of 152 km^2 are served by the co-treatment facility at Ukkadam. Desludging is performed through vacuum trucks with 6000 litres capacity which discharge or decant the FS in to an open drain (nalla), which carries sewage to the plant. This nalla is the only decanting site for FS discharge and is located about 500 meters upstream of the STP. The wastewater (sewage sludge) flow in the plant ranges from 25 to 30 MLD leaving a spare treatment

Figure 13: Schematic representation of the process flow of Ukkadam STP



capacity of 40 to 45 MLD which enabled for the execution of co-treatment of FS/ septage at the STP. About 100 trucks of FS is received in a day which corresponds to 0.6 MLD of FS which is being mixed/ added to nearly 30 MLD of sewage, thus the amount of FS which is added to sewage water is nearly 2 per cent of the current sewage flow. The FS is mostly received from household septic tanks. The plant is located near solid sorting factory. Sequential Batch Reactor (SBR) technology and mechanical dewatering are the treatment processes adapted for the treatment of liquid and solids in FS and sewage sludge.

Ukkadam STP is based on SBR process and comprises of the following components: Sewage sludge along with FS enters into the STP through the inlet chamber which is followed by a wet well. The sludge then passes through screen chambers, 20 mm coarse screen followed by 6 mm fine screen which helps in the removal of inert solid waste, sand and silt from the sludge. From here, the sludge enters into grit chamber (with 1 mm screen) where removal of grit occurs. From the grit chamber, the sludge enters into the SBR basin which has four chambers.

A typical cycle in the SBR process in Ukkadam STP takes about 3 h to complete which includes, 1.5 h for filling and aeration followed by 45 min each for sedimentation/ settling and decanting and hence 8 such cycles are run in 24 h (1 day). The plant has eight 210 HP capacity blowers of which 6 will run at a time. From SBR, the water enters into chlorine contact tanks for tertiary treatment. The water is allowed to stay for 30 min in these tanks for complete removal of pathogens. About 30-35 million litres of treated water is generated in a day which is discharged into nearby Noyyal River through a canal. The settled sludge from

SBR is transferred to the settling tank / sludge thickener and then to the sludge sump / sludge digestion tank from where it is carried to the centrifuge unit through screw feeding pumps.

The settled sludge from screen and grit chambers, and the sludge received after centrifugation are dumped in sludge drying bed for drying. Approx. 300—500 kg of dry sludge is generated in a month which is given free of charge to the Forest College for use in landfills. Receiving industrial effluent sometimes in place of FS by vacuum trucks was one of the challenges faced in the plant, as the industrial effluent adds more contaminants especially heavy metals into the treatment system which requires special treatment for removal.

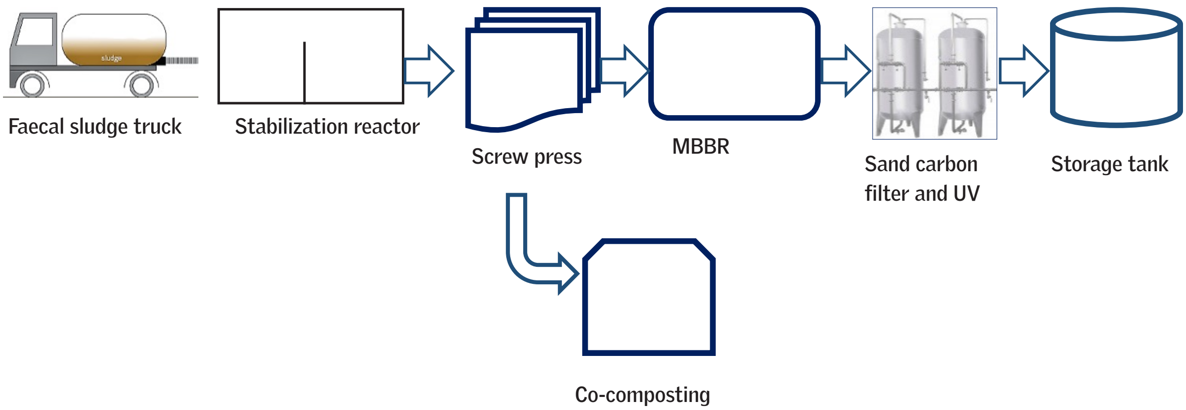
Periyanaickenpalayam FSTP

The FSTP has been set up in the town panchayat of Periyanaickenalayam (PNP) in Coimbatore District of Tamil Nadu by Tamil Nadu Urban Sanitation Support Programme (TNUSSP) with the support of BMGF which became operational from April 2019. The plant has a capacity of 25 KLD which was designed to serve a population of over one lakh across five town panchayats of PNP, Gudalur, Idikarai, Narasimhanaicken-Palayam and Veerapandi in Coimbatore District. Desludging is performed through vacuum trucks, which has an average capacity of 3000-5000 litres. During the study period, the FSTP was running in its full capacity by receiving 5-6 vacuum trucks per day. The FS is mostly received from household septic tanks. The plant is located near municipal solid waste dump yard. The technology adapted was electromechanical which includes MBBR and mechanical dewatering for the treatment of liquids and solids of FS respectively.

FS collected from various containments in the city by vacuum trucks is discharged at septage receiving station (SRS) of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. The sludge then enters into septage storage tank where it is stored for 3 days for effective homogenization of FS. The storage tank has 4 chambers with baffles and functions both as an anaerobic reactor and settler assisting in the anaerobic digestion and settling of solids in FS. Thus, stabilization and solid-liquid separation of FS takes place in the FS/ septage storage tank. After solid-liquid separation, the liquid part of FS enters into MBBR unit and the solid part of FS enters into the dewatering unit for solid-liquid separation by mechanical dewatering using screw press. Cationic polymers are added in screw press during this step to help in flocculation of sludge. The filtrate from screw press enters into MBBR unit for treatment.

From MBBR, the liquid stream passes to tertiary treatment unit with modules viz.

Figure 14: Schematic representation of the process flow of Perinakenpalayam FSTP



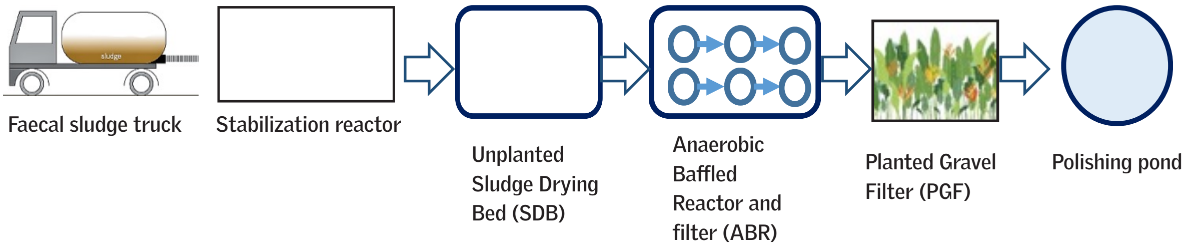
packed sand filter (PSF), Activated carbon filter (ACF) followed by UV radiation which helps in the removal of pathogenic microorganisms. About 21,000 litres of treated water is generated in a day which is used for gardening purpose and landscaping within the premises of FSTP. The solids collected after screw press are dried; nearly 300-400 Kg of dry sludge is generated in a day which is used for co-composting with organic part of Municipal Solid Waste (MSW). Windrow method was used for composting which took 45-60 days to attain maturity, however utilisation of co-compost is not yet initiated. Space constraint for co-composting was one of the challenges faced in the FSTP. Optimisation of co-composting process specifically mixing ratio of dry FS and MSW/vegetable waste was required.

Thuraiyur FSTP

The FSTP has been set up in the municipal town of Thuraiyur in Tiruchirappalli District of Tamil Nadu by Thuraiyur Municipality with the support from Tamil Nadu State Government which was commissioned in February 2021. The plant has a capacity of 20 KLD which was designed to serve a total population of 32,439 people residing in 8,674 households in Thuraiyur municipality. Desludging is performed through vacuum trucks with 4000 litres capacity. During the study period, the FSTP was found to be running in 60-80% of its treatment capacity by receiving 3-4 vacuum trucks per day. The FS is mostly received from household septic tanks. The plant is surrounded by agricultural fields and water bodies. Unplanted Sludge Drying Bed (SDB) and DEWATS technology were adapted for the treatment of solids and liquids of FS respectively.

The faecal sludge is made to pass through screen and grit chamber for the removal of floatable material and grit which then gets collected in a storage tank/

Figure 15: Schematic representation of the process flow in Thuraiyur FSTP



stabilization reactor. Stabilization of FS takes place in the stabilization reactor by anaerobic digestion. The partially stabilized FS is later pumped into the sludge drying beds where dewatering of sludge by evaporation and gravity, and thus solid-liquid separation of FS takes place. The leachate from SDBs which percolated through the filter structure of SDB by gravity gets collected in a collection tank.

From the collection tank, the leachate (liquid part of FS) enters into the Integrated Settler and Anaerobic Filter (ISAF) unit. The settler is 2 chambered and the AF has 3 chambers. Settling and anaerobic digestion of solids in the leachate takes place in IS and AF respectively which results in reduction of suspended solids from the leachate. From the ISAF unit, the partially treated water enters into the Horizontal Planted Gravel Filter (PGF), where nutrients and solids removal takes place. Finally, the water from the PGF gets collected in a polishing pond which helps in the removal of unpleasant odour and microorganisms from the water by exposure to air and sun light. The treated water generated is used for gardening purpose in the FSTP.

After dewatering, the sludge present in the SDBs is allowed to dry, which is later removed and given for co-composting. The reuse of co-compost in agricultural fields is not yet initiated. About 3000 kg of dried FS is generated in a month. Presence of limited vacuum trucks (1 No.) for delivering FS was one of the challenges faced in the FSTP. The FSTP is running with solar energy thus making the system energy efficient, however, energy derived from solar radiation is not sufficient to meet the energy requirements of the FSTP.

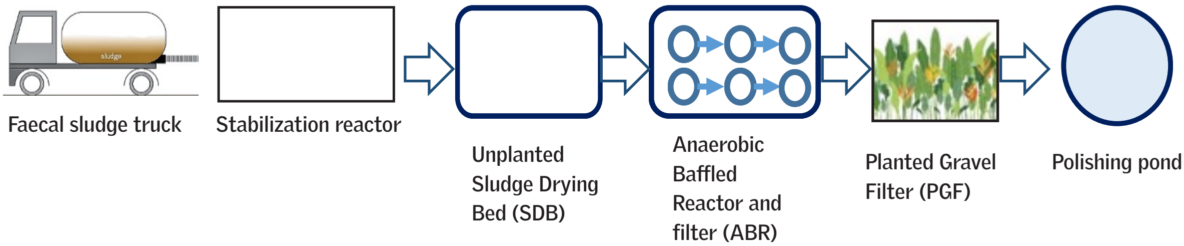
Tirumangalam FSTP

The FSTP has been set up in the municipal town of Tirumangalam in Madurai District of Tamil Nadu by Tirumangalam Municipality with the support from Tamil Nadu State Government which was commissioned in September 2019. The plant has a capacity of 40 KLD which was designed to serve a total population of 51,194 people residing in 13,564 households in Tirumangalam municipality. Desludging is performed through vacuum trucks with 2000 litres capacity. During the study period, the FSTP was found to be running far below its treatment capacity by receiving only 3 vacuum trucks in a week. The FS is mostly received from household septic tanks. The plant is located in a residential area. Unplanted Sludge Drying Bed (SDB) and DEWATS technology were adapted for the treatment of solids and liquids of FS respectively.

The faecal sludge (FS) is made to pass through screen and grit chamber for the removal of floatable material and grit which then gets collected in a storage tank/ stabilization reactor. The partially stabilized FS is later pumped into the SDBs where dewatering of sludge and solid-liquid separation takes place. In total, there are 24 SDBs distributed in 4 separate units of 6 SDBs each. In SDB, the water (leachate) percolates through the 2 feet long perforated bricks present in the bed of SDB by gravity and gets collected in a collection tank. From the collection tank, the leachate (liquid part of FS) enters into the Integrated Settler and Anaerobic Filter (ISAF) unit where partial removal of organic material takes place. The settler is 2 chambered and the AF has 3 chambers.

From the ISAF unit, the partially treated water enters into the Horizontal Planted Gravel Filter (PGF), and gets collected in a polishing pond. About 10000 litres of treated water is generated in a day which is used for agriculture purpose. After dewatering, the sludge present in the SDBs is allowed to dry for 15 days, which is later removed, pelletized, powdered and used directly for gardening in the FSTP and also sold to farmers at a nominal price for using in agricultural fields. About 300 kg of dried FS is generated in a month. The FSTP is running with solar energy thus making the system energy efficient.

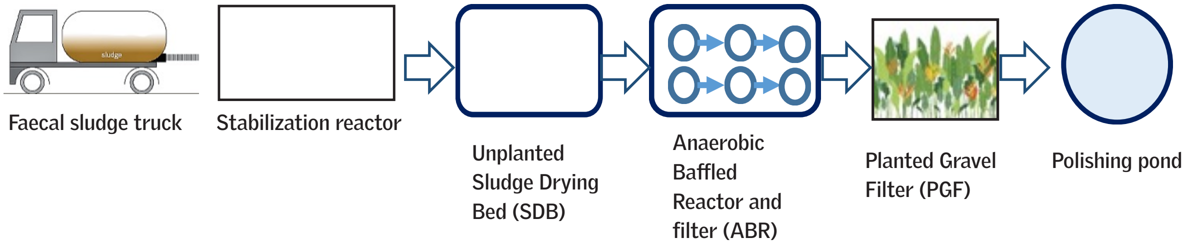
Figure 16: Schematic representation of the process flow in Tirumangalam FSTP



Vikramasingapuram FSTP

The FSTP has been set up in the municipal town of Vikramasingapuram (V. K. Puram) in Tirunelveli District of Tamil Nadu by TNUSSP with the support of BMGF which became operational from February 2021.The plant has a capacity of 30 KLD which was designed to serve a total population of around 57,286 people from a cluster of ULBs namely Vikramasingapuram and Alwarkurichi. Desludging is performed through vacuum trucks with either 1500 and/or 5000 litres capacity. During the study period, it was observed that the FSTP was under-utilized by receiving only R2 vacuum trucks per day. The FS is mostly received from household septic tanks. The plant is located near municipal solid waste management station and lies in the vicinity of Thamarabharani River.

Figure 17: Schematic representation of the process flow in Vikramasingapuram FSTP



Unplanted Sludge Drying Bed (SDB) and DEWATS technology were adapted for the treatment of solids and liquids of FS respectively. The faecal sludge (FS) is made to pass through screening and grit chamber for the removal of solid waste and grit and gets collected in a storage tank/ stabilization reactor. Stabilization of FS by anaerobic digestion takes place in the stabilization reactor. The partially stabilized FS is later pumped into the sludge drying beds where dewatering of sludge by evaporation and gravity, and thus solid-liquid separation of FS takes place. In total, there are 12 SDBs distributed in 3 separate units of 4 SDBs each. The leachate from SDBs which percolated through the filter structure of SDB by gravity gets collected in a collection tank. From the collection tank, the leachate (liquid part of FS) enters into the Integrated Settler and Anaerobic Filter (ISAF) unit. The settler is 2 chambered and the AF has 3 chambers. Settling and anaerobic digestion of solids in the leachate takes place in IS and AF respectively which results in reduction of suspended solids from the leachate.

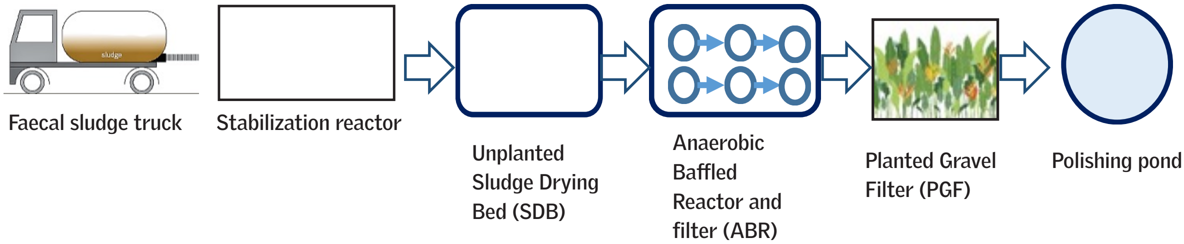
From the ISAF unit, the partially treated water enters into the Horizontal Planted Gravel Filter (PGF), where nutrients and solids removal takes place. Finally, the water from the PGF gets collected in a polishing pond which helps in the removal of unpleasant odour and microorganisms from the water by exposure to air and sun light. About 2000 litres of treated water is generated in a day which is used for gardening and agriculture purpose in the FSTP. After dewatering, the sludge present in the SDBs is allowed to dry for 40-42 days in the SDB, later it is removed and used for co-composting with Municipal Solid Waste (MSW), and the co-compost is used in agricultural fields. However, the amount of dried FS generated was only 1000 kg per month. Receiving sufficient amount of FS by vacuum trucks was one of the challenges faced in the FSTP. The FSTP is running with solar energy thus making the system energy efficient.

Shenkottai FSTP

The FSTP has been set up in the municipal town of Shenkottai in Tenkasi District of Tamil Nadu by Shenkottai Municipality with the support from Tamil Nadu State Government which was commissioned in January 2021. The plant has a capacity of 20 KLD which was designed to serve a total population of 26,823 people residing in 7,146 households in Shenkottai municipality. Desludging is performed through vacuum trucks with 1500-5000 litres capacity. During the study period, the FSTP was found to be running far below its treatment capacity by receiving only 5-6 or 10 trucks only once in a week/ 10 days. The FS is mostly received from household septic tanks. The plant is located in a residential area. The plant is based on Unplanted Sludge Drying Bed (SDB) and DEWATS technology.

The faecal sludge (FS) is made to pass through screen and grit chamber which then gets collected in a storage tank/ stabilization reactor. The partially stabilized FS is later pumped into the SDBs where dewatering of sludge and solid-liquid separation takes place. In total, there are 24 SDBs distributed in 4 separate units of 6 SDBs each. The leachate from SDBs gets collected in a collection tank. From the collection tank, the leachate (liquid part of FS) enters into the Integrated Settler and Anaerobic Filter (ISAF) unit. The settler is 2 chambered and the AF has 3 chambers. From the ISAF unit, the partially treated water enters into the Planted Gravel Filter (PGF), and finally gets collected in a polishing pond. The final treated water is used for gardening purpose in the FSTP. After dewatering,

Figure 18: Schematic representation of the process flow of Shenkottai FSTP



the sludge present in the SDBs is allowed to dry for 15 days, which is increased to 25 days during rainy season. The dried sludge is later removed and stored and not reused. Only around 250 kg of dried FS is generated in a month. Amount of FS received, and receiving FS every day for treatment were the main challenges faced in the FSTP. The O&M cost of the FSTP is about Rs 10 lakh per annum.

Erode STP

The 50.55 MLD STP has been set up in Peelamedu Village in Vendipalayam area of Erode city by Erode City Municipal Corporation (ECMC), to treat sewage generated (30 MLD) from all the 60 wards comprising of 4,95,957 people living in

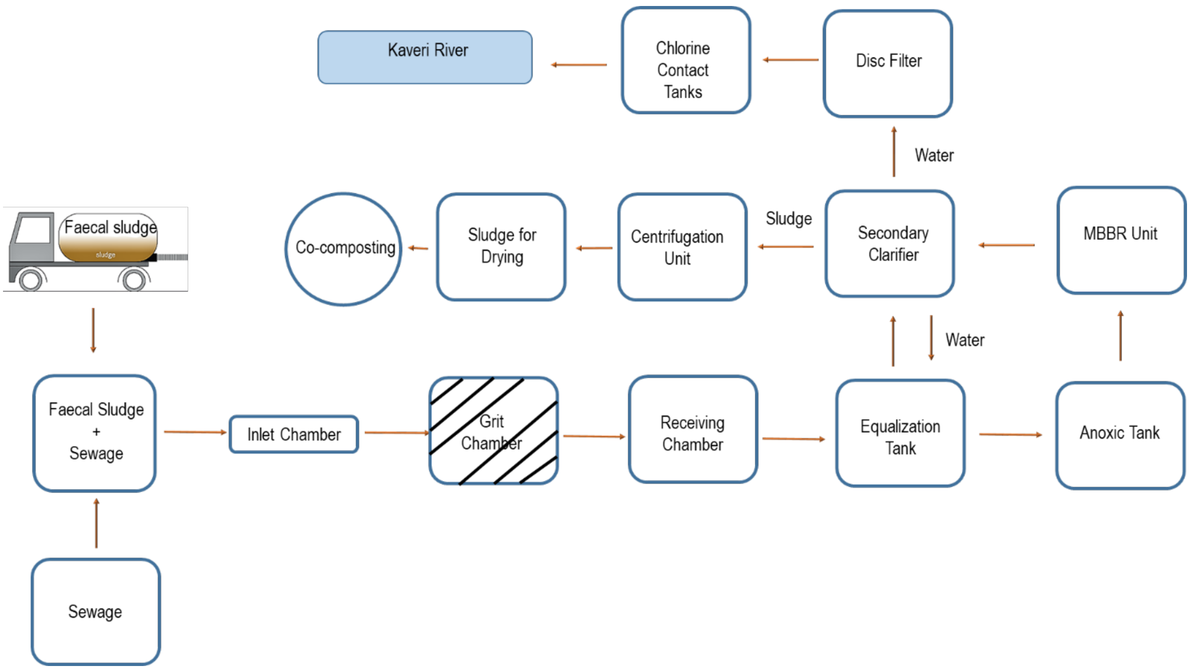
1,38,497 households under ECMC. However, currently sewage from only 27 wards (~8 MLD) with UGDSS is being treated in the Erode STP which was commissioned in July 2019. The remaining spare treatment capacity of 20.55 MLD enabled for the implementation of co-treatment of FS/ septage at the STP.

Desludging is performed through vacuum trucks with 4000 and 6000 litres capacity. The wastewater (sewage sludge) flow in the plant ranges from 19 to 25 MLD leaving a spare treatment capacity of 25.55 to 31.55 MLD which enabled for the execution of co-treatment of FS/ septage at the STP. About 5-10 trucks of FS is received in a day which corresponds to only 0.06 MLD of FS (when ten 6 KL trucks are considered) which is being mixed/ added to nearly 25 MLD (maximum sewage flow) of sewage, thus the amount of FS which is added to sewage water is nearly 0.24% of the current sewage flow. The FS is mostly received from household septic tanks. The plant is located near River Kaveri. Moving Bed Biofilm Reactor (MBBR) and mechanical dewatering are the treatment processes adapted in Erode STP for the treatment of liquid and solids in FS and sewage sludge.

Erode STP is based on MBBR technology and comprises of the following components: Grit chamber, receiving tank, equalization tank, anoxic tank, MBBR tank, aeration tank, secondary clarifier, disc filter and chlorine contact tank as shown in the figure below. Briefly, mixed sewage sludge and FS enters into the STP through the inlet chamber. Initially, the sludge passes through grit chamber, followed by receiving chamber and equalization tank. Before entering into MBBR unit, it enters into anoxic tank for anaerobic digestion. In MBBR unit, in the presence of aeration, the sludge gets digested aerobically by bacterial biofilms on plastic carriers due to increase in contact time between solids and bacterial biomass on the plastic carriers. The sewage sludge then passes to secondary clarifier where solids are settled and the liquid stream passes into disc filter and finally to the chlorine contact tanks for treatment. The settled sludge from secondary clarifier is transferred to the centrifugation unit where solid sludge is separated and liquid is recirculated to the equalization tank.

About 18-25 million litres of treated water is generated in a day which is discharged into the nearby Kaveri River through a canal. The settled sludge from grit chamber, and the sludge received after centrifugation are dumped in sludge drying bed for drying. Approx. 300-500 kg of dry sludge is generated in a month which is given for co-composting.

Figure 19: Schematic representation of the process flow of Erode STP



Tiruchirapally STP

The 58 MLD STP has been set up at Panjappur in Tiruchirappalli by Tamil Nadu Water Supply and Drainage (TWAD) Board, whose operation and maintenance is carried over by Tiruchirappalli City Corporation (TCC). Currently, the STP serves all parts of the city covered with either partial (12.95 km^2) or complete (51.31 km^2) UGSS. Estimates suggest that the STP serves nearly 44,000 house connections with multiple households in each connection. STP having a capacity of 88 MLD with two treatment trains of 30 MLD and 58 MLD respectively was installed at Panjappur, but only 58 MLD train became operational which was commissioned in 2008. Co-treatment of FS with sewage was started in 2012 with an aim to eliminate the unauthorized discharge of untreated FS in to open areas and water bodies in the city thereby preventing pollution.

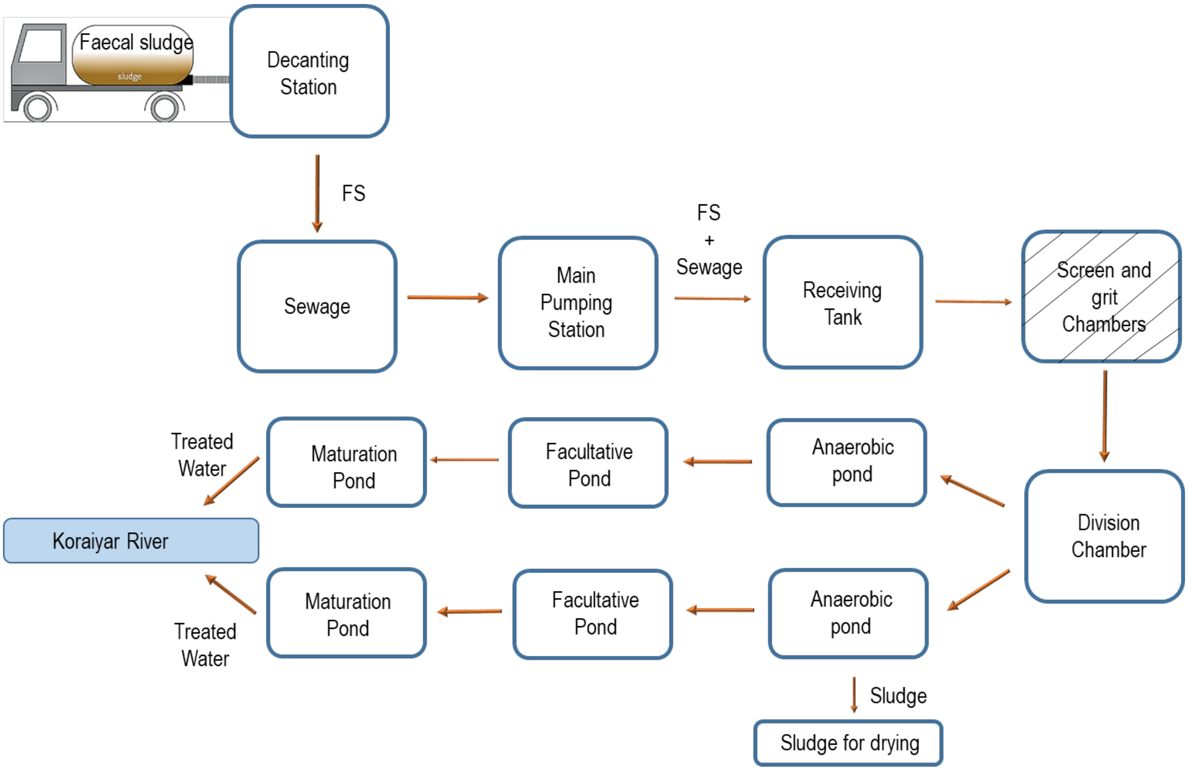
Desludging is performed through vacuum trucks with 6000 litres capacity which discharge or decant the FS in 4 decanting stations at Anna Stadium, Thanjavur Road, Vayalur Road, and Vasudevan Street from where the FS eventually enters into the STP for further treatment through the existing sewerage system. The wastewater (sewage sludge) flow in the plant ranges from 30 to 40 MLD leaving a spare treatment capacity of 18 to 28 MLD which enabled for the execution of co-treatment of FS/ septage at the STP. About 80 trucks of FS in total are received in a day in all 4 decanting stations which corresponds to 0.48 MLD of FS which is being mixed/ added to nearly 40 MLD of sewage, thus the amount of FS which is added to sewage water is nearly 1.2% of the current sewage flow. The FS is mostly received from household septic tanks, and also occasionally from public toilets and hospitals. The plant is located near Koraiyar River.

Tiruchirapally STP is based on Waste Stabilization Pond (WSP) technology and comprises of the following components: Receiving tank, Pretreatment unit (screen chamber, grit chamber), anaerobic pond, facultative pond and Polishing pond/ maturation pond. Briefly, the sewage from the city along with the FS received from decanting stations reaches the receiving tank of STP through two separate lines from each of the 2 Main Pumping Stations (MPSs) present in the city which pump the sewage from UGSS to STP. The combined sludge then passes through screen and grit chambers for the removal of inert floatable solid waste and grit respectively. From here, the sludge is divided into 2 parts in division chamber and each part flows into an anaerobic pond followed by facultative pond and finally to a maturation pond which forms part of the WSP unit.

The 3 ponds are arranged sequentially in the order of decreasing depths which promote step-wise treatment of sludge. Settling of solids and anaerobic digestion by anaerobic bacteria takes place in deeper anaerobic ponds which reduces organic load of sludge, oxygen production by algae for the growth of aerobic bacteria which help in aerobic degradation of solids in sludge occurs in facultative ponds which further reduces the organic load, and finally photosynthesis which rises pH of water and exposure to sunlight (UV) occurs in maturation ponds which helps in the removal of pathogens from the treated water.

About 40 million litres of treated water is generated in a day which is discharged directly into the nearby Koraiyar River which finally flows into River Cauvery. During the study period, the treated waste water was not being reused. It was observed that, the settled sludge accumulated in anaerobic ponds is periodically removed and collected in a site and not being reused. Receiving industrial effluent sometimes in place of FS by vacuum trucks was one of the challenges faced in the plant, as the industrial effluent adds more contaminants especially heavy metals into the treatment system which requires special treatment for removal.

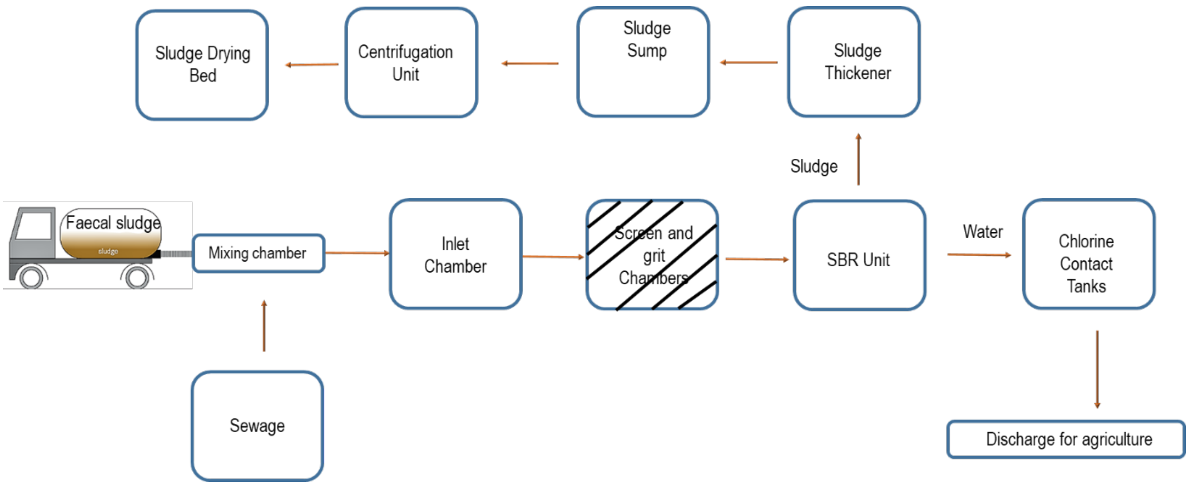
Figure 20: Schematic representation of the process flow of Trichy STP



Madurai STP

The 125 MLD STP has been set up in Avaniyapuram located in the eastern part of Madurai city by Madurai City Corporation along with 45 MLD STP in Sakkimangalam to treat about 162.8 MLD (in 2014) of wastewater generated in the city. The 125 MLD STP was commissioned in 2011.Desludging is performed through vacuum trucks with 5000 litres capacity which discharge or decant the FS. The wastewater (sewage sludge) flow in the plant is only20 MLD leaving a spare treatment capacity of 105 MLD which enabled for the execution of co-treatment of FS/ septage at the STP. Only 1 truck of FS is received in a day which corresponds to only 0.005 MLD of FS which is being mixed/ added to nearly 20 MLD of sewage, thus the amount of FS which is added to sewage water is nearly 0.025% of the current sewage flow. The FS is mostly received from household septic tanks. The plant is located near agricultural fields and water bodies (Perungudi canal). Sequential Batch Reactor (SBR) technology and mechanical dewatering are the treatment processes adapted for the treatment of liquid and solids in FS and sewage sludge.

Figure 21: Schematic representation of the process flow of Madurai STP

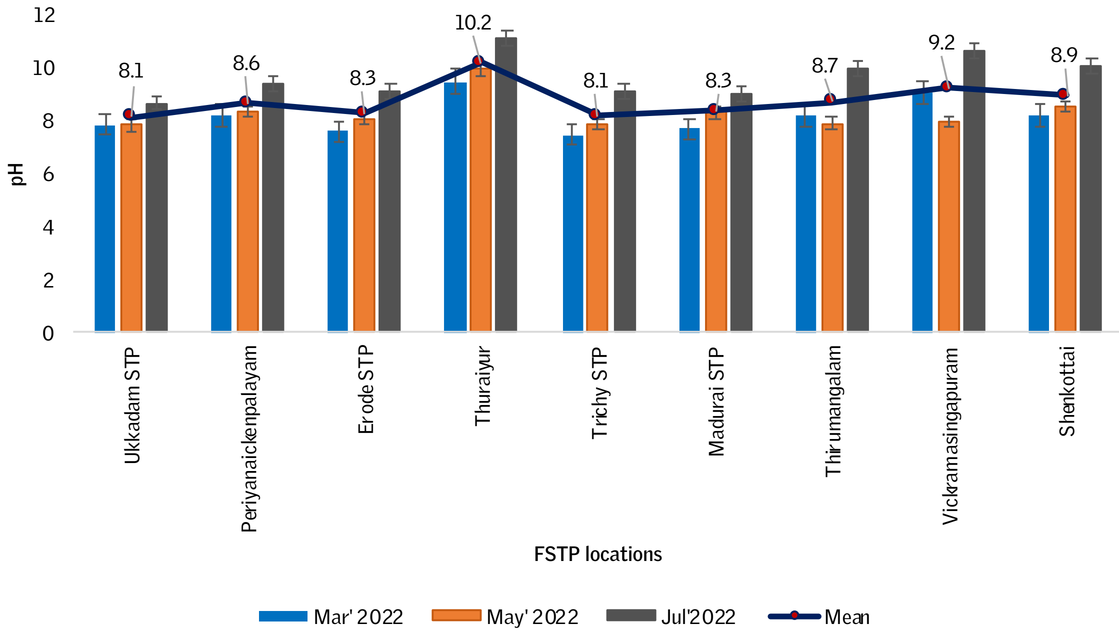


Madurai STP is based on SBR process and comprises of the following components: Sewage sludge mixed with FS enters into the STP through the inlet chamber. The sludge then passes through screen and grit chambers for removal of inert solids and grit. From the grit chamber, the sludge enters into the SBR basin which has six chambers. A typical cycle in the SBR process in Madurai STP takes about 3 h to complete which includes, 1.5 h for filling and aeration followed by 45 min each for sedimentation/ settling and decanting and hence 8 such cycles are run in 24 h (1 day). From SBR, the water enters into chlorine contact tanks for tertiary treatment. The water is allowed to stay for 30 min in these tanks for complete removal of pathogens. About 19.5 million litres of treated water is generated in a day which is used in agricultural land. The settled sludge from SBR is transferred to the settling tank / sludge thickener and then to the sludge sump / sludge digestion tank from where it is carried to the centrifuge unit through screw feeding pumps. The settled sludge from screen and grit chambers, andthe sludge received after centrifugation are dumped in sludge drying bed for drying. Approx. 30-50 tonnes of dry sludge is generated in a month which is given to the solid waste division for use in landfills.

Performance evaluation of FSTPs in the state

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. Of these, five important parameters are represented here to evaluate the performance.

Graph 22: Average pH value of the treated discharge water



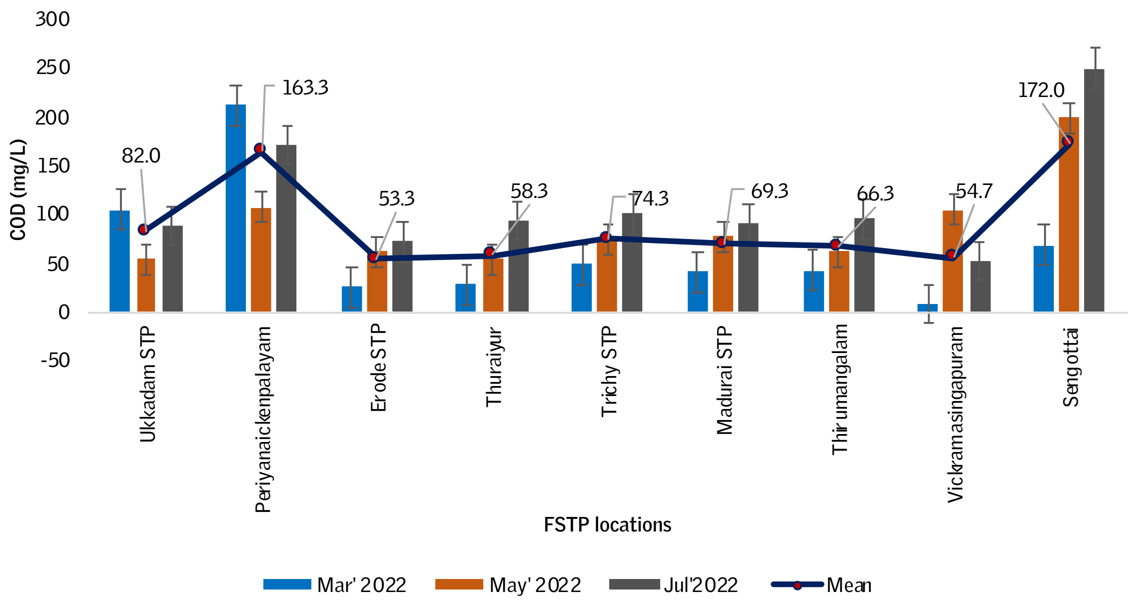
pH

The average pH of the treated discharge water from all the FSTP locations ranges from pH-8.1 to 10.2(Fig: 2.1), which is slightly alkaline. The discharge standard for the pH is ranging from 6.0-9.0. A pH outside the range of 6 to 9 indicates an upset in the biological process that will inhibit anaerobic digestion of organic material. The discharge water from Thuraiyur (pH 10.2) and Vikramasingapuram (pH 9.2) showed a little higher value than the discharge standard. The pH of the discharge water from all other locations is within the limit of the discharge standard.

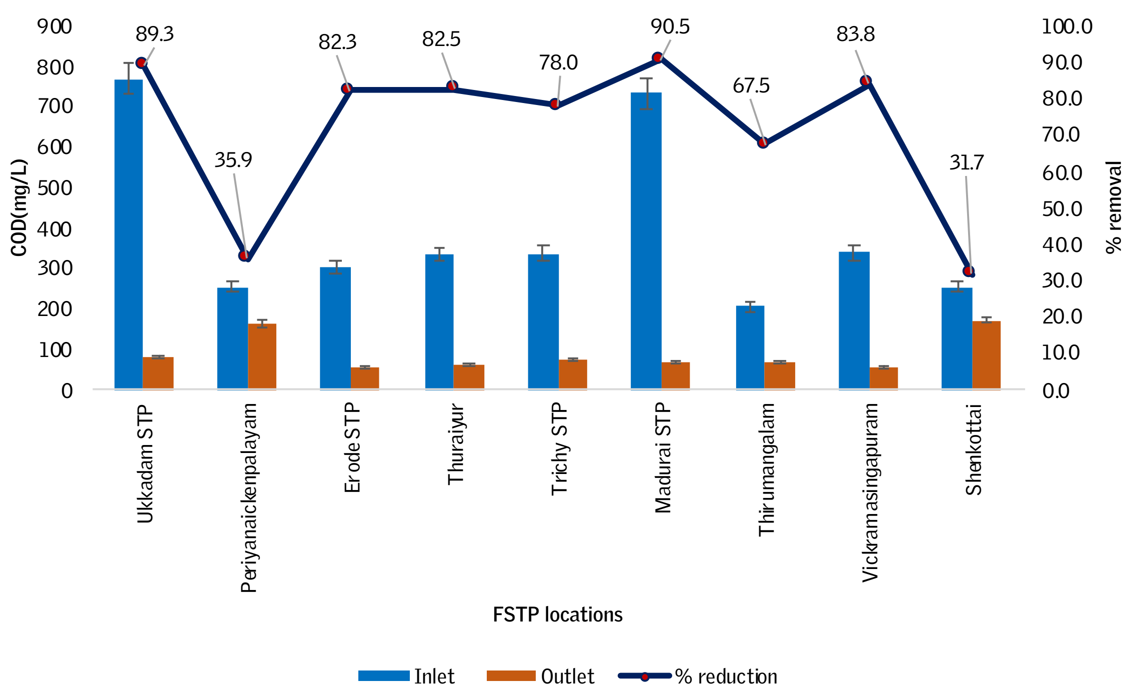
Chemical Oxygen Demand (COD)

The average COD value of the treated discharge water ranges from 53.3 mg/L to 172 mg/L. According to MoEF&CC, the discharge standard for COD is 50 mg/L. Periyanaickenpalayam (163.3 mg/L) and Shenkottai (172 mg/L) showed the high COD level in the outlet water, which is even above 100 mg/L. Other FSTPs and STP co-treatment systems showed a little higher COD values with respect to the standard limit for the discharge in the outlet water.

Graph 23: Average COD (3 months) value of the treated discharge water



Graph 24: Per cent removal of COD by the treatment systems



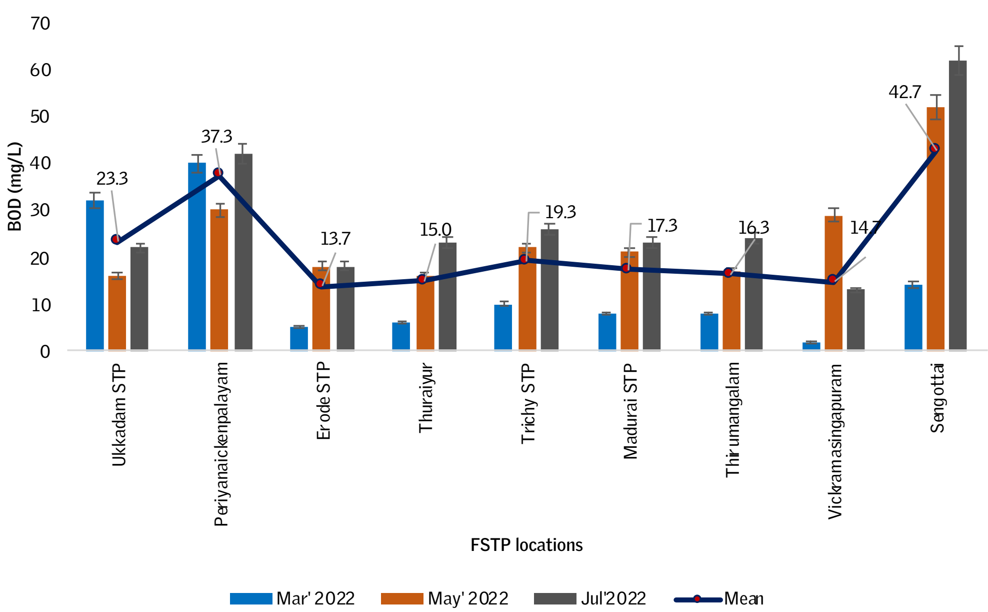
The per cent removal of COD from inlet to outlet ranges from 31.7 to 90.5 % (Fig: 2.3) that represents the treatment potential of the systems to remove organics. The STP co-treatment systems in Madurai, Ukkadam, Erode and Trichy showed high per cent removal of COD (90.5 to 78%). Periyanaickenpalayam and Shenkottai showed less than 40% removal efficacy.

Biological Oxygen Demand (BOD)

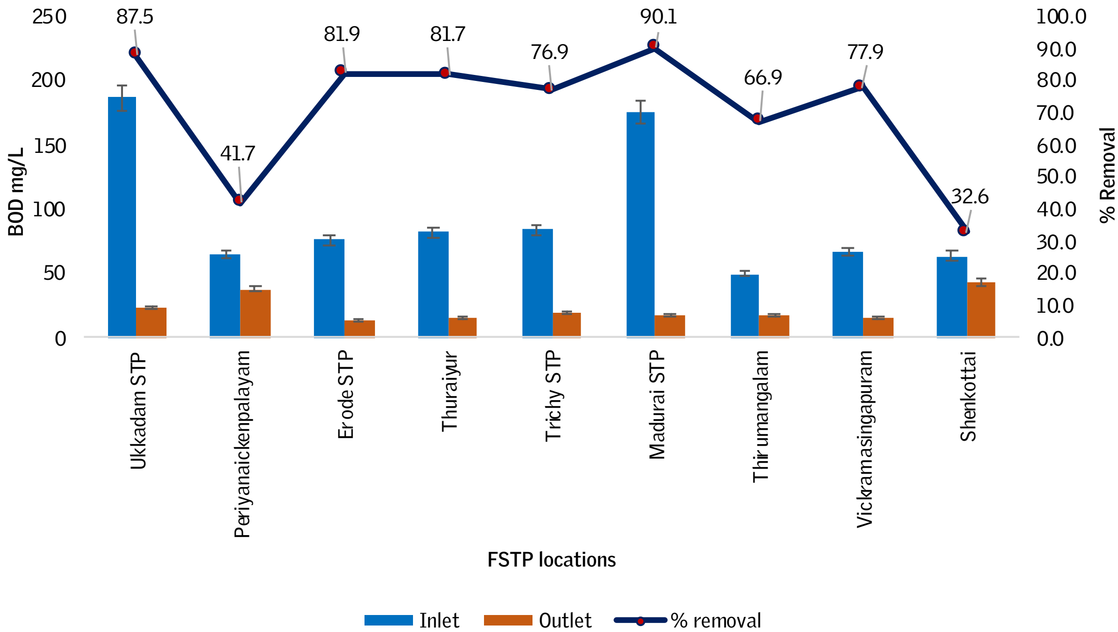
Amongst the evaluated treatment systems, the average BOD value of the treated discharge water ranges from 13.7 mg/L to 42.7 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20mg/L and non-metro cities is 30 mg/L. All the evaluated treatment systems are in non-metro cities and most of them showed the BOD value under the discharge limit. However, Periyanaickenpalayam and Shenkottai showed the BOD of the discharge water as 37.3 mg/L and 42.7 mg/L, respectively which is above the discharge limit.

The per cent removal of BOD from inlet to outlet ranges from 32.6 to 90.1 % that depicts the BOD removal efficacy of the systems. The STP co-treatment systems (Madurai-90.1% and Ukkadam-87.5%) showed high per cent BOD removal. Amongst the evaluated FSTPs, Thuraiyur showed the highest removal efficiency (81.7%) whereas Periyanaickenpalayam and Shenkottai showed lowest removal efficacy with 41.7 and 32.6 % respectively. Therefore, it can be inferred that STPs showed better BOD removal in comparison to FSTPs.

Graph 25: Average three-month BOD value of the treated discharge water



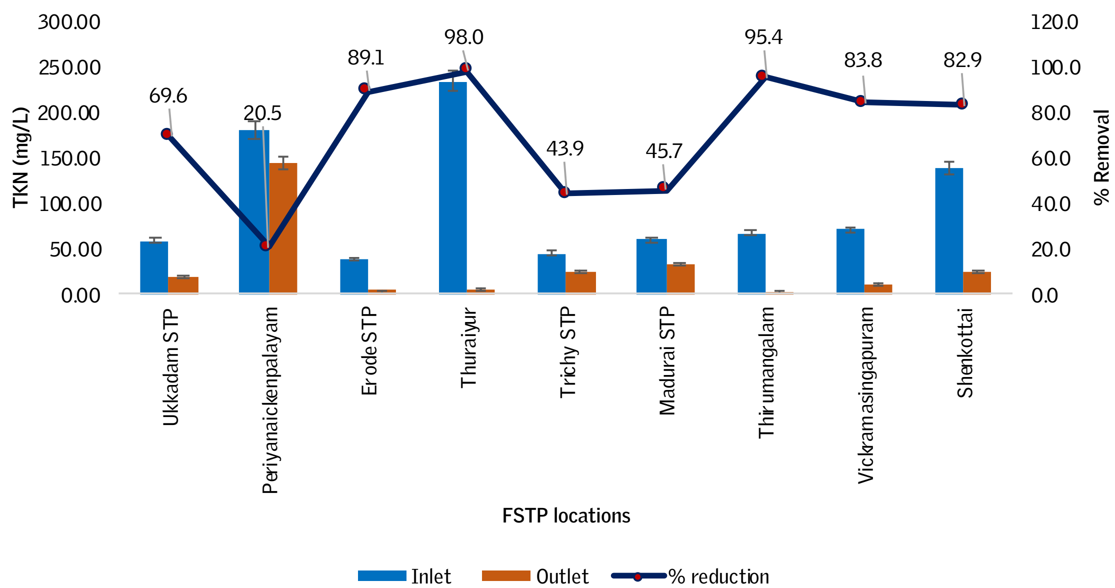
Graph 26: Per cent removal of BOD by the treatment systems



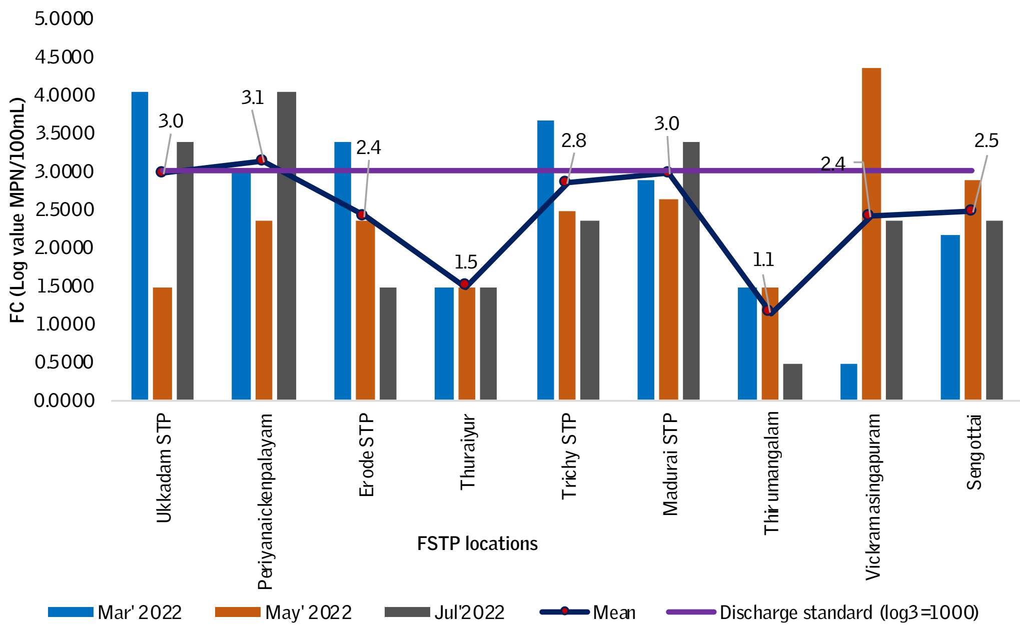
Total Kjeldahl Nitrogen (TKN)

The removal of TKN was observed in the evaluated FSTPs in the range of 20.5 to 98.0 per cent. Lowest removal efficacy is observed in Periyanaickenpalayam FSTP (20.5%). The highest removal efficacy was showed for Thuraiyur FSTP and Trichy STP co-treatment (98%).

Graph 27: Per cent removal of Total Kjeldahl Nitrogen by the treatment systems



Graph 28: Faecal coliform count in the treated discharge water from the treatment systems



Faecal Coliform

The discharge limit of faecal coliform for unrestricted irrigation is R1000 MPN/100 ml. Out of the evaluated treatment systems, most of the FSTP outlet water came below the prescribed limit set by MoEF&CC regulations (R1000 MPN/100mL). However, the Periyanaickenpalayam FSTP showed a little higher FC value than the standard limit in spite of having a tertiary treatment i.e. sand filter, activated carbon filter and UV disinfection.

SUMMARY

- The average pH of the treated discharge water from all the FSTP locations ranges from pH 8.1 to 10.2. Discharge water from Thuraiyur (pH 10.2) and Vikramasingapuram (pH 9.2) shows a little higher value than the discharge limit.
- The per cent removal of COD from inlet to outlet ranges from 31.7 to 90.5 per cent. Periyanaickenpalayam (163.3 mg/L) and Shenkottai (172 mg/L) showed high COD level in the outlet water.
- The STP co-treatment systems in Madurai, Ukkadam, Erode and Trichy showed high per cent removal of COD (90.5 to 78 per cent).
- The per cent removal of BOD from inlet to outlet ranges from 32.6 to 90.1 per cent; Periyanaickenpalayam and Shenkottai showed lowest removal efficacy with 41.7 and 32.6 per cent, respectively
- The STP co-treatment systems (Madurai-90.1 per cent and Ukkadam-87.5 per cent) showed high per cent BOD removal
- The highest organic nitrogen removal efficacy was at Thuraiyur FSTP and Trichy STP and co-treatment plant (98 per cent).
- Periyanaickenpalayam FSTP showed a little higher faecal coliform value than the standard limit (1000MPN/100mL) in spite of having a tertiary treatment like UV disinfection.

Odisha

Odisha is a coastal state on the eastern side of India comprising 30 districts. It is the tenth largest state in terms of area (155,707 km2) and eleventh largest in terms of population size (41.9 million). The key focus of sanitation interventions in urban India has been to ensure access to toilets and construction of sanitation infrastructure such as a sewerage network and sewage treatment plants As per mandate under AMRUT programme,

The Orissa Water Supply & Sewerage Board (OWSSB) was established for the rapid development and proper regulation of water supply and sewerage services in the State. The OWSSB executes sewerage projects and after completion, hands them over to the PHEO for operation and maintenance (O&M). It is also the State Level Nodal Agency for the implementation of projects related to urban sanitation (including AMRUT, SBM (Urban)) in the State. Further, the OWSSB functions as the State Sanitation Nodal Agency (SSNA) for the successful implementation of the OUSS. The SSNA is be supported by the SBM Project Management Unit (PMU) Cell comprising of qualified professionals and support staff to provide technical, managerial, strategic and professional assistance.

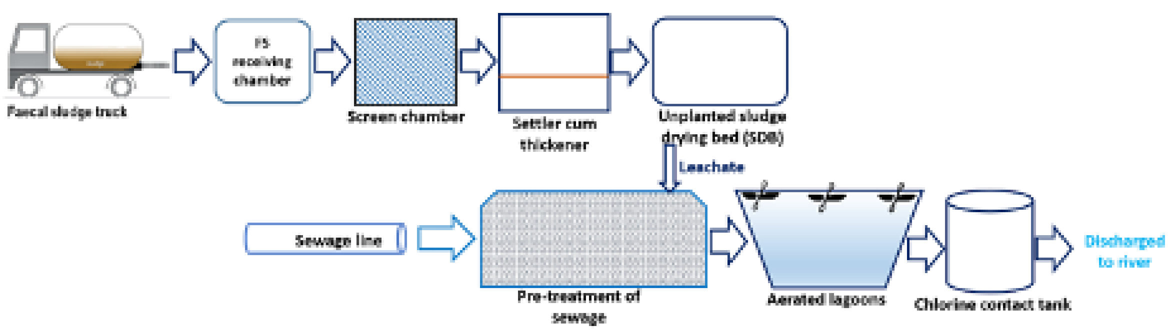
The OWSSB has constructed a 50 KLD capacity Septage Treatment Plant (SeTP) at Mangalaghat, Puri in October, 2017. The SeTP employs co-treatment method for treatment of septage where the liquid faction is treated in a Sewerage Treatment Plant (STP) located adjacent to the SeTP

Puri FSTP

Mangala Ghat STP, having capacity of 15 MLD, is located in Puri on the banks of river Dhaudia. Septage treatment plant has been constructed exactly beside the above STP to treat the leachate along with the incoming sewage water. During the survey, it was observed that FSTP was running with 70 per cent capacity.

The FSTP is working on the principle of Solid-Liquid separation of FS followed by co-treatment of the liquid fraction in STP. The plant has an elevated unloading platform and FS is discharged from the tankers into the receiving chamber. Faecal sludge is then passed through an inlet channel where screen is placed at an angle of 45° to remove the inert materials. The septage then flows to the settling cum thickening tank where the sludge holding time is maintained as 10 days. Thickened sludge from the bottom of the settling-thickening tanks is pumped to the unplanted sludge drying beds where the sludge is dried completely under direct sunlight. The leachate from the bottom of the SDBs is collected into the leachate sump and pumped from time to time along with supernatant from S-T tanks to the pre-treatment unit of the STP for subsequent treatment along with sewage water. Further, the combined water stream flows to the aerated lagoons and finally the effluent is discharged to the river after chlorination.

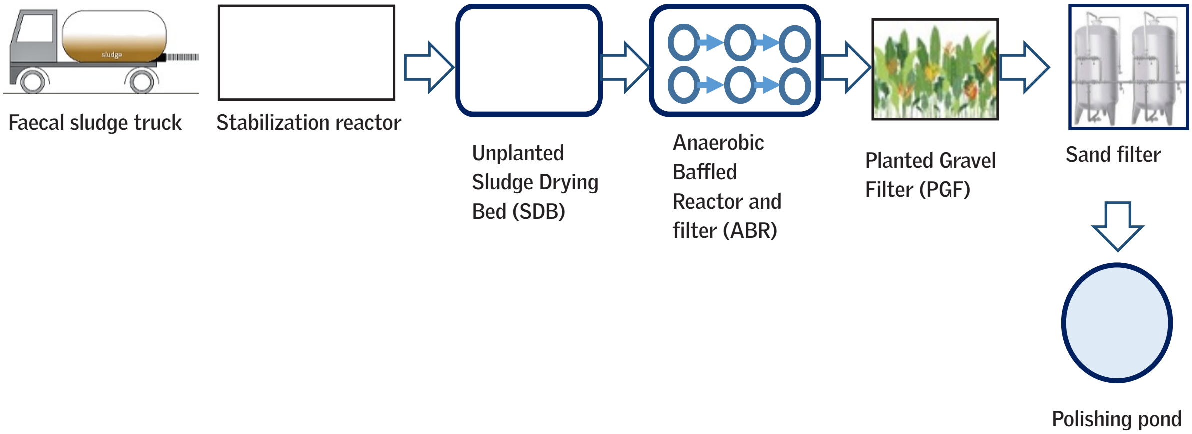
Figure 22: Schematic representation of the process flow in Puri co-treatment plant



Balasore FSTP

The FSTP with DEWAT system and treatment capacity of 60 KLD was commissioned in January, 2020 to address safe disposal of septage collected from nearby localities. During survey, it was observed that FSTP was running with 40 per cent capacity.

Figure 23: Schematic representation of the process flow of Balasore FSTP



The treatment consists of a screening chamber followed by two parallel rows of settling cum thickening tank and then ABR with anaerobic filter. Thickened sludge from the bottom of the S-T tank is pumped to the unplanted sludge drying beds where the solid part is dried under sunlight and finally stored in the dry-sludge storage yard. The liquid from the bottom of the SDB is collected in the leachate sump and it is then pumped to the ABR inlet from time to time. The effluent from outlet of the anaerobic filter flows to PGF where some of the nutrients are up taken by the plants. The next unit in the treatment system is a sand filtration set up which is used for the removal of any suspended or floatable materials. After filtration, the effluent is collected in the polishing pond, and diverted for gardening purpose in the FSTP site.

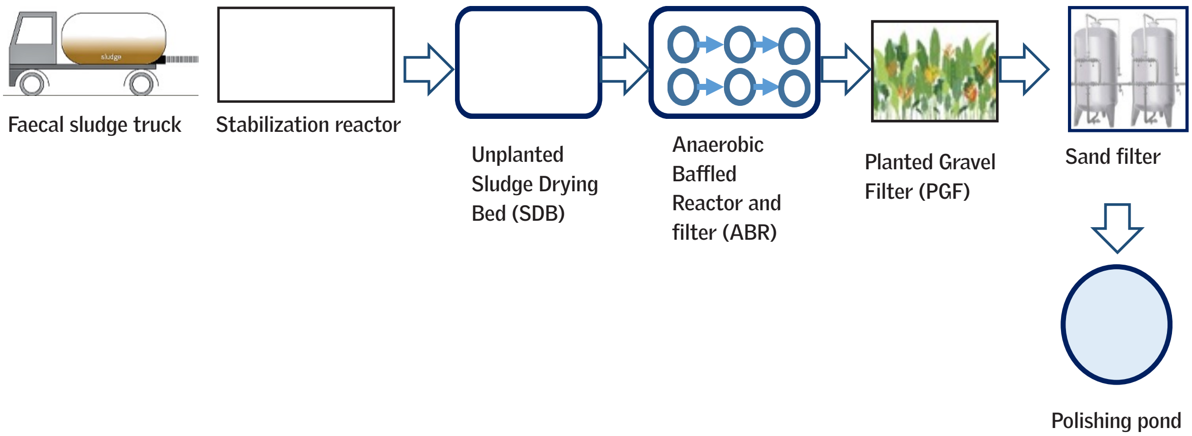
The septage or faecal sludge is mainly collected from household septic tanks and single pits. Sometimes, the sludge is also received from nearby hospitals. Desludging is conducted through five cesspool trucks having varied capacity of 1-3 KL each.

Baripada FSTP

The FSTP is designed on DEWATs process and was commissioned in the month of January, 2019, having capacity to treat 50 KL of sludge per day. The plant is operated under the jurisdiction of Baripada Municipality in Mayurbhanj District in the state of Odisha. Septage is mainly collected from household septic tanks or single pits from the adjacent localities by cesspool trucks of 3 KL capacity.

The first unit of the treatment plant is a screening chamber which is followed by two parallel rows of settling cum thickening tank and then ABR with anaerobic

Figure 24: Schematic representation of the process flow in Baripada FSTP



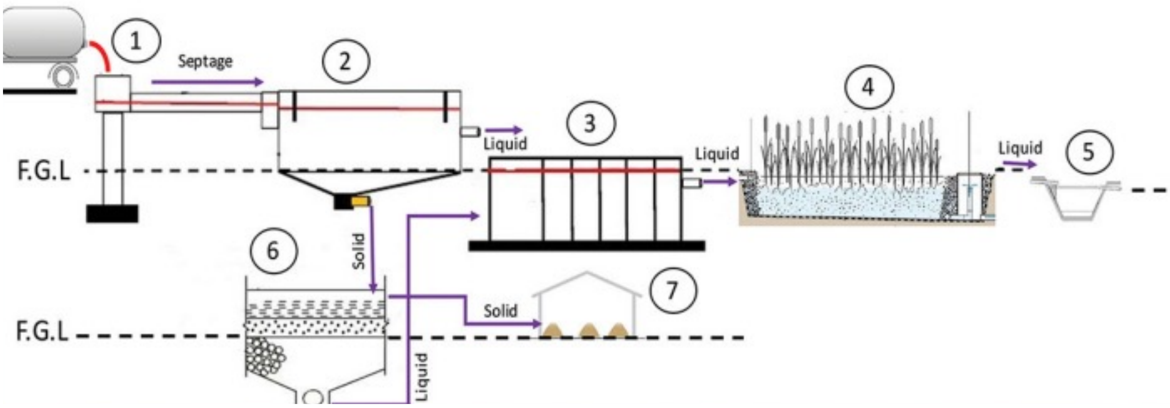
filter. Sludge from the bottom of the S-T tank is transferred to the unplanted sludge drying beds where the solid part is dried under sunlight and finally stored in the dry-sludge storage yard. The liquid from the bottom of the SDB is collected in the leachate sump and it is then pumped to the ABR inlet periodically. The effluent from outlet of the anaerobic filter is passed through PGF and sand filter and finally stored in the polishing pond. The water stored in the polishing pond is used for horticulture in the premises.

During survey the performance of the FSTP was observed to be unsatisfactory due to malfunctioning of the extraction pump installed at the bottom of the Settling cum Thickening tank. As a consequence, the solid entered into the ABR chambers followed by slow escape of particulates to the Anaerobic Filter and then to PGF/ Sand Filter Bed before entering to the Polishing Pond. Thus, the effluent from subsequent units after S-T tank was contaminated due to the overflow of sludge from S-T tank which drastically reduced the efficiency of the plant.

Bhubaneswar FSTP

Bhubaneswar FSTP is located in the south-eastern part of Odisha's capital, Bhubaneswar. The AMRUT (Atal Mission for Rejuvenation & Urban Transformation) scheme funded the project and OWSSB (Odisha Water Supply & Sewerage Board) designed it and supervised the construction. The FSTP started operation in June 2018 and was designed with DEWATs system with a capacity of 75 MLD with possible expansion plan to 150 MLD. It is the first and the only FSTP of the city, which mainly relies on onsite sanitation systems.

Figure 25: Schematic representation of the process flow in Bhubaneswar FSTP



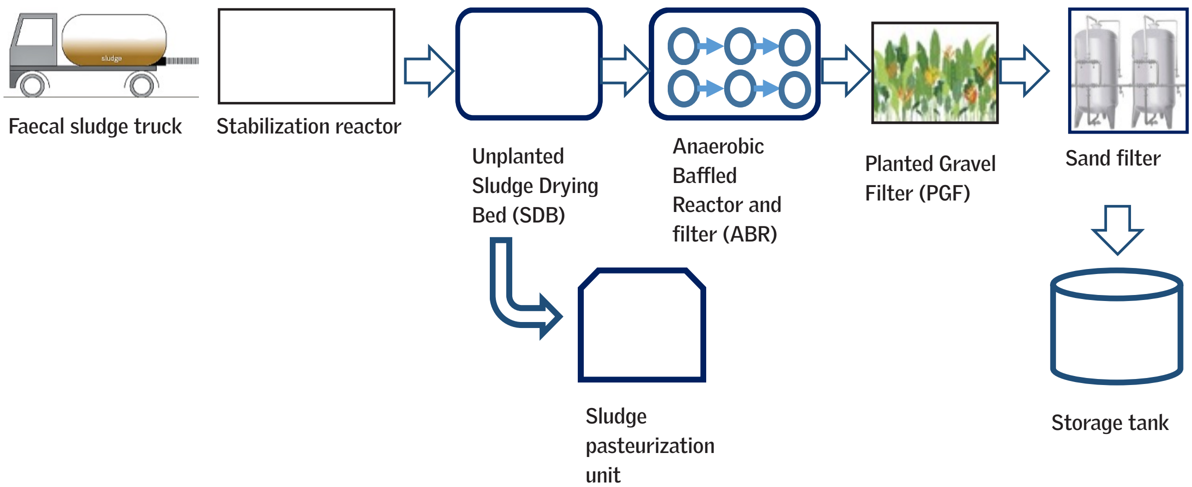
The faecal sludge received in the receiving chamber flows by gravity to the subsequent treatment unit consisting of two settling-thickening tanks and eight unplanted drying beds. The leachate from the sludge drying beds is treated in two parallel series of anaerobic baffled reactors with anaerobic filters. The next unit is the horizontal flow constructed wetlands, where the leachate undergoes tertiary treatment. This is followed by slow sand filters which removes the pathogens including bacteria, viruses and protozoa. The effluent is stored in a polishing pond equipped with an aeration pump. The dried sludge is stored in the storage shed.

Dhenkanal FSTP

FSTP Dhenkanal, having capacity of 27 KLD, is Odisha`s first FSTP to serve the purpose of completing the sanitation value chain. It was built by collective action of sanitation alliances with Dhenkanal Municipality and Government of Odisha. The main treatment steps followed in this FSTP are solid-liquid separation, stabilization, dewatering of sludge and pathogen removal.

The faecal sludge is conveyed to the FSTP through desludging trucks. The treatment modules for solid components are: feeding tank (FT) with screen chamber, stabilization reactor, unplanted sludge drying bed (SDB) with green house solar drier roof (GHSD). Treatment modules for liquid components are as follows: integrated anaerobic baffled reactor with filter chambers, planted gravel filter (PGF), sand and carbon filter followed by UV exposure and collection tank. The treatment system also consists of a sludge pasteurization unit where the dried sludge from the SDB is decontaminated from pathogens for safe usage in agriculture.

Figure 26: Schematic representation of the process flow in Dhenkanal FSTP

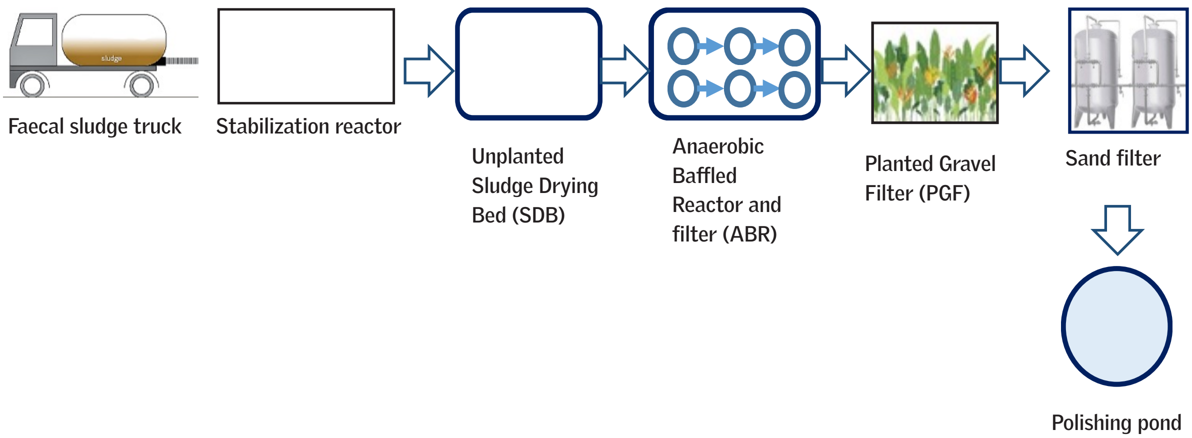


Berhampur FSTP

The plant was constructed at Mahuda on 1.5 acre of land and commissioned on 26 October 2018. It was designed to process 40 KLD of faecal sludge & septage which is transported through cesspool trucks from nearby locations. Desludging is performed through two types of tanker having 3 KL or 5 KL capacity. Sludge is received from household, community & public toilets. The FSTP was running at its full capacity.

The treatment process starts from screening chamber followed by two parallel rows of settling cum thickening tank and then ABR with Anaerobic Filter. Sludge from the bottom of the tank is transferred to the unplanted sludge drying beds where the solid part is dried under sunlight and finally stored in the dry-sludge storage yard. The supernatant from the top of the S-T tank flows to the ABR. The liquid from the bottom of the SDB is collected in the leachate sump and it is then pumped to the ABR inlet from time to time. The effluent from outlet of the Anaerobic Filter is passed through PGF and sand filter and finally stored in the polishing pond. The water stored in the polishing pond is used for horticulture in the premises.

Figure 27: Schematic representation of the process flow in Berhampur FSTP

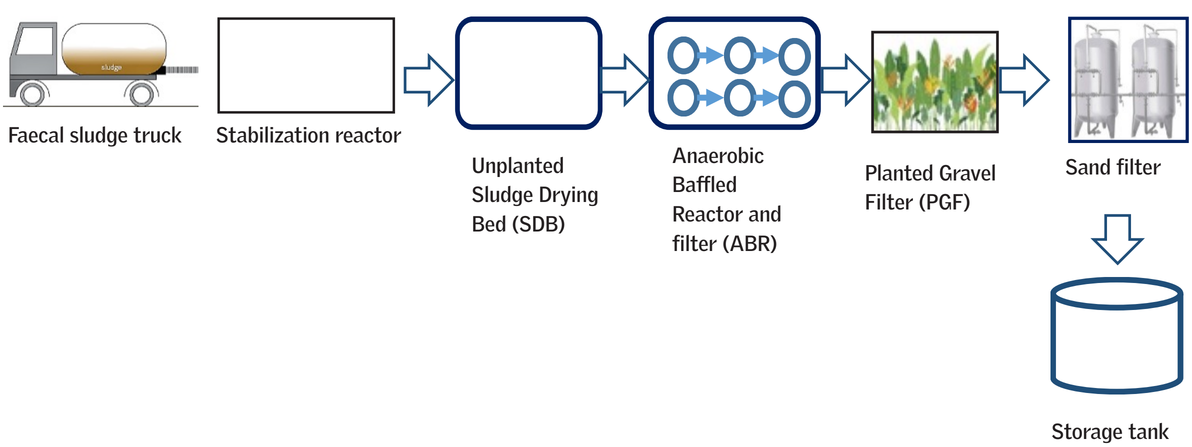


Angul FSTP

FSTP with a capacity of 18 KLD located in Angul district of Odisha was commissioned in the month of January, 2020. During survey, the FSTP was running with almost 83% capacity. The treatment starts by the removal of coarse particles such as sand and grit in screen & grit chamber followed by stabilization of sludge in two separate rows of stabilization reactors. Further, it moves to the sludge drying beds where the solid part is separated. Each sludge drying bed consists of two parallel rows of six drying beds covered with semi-circular translucent roof to expedite the drying process. Finally, the dried sludge is stored in the dry-sludge storage yard for subsequent use in soil conditioning.

The liquid portion after percolating through SDB is collected in respective leachate

Figure 28: Schematic representation of the process flow in Angul FSTP



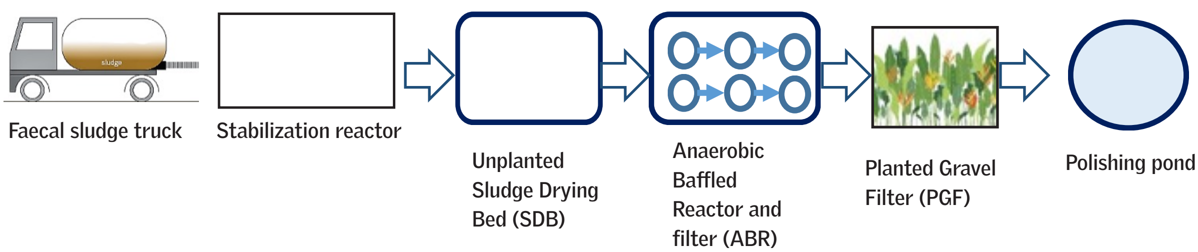
sumps which in course are connected to a common ABR with anaerobic filter. The effluent from the outlet of the Anaerobic Filter is passed through PGF followed by sand & carbon filter and then exposed to UV irradiation. Finally, the treated water is stored in the water collection tank until usage. The water is used for horticulture in the premises.

Sambalpur FSTP

Sambalpur FSTP is situated at Khandual, nearly 10 km from the main city. The FSTP became operational on 26 October, 2018 with a treatment capacity of 20 KLD.

The treatment consists of a receiving & screening chamber followed by two parallel rows of settling cum thickening tank and then ABR. Thickened sludge from the bottom of the S-T tank is pumped to the unplanted sludge drying beds where the solid part is dried under sunlight and finally stored in the dry-sludge storage yard. The supernatant from the top of the S-T tank flows to the ABR. The liquid from the bottom of the SDB is collected in the leachate sump and it is also pumped to the ABR inlet from time to time. The effluent from the outlet of the ABR is passed through two successive beds of PGF and finally stored in the polishing pond. The effluent collected in polishing pond is used for horticulture & watering the plants in the premises.

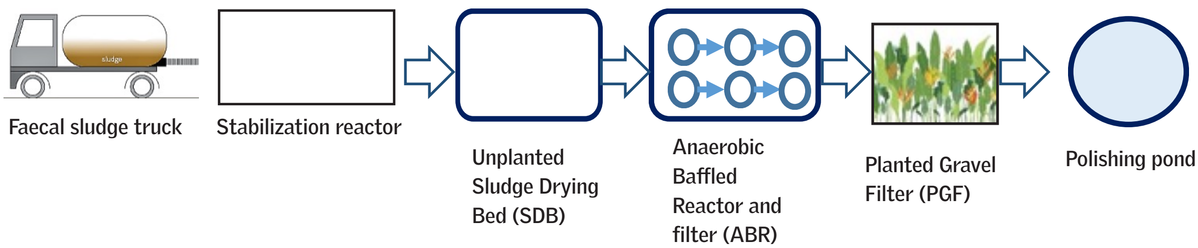
Figure 29: Schematic representation of the process flow in Sambalpur FSTP



Rourkela FSTP

The construction of the FSTP was executed by the Odisha Water Supply & Sewerage Board (OWSSB) at Balughat in Rourkela. The project was planned under the Atal Mission for Rejuvenation and Urban Transformation programme (AMRUT). The plant was designed to process 40 KLD septage which is mainly collected from household septic tanks in cesspool trucks having capacity of 3 KL each. The treatment plant was running at 60 per cent of its capacity.

Figure 30: Schematic representation of the process flow in Rourkela FSTP



The treatment process starts with a screening chamber followed by two parallel rows of settling cum thickening tank and then ABR with Anaerobic Filter. Sludge from the bottom of the S-T tank is transferred to the unplanted sludge drying beds where the solid part is dried under sunlight and finally stored in the dry-sludge storage yard. The liquid from the bottom of the SDB is collected in the leachate sump and it is then pumped to the ABR inlet from time to time along with the supernatant flowing from the top of the S-T tank. The effluent from the outlet of the anaerobic filter is passed through PGF and stone filter and finally collected in the polishing pond. The water stored in the polishing pond is used for horticulture in the premises of FSTP site.

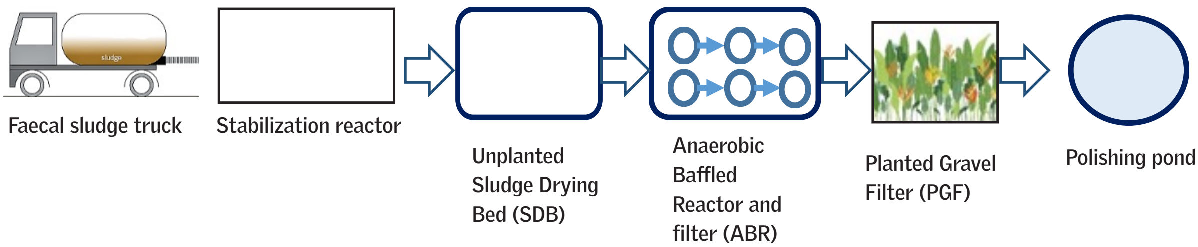
Kashinagar FSTP

The FSTP has been set up in the town of Kashinagar, a Notified Area Council (NAC) in Gajapati District of Odisha by ULB which was commissioned in November 2021. The plant has a capacity of 10 KLD. During the study period, the FSTP was not running in full capacity; only FS from 3 vacuum trucks of '3000 litres' capacity was received in a week. The FS is mostly received from household septic tanks. The plant is near to forest area.

The technology adapted was DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. The CAPEX of the FSTP is Rs. 3 crores. O & M cost is Rs. 76000/- per month, while earning of FSTP received from households for desludging of FS is only around Rs. 9000/- per month.

FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get

Figure 31: Schematic representation of the process flow in Kashinagar FSTP



settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB and allowed to stay for 3-4 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms. About 1000 litres of treated water is generated in a day which is used for gardening purpose within the premises of FSTP. The dried sludge is removed from SDB and stored in sludge storage shed. About 2,000 kg of dry sludge is generated in a month and used for land filling.

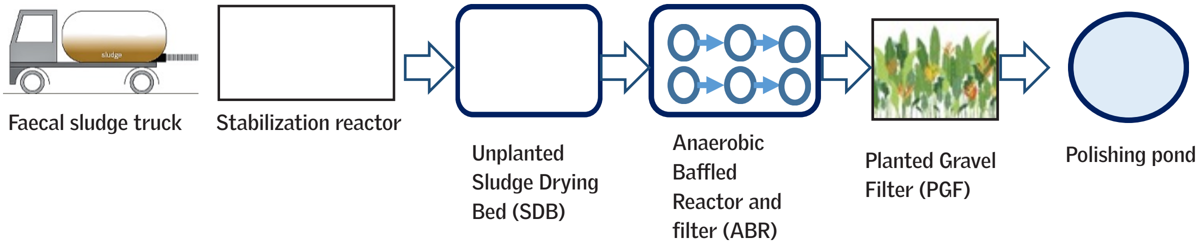
Nimapada FSTP

The FSTP has been set up by ULB in the town of Nimapada, a NAC in the Puri District of Odisha. The FSTP was commissioned in May 2022. The plant has a capacity of 10 KLD. During the study period, the FSTP was not running in full capacity; only FS from 3-4 vacuum trucks of '3000 litres' capacity was received in a week. The FS is received from household, community and public toilets, and hospitals. The plant is located near agricultural land.

The technology adopted is DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. Receiving of less FS and availability of only 1 cesspool truck only from ULBs is the challenge faced by the FSTP.

FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB and allowed to stay for 3-four weeks for drying. Leachate

Figure 32: Schematic representation of the process flow in Nimapada FSTP



from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From ABR, the partially treated water enters into PGF which are four in number for nutrient removal.

Later, the water enters into polishing pond for the removal of odour and microorganisms. About 7000-8000 litres of treated water is generated in a day which is used for gardening purpose within the premises of FSTP. The dried sludge is removed from SDB and stored in sludge storage shed. About 5-7.5 kg of dry sludge is generated in a month which is currently not being reused.

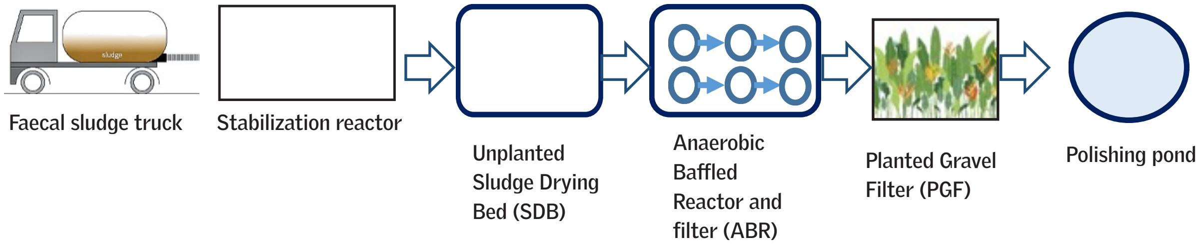
Hinjilcut FSTP

The FSTP has been set up in the municipal town of Hinjilcut of Ganjam District in Odisha by ULB which was commissioned in 2021. The plant has a capacity of 10 KLD. During the study period, the FSTP was running with full capacity by receiving 2-3 '3000 litres' capacity vacuum trucks of FS per day. The FS is mostly received from household septic tanks. The plant is near to forest area. The technology adapted was DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment.

The CAPEX of the FSTP is Rs. 3 crores. O & M cost is Rs. 80,000/- per month, while earning of FSTP received from households for desludging of FS is around Rs. 40,000/- to Rs. 60,000/- per month.

FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS.

Figure 33: Schematic representation of the process flow in Hinjilcut FSTP



From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms. However, water from PGF has not yet reached the polishing pond during the study period. The dried sludge is removed from SDB and stored in sludge storage shed. About 16 tonnes of dry sludge is generated in a month which is not being reused.

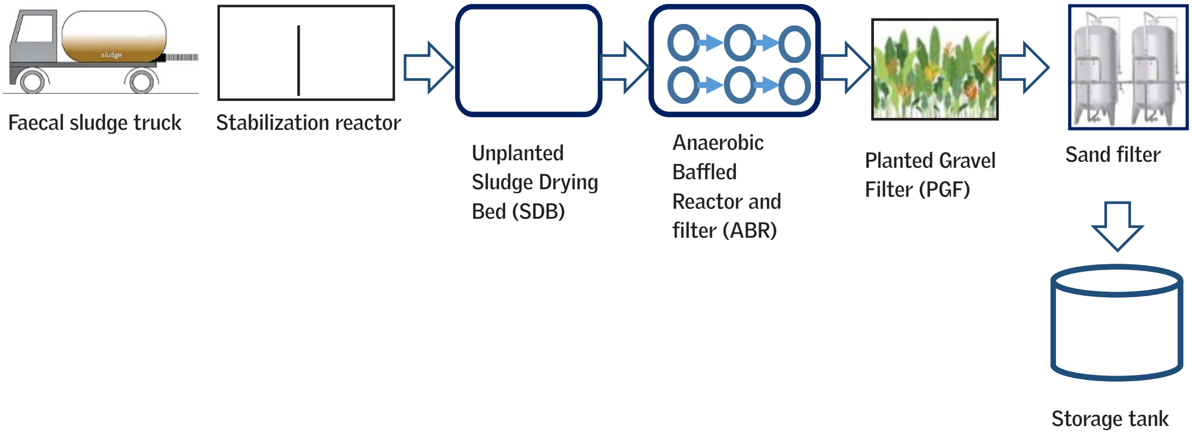
Choudwar FSTP

The FSTP has been set up in the municipal town of Choudwar of Cuttack District in Odisha by ULB which was commissioned in 2020. The FSTP is operated by Self Help Group (SHG). The plant has a capacity of 12 KLD. During the study period, the FSTP was running around 60-70% of its treatment capacity. FS of about 4-5 vacuum trucks with '1000-3000 litres' capacity is received in a day. Cesspool trucks were operated by ULB (1000 litres capacity) and private desludgers (3000 litres capacity). The FS is mostly received from household septic tanks. The plant is located close to a residential area.

The technology adapted was DEWATS with stabilization reactor (SR), unplanted sludge drying beds (SDB) for primary treatment, settler and anaerobic filter (AF) followed by planted gravel filter (PGF) for secondary treatment, and, activated sand and carbon filter (ASCF) and UV for tertiary treatment. The CAPEX of the FSTP is Rs. 2.25-2.3 crores excluding land cost. O & M cost is Rs. 58,000/- per month.

FS collected from various containments in the town by vacuum trucks is discharged

Figure 34: Schematic representation of the process flow in Choudwar FSTP



at the sludge receiving unit/ screening chamber of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into SR where anaerobic digestion of sludge takes place resulting in the reduction of organic load. Subsequently, the partially treated FS is pumped into SDB and allowed to stay for 2-3 weeksfor drying. Leachate from the SDB enters into settler and AF for organic matter decomposition by anaerobic digestion resulting in reduction of COD and TSS. From the Settler and AF, the partially treated water enters into PGF, which are two in number for the removal of color, odour and nutrients; here oxygen enrichment of wastewater also takes place. Later, the water passes through ASCF for the final reduction in BOD, COD and TSS to acceptable limits, and UV for the removal of microorganisms, and finally the treated water gets collected in a collection tank for reuse.

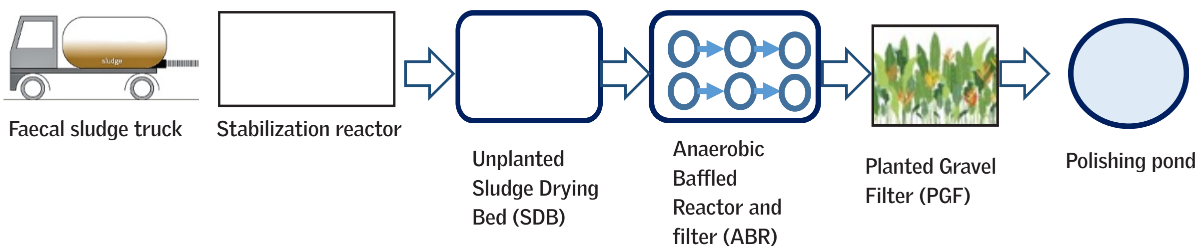
About 9,000 litres of water is generated per day which is used for gardening, landscaping inside the plant premises and also for cleaning of cesspool truck. The dried sludge is removed from SDB and stored in sludge storage shed. About 1,000 kg of dry sludge is generated in a month which is not reused until now. However, setup for a co-composting unit for reuse of the dry sludge is planned in the future.

Bhadrak FSTP

The FSTP has been set up by ULB in Bhadrak city which is the district headquarters of Bhadrak district in Odisha. The FSTP was commissioned in September 2021 with a capacity of 30 KLD to serve a population of 1,24,715 people. During the study period, the FSTP was running in full capacity with FS of about 7-8 vacuum trucks each with '3000 litres' capacity being received in a day. The FS is received from household, community and public toilets, and hospitals. The plant covers an area of 2.5 acres which is constructed in the outskirts of the city near to village area. The technology adapted was DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. The CAPEX of the FSTP is Rs. 3.46 crores. O & M cost of the FSTP is Rs. 92,000/- per month.

FS collected from various containments in the city by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids

Figure 35: Schematic representation of the process flow in Bhadrak FSTP



get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB (6 in number), which are covered with movable asbestos roof, and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms.

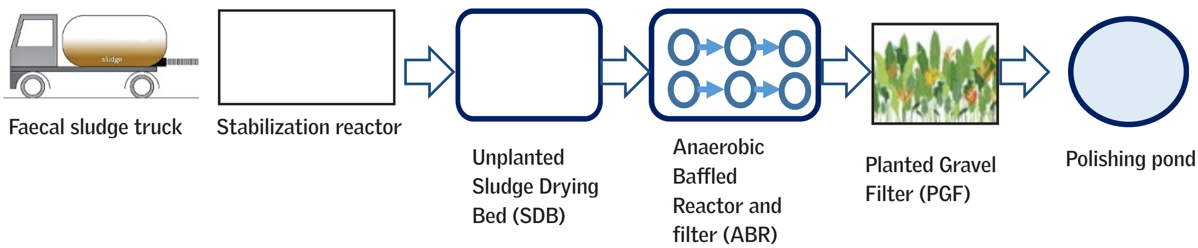
About 16,000 litres of water is generated per day which is used for landscaping within the plant premises. The dried sludge is removed from SDB and stored in sludge storage shed. About 200 kg of dry sludge is generated in a month which is not reused until now.

Talcher FSTP

The 20 KLD FSTP has been set up by ULB in Talcher of Angul District in Odisha which was commissioned in 2021. During the study period, the FSTP was running much below (<10%) the treatment capacity, as it was receiving only 0-1 truck of '2500 litres capacity' per week (a total of 30-33 trucks were received in a year). The FS is received from household, community and public toilet septic tanks. The plant is located in a very interior location inside the forest area. The technology adopted is DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment.Capex of the FSTP is 2.75 crores, while the O & M cost is Rs. 76,000/- per month. One major challenge faced by the FSTP is FS not being received on a daily basis.

FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR,the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms. However, water from PGF has not yet reached the polishing pond during the study period. The dried sludge is removed from SDB and stored in sludge storage shed. About 1000 kg of dry sludge is generated in a month which is not reused until now.

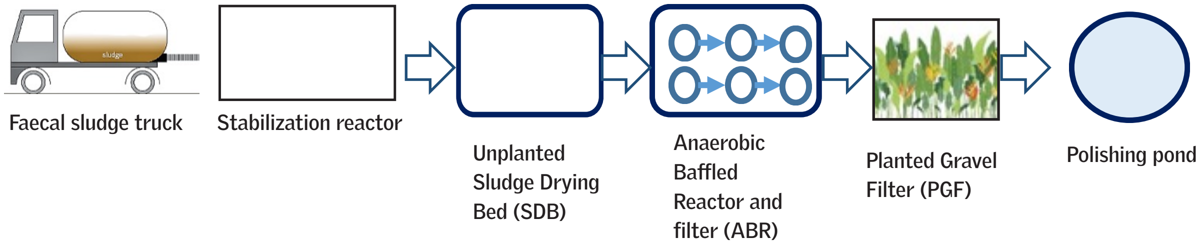
Figure 36: Schematic representation of the process flow in Talcher FSTP



Khordha FSTP

The 20 KLD FSTP has been set up by ULB in the municipal town of Khordha, the headquarters of Khordha District in Odisha. The FSTP was commissioned in November 2020. During the study period, the FSTP was running in full capacity, by receiving 4-5 trucks of '3500-4000 litres capacity' per day. The FS is received from household, community and public toilets. The plant occupies a total area of 1 acre and is located near industrial area. The technology adapted was DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and horizontal planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment.

Figure 37: Schematic representation of the process flow in Khordha FSTP



FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB, which are 4 in number covered with movable asbestos roof, and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms.

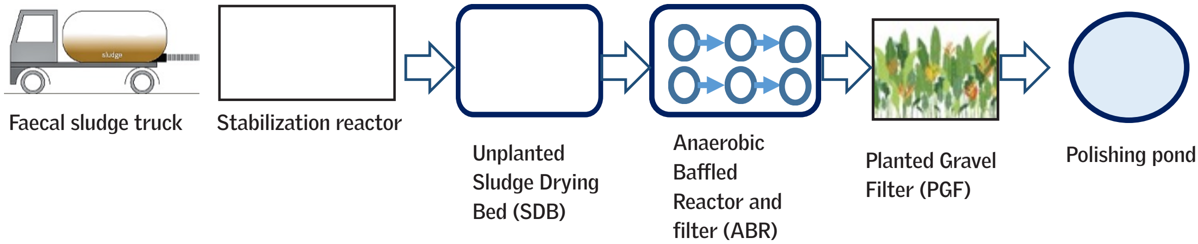
About 15,000 litres of water is generated per day in the FSTP which is used for landscaping within the plant premises. The dried sludge is removed from SDB and stored in sludge storage shed and is not reused until now, except for gardening purpose sometimes within the plant premises.

Jatni FSTP

The 20 KLD FSTP has been set up by ULB in the municipal town of Jatni belonging to Khordha District in Odisha. The FSTP was commissioned in May 2021. During the study period, the FSTP was running in full capacity, by receiving 20 trucks of '1000 litres, 3000 litres or 4000 litres capacity' per day. The FS is received from household, community and public toilet septic tanks. The plant occupies a total area of 1.5 acres and is located near mines.

The FSTP is operated with solar power. The technology adopted is DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and horizontal planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment.

Figure 38: Schematic representation of the process flow in Jatni FSTP



FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms.

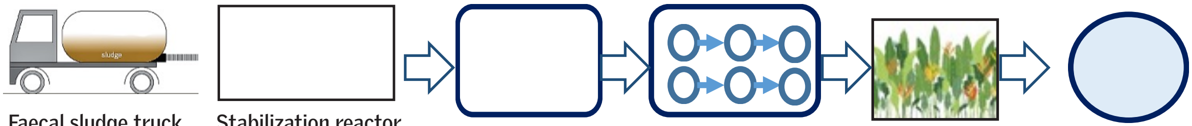
The water generated in the FSTP is used for gardening within the plant premises, and for cleaning roads and railway tracks. The dried sludge is removed from SDB and stored in sludge storage shed and is not reused until now.

Paralakhemundi FSTP

The 20 KLD FSTP has been set up by ULB in the municipal town of Paralakhemundi, the headquarters of Gajapati District in Odisha. The FSTP was commissioned in 17th November, 2021. During the study period, the FSTP was not running in full capacity; only 1-2 trucks of '3000 litres capacity' were received in a day. The FS is received from household septic tanks. The plant is located near forest area. The FSTP is operated with power grid.

The technology adapted was DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and horizontal planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. The Capex of the FSTP is 3 crores. The O & M cost is Rs. 76,000/- per month, while revenue generated from FSTP (from households for desludging) is Rs. 30,000/- per month.

Figure 39: Schematic representation of the process flow in Paralakhemundi FSTP



FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms.

About 1000 litres of water is generated per day which is used for gardening purpose within the premises of the FSTP. The dried sludge is removed from SDB and stored in a sludge storage shed and is not reused until now. About 1.5 tonnes of dry sludge is generated per month.

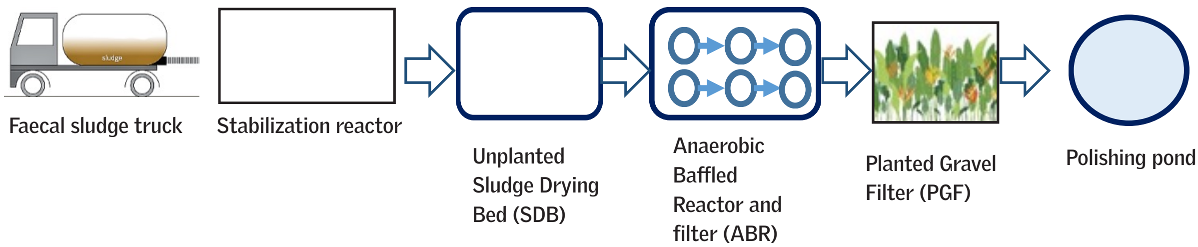
Jagatsinghpur FSTP

The 20 KLD FSTP has been set up by ULB in the municipal town of Jagatsinghpur, the headquarters of Jagatsinghpur District in Odisha. The FSTP was commissioned in 2022. During the study period, the FSTP was running in full capacity by receiving not less than 4 trucks of '3000 litres capacity' in a day. The FS is received from household septic tanks. The plant is located in a well-populated area of the town.

The technology adapted was DEWATS with settling cum thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and horizontal planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. The Capex of the FSTP is Rs 3.5 crore. The O&M cost is Rs 80,000 per month, while revenue generated is Rs 50,000 per month.

FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid

Figure 40: Schematic representation of the process flow in Jagatsinghpur FSTP



waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB, which are 4 in number covered with movable asbestos roof, and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms.

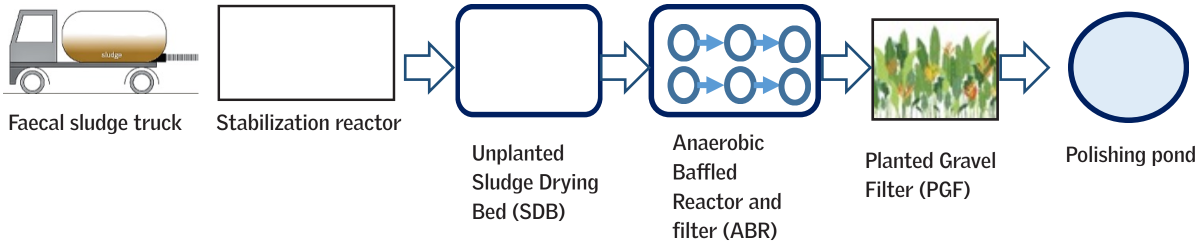
About 10,000 litres of water is generated per day which is used for gardening purpose within the premises of the FSTP. The dried sludge is removed from SDB and stored in a sludge storage shed and is not reused until now. About 5 tonnes of dry sludge is generated per month.

Surada FSTP

The 10 KLD FSTP has been set up by ULB in Surada town, a NAC in the Ganjam District of Odisha. The FSTP was commissioned in December 2021. During the study period, the FSTP was not running in full capacity; only FS from 7-8 vacuum trucks of '1000 litres capacity' were received in a week. The FS is received from household septic tanks. The plant is located near forest area.

The technology adapted was DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and horizontal planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. The Capex of the FSTP is 3 crores. The O & M cost is Rs. 100,000/- per month, while revenue generated from FSTP (from households for desludging) is only Rs. 12,000/- to 15,000/- per month.

Figure 41: Schematic representation of the process flow in Surada FSTP



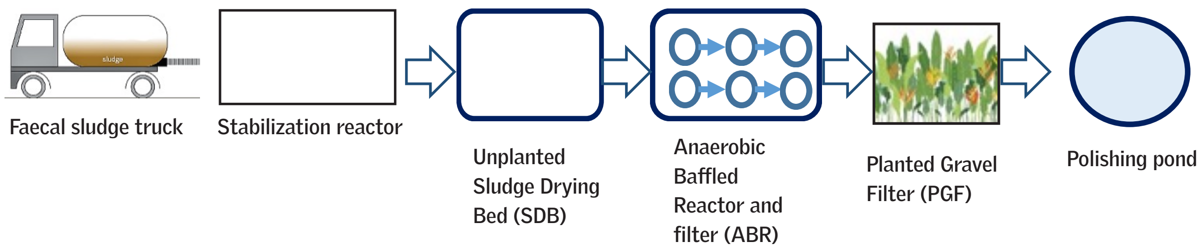
FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB, and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms. However, as the FSTP is receiving very less amount of FS, very less amount of water is entering into ABR, which is not sufficient to reach into PGF. So, during the study period, the water has not reached PGF and polishing pond for treatment. Hence, plants in the PGF are dried and not growing.

The dried sludge is removed from SDB and stored in a sludge storage shed and is not reused until now. About 10-12 tonnes of dry sludge is generated per month.

Asika FSTP

The 10 KLD FSTP has been set up by ULB in the town of Asika, a NAC in the Ganjam District of Odisha. The FSTP was commissioned in August 2021. During the study period, the FSTP was not running in full capacity; only FS from 5 vacuum trucks of '3000 litres capacity' were received in a week. The FS is received from household septic tanks. The plant is located near forest area.

Figure 42: Schematic representation of the process flow in Asika FSTP



The technology adapted was DEWATS with settling-thickening tank (STT) and unplanted sludge drying beds (SDB) for primary treatment, ABR and horizontal planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. The Capex of the FSTP is 1.5 crores. The O & M cost is Rs. 30,000/- per month, while revenue generated from FSTP (from households for desludging) is Rs. 20,000/- per month. Less plants with stunted growth were observed during the study period in PGF, which is because of water not reaching PGF from ABR.

FS collected from various containments in the town by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS flows into STT where the solids get settled while the supernatant flows into ABR. The settled sludge from STT is then pumped into SDB, and allowed to stay for 2-3 weeks for drying. Leachate from the SDB enters into ABR; Leachate along with FS supernatant undergoes treatment in ABR by anaerobic digestion resulting in reduction of COD and TSS. From the ABR, the partially treated water enters into PGF which are four in number for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms.

About 2000 litres of water is generated per day which is used for gardening purpose within the premises of the FSTP. The dried sludge is removed from SDB and stored in a sludge storage shed and is not reused until now. About 20 tonnes of dry sludge is generated per month.

Performance evaluation of treatment systems in Odisha

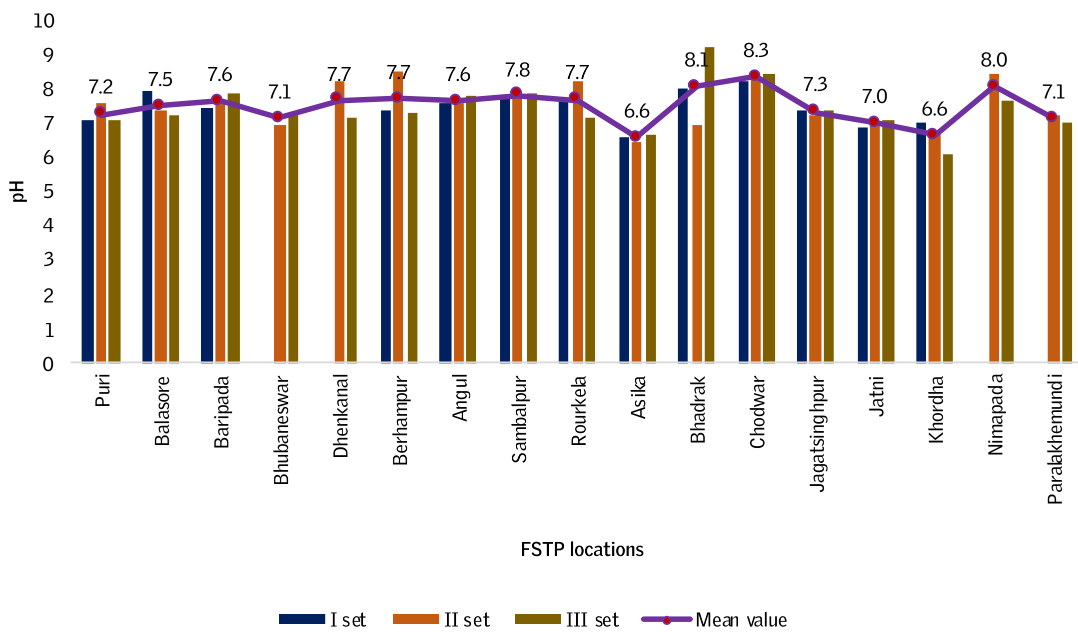
pH

The average pH of the treated discharge water from all the FSTP locations ranges from pH-6.6 to 8.3, which is slightly alkaline. The discharge standard for the pH is ranging from 6.0-9.0. A pH outside the range of 6 to 9 indicates an upset in the biological process that will inhibit anaerobic digestion of organic material. The pH of the discharge water from all locations evaluated is close to neutral pH and within the limit of the discharge standard.

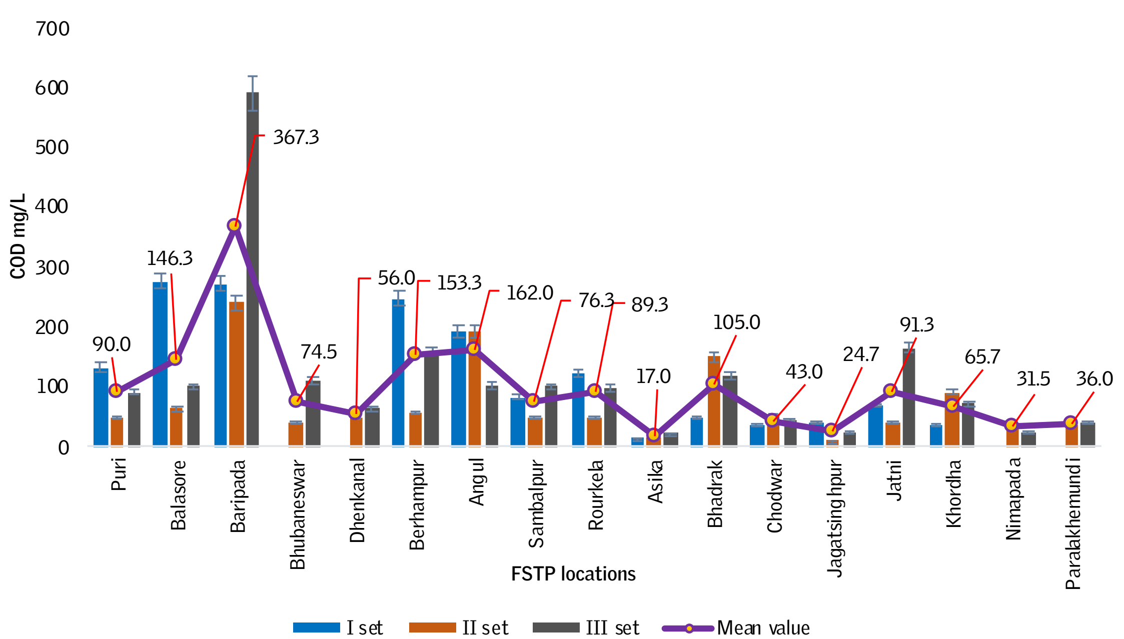
Chemical Oxygen Demand (COD)

The average COD value of the treated discharge water ranges from 17 mg/L to 367 mg/L. According to MoEF&CC, the discharge standard for COD is 50 mg/L. In all the locations, the COD values are above the discharge limit. The Baripada (367.3 mg/L), Balasore (146.3 mg/L) Berhampur (153.3 mg/L) and Angul (162

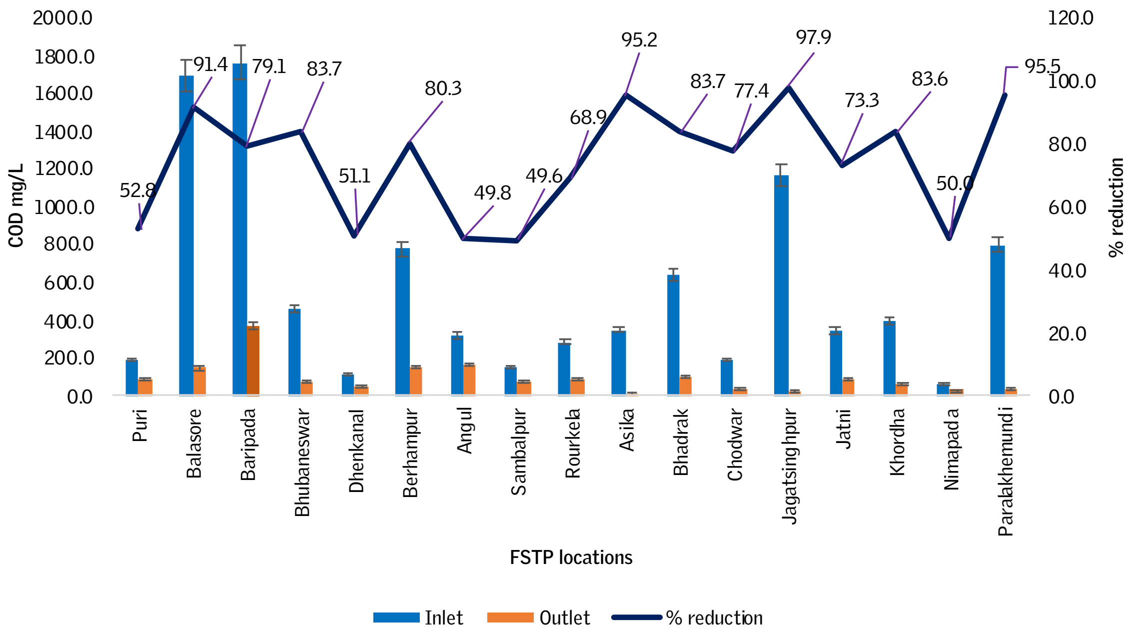
Graph 29: Average pH value of the treated discharge water



Graph 30: Average COD (3 set) value of the treated discharge water



Graph 31: Per cent removal of COD by the treatment systems



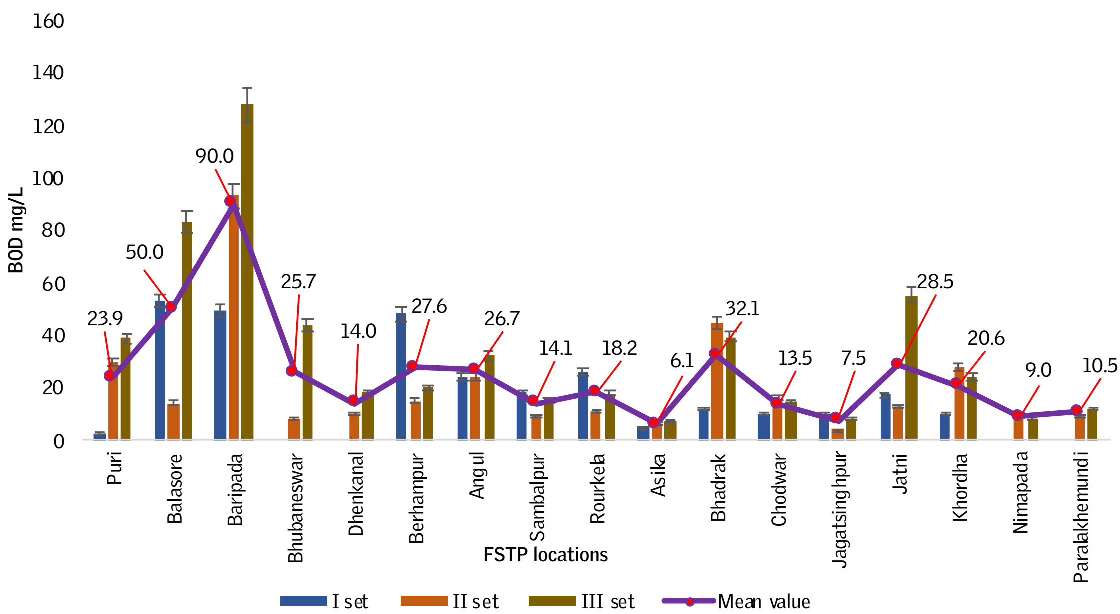
mg/L) showed high COD level in the outlet water, which is very much higher than 50 mg/L. Other FSTPs exhibited a little higher COD values with respect to the standard limit prescribed for the discharge water.

The per cent removal of COD from inlet to outlet ranges from 49.6 to 97.9 % (Fig: 3.3) that represents the treatment efficacy of the systems to remove organics. The highest COD removal percentage was obtained for Paralakhemundi and Jagatsinghpurwhereas lowest for Angul and Sambalpur. Interestingly, in spite of having the higher removal efficiency, the COD level in outlet of Balasore and Baripada sites showed higher value than the discharge water standard limit. This is attributed to higher inlet COD load that is due to the malfunctioning of solid liquid separation unit of Balasore plant at the time of sampling.

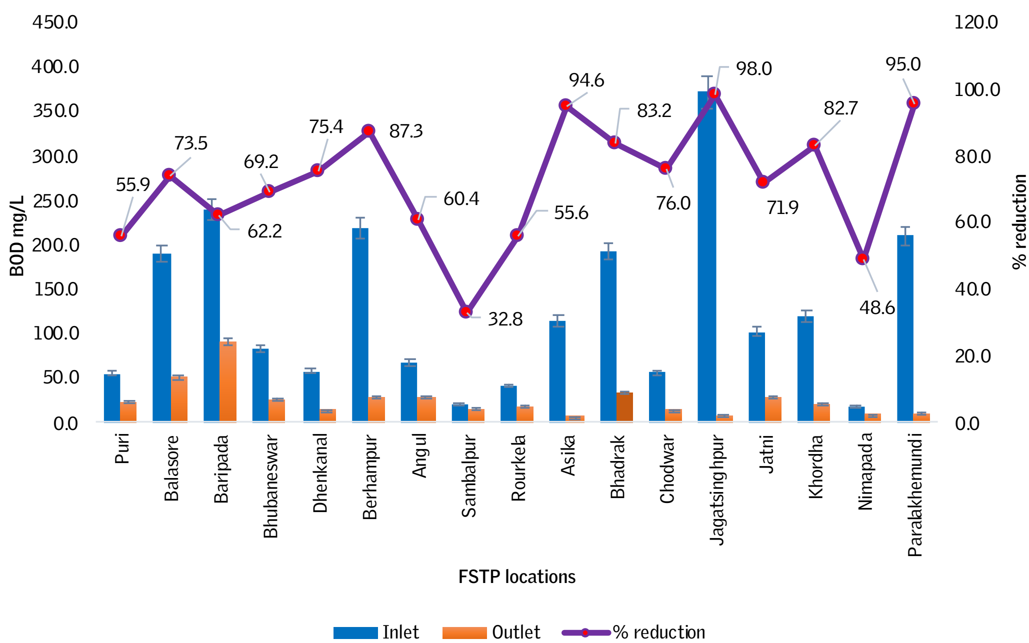
Biological Oxygen Demand (BOD)

Out of all the evaluated treatment systems, the average BOD value of the treated discharge water ranges from 6.1 mg/L to 90 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20 mg/L and non-metro cities 30 mg/L. The evaluated FSTPs are in non-metro cities and most of them showed BOD value under the discharge limit. However, the BOD value for Balasore, Baripada and Bhadrak was observed to be 50.0 mg/L, 90.0 mg/L, and 32 mg/L respectively that is above the discharge limit.

Graph 32: Average three-month BOD value of the treated discharge water



Graph 33: Per cent removal of BOD by the treatment systems



The per cent removal of BOD from inlet to outlet ranges from 32.8% to 98.0% that depicts the BOD removal efficacy of the systems. The highest BOD removal was observed for Jagatsinghpur (98.0%) and the lowest for Sambalpur (32.8%). All the FSTPs showed more than 50% BOD removal efficiency except for three sites, Sambalpur, Nimapada and Dhenkanal.

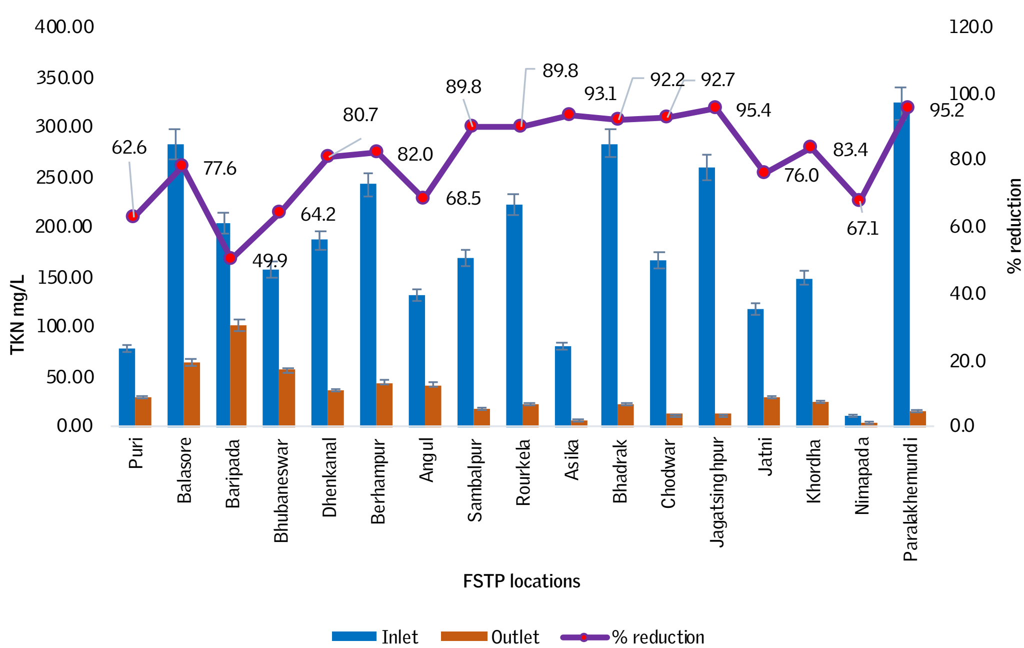
otal Kjeldahl Nitrogen (TKN)

The removal of nitrogen was observed in the evaluated FSTPs in the range of 49.9 to 95.2 per cent. Lowest removal efficacy was observed in the Baripada FSTP (49.9%). The highest removal efficacy was showed by Paralakhemundi FSTP (95.2%).

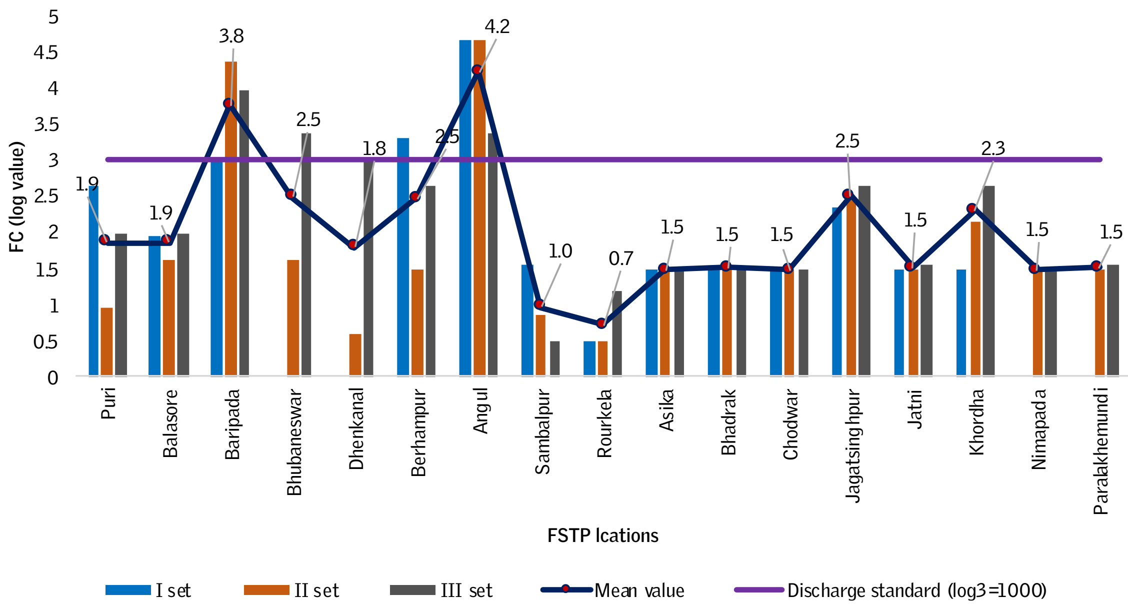
Faecal Coliform

The guideline limit for faecal coliform bacteria in unrestricted irrigation is R1000 MPN/100 mL. In the treatment system evaluated, all the FSTPs outlet water came below the prescribed limit set by MoEF&CC regulations (R1000 (log 3.0) MPN/100mL) except for Baripada and Angul FSTPs, which is higher than the standard limit. Here, it should be noted that Angul FSTP is having UV disinfection unit still FC is higher than discharge limit. This shows that UV system was not working significantly and requires periodic monitoring and maintenance.

Graph 34: Per cent removal of Total Kjeldahl Nitrogen by the treatment systems



Graph 35: Faecal coliform count in the treated discharge water from the treatment systems



SUMMARY

- In Odisha, the study was conducted for 16 FSTPs and one STP co-treatment plant (Puri) over a period of six months; samples were collected in alternate months.
- The pH of the discharge water from all locations evaluated is close to neutral pH and within the limit of the discharge standard.
- In all evaluated FSTP locations except five, the COD values are above the discharge limit (50 mg/L). The highest COD removal percentage was obtained for Paralakhemundi and Jagatsinghpur, whereas the lowest were for Angul and Sambalpur.
- All the evaluated FSTPs showed BOD value under the discharge limit, except for Balasore and Baripada that was observed to be 50.0 mg/L and 90.0 mg/L, respectively.
- The highest BOD removal was observed for jagatsinghpur (98 per cent) and the lowest for Sambalpur (32.8 per cent).
- The highest nitrogen removal efficacy was showed by Paralakhemundi (95.2 per cent) whereas the lowest removal efficacy was observed in Baripada (49.9 per cent).
- Faecal coliform value of all the FSTPs outlet water came below the prescribed limit set by MoEF&CC regulations (≤1,000 (log 3.0) MPN/100mL), except for Baripada and Angul FSTPs.

Rajasthan

The Rajasthan Urban Sector Development Program (RUSDP) will complement the past and ongoing efforts of Government of Rajasthan (GOR) to improve water supply and waste water services to the residents of the state of Rajasthan. The program component of the RUSDP will support policy reforms and consolidate institutional development and governance improvement in the urban sector in the state, while the investment component of the RUSDP will invest in water distribution network improvements and sewerage systems in the six project cities each having a population of more than 100,000, and identified considering the lack of basic services at present and willingness to undertake reforms and institutional restructuring.

RUSDP will be implemented over a five-year period beginning in March 2015, and will be funded by ADB via a sector development program (SDP) loan modality. RUSDP program was conceived to include a grant component contributed by BMGF through the RUIDP's existing framework to address the issue of decentralized wastewater and city-wide Faecal Sludge and Septage Management (FSSM) across Rajasthan.

In Rajasthan, many efforts have been put forward for FSSM in recent years. RUSDP through grants support from BMGF are developing pilot project in ULBs like Phulera, Lalsot and Khandela to build very 1st FSTP of state and further adoption of town specific FSSM regulations. These selected towns do not have underground sewerage system where citywide FSSM can be easily implemented. Further, through the Sanitation Capacity Building Platform (SCBP), a group of experts and organizations committed to the goal of sanitation has structured a program on sensitization, Capacity Building and Technical support in Rajasthan.

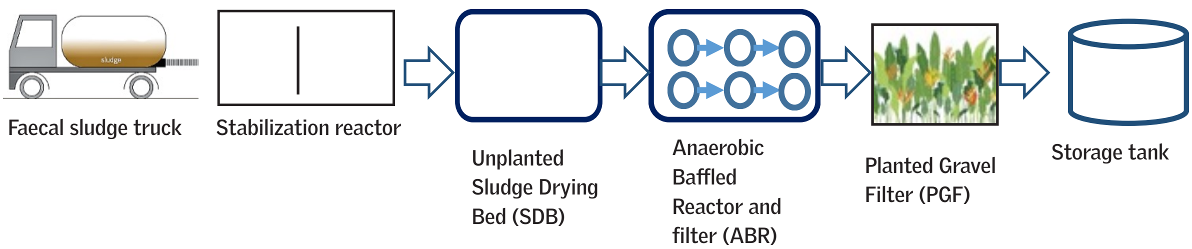
This platform is supporting incremental changes and capacity building for proposed towns of state for FSSM. These efforts by various agencies and pro-activeness of Government of Rajasthan have started an initiative to prepare DPRs of more than 100 towns for FSSM in the state. Numerous other attempts are on-going, being implemented by state government, ULBs, NGOs, and various other agencies regarding FSSM to ensure incremental efforts towards the vision of complete sanitation in Rajasthan

Phulera FSTP

Phulera lies in the north-western part of Jaipur district and approximately 70 km away from Jaipur. FSTP was constructed and designed by IPE Global Limited and became operational from April 2020. It was designed for a capacity of 20 KLD and is based on DEWAT system.

The treatment consists of two parallel rows of screening chamber, stabilization reactor and ten unplanted drying beds in each row. The leachate is collected in a collection tank followed by treatment in an integrated settler & anaerobic filter and planted gravel bed. The effluent is stored in the final collection tank and is used for horticulture & for watering plants in the garden. The dried sludge is stored in a storage shed.The septage or faecal sludge is mainly collected from household septic tanks and single pits. Desludging is conducted through two cesspool trucks commonly called as vacuum trucks having capacity of 4500 litres each. During survey, FSTP was running with 50 per cent capacity.

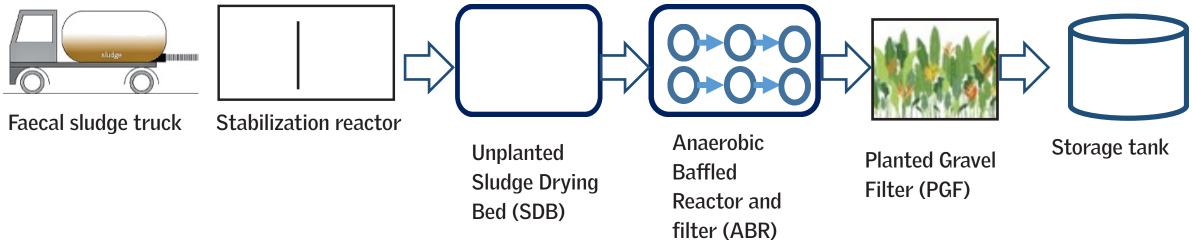
Figure 43: Schematic representation of the process flow of Phulera FSTP



Lalsot FSTP

Lalsot town is located in Dausa district of Rajasthan. The municipality is divided into 25 wards and 19 revenue villages with 7710 households and population of 45319. FSTP was constructed and designed by IPE Global Limited and became operational from November, 2019. It was designed for a capacity of 20 KLD and is based on

Figure 44: Schematic representation of the process flow of Lalsot FSTP



DEWAT system. During survey, FSTP was running with less than 50% capacity. The treatment consists of two parallel rows of screening chamber, stabilization reactor and eight unplanted sludge drying beds in each row. The retention time of the sludge in stabilization reactor and unplanted sludge drying bed was observed to be 10 and 14 days respectively. The leachate is collected in a collection tank followed by its treatment in an integrated settler & anaerobic filter and horizontal planted gravel filter bed. The effluent is stored in the final collection tank which is used for horticulture. The dried sludge is stored in a storage shed.

The septage or faecal sludge is mainly collected from household septic tanks. Desludging is conducted through two cesspool trucks having 1000 and 4000 litres capacity.

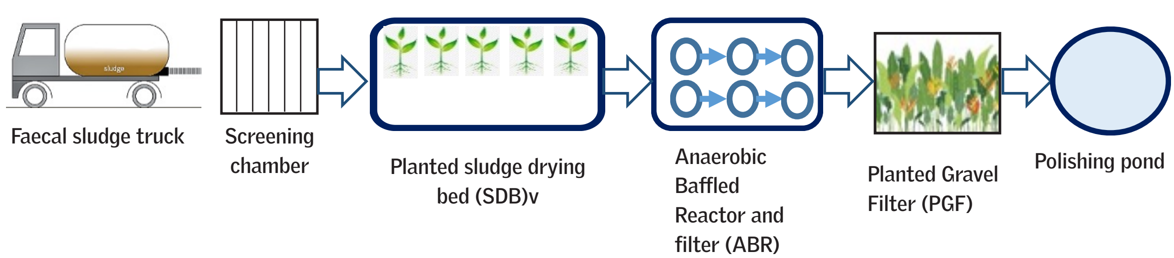
Khandela FSTP

Khandela is located in Sikar district of Rajasthan. FSTP was constructed and designed by IPE Global Limited and became operational from July, 2020. It was designed for a capacity of 10 KLD and is based on DEWAT system.

The treatment plant consists of 12 planted sludge drying beds divided into three rows. Each sludge drying bed is attached with a screening chamber where septage is discharged to the plant. The leachate is collected in a collection tank followed which it is treated in an integrated settler & anaerobic filter and planted gravel filter bed. The effluent is stored in the polishing pond and finally it is used for horticulture. The dried sludge is stored in a storage shed located at the center of the plant.

The septage or faecal sludge is mainly collected from household septic tanks. Desludging is conducted through a cesspool truck having 4000 litres sludge carrying capacity. Presently, the plant is underutilized and on an average 4–5 tanks full of septage are discharged to the FSTP per month for treatment.

Figure 45: Schematic representation of the process flow of Khandela FSTP



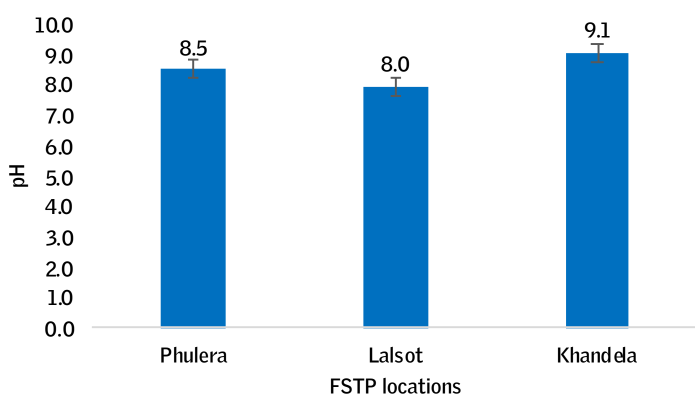
Performance evaluation of FSTPs in Rajasthan

The treatment efficiency of faecal sludge treatment plants (FSTPs) and STP co-treatment system in Uttar Pradesh were analysed in three different phases. The study period ranged from two to nine months, depending on the accessibility of the FSTPs. The selection of FSTPs was based on the different treatment principles and geographic locations. 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.

pH

The average pH of the treated discharge water from all the FSTP locations ranges from pH-8.0 to 9.1, which is near neutral to slightly basic. The effluent discharge standard for the pH is ranging from 6.0-9.0. A pH outside the range of 6 to 9 indicates an upset in the biological process that will inhibit anaerobic digestion of organic material. The pH of the discharge water from all the locations were within the limit of the discharge standard except for Khandela, where it showed pH 9.1.

Graph 36: Average pH value of the treated discharge water

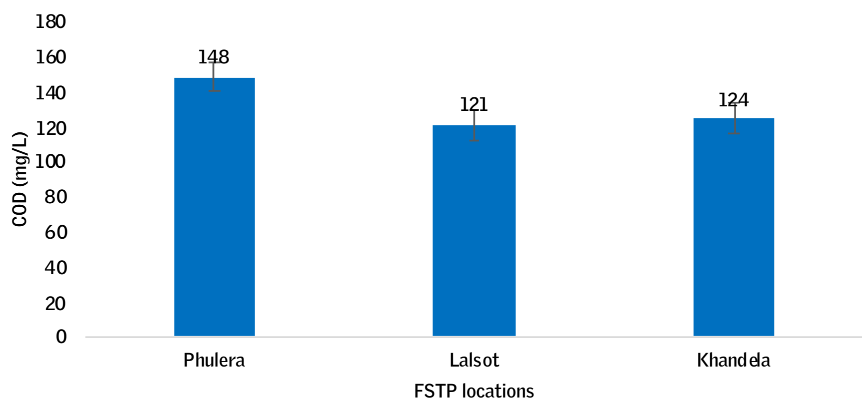


Chemical Oxygen Demand (COD)

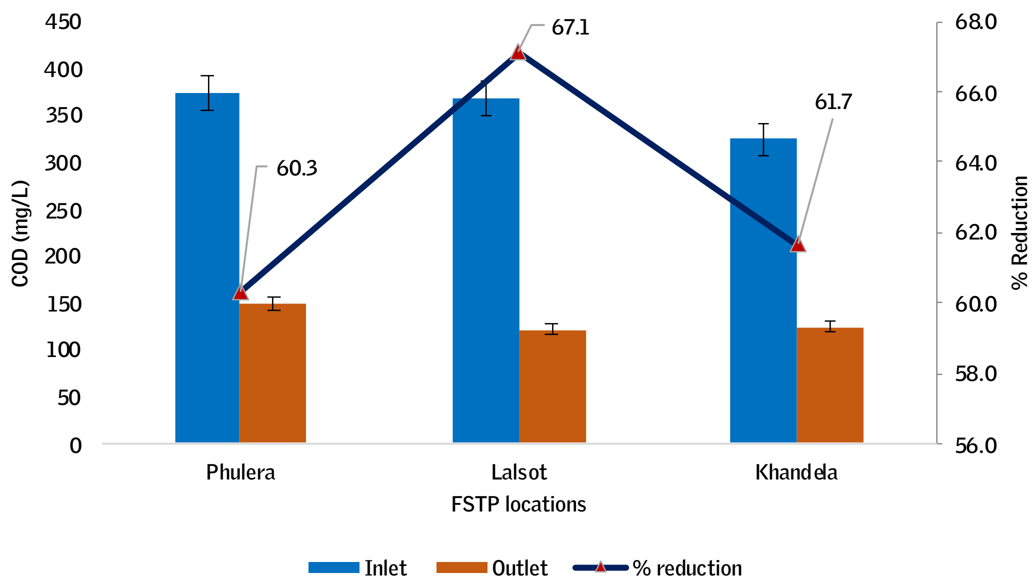
The average COD value of the treated discharge water ranges from 121 mg/L to 148 mg/L. According to MoEF&CC, the discharge standard for COD is 50 mg/L. All the three FSTPs showed a higher COD value than the discharge limit for outlet water.

The per cent removal of COD from inlet to outlet ranges from 60.3 to 67.1 % that shows the treatment efficacy of the systems to remove organic pollutants. All the 3 FSTPs showed almost similar (60-67%) removal efficacy of COD.

Graph 37: Average COD (5 months) value of the treated discharge water



Graph 38: Per cent removal of COD by the treatment systems

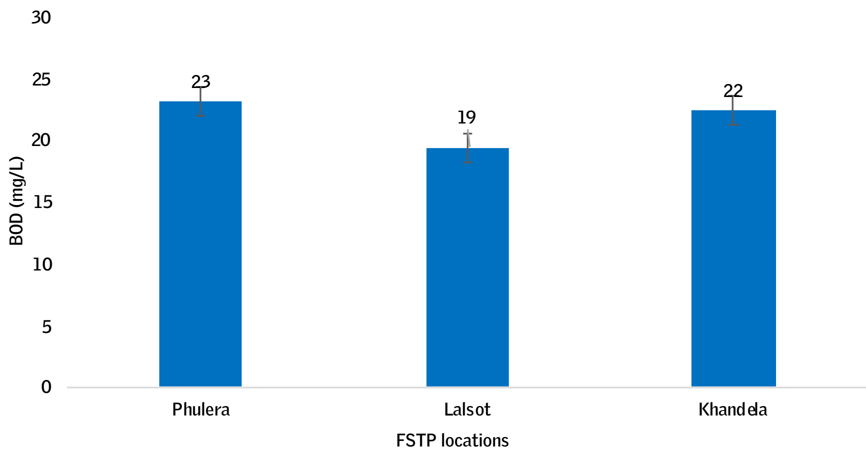


Biological Oxygen Demand (BOD)

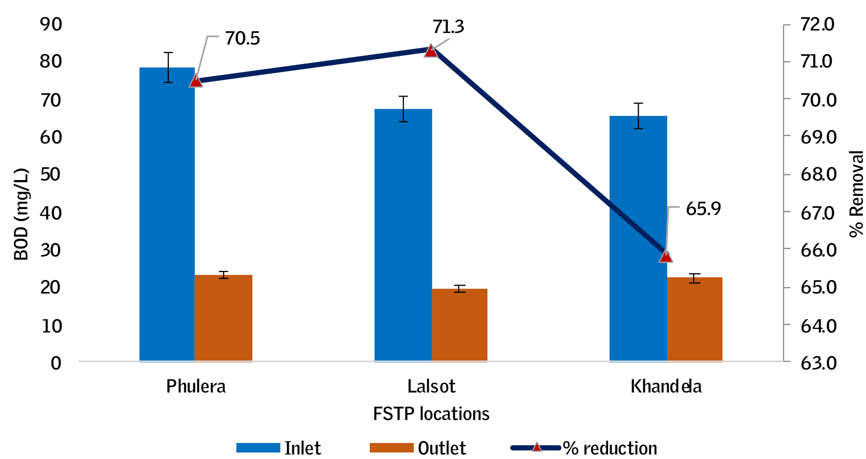
The average BOD value among the studied treatment systems for the treated discharge water ranges from 19 mg/L to 23 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20 mg/L and non-metro cities 30 mg/L. In all FSTPs, the BOD is under the discharge limit prescribed for the non-metro cities.

The BOD removal efficiency of the systems ranges from 65.9 to 71.3 % for outlet water. The Lalsot FSTP (71.3 %) showed highest per cent removal of BOD among all three evaluated FSTP.

Graph 39: Average BOD (5 months) value of the treated discharge water



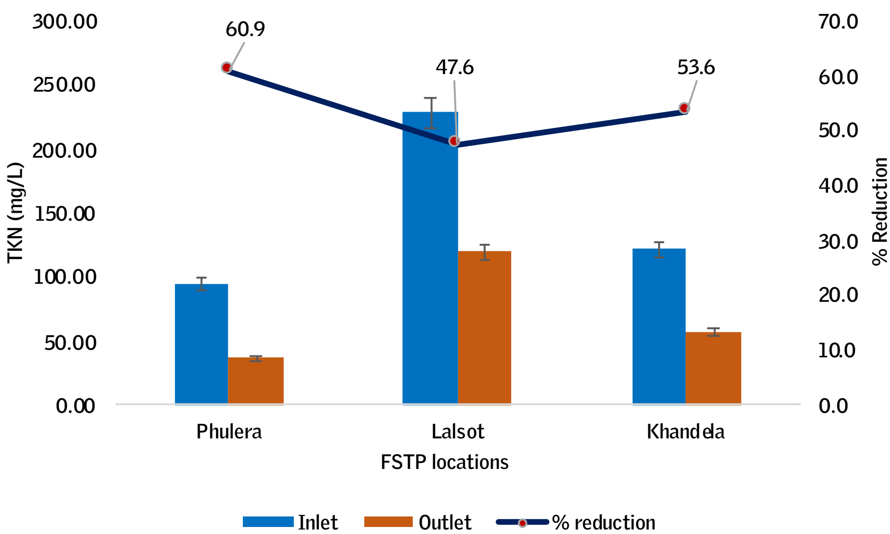
Graph 40: Per cent removal of BOD by the treatment systems



Total Kjeldahl Nitrogen (TKN)

The removal of TKN was observed the range of 47.6 to 60.9 per cent for evaluated FSTPs. Phulera FSTP showed highest removal efficiency (60.9%).

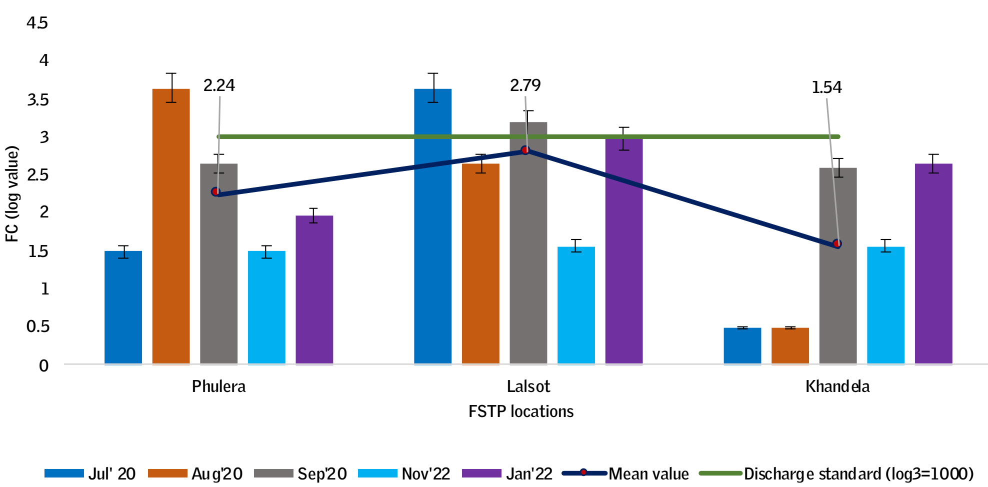
Graph 41: Per cent removal of Total Kjeldahl Nitrogen by the treatment systems



Faecal coliform

The guideline limit for faecal coliform bacteria in unrestricted irrigation is R1000 MPN/100 ml. The FC value for all three evaluated FSTP outlet water came below the prescribed limit set by MoEF&CC regulations (R1000 (log 3.0) MPN/100mL).

Graph 42: Faecal coliform count in the treated discharge water from the treatment systems



SUMMARY

- In all the three FSTPs in Rajasthan, after solid-liquid separation, the liquid fraction is treated through a DEWAT system with a combination of anaerobic baffled reactor and filter (ABR) and planted gravel filter (PGF); finally, the treated water is stored in a collection tank.
- The pH of the discharge water from all the locations was within the limit of the discharge standard — except in Khandela, where it showed a pH of 9.1.
- The performance of all treatment systems showed a similar pattern in removing organic pollutants in the form of COD and BOD with 60-67 per cent and 65-71 per cent removal efficiency, respectively.
- The faecal coliform load is fluctuating — average count for the five-month analysis showed that the discharge water is under the limit set by MoEF&CC.

Uttar Pradesh

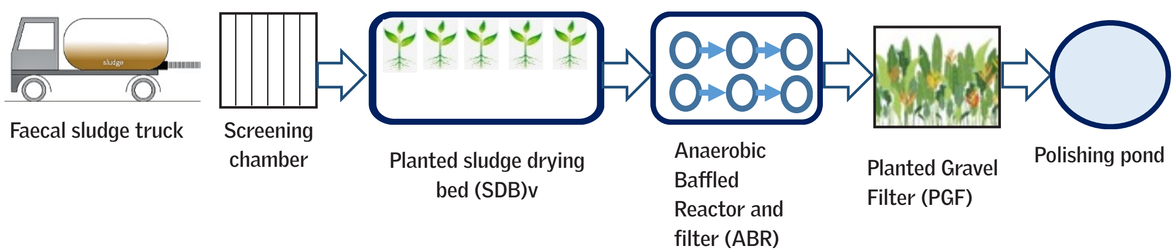
In the event of septic tanks or pit latrines becoming full, the sludge that is collected from them is largely discharged untreated into open drains, irrigation fields, open lands or surface waters. Untreated FS discharge in the open environment poses serious public health related risks. To address this issue, the Ministry of Housing & Urban Affairs (MoHUA) promulgated the National Faecal Sludge and Septage Management Policy in 2017 to achieve the goal of making all Indian cities and towns totally sanitized, healthy, and livable. To ensure sustainable good sanitation practices with improved onsite sanitation, together with faecal sludge and septage management, the policy was specially directed towards the poor community of the country.

To mitigate the challenges in protecting public health and environment, several faecal sludge treatment plants (FSTPs) have been setup in different locations of Uttar Pradesh and some of them are in installation phase. Those FSTPs have been designed by adopting diverse technologies depending on final end uses or disposal options of sludge and liquid streams. Simultaneously, extensive efforts have also been initiated to investigate the co-treatment of faecal sludge through existing sewage treatment plants (STPs) with various technologies in several municipalities and urban local bodies (ULBs).

Jhansi FSTP

The Jhansi FSTP was designed initially for a capacity of 6 KLD. There is one more treatment system constructed in the same campus with 12 KLD capacity. Both systems are with same treatment modules, screened faecal sludge is applied onto planted drying beds (PDBs), which are porous media (sand and gravel) that are planted with emergent macrophytes. PDBs are loaded with layers of sludge that are subsequently dewatered and stabilized through multiple physical and biological mechanisms. The percolate from the PDBs is treated in an integrated settler and anaerobic filter followed by Planted gravel filter and finally aerated in a polishing pond.

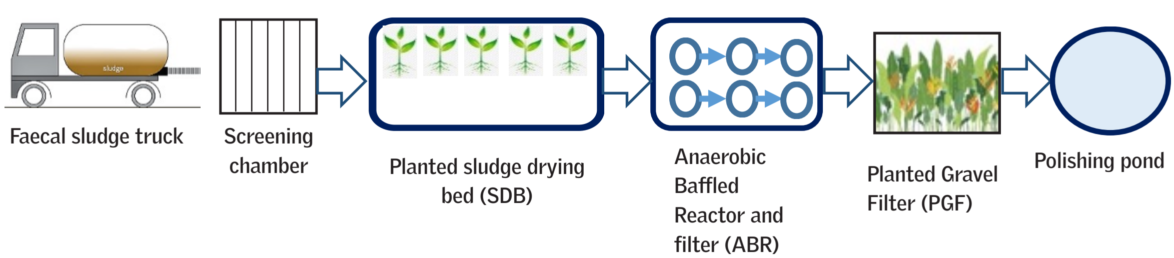
Figure 46: Schematic representation of the process flow in Jhansi FSTP



Amethi FSTP

Amethi is a small town located in the Amethi district in Uttar Pradesh. A Fecal sludge treatment plant with a capacity of 3 KLD was constructed in October 2021 in Benipur Panchayat. The treatment technology is based on planted drying beds for dewatering or solid-liquid separation and DWWTs for treating the separated liquid. The DWWTs consist of an anaerobic stabilization reactor, anaerobic filter, Planted gravel filter and Polishing Pond. The treatment plant receives faecal sludge from household toilets as well as public toilets. The average faecal load received is 3 trucks per week with each truck capacity in between 4-5 KL. Due to this, the treatment system is running at 60-70% of the total capacity. Further, the treated water is used for gardening and horticulture purpose.

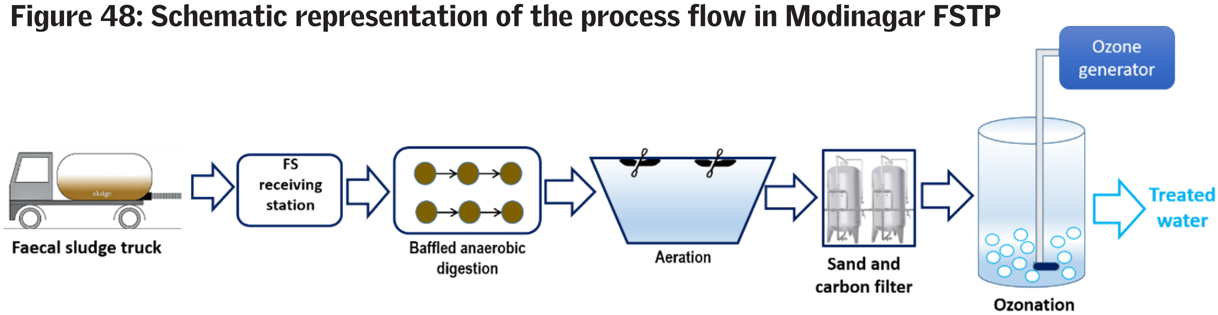
Figure 47: Schematic representation of the process flow in Amethi FSTP



Modinagar FSTP

Faecal sludge treatment plant (FSTP) was designed with the treatment capacity of 32 KLD for treatment of faecal sludge in Modinagar city of district Ghaziabad. Treatment system is a combination of different technologies that were integrated together for treatment of faecal sludge. Treatment process is named as hyper-core system in which faecal sludge firstly undergoes the baffled anaerobic digestion and then clarifier-led aeration followed by tertiary treatment equipped with carbon filter, sand filter and ozonation.

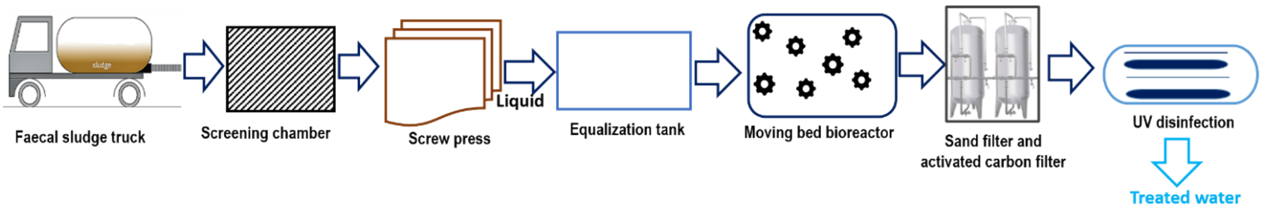
Figure 48: Schematic representation of the process flow in Modinagar FSTP



Loni FSTP

Loni is a town located in Ghaziabad district in Uttar Pradesh. A Faecal sludge treatment plant with a treatment capacity of 32 KLD was commissioned in the year 2021 in Loni. The treatment system consists of a screen chamber for separating the coarse materials from the faecal sludge followed by a screw press to separate the solids and liquid. The liquid part is received by an equalization tank and further received by moving bed biofilm reactor (MBBR). The treated water from MBBR is further treated via tertiary process including sand filter, carbon filter and UV treatment. Even though the plant receives 4 trucks per day, the treatment plant is not running at its full capacity.

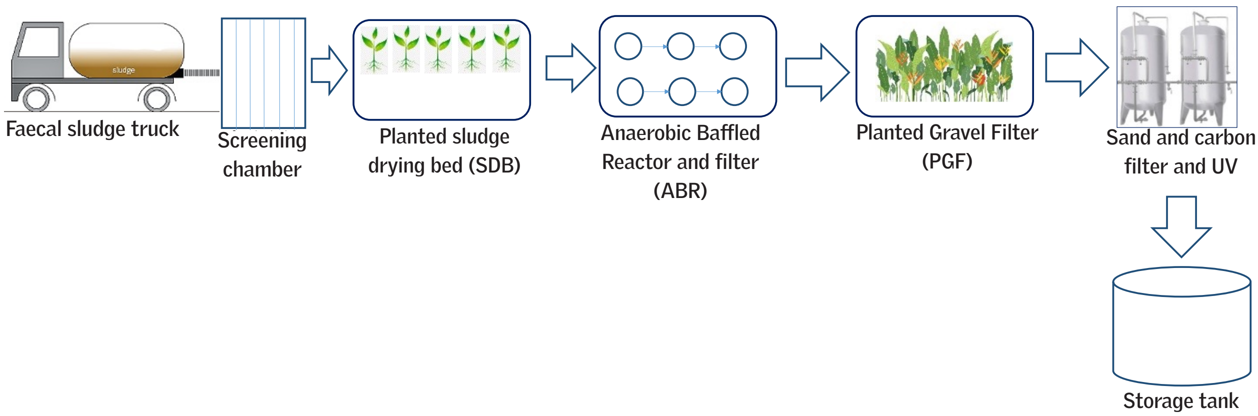
Figure 49: Schematic representation of the process flow in Loni FSTP



Chunar FSTP

The FSTP at Chunar was commissioned in 2021 with a capacity of 10 KLD. The FSTP receives fecal sludge from different sources in Chunar city and is running in full capacity by receiving 3 trucks of 3.5 KL capacity per day. The faecal sludge is first made to pass through the screening chambers for the retention of coarse materials/ solid waste present in the faecal sludge. The liquid sludge is conveyed to planted sludge drying beds (PDBs), the planted sludge drying beds are structures with sloped base for holding graded filter media. The dried sludge removed from the planted drying beds stored separately. The effluent wastewater is then treated in two stages (primary and secondary stage) in DWWTs modules. The effluent from planted gravel filter is discharged to tertiary treatment units such as Dual Media Filter, Activated Carbon Filter and UV Disinfection. The treated wastewater is stored in a collection tank from where it is reused for horticulture/ agriculture through pumping.

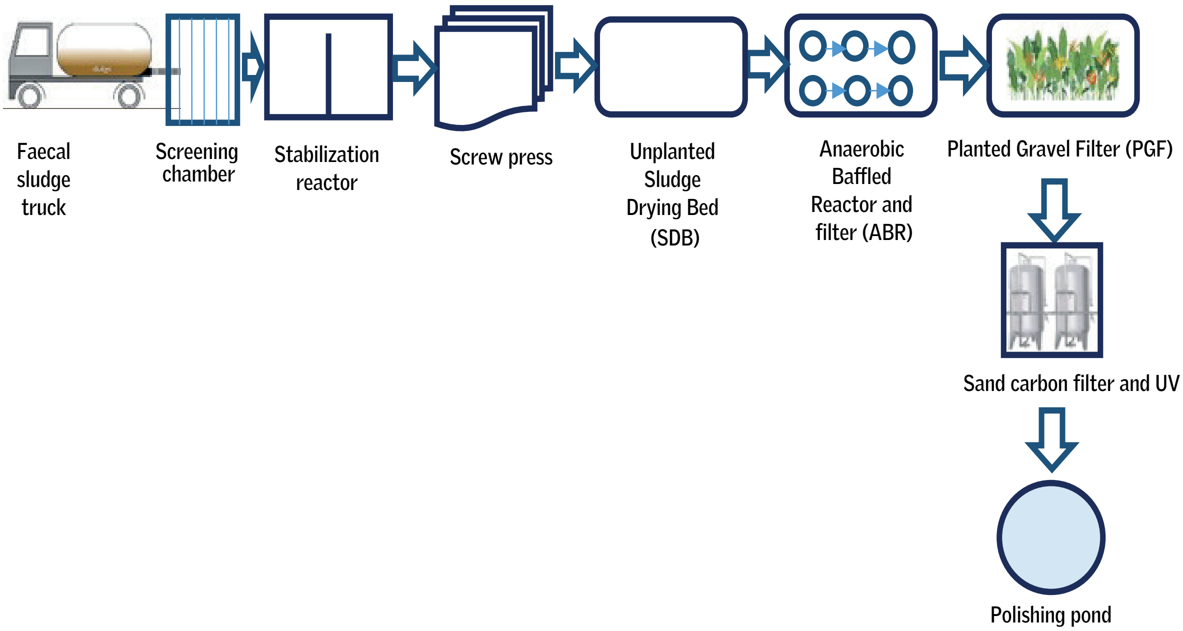
Figure 50: Schematic representation of the process flow in Chunar FSTP



Unnao FSTP

The town of Unnao—which lies between Lucknow and Kanpur—is the headquarters of Unnao district in Uttar Pradesh. Sixteen wards in the town are considered to generate faecal sludge that is not covered by the underground drainage system of Unnao. The onsite sanitation units of faecal sludge are desludged by mechanical equipment such as vacuum pumps to the tanker, which is transported to FSTPs located in the outskirts of the city. The FSTP can handle 32 KLD of faecal sludge generated from onsite sanitation systems. The technology involves a grit chamber to separate inert material, followed by a thickening tank and stabilization of sludge in a stabilization reactor. The discharge then enters a screw press and in the presence of flocculants, solids are separated from wastewater. Solids are transferred to the sludge drying beds, where residual water is collected at the bottom of the bed. The percolated water is then mixed with the main stream wastewater from the screw press in the equalization tank and further treated by DEWATS technology consists of integrated settler and ABR, anaerobic filters, planted gravel filter, sand filter, activated carbon filter and, finally, UV treatment and discharged into polishing pond.

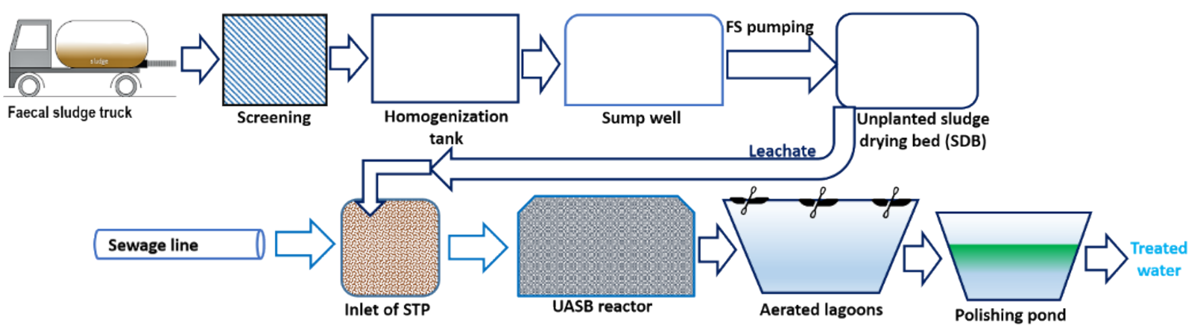
Figure 51: Schematic representation of the process flow in Unnao FSTP



Bijnor FSTP

Bijnor faecal sludge treatment plant (FSTP) was commissioned in July, 2018 for co-treatment of domestic sewage along with faecal sludge and septage (FSS) obtained from various onsite sanitation systems (OSS) of Bijnor city. Plant is functional with treatment capacity of 24MLD for total sewage and 20KLD specifically for faecal sludge. Treatment technology consists of solid-liquid separation by gravity settling followed by up-flow anaerobic sludge blanket (UASB), aerated lagoon and finally chlorination.

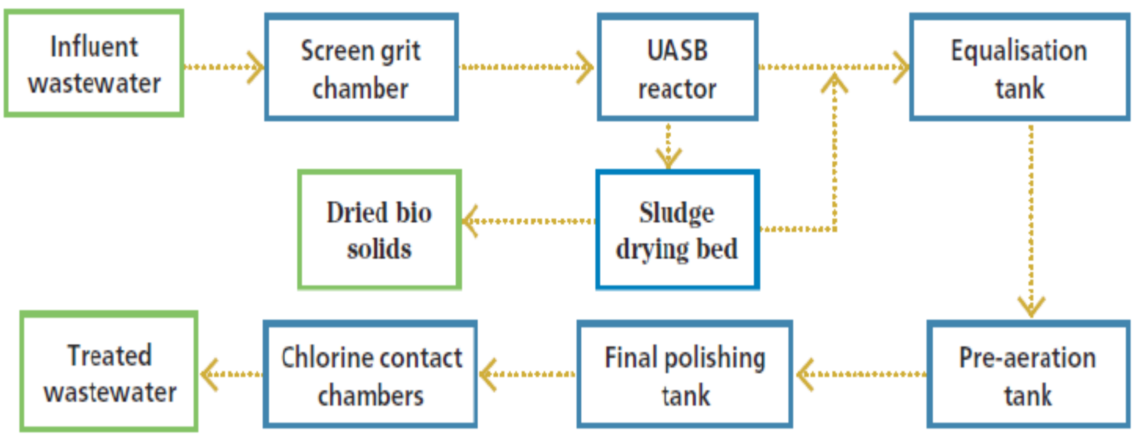
Figure 52: Schematic representation of the process flow in Bijnor FSTP



Bharwara STP

Bharwara STP is located at Bharwara in Gomti Nagar, Lucknow. It is recognized as Asia's largest STP. It is based on UASB Reactor technology and is spread across 120 hectares area. The sewage at the inlet of the STP comes from the main pumping station located at Gwari. The inlet of the STP is distributed into three distribution streams: A, B and C. Each has a capacity of 115 MLD. The wastewater treated in Upflow Anaerobic Sludge Blanket (UASB) reactors. UASB is an anaerobic process that forms a blanket of granular sludge which suspends in the tank. The treated wastewater from the UASB reactor is then taken to the pre-aeration tank, where the wastewater is aerated with the help of surface aerators. From the pre-aeration unit, treated wastewater is then taken to final polishing pond.From final polishing pond, the treated wastewater is taken to chlorine contact chambers, the water is then released to the river Gomti.The co-processing of FS in Bharwara STP is conducted by mixing septage from tanker with sewage water in pumping stations.

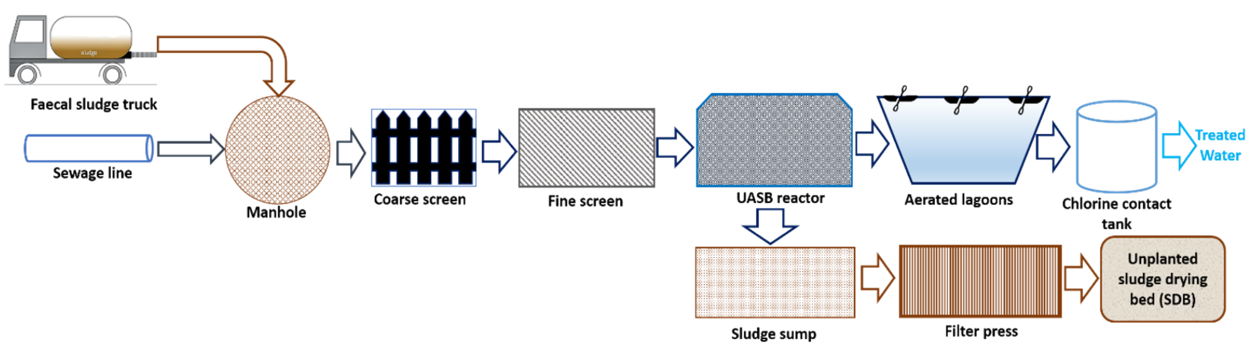
Figure 53: Schematic representation of the process flow in Bharwara STP



Bingawan STP

This is situated on the bank of river Pandu near village Bingawan. The STP has an installed capacity of 210 MLD and presently receives wastewater flows to around 150 MLD. The STP covers the southern parts of the city including Kakadeo, Shastri Nagar, Geeta Nagar, Anwarganj, etc. A manhole, for receiving septage, has been constructed at the entrance of the STP into which private desludging operators decant their tankers. The septage mixes with the sewage in the manhole and is diverted to the inlet chamber of the STP prior to the preliminary treatment process. The combined wastewater stream subsequently undergoes the entire treatment cycle. The plant was commissioned on October, 2015. The STP is based on UASB Reactor technology. Solid waste is first separated from the wastewater stream by Coarse Screening process (in manual &mechanical screening chamber). Sewage water is then sent to the main pumping station. The wastewater is then passed through Fine Screen chamber (3 mechanical & 2 manual screens) followed by Mechanical Degritter and then division box to enter into the UASB Reactors.

Figure 54: Schematic representation of the process flow in Bingawan STP



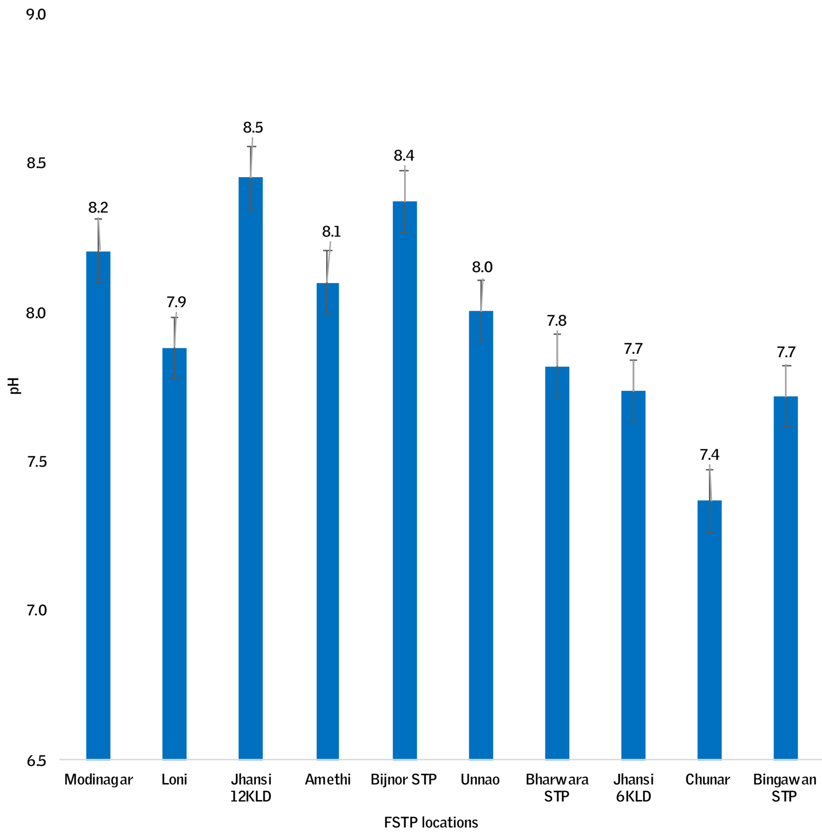
Performance evaluation of FSTPs in Uttar Pradesh

The treatment efficiency of faecal sludge treatment plants (FSTPs) and STP co-treatment system in Uttar Pradesh were analysed in three different phases. The study period ranged from two to nine months, depending on the accessibility of the FSTPs. The selection of FSTPs was based on the different treatment principles and geographic locations. 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.

pH

The average pH of the treated discharge water from all the FSTP locations ranges from pH-7.4 to 8.7, which is near neutral to slightly basic. The effluent discharge standard for the pH is ranging from 6.0-9.0. A pH outside the range of 6 to 9 indicates an upset in the biological process that will inhibit anaerobic digestion of organic material. The pH of the discharge water from all the locations is within the limit of the discharge standard.

Graph 43: Average pH value of the treated discharge water

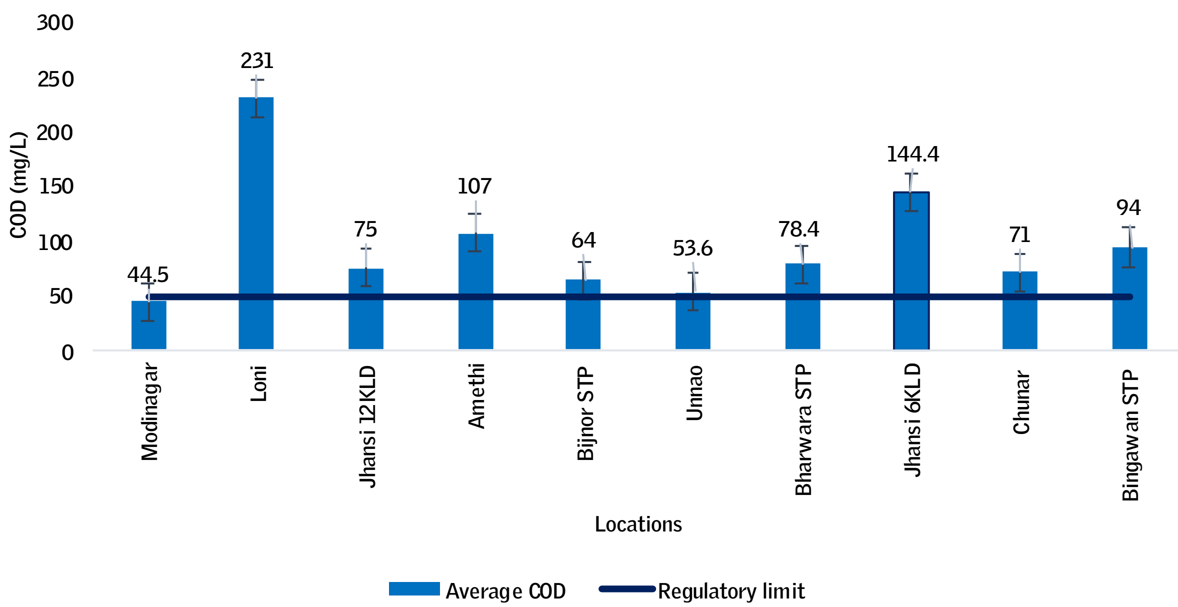


Chemical Oxygen Demand (COD)

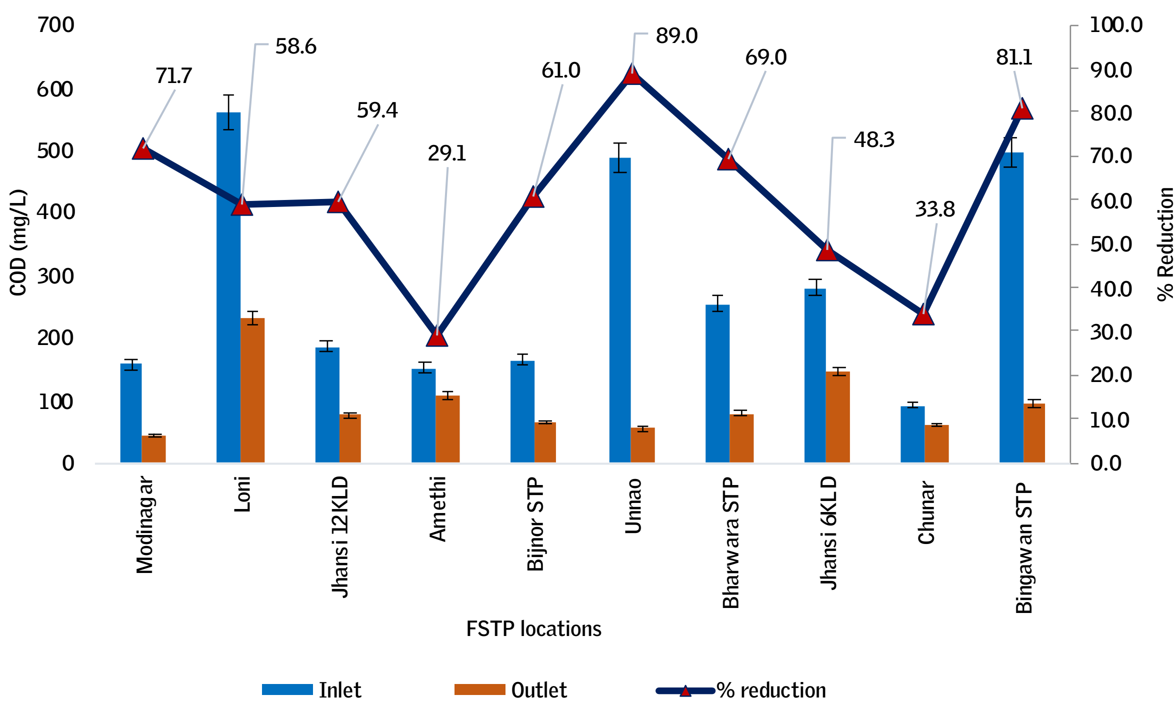
The average COD value of the treated discharge water ranges from 53.6 mg/L to 231mg/L. According to MoEF&CC, the discharge standard for COD is 50mg/L. Modinagar (pilot plant) showed value below the standard limit whereas Unnao (53.6 mg/L) and Bijnor (64 mg/L) are slightly above the standard value. In all other sites, the average COD value of the discharge water was found higher than the standard values.

From the analysis, it was found that the treatment systems reducing the COD in inlet to outlet ranging from 29.1 to 89 per cent. Amethi showed less reduction per cent (29.1) and Unnao (89%) and Modinagar (71.7%) showed the highest treatment efficiency in terms of COD removal.

Graph 44: Average COD value of the treated discharge water



Graph 45: Per cent removal of COD by the treatment systems

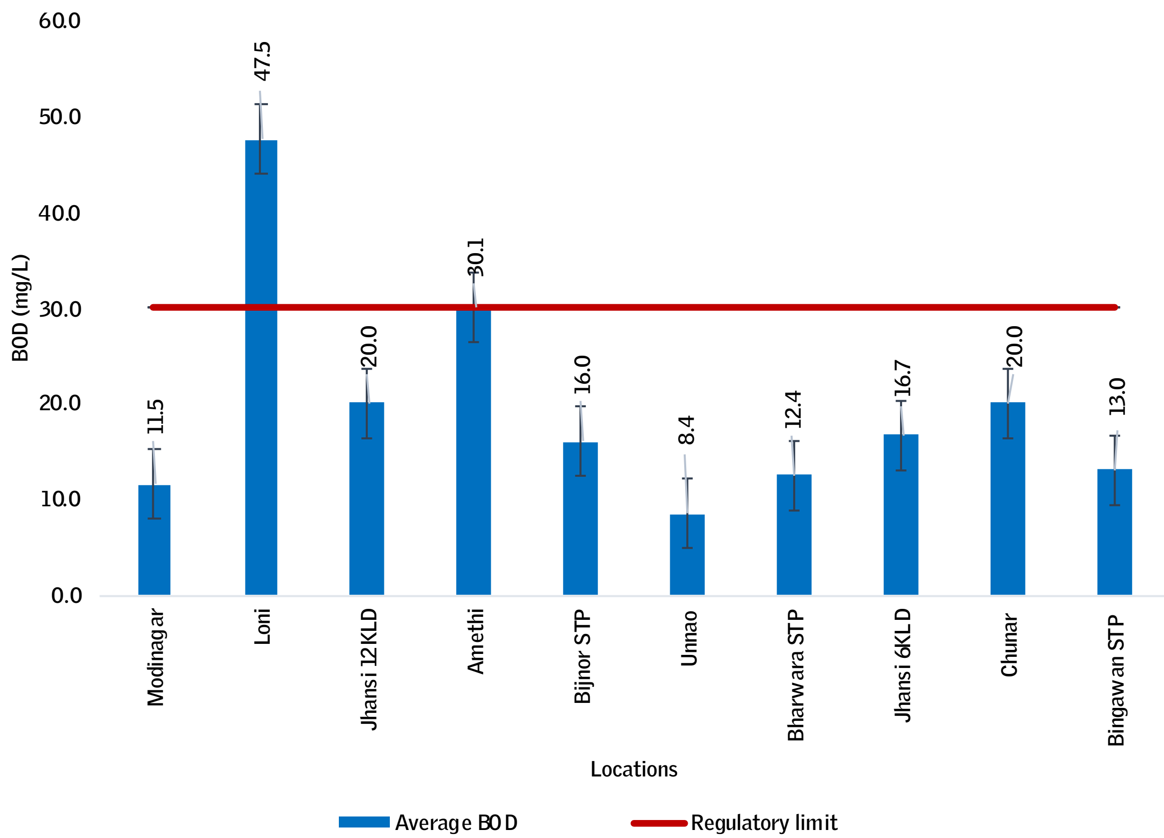


Biological Oxygen Demand (BOD)

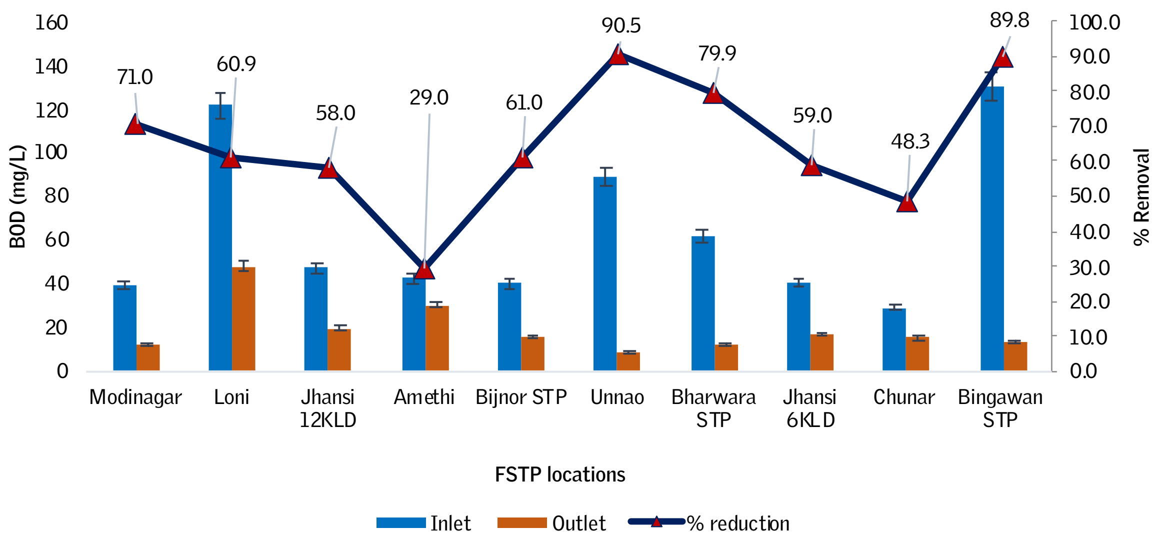
In the treatment systems evaluated, the average BOD value of the treated discharge water ranges from 8 mg/L to 48 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20mg/L and non-metro cities 30 mg/L. Amongst all FSTPs and STP co-treatments, the treated water BOD is under the discharge limit except for Loni and Amethi (single set sample).

A reduction of 29.0 to 90.5 per cent was observed in the most of the treatment sites. However, a less (29%) BOD removal was observed in Amethi FSTP thwhichhows its less treatment efficiency. Unnao FSTP (90.5%) showed high removal efficacy followed by Bingwan (89.8%) and Bharwara (79.9%) STP co-treatment systems.

Graph 46: Average BOD value of the treated discharge water



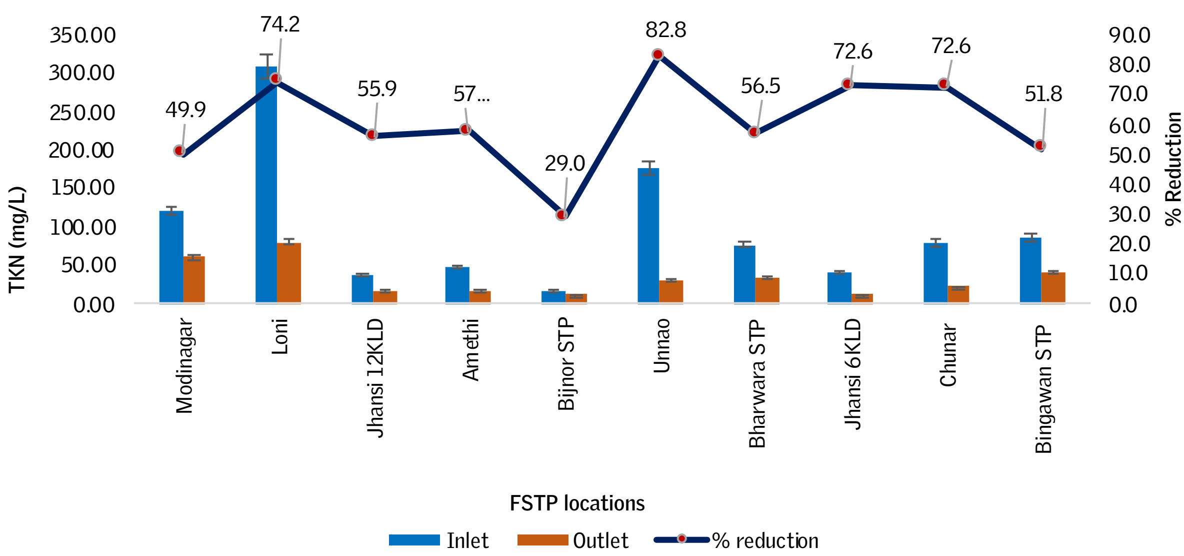
Graph 47: Per cent removal of BOD by the treatment systems



Total Kjeldahl Nitrogen (TKN)

The removal percentage of TKN in the evaluated FSTPs was observed to be in the range of 29.0 to 82.8 per cent. Unnao FSTP showed highest removal efficacy (82.8%) whereas Bijnor FSTP showed the lowest removal efficiency.

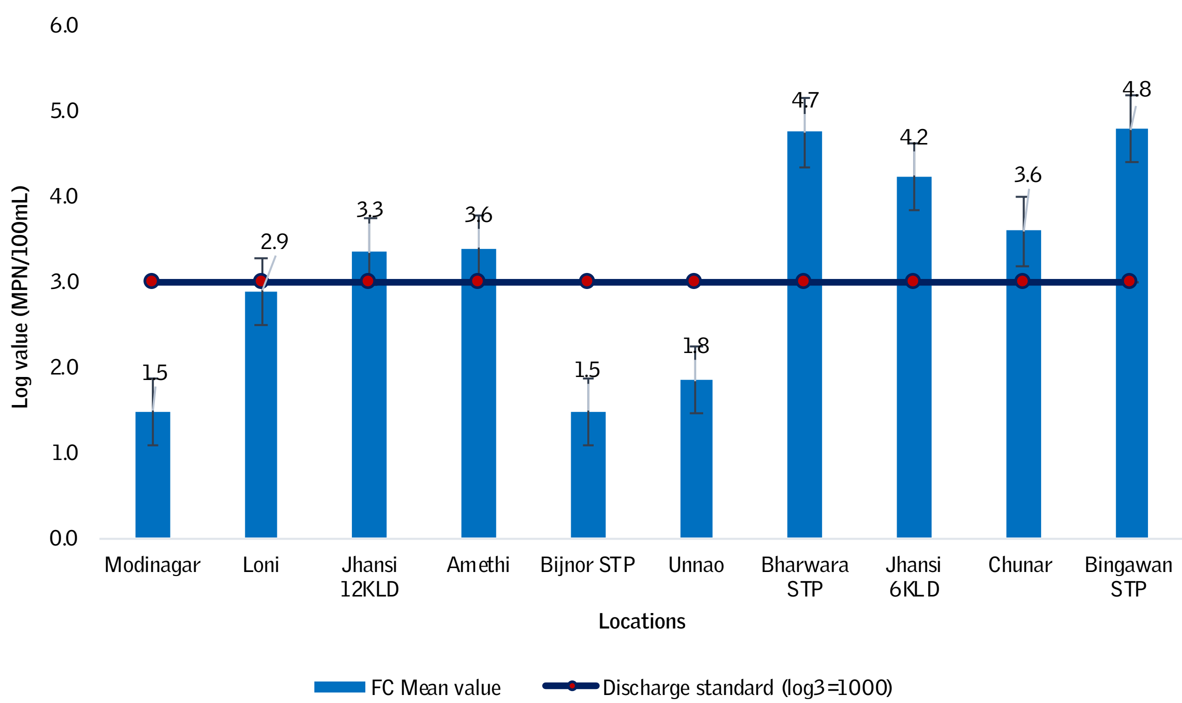
Graph 48: Per cent removal of Total Kjeldahl Nitrogen by the treatment systems



Faecal coliform

The guideline limit for faecal coliform bacteria in unrestricted irrigation is R1000 MPN/100 ml. In the treatment system evaluated ,the outlet water of Modinagar, Loni, Unnao FSTPs and Bijnor co-treatment system came below the prescribed limit set by MoEF&CC regulations (R1000 MPN/100mL) (Fig:4.7). However, Both FSTPs of Jhansi and Amethi showed FC value higher than the discharge limit that is due to lack of any kind of tertiary treatment at these sites. Moreover, Chunar FSTPs also showed high FC value than prescribed standard in spite of having the tertiary treatment system but it was not functional due to electricity issue at the time of sample collection. Amongst the STPs, Bharwara and Bingawan showed high FC value than the standard limit as most of the STPs in India are not maintaining the FC count under the standard limit, in spite of the post treatment systems like chlorine dosing. The microbial load in outlet water couldn't be controlled with predefined chlorine doses since the microbial load in influent water was varying in wide range.

Graph 49: Faecal coliform count in the treated discharge water from the treatment systems



SUMMARY

- In Uttar Pradesh, seven FSTPs and three STP co-treatment systems were investigated for performance efficiency.
- For STP co-treatment systems in Bharwara and Bingawan, the faecal sludge is directly mixed with sewage whereas in Bijnor STP, only the leachate is mixed with sewage for co-treatment.
- The treatment systems were found to be reducing the COD level ranging from 29-89 per cent.
- BOD reduction of 29-90 per cent was observed in all the treatment plants.
- The COD values of the treated water ranges from 44 -231 mg/L whereas MoEF&CC standard value is below 50mg/L. Modinagar (pilot plant) showed the value well below the standard limit, Bijnor and Unnao are slightly above the margin of the standard values.
- Except in two locations (Loni 47.5 mg/L and Amethi 30.1mg/L)), the BOD values were significantly below the standard limit (<30mg/L) of MoEF&CC given for non-metro cities.
- Out of the 10 treatment plants evaluated, only four attained the faecal coliform count within the discharge standard limits (<1,000 MPN/100 mL) as recommended by MoEF&CC.

Chhattisgarh and Madhya Pradesh

Untreated faecal sludge discharge in the open environment poses serious public health related risks. To address this issue, the Ministry of Housing & Urban Affairs (MoHUA) promulgated the National Faecal Sludge and Septage Management Policy in 2017 to achieve the goal of making all Indian cities and towns totally sanitized, healthy, and livable. To mitigate the challenges in protecting public health and environment, several faecal sludge treatment plants (FSTPs) have been setup in different locations of India. Like other states in India, Madhya Pradesh and Chhattisgarh, also faces a problem of illegal and unauthorized dumping of untreated septage waste and little state involvement. This presents an urgent need for improved fecal sludge management. However, due to limited operating experience on specific design, there is inadequate treatment performance and thus failure of technologies. Therefore, monitoring the performance evaluation of different technologies of FSTP operation in India was required.

The State of Madhya Pradesh has made considerable strides to improve its urban sanitation landscape since the launch of Swachh Bharat Mission in year 2014. Barring 49 bigger urban Local Bodies which are covered through sewerage networks, most rely on on-site sanitation systems for their faecal sludge and liquid waste management. To particularly meet the FSSM needs of these smaller ULBs (with a population of 20,000), the Directorate of Urban Administration and Development has created a low cost mini FSTP model which has been successfully piloted in Shahganj and is being replicated across the state. Simultaneously, extensive efforts have also been initiated to investigate the co-treatment of faecal sludge through existing sewage treatment plants.

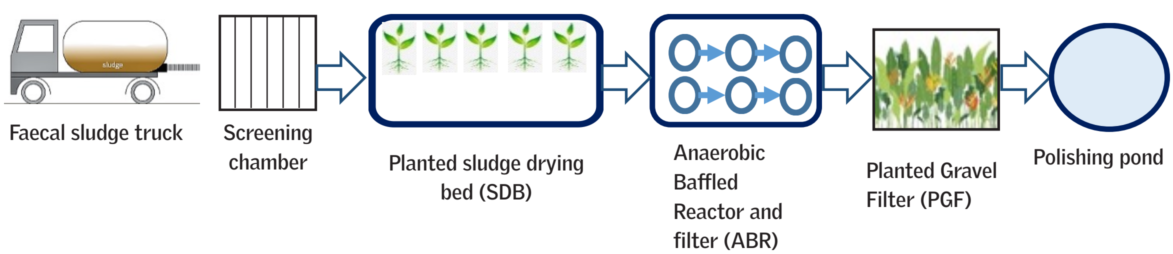
Chhattisgarh

Patora FSTP

The 9 KLW (kilolitre per week) FSTP has been set up by Water-Aid India in Patora village, which is also a Gram Panchayat located in Patan tehsil of Durg district inChhattisgarh. The FSTP was commissioned in August 2021. During the study period, the FSTP was running in full capacity by receiving FS from 2-3 vacuum trucks of '4000 litres capacity' in a week. The FS is received from septic tanks in household, community and public toilets. The plant is located near agriculture land. The technology adapted was DEWATS with planted sludge drying beds (PDB) for primary treatment, integrated settler and anaerobic filter (ISAF), and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. Capex of the FSTP is Rs. 36 Lakhs. The O & M cost is Rs. 12,300/- per month, while revenue generated from FSTP (from households for desludging) is Rs. 50,000/- to Rs. 60,000/- per month. Receiving of FS more than the treatment capacity of the plant frequently and less than the treatment capacity of the plant sometimes is one of the problems faced at the FSTP.

FS collected from various containments in the village by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS enters into PDB, where sludge gets settled and leachate enters into PDB for further treatment. Leachate from the PDB enters into the ISAF where settling of suspended solids takes place followed by treatment by anaerobic digestion resulting in the reduction of COD and TSS. The partially treated water is pumped from ISAF into PGF for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms. About 8000-8500 litres of water is generated per week which is used for gardening purpose within the premises of the FSTP. During the study period, the dried sludge is not yet removed from the PDB, as the maximum sludge receiving capacity of PDB is not yet reached.

Figure 55: Schematic representation of the process flow in Patora FSTP



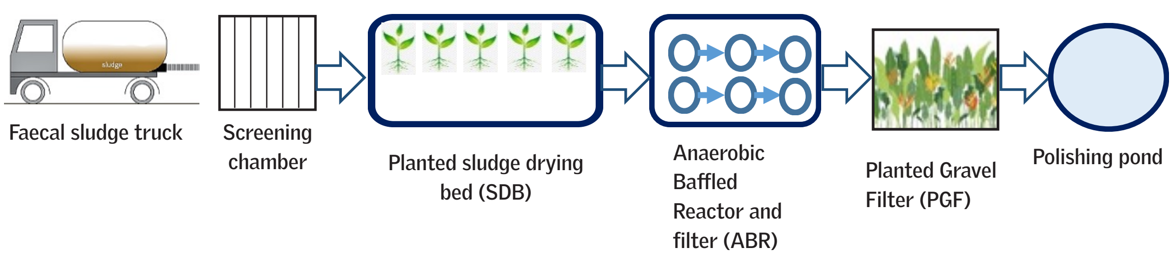
Kumhari FSTP

The 6 KLD FSTP has been set up by Water-Aid India in Kumhari city, which is located in Dhamdha tehsil of Durg district in Chhattisgarh. The FSTP was commissioned in November 2021. During the study period, the FSTP was running in full capacity by receiving FS from 2 vacuum trucks of '3000 litres capacity' in a day. The FS is received from septic tanks and pit latrines in household, community, hospitals and public toilets. The plant is located near agriculture land. The technology adopted is DEWATS with planted sludge drying beds (PDB) for primary treatment, integrated settler and anaerobic filter (ISAF), and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. The O & M cost of desludging vehicle is Rs. 15,000/- to 20,000/- per month, while the salary of FSTP employee is 12,000/- per month. Receiving of FS more than the treatment capacity of the plant sometimes is one of the problems faced at the FSTP.

FS collected from various containments in the city by vacuum trucks is discharged at the sludge receiving unit of the plant which is fitted with screen to remove solid waste, floatables and grit from FS. Then the FS enters into PDB, which are 7 in number, where the sludge gets settled, and the leachate flows into the ISAF for further treatment. In the ISAF, settling of suspended solids takes place followed by treatment by anaerobic digestion resulting in the reduction of COD and TSS. The partially treated water flows from ISAF into horizontal PGF for nutrient removal. Later, the water enters into polishing pond for the removal of odour and microorganisms.

About 4,000 litre of water is generated per day which is used for gardening purpose within the premises of the FSTP. During the study period, the dried sludge is not yet removed from the PDB, as the maximum sludge receiving capacity of PDB is not yet reached.

Figure 56: Schematic representation of the process flow in Kumhari FSTP



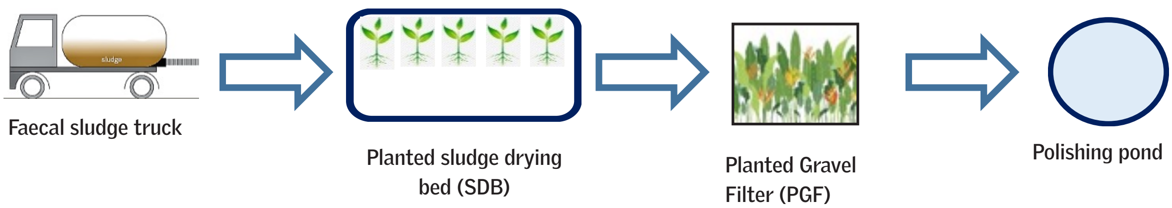
Madhya Pradesh

Kalibillod FSTP, Indore

The 3 KLD FSTP has been set up by Water-Aid India in Kalibillod village, which is located in Depalpur tehsil of Indore district in Madhya Pradesh. The FSTP was commissioned in 2020. During the study period, the FSTP was running only 60-70% of its capacity by receiving FS from 4 vacuum trucks of '4000 litres capacity' in a week. The FS is received from households. The technology consists of planted sludge drying beds (PDB) for primary treatment, and planted gravel filter (PGF) for secondary treatment, and polishing pond for tertiary treatment. One of the major problems faced by Indore FSTP is unavailability of trucks for desludging, and hence, receiving of less FS load than the treatment capacity.

FS collected from various containments in the village by vacuum trucks is discharged into PDB. The leachate from PDB flows into PGF for nutrient removal. Further, the treated water enters into polishing pond for removal of pathogens. The water generated in the FSTP has not been reused so far. The dried sludge removed from the PDB is stored in a sludge storage shed.

Figure 57: Schematic representation of the process flow in Kalibillod FSTP



St Allantois STP co-treatment plant

The 100 KLD co treatment plant is located inside college campus of St. Allantois institute of technology, Jabalpur, Madhya Pradesh. Plant is built and maintained by Hindustan ecosoft pvt. Ltd. The plant is equipped with standard version of Mizuchi treatment technology that does not include ant tertiary treatment. The Mizuchi is a natural bio-filter with specially designed zones for reduction and removal of contaminants through a series of components such as trickle filtration of sewage over layered natural media followed by attached growth process, bacteria and enzymes. Water part of sewage passes through aforementioned layers resulting into the reduction BOD, COD and several other associated contaminants. On the other side, Sludge part of sewage retains on the surface of media and treated by vermi-composting. The treated water generated from this version of mizuchi can be used for gardening, landscaping or discharged safely into the environment. It is a unique technology which generates nutrient-rich bio-solid along with treated water that is used for agriculture or horticulture inside the society only.

OJAS Imperia STP co-treatment plant

The 100 KLD co treatment plant is located inside a residential society named Ojas Imporia, Jabalpur, Madhya Pradesh. Plant is built and maintained by Hindustan Ecosoft Pvt. Ltd. The plant is equipped with the advanced version (tertiary treatment) of Mizuchi treatment technology. The Mizuchi is a natural biofilter with specially designed zones for reduction and removal of contaminants through a series of components such as trickle filtration of sewage over layered natural media followed by attached growth process, bacteria and enzymes. Water part of sewage passes through aforementioned layers resulting into the reduction BOD, COD and several other associated contaminants. Treated water further undergoes tertiary treatment by multi grade sand filter and activated carbon filter. On the other side, Sludge part of sewage retains on the surface of media and treated by vermi-composting. Sludge retains on the surface of media and treated by vermi-composting. This version integrates MGF and ACF into the Mizuchi for the efficient removal of suspended solids. The treated water can be used for agriculture and general cleaning. It is a unique technology which generates nutrient-rich bio-solid along with treated water that is used for agriculture or horticulture.

Elanza STP

This 50 KLD treatment plant is located inside the residential society named Elanza. It works on the principle of two technologies namely Mizuchi and Terra. Initially, sewage water is discharged into the settling chamber from where it is pumped and sprayed onto a natural biofilter system made up of earthworms, bacteria and enzymes. This natural biofilter technology is termed as Mizuchi. The greywater passes through this natural media initially, where the removal of contaminants occurs by the action of bacterial enzymes and earthworms. Moreover, the solid part (sludge) which settles in natural biofilter media gets treated via earthworms and bacteria. The treated water then passes through 'Terra' which is a system consisting of medium and small sized pebbles. The final treated water which comes out of Terra system is used for gardening purpose.

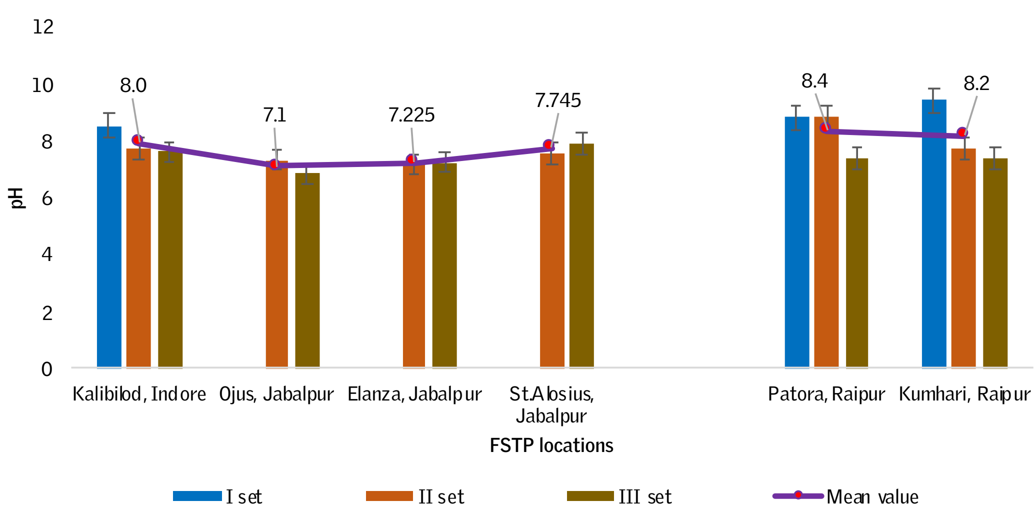
Performance evaluation of FSTPs in Madhya Pradesh and Chhattisgarh

The treatment efficiency of faecal sludge treatment plants (FSTPs) and in Madhya Pradesh and Chhattisgarh were analysed in three different phases. The study period was six months, depending on the accessibility of the FSTPs. The selection of FSTPs was based on the different treatment principles and geographic locations. 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.

pH

The average pH of the treated discharge water from all the FSTP locations ranges from pH 7.1 to 8.0, in the four treatment plants in the state of MP and the two locations in the Chhattisgarh showed the discharge water pH is in 8.2 to 8.4. which is slightly alkaline. The effluent discharge standard for the pH is ranging from 6.0-9.0. The pH of the discharge water from all the locations is within the limit of the discharge standard.

Graph 50: Average pH value of the treated discharge water

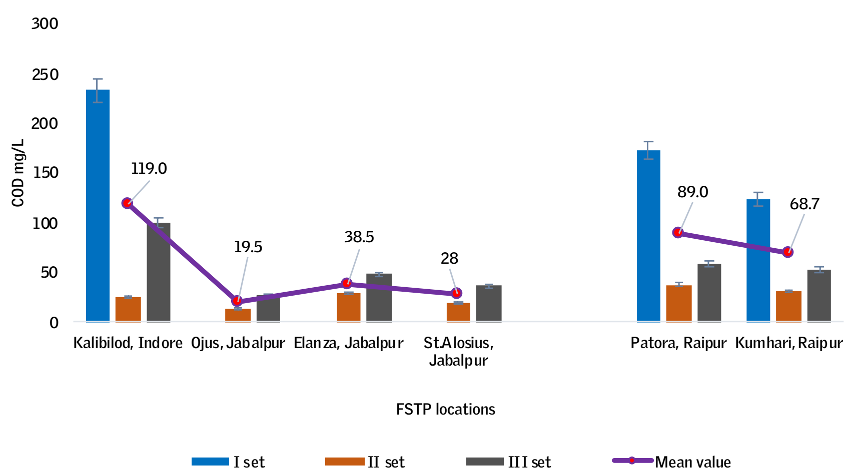


Chemical Oxygen Demand (COD)

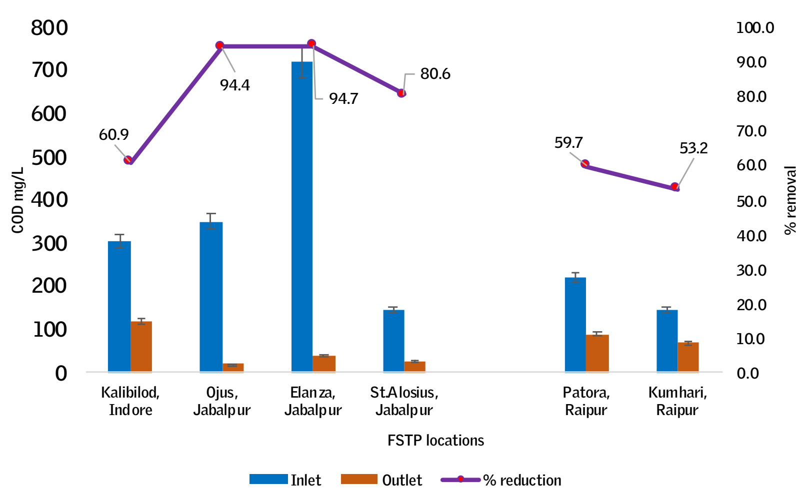
The average COD value of the treated discharge water ranges from 28.0 mg/L to 119 mg/L in the different locations of the both states. According to MoEF&CC, the discharge standard for COD is 50mg/Lthe three treatment systems (Miguchi) inJabalpur showed value below the standard limit whereas Kalibilod (119 mg/L),Patora (89 mg/L) andKumhari (68.7 mg/L) are above the standard value.

From the analysis, it was found that the treatment systems reducing the COD in inlet to outlet ranging from 53.2 to 94.7 per cent. Mizuchi treatment systemsshowed the highest treatment efficiency in terms of COD removal, which is above 80 %.

Graph 51: Average COD value of the treated discharge water



Graph 52: Per cent removal of COD by the treatment systems

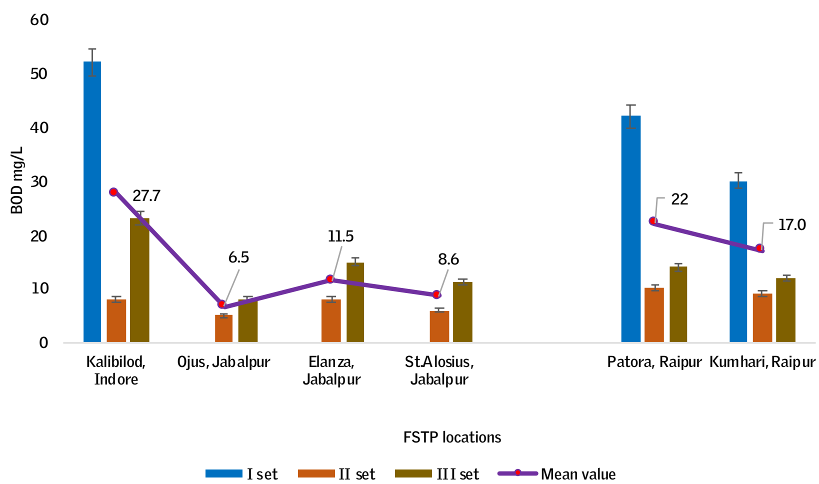


Biological Oxygen Demand (BOD)

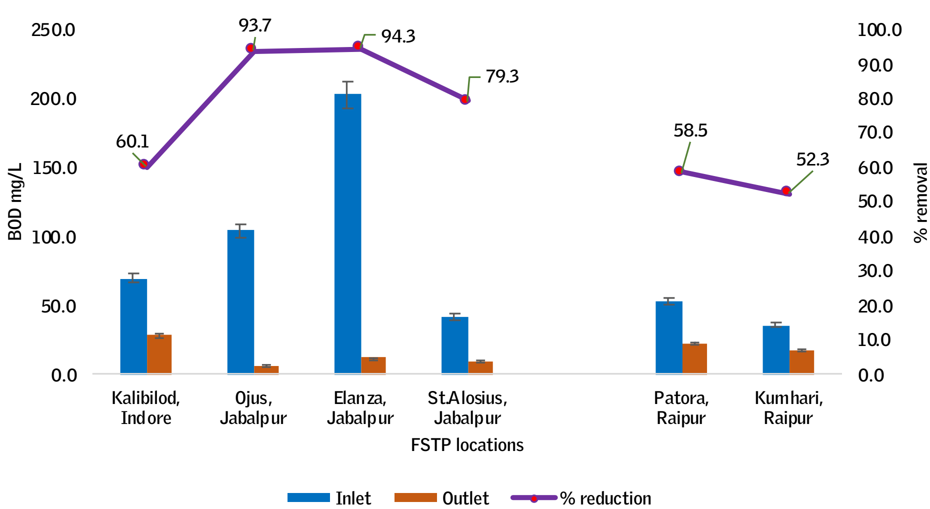
In the treatment systems evaluated, the average BOD value of the treated discharge water ranges from 6.5 mg/L to 27.7 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20mg/L and non-metro cities 30 mg/L. All the treatment systems in the states, the treated discharge water BOD is under the discharge limit.

The reduction of 52.3 to 94.3 per cent was observed in the treatment sites. The per cent BOD removal was observed in Elanza and the lowest in Kalibilod in Madhya Pradesh. In Chhattisgarh, both the sites exhibited BOD removal above 50 per cent.

Graph 53: Average BOD value of the treated discharge water



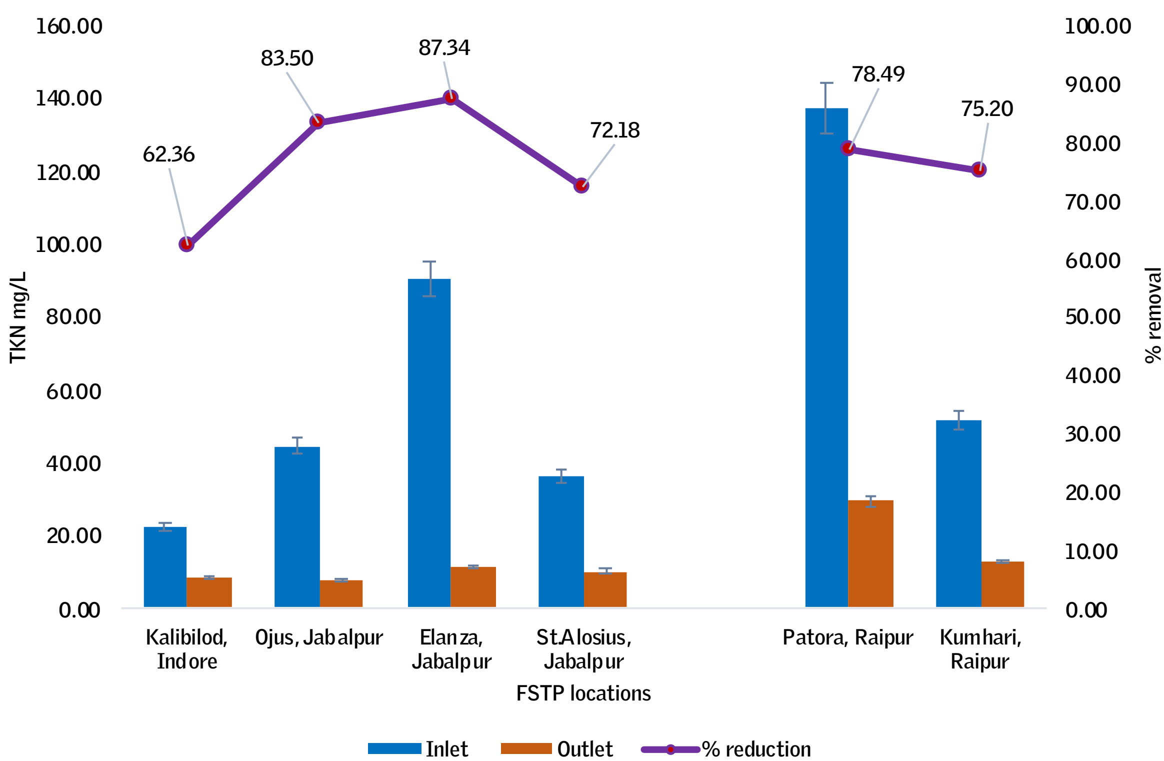
Graph 54: Per cent removal of BOD by the treatment systems



Total Kjeldahl Nitrogen (TKN)

The removal percentage of TKN in the evaluated FSTPs was observed to be in the range of 62.3 to 87.3 per cent. Jabalpur plants (Miguchi) are showed highest removal efficacy.

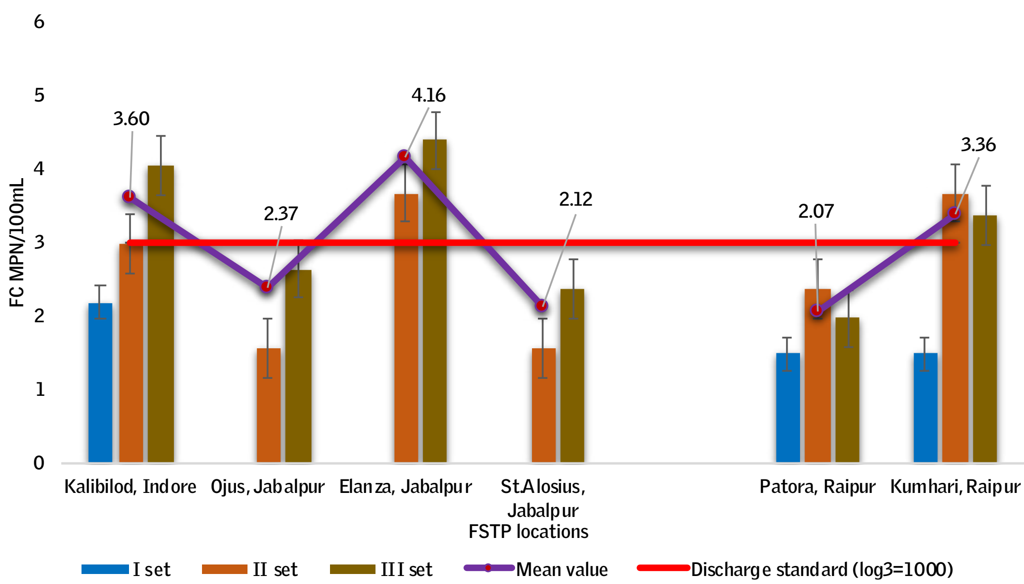
Graph 55: Per cent removal of Total Kjeldahl Nitrogen by the treatment systems



Faecal coliform

The guideline limit for faecal coliform bacteria in unrestricted irrigation is R1000 MPN/100 ml. In the treatment system evaluated, the outlet water of Kalibilod and Elanza in Madhya Pradesh and Kumhari in Chhattisgarh showed FC values above the prescribed limit set by MoEF&CC regulations (R1000 MPN/100mL).

Graph 56: Faecal coliform count in the treated discharge water from the treatment systems



SUMMARY

- Performance evaluation was done of four FSTPs in Madhya Pradesh (Kalibillod, Elanza, Ojas, and St Allantois) and two in Chhattisgarh (Kumhari and Patora). Except for Kalibillod, all the three FSTPs of Jabalpur in MP are equipped with Mizuchi technology.
- The pH of the discharge water from all the locations is within the limit of the discharge standard.
- For COD removal, all the sites with Mizuchi treatment systems showed the highest treatment efficiency (above 80 per cent) whereas the Kumhari FSTP exhibited the lowest removal efficiency (50.2 per cent). So, three treatment systems (Mizuchi) in Jabalpur, MP showed a value below the standard limit whereas Kalibilod, Patora, and Kumhari are above the standard value (<50mg/L).
- In all the treatment systems in both states, the treated discharge water BOD is under the discharge limit. Amongst the sites of Madhya Pradesh, the per cent BOD removal was observed the highest (94.3 per cent) in Elanza (Mizuchi) and the lowest (60.1 per cent) in Kalibillod. In Chhattisgarh, both sites exhibited BOD removal of above 50 per cent.
- The removal percentage of TKN in the evaluated FSTPs was observed to be in the range of 62.3 to 87.3 per cent. Jabalpur plants (Mizuchi) showed the highest removal efficacy.
- Therefore, amongst the sites of both states Mizuchi system was observed to be the better in terms of removal of BOD, COD, and Nitrogen.
- In the treatment systems evaluated, the outlet water of Kalibillod, Elanza and Kumhari showed FC values above the prescribed limit set by MoEF&CC regulations (≤1,000 MPN/100mL). Two sites in Jabalpur (St Allantois and Ojas) and Patora show the FC value within the standard limit.

Uttarakhand

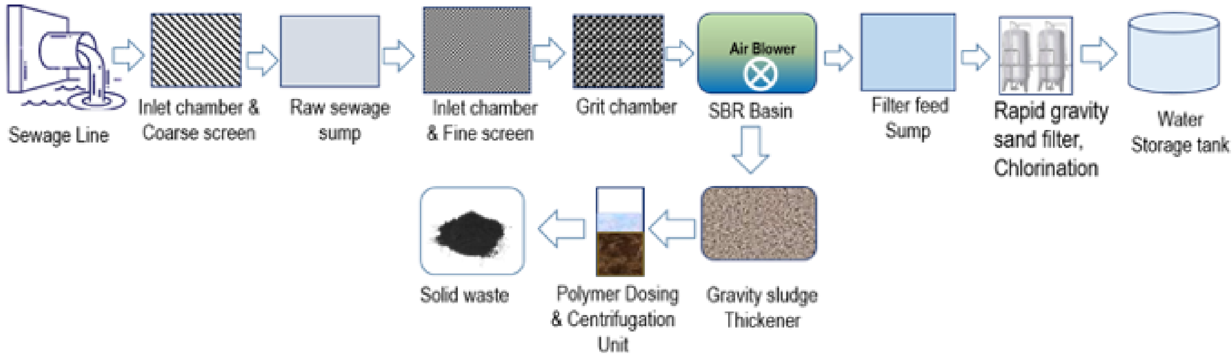
Swachh Bharat Mission has impacted in 95% of the state attaining ODF status, however it did not provide a solution to the treatment of black water (wastewater from containing solid and liquid excreta). Under SBM 2.0, the government is trying to tap other aspects of sanitation including safe containment, transportation, treatment & disposal of faecal sludge and septage from toilets. The fund sharing pattern between the Centre and State will be 90:10 for Uttarakhand as it is a Himalayan State. 8 out 13 districts lie in entirely hilly terrains; therefore, laying of sewerage infrastructure poses significant challenges. Most cities lacking in septage collection, treatment & disposal facilities and regulations. The state issued guidelines to all ULBs to establish a regulatory framework for construction of OSS collection, transportation and disposal of Faecal Sludge and Septage. This mandated the formation of Septage Management Cells (SMC) at ULB level and Monitoring Committee at District Level.

The Uttarakhand Urban Development Directorate signed an agreement with the Technical Support Unit (NIUA) to build state capacity on FSSM through capacity development, technical support, policy and advisory support specifically on FSSM. In January 2021, the River Rejuvenation Committee (RRC) which was constituted as per the order of the National Green Tribunal, under the leadership of the Chief Secretary, laid down the pre-requisite of including co-treatment in STPs from the design stage itself while existing STPs have to ensure the scientific addition of co-treatment. Co-treatment is proposed in existing STPs in several cities (Dehradun, Haridwar, Rishikesh, Srinagar, Ramnagar).

Lakkarghat STP

The 26 MLD STP at Lakkarghat is a newly constructed installation located in Rishikesh and is based on the Sequencing Batch Reactor (SBR) process. It was commissioned in September 2020 and presently running with more or less 50% capacity. The treatment technology comprises of receiving chamber, coarse screen, raw sewage sump, inlet chamber, fine screen (manual and mechanical), grit chamber, SBR basin, chlorine contact tank, sludge sump, gravity sludge thickener and centrifuge as shown in the figure below. In the course of the survey, SBR process was adopted with 1:30 hrs. of aeration & filling followed by 45 minutes settling & 45 minutes decanting. Tertiary treatment is accomplished by chlorine dosing to the final concentration of 1 ppm to the discharged effluent. On the other hand, dry sludge is collected through gravity sludge thickener followed by polymer dosing tank and centrifugation.

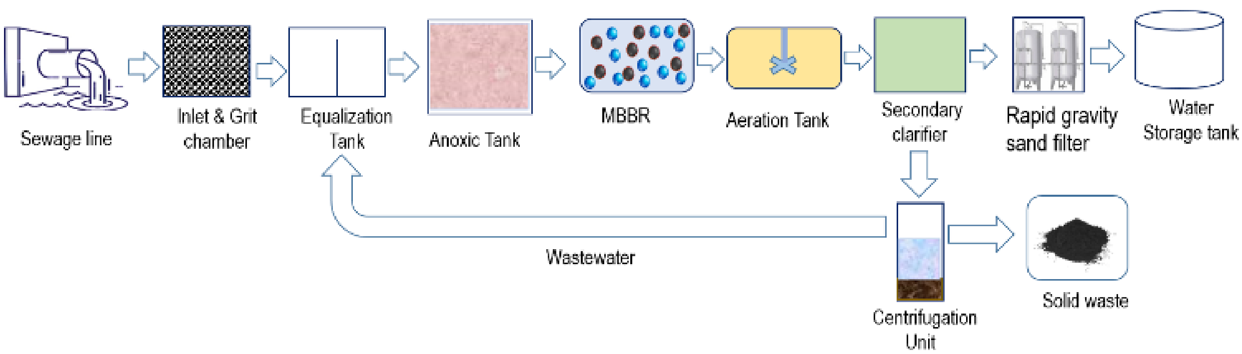
Figure 58: Schematic representation of the process flow in Lakkarghat STP



Chorpani STP

The 5 MLD STP at Chorpani, Rishikesh is based on the MBBR (Moving Bed Biofilm Reactor) technology. During the survey, STP was running with more or less 90% capacity. Treatment technology comprises of grit chamber, equalization tank, anoxic tank, MBBR tank, aeration tank, and secondary clarifier. The tertiary treatment of water is accomplished by rapid gravity sand filter and chlorine contact tank as shown in the figure below. The settled solid sludge from secondary clarifier is transferred to the centrifugation unit where solid sludge is separated and liquid is recirculated to the equalization tank. Finally the effluent is discharged to the river Chandrabhaga.

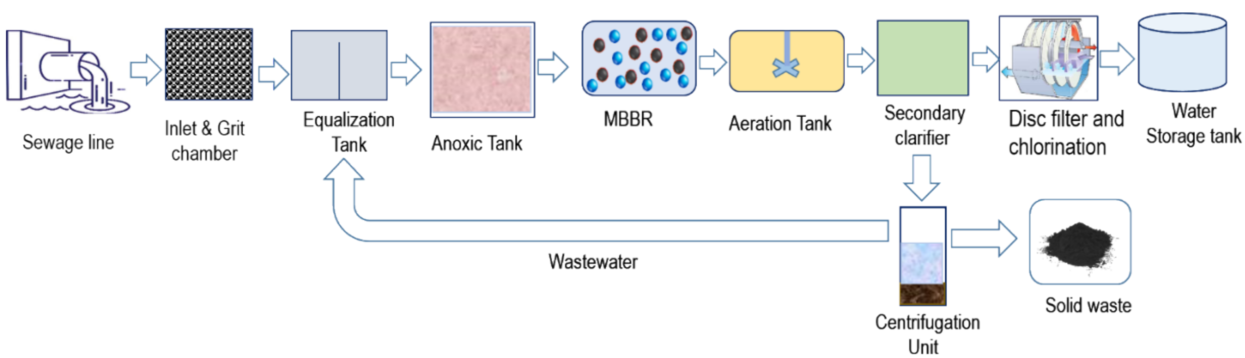
Figure 59: Schematic representation of the process flow in Chorpani STP



Chandreswar STP

Chandreswar STP is also located in Rishikesh. It has a capacity of 7.5 MLD. The plant is operated on MBBR technology which consists of grit chamber, receiving tank, equalization tank, anoxic tank, MBBR tank, aeration tank, secondary clarifier, disc filter and chlorine contact tank as shown in the figure below. The settled sludge from secondary clarifier is transferred to the centrifugation unit where solid sludge is separated and liquid is recirculated to the equalization tank. The effluent is directly discharged to the main stream of river Ganga.

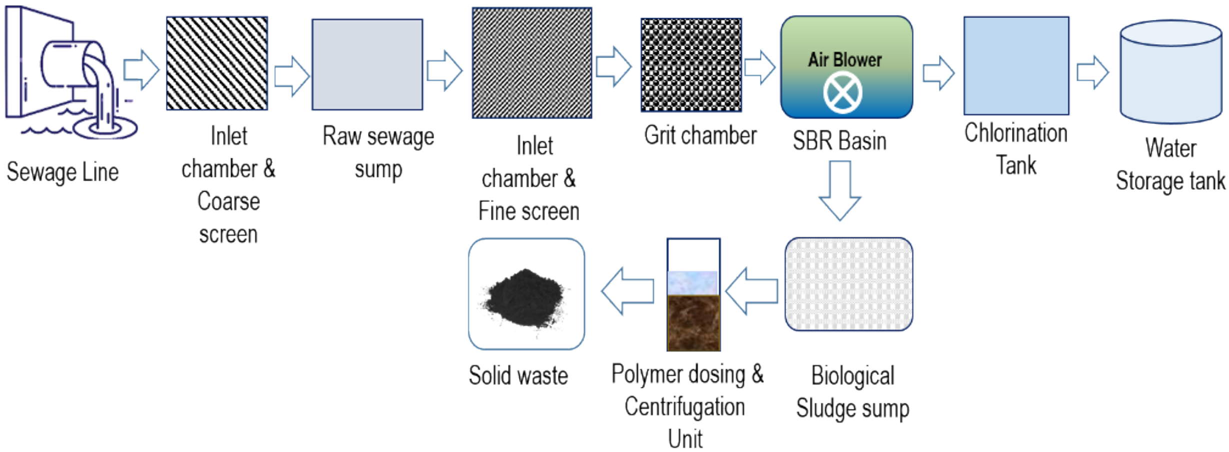
Figure 60: Schematic representation of the process flow in Chandreswar STP



Tapovan STP

The 3.5 MLD STP at Tapovan is located in Rishikesh and is based on the Sequencing Batch Reactor (SBR) process. It was commissioned in April 2016. It comprises of receiving chamber, raw sewage sump, pump house, inlet chamber, fine screen (manual and mechanical), grit chamber, SBR basin, chlorine contact tank, sludge sump and centrifuge as shown in the figure below. In the course of the survey, SBR process was adopted with 2:00hrs aeration & filling followed by 45 minutes settling & 1:15 hrs decanting. Tertiary treatment is accomplished by chlorine dosing to the final concentration of 0.1 ppm to the discharged effluent. In the first visit, STP was observed to be underutilized in lockdown environment and no effluent was generated to be discharged to the river Ganga.

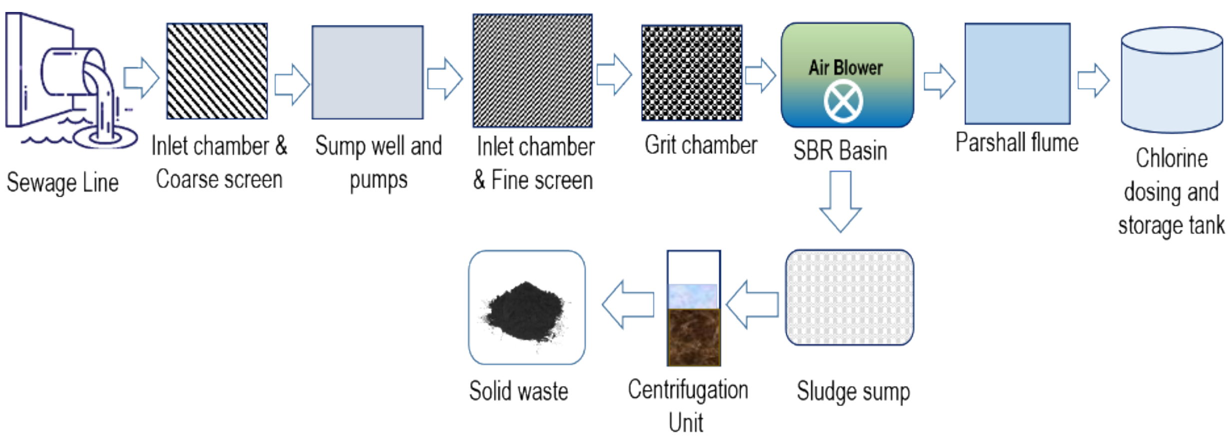
Figure 61: Schematic representation of the process flow in Tapovan STP



Mothrowala-I STP

The 20 MLD STP at Mothrowala-I, Dehradun was commissioned in September 2018. During the survey, STP was running with 85–100% capacity. It is based on the SBR process and comprises of an inlet chamber, coarse screens, sump well & pumps, inlet chamber of STP, fine screens, grit chamber, SBR basin and chlorination tank. The settled sludge from SBR is transferred to excess sludge sump by surplus activated sludge pumps. The excess sludge is then pumped along with poly-electrolyte to centrifuge decanter for dewatering. In the course of the survey, SBR process was adopted with 2:00 hrs aeration followed by 30 minutes settling & 1:00 hr decanting. The dewatered sludge is disposed of in agricultural fields. The effluent is discharged to the Rispana River, a tributary of the Song River.

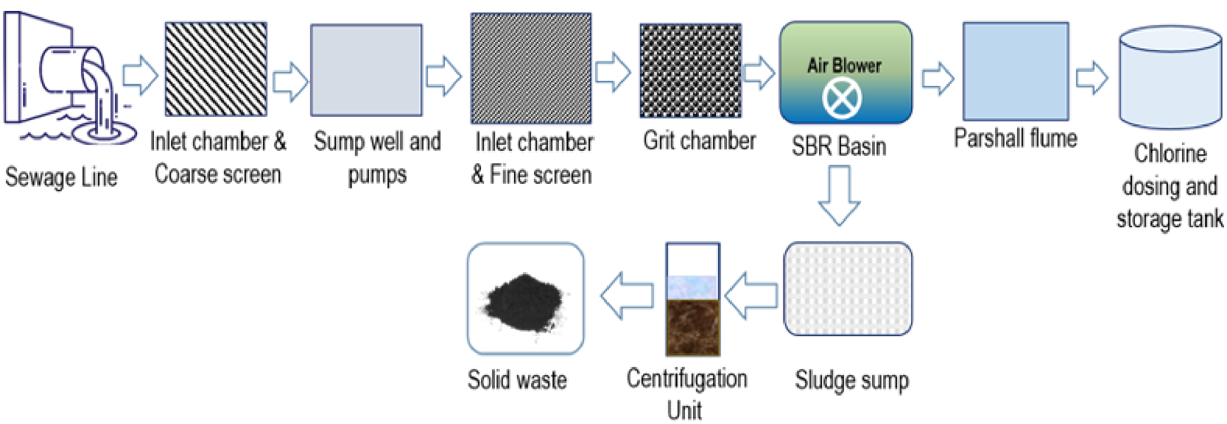
Figure 62: Schematic representation of the process flow in Mothrowala-I STP



Mothrowala-II STP

Mothrowala-II is located in the adjacent premises of Mothrowala-I STP. During the survey, STP was running with more or less 50% capacity. Similar to Mothrowala-I, it's a 20 MLD treatment plant which is based on SBR technology comprises of an inlet chamber, coarse screens, sump well & pumps, inlet chamber of STP, fine screens, grit chamber, SBR basin and chlorination tank. In the course of the survey, SBR process was adopted with 2:00 hrs aeration followed by 30 minutes settling & 1:00 hrdecanting. The effluent is discharged to the Rispana River. The settled sludge from SBR is transferred to excess sludge sump by surplus activated sludge pumps. The excess sludge is then pumped along with poly-electrolyte to centrifuge decanter for dewatering.

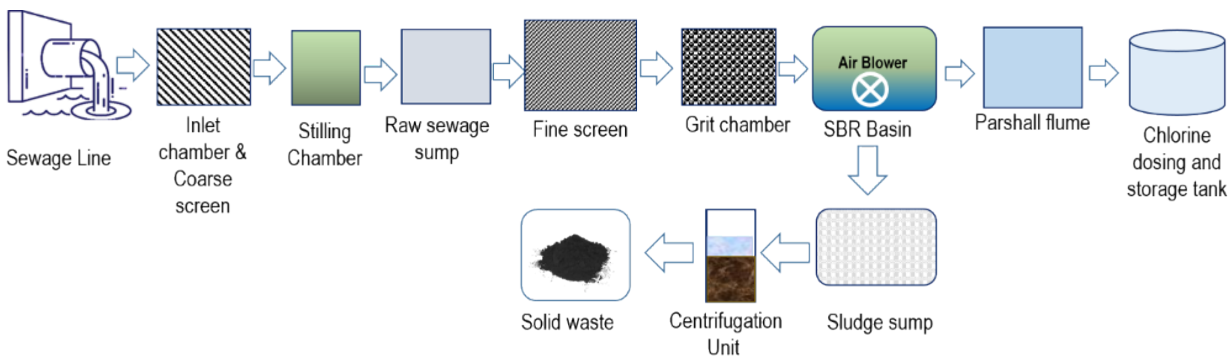
Figure 63: Schematic representation of the process flow in Mothrowala-II STP



Indira Nagar STP

The 5 MLD STP at Indira Nagar, Dehradun is based on the SBR process. It comprises of receiving chamber, coarse screen (manual and mechanical), raw sewage sump, pump house, stilling chamber, fine screen (manual and mechanical), grit chamber, Parshall flume, SBR basin, chlorine contact tank, sludge sump and centrifuge as shown in the figure below. The solid waste generated from the plant is utilized for land filling & agricultural usage. In course of survey SBR process was adopted with 2:02 hrs aeration & filling followed by 45 minutes settling & 1:17 hrs decanting. During the survey, STP was running with more or less 120% capacity. During the survey, the plant was sometimes operated with an excess load of more than 5 MLD of designed capacity.

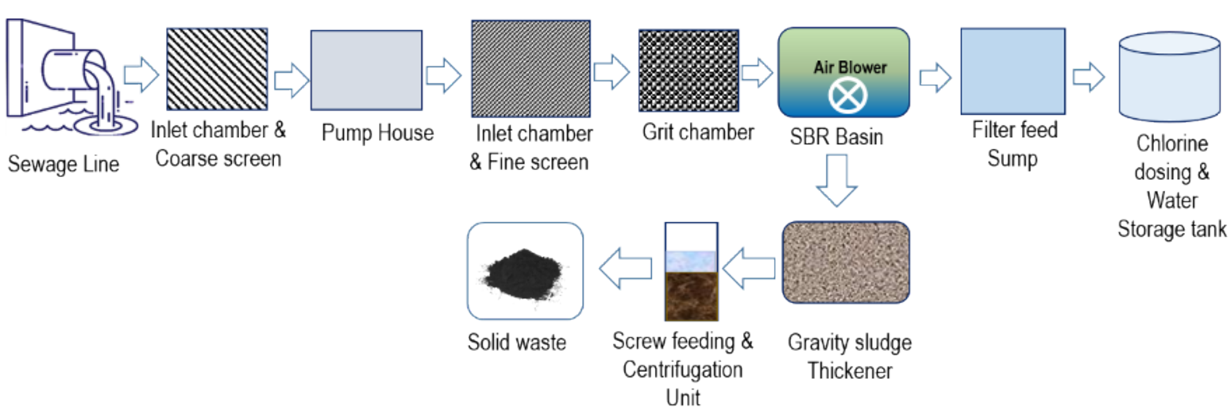
Figure 64: Schematic representation of the process flow in Indira Nagar STP



Jagjeetpur-I STP

Jagjeetpur 68MLD STP is considered to be the biggest STP located in Haridwar. Three STPs (68MLD, 27MLD & 18MLD) were constructed side by side in the same location where 68MLD is the recent one and was commissioned in the month of January, 2020. During the survey, STP was running with approximately 80% capacity.It is based on the SBR process and comprises of receiving chamber, coarse screen and pump house followed by the inlet chamber, fine screens, grit chamber, SBR basin and chlorination tank. The settled sludge from SBR is transferred to the sludge thickener and then to the sludge sump from where it is carried to the centrifuge unit through screw feeding pumps. The dried sludge is then dumped in a piece of land inside the plant premises. In the course of the survey, SBR process was adopted with 90 minutes aeration with filling followed by 30 minutes settling & 60 minutes decanting. After chlorination the effluent stream is mixed with another stream of effluent generated by adjacent STPs and the combined stream is discharged to the river Ganga.

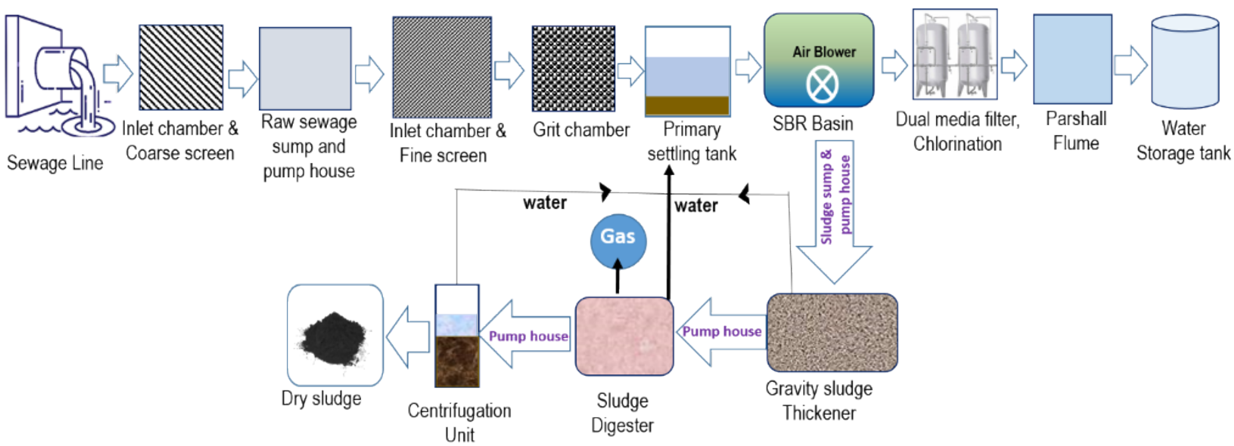
Figure 65: Schematic representation of the process flow in Jagjeetpur-I STP



Jagjeetpur-II STP

The 27 MLD STP located in Jagjeetpur was commissioned in April 2010. The STP has a primary settling tank followed by a Sequencing Batch Reactor (SBR). STP is comprised of a receiving chamber, coarse screen (manual and mechanical), raw sewage sump, pump house, inlet chamber, fine screen (manual and mechanical), grit chamber, parshall flume, primary clarifier (settling tank), SBR basin, dual media filters, chlorine contact tank, sludge sump, sludge thickener, and centrifuge. Sludge digesters existing at the STP are used for anaerobic digestion of the sludge and the biogas generated is used as fuel.

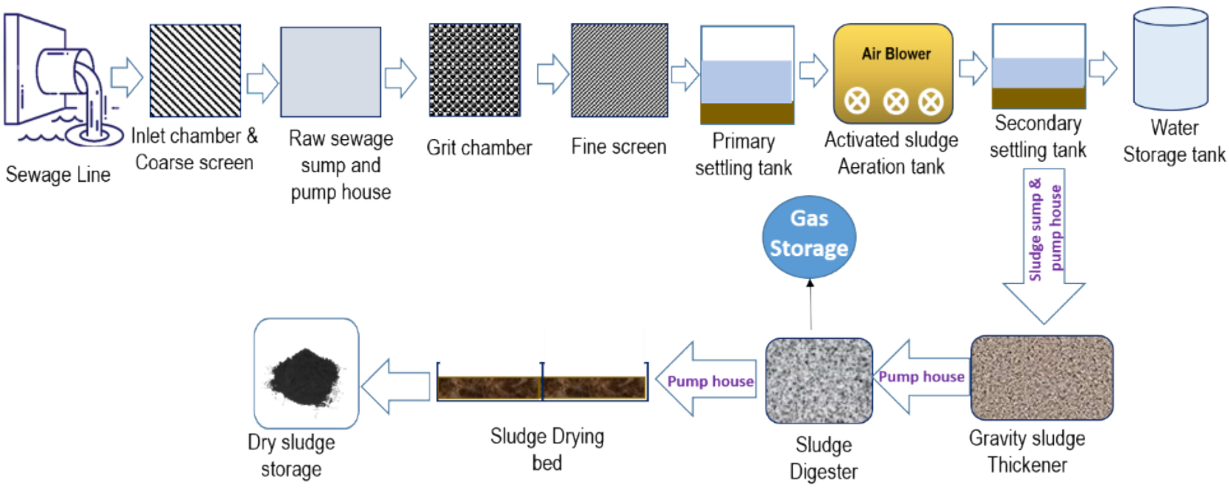
Figure 66: Schematic representation of the process flow in Jagjeetpur-II STP



Jagjeetpur-III STP

This is the smallest STP (18 MLD) in the cluster of three STPs in Jagjeetpur and the technology is based on Activated Sludge Process. The STP was commissioned in the year 1990. The process sequence starts from inlet point followed by coarse screen, grit chamber, fine screen, primary settling tank, activated sludge aeration tank, secondary settling tank and finally chlorination. The settled sludge in secondary settling tank is transferred to the sludge sump and then thickener and finally to the sludge digester. The biogas generated in the sludge digester is stored in the dedicated storage tank and subsequently used as fuel. Digested sludge is transferred to the sludge drying bed and dried under sunlight. On the other hand, after chlorination the effluent is discharged to the river Ganga. In the dry season, sometimes the effluent is also used for agricultural purpose.

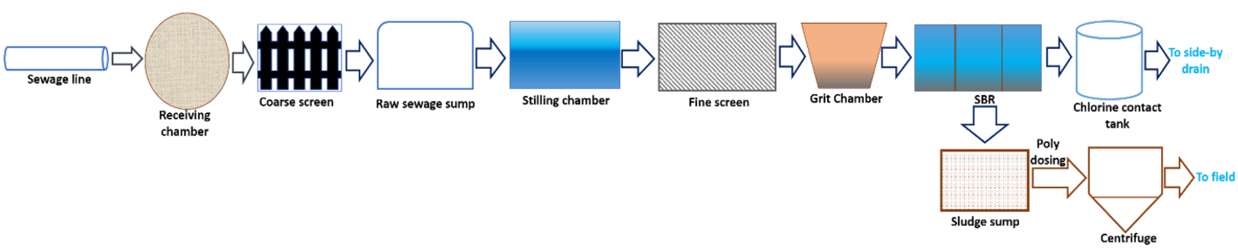
Figure 67: Schematic representation of the process flow in Jagjeetpur-III STP



Sarai-I STP

The 18 MLD STP at Sarai is based on the SBR technology. It is located in Haridwar and was commissioned in April 2014. During the survey, the STP was running with almost 100% capacity. The STP treatment technology is comprised of receiving chamber, coarse screen (manual and mechanical), raw sewage sump, pump house, stilling chamber, fine screen (manual and mechanical), grit chamber, parshall flume, SBR basin, chlorine contact tank, sludge sump and centrifuge.

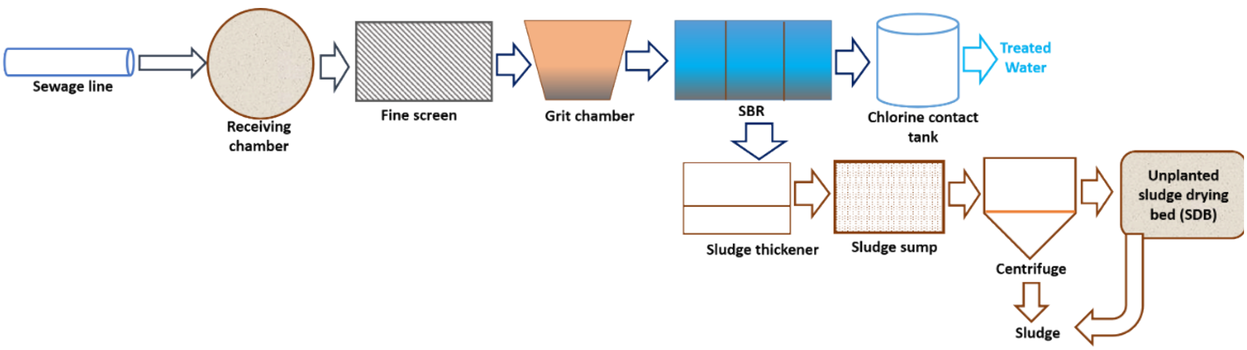
Figure 68: Schematic representation of the process flow in Sarai-I STP



Sarai-II STP

The 14 MLD STP is located at Sarai (Haridwar) and is based on the SBR technology. It was commissioned in December 2019. During the survey, the STP was running above 100% capacity. Influent is diverted to the STP through Pandewala Pumping Station. It was informed that the faecal sludge is mixed with sewage water in the pumping station only. The STP treatment system comprised of receiving chamber, fine screen, grit chamber, SBR basin and chlorine contact tank. After chlorination the effluent is discharged to a dry river. Sludge from the BSR basin is transferred to the sludge thickener followed by biological sludge sump and then centrifugation unit. If the moisture content in the sludge after centrifugation is less, dried sludge is directly stored in the storage yard. Otherwise the wet sludge is dried in a sludge drying bed.

Figure 69: Schematic representation of the process flow in Sarai-II STP



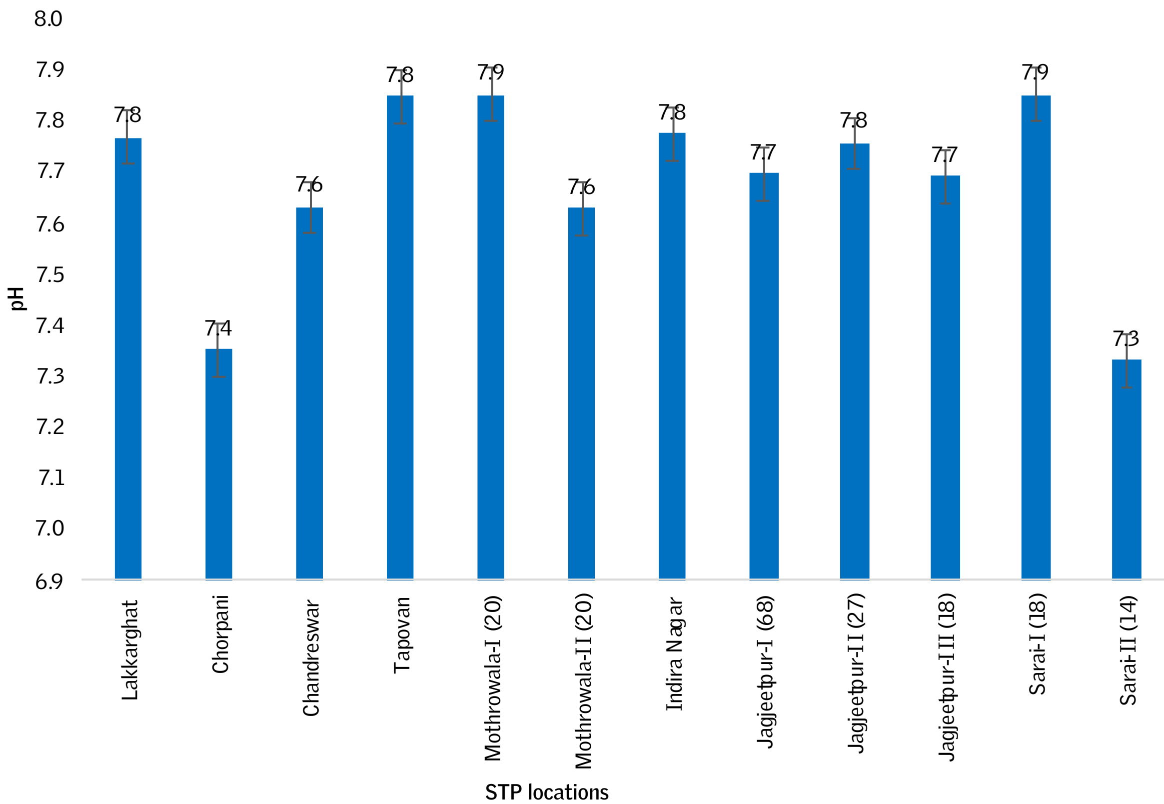
Performance evaluation of FSTPs in Uttarakhand

The selection of STPs was based on the different treatment principles and geographic locations. 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.

pH

The average pH of the treated discharge water from all the FSTP locations ranges from pH-7.3 to 7.9, which is near neutral to slightly basic. The effluent discharge standard for the pH is ranging from 6.0-9.0. The pH of the discharge water from all the locations are within the limit of the discharge standard. A pH outside the range of 6 to 9 indicates an upset in the biological process that will inhibit anaerobic digestion of organic material.

Graph 57: Average pH value of the treated discharge water

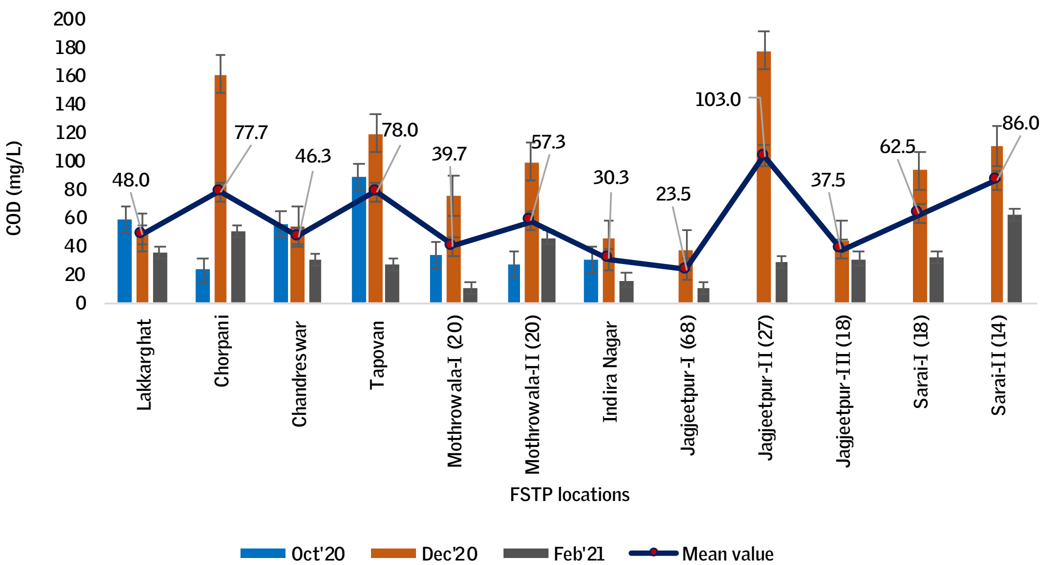


Chemical Oxygen Demand (COD)

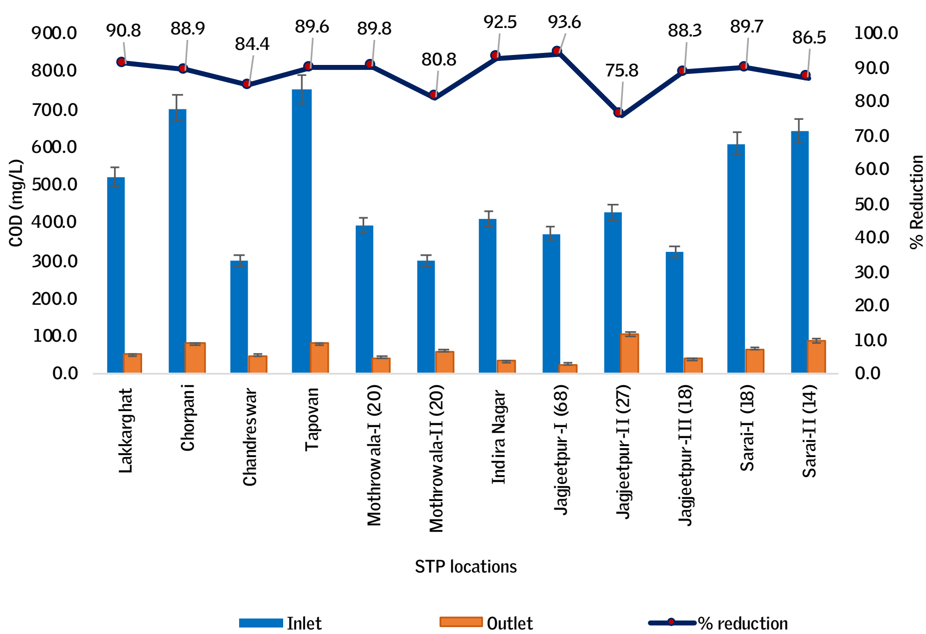
The average COD value of the treated discharge water ranges from 23.5 mg/L to 103.0 mg/L. According to MoEF&CC, the discharge standard for COD is 50 mg/L. Out of the 12 STPs evaluated, only 6 STPs (Lakkarghat, Chandreswar, Mothrowala-I, Indira Nagar, Jagjeetpur-18 & 68 MLD) showed COD valuesbelow the standard limit. Jagjeetpur (27 MLD) plant showed the highest COD value whereas Jagjeetpur (68 MLD) plant showed the lowest COD value in the discharge water.

From the analysis, it was found that the treatment systems reducing the COD in inlet to outlet ranging from 75.8 to 93.6 per cent. All STPs showed COD removal percentage above 75%.

Graph 58: Average COD (three months) value of the treated discharge water



Graph 59: Per cent removal of COD by the treatment systems

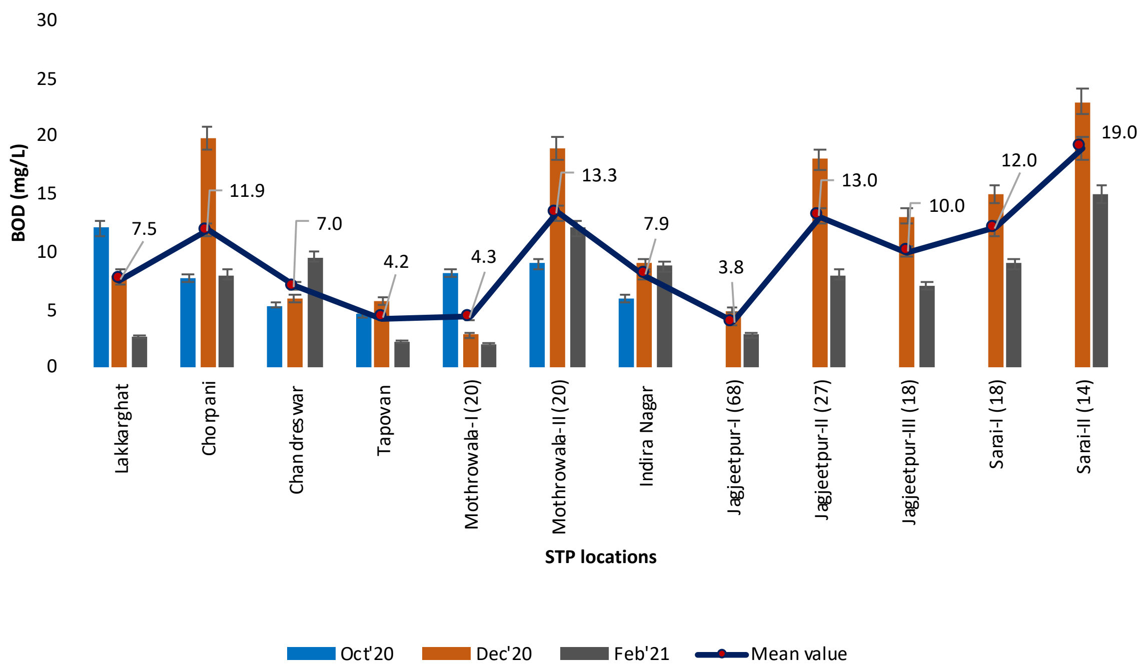


Biological Oxygen Demand (BOD)

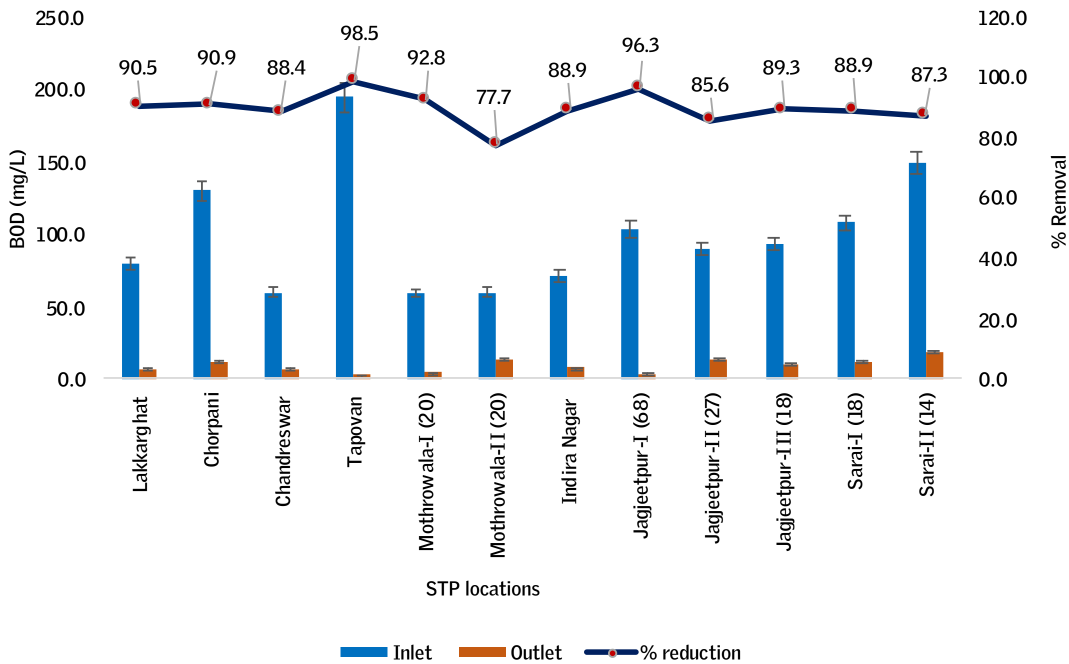
In the evaluated treatment systems, the average BOD value of the treated discharge water ranges from 4.2 mg/L to 19.0 mg/L. According to MoEF&CC, the discharge standard for BOD in metro cities is 20mg/L and non-metro cities 30 mg/L. For all the STP co-treatments, the treated water BOD is under the discharge limit below 20mg/L.

A reduction of 77.7 to 98.5 per cent was observed in the most of the treatment sites. Tapovan STP (98.5%) showed the highest per cent removal efficacy and Mothrowala II (77.7%) showed the lowest removal efficacy.

Graph 60: Average BOD value of the treated discharge water



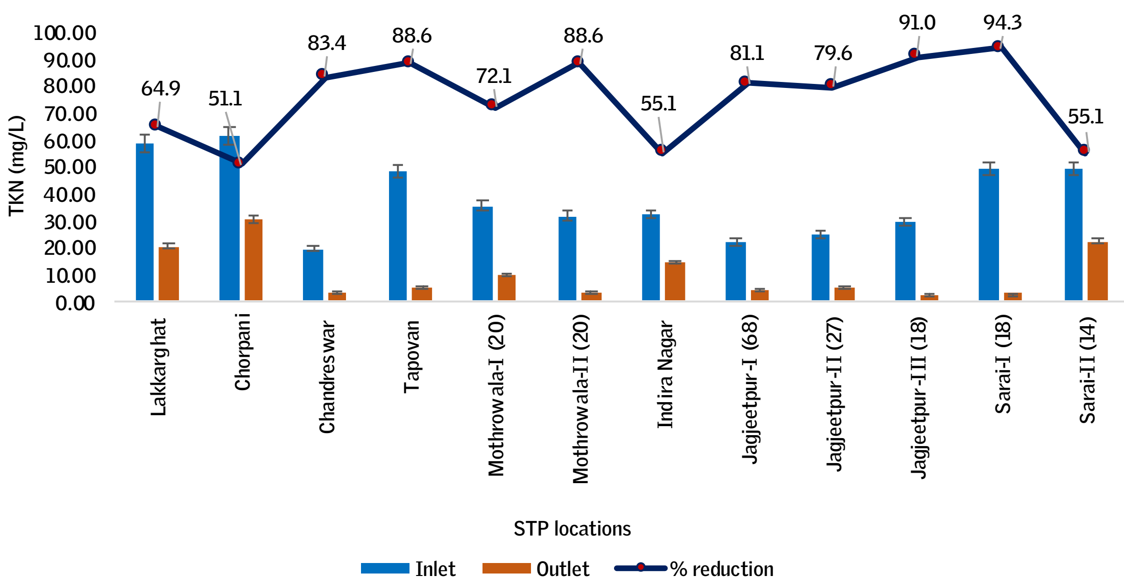
Graph 61: Per cent removal of BOD by the treatment systems



Total Kjeldahl Nitrogen (TKN)

The removal of TKN was observed in the evaluated STPs in the range of 51.1 to 94.3 per cent. 18 MLD Sarai-I STP showed highest removal efficacy (94.3%) whereas Chorpani showed the lowest removal efficiency of 51.1%.

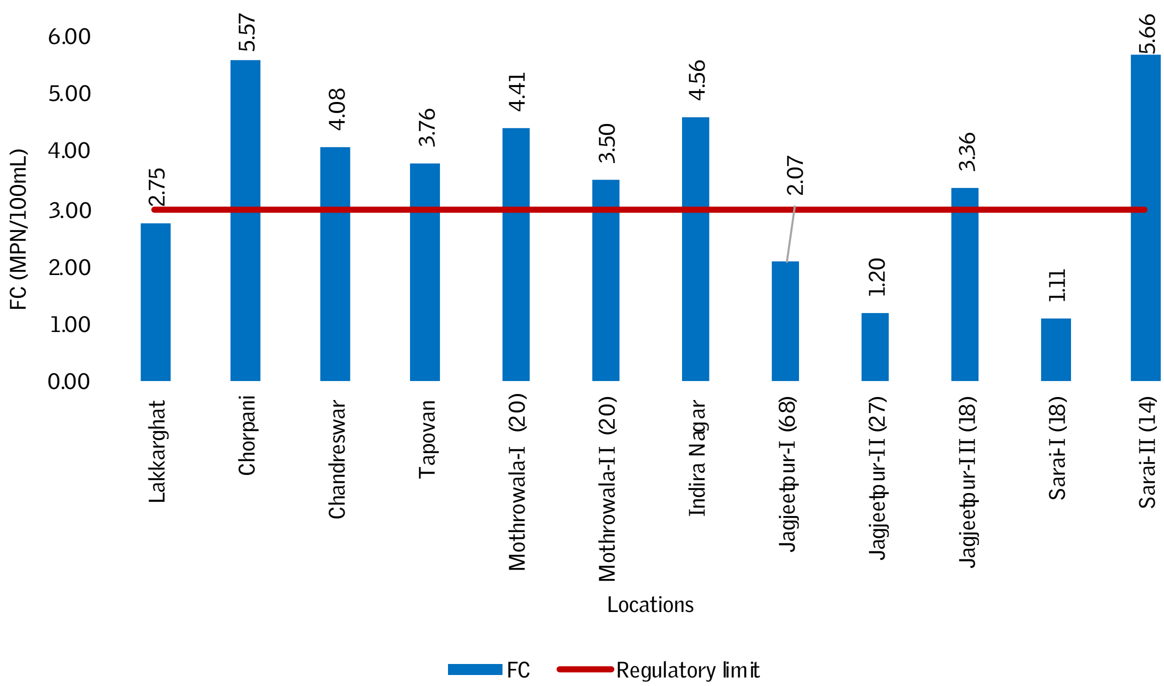
Graph 62: Per cent removal of Total Kjeldahl Nitrogen by the treatment systems



Faecal coliform

The guideline limit for faecal coliform bacteria in unrestricted irrigation is R1000 MPN/100 ml. Out of 12 treatment system evaluated, 7 STP outlet water showed faecal coliform value below the prescribed limit set by MoEF&CC regulations (R1000 (log 3.0) MPN/100mL). Five out of 12 have high content of microbial load as the disinfection process like chlorination was not effective in these STPs. Like most of the STPs in India, these five STPs are also not maintaining the faecal coliform count under the standard limit, in spite of the post treatment systems like chlorine dozing. The microbial load in outlet water couldn't be controlled with predefined chlorine doses since the microbial load in in-fluent water varies in wide range. The microbial discharge quality in STPs is completely dependent on the tertiary treatment and how effectively chlorination (chlorine dosing) is used to treat the final discharge water, and not dependent on which technology is used in that STP for the treatment of wastewater.

Graph 63: Faecal coliform count in the treated discharge water from the treatment systems



SUMMARY

- In the course of the study, four types of STP technologies were investigated for performance efficiency of the sewage water treatment process along with septage — Sequencing Batch Reactor (SBR), Moving Bed Biofilm Reactor (MBBR), Activated Sludge Process (ASP) and Up-flow Anaerobic Sludge Blanket (UASB).
- In almost all circumstances, average per cent removal of COD, BOD and nitrogen was observed to be relatively high in SBR technology. Increased efficiency of treatment technology was noticed in Lakkarghat, Mothrowala 20 MLD, Indira Nagar, Jagjeetpur 68 MLD and Jagjeetpur 18 MLD STPs, where BOD &COD concentration was determined to be well within the regulatory limit of 20 mg/l and 50mg/L, respectively.
- In Tapovan, Mothrowala II, Jagjeetpur 27 MLD and Chorpani STP, Sarai I & II, the COD value in effluent water was above the regulatory limit, but BOD was under the regulatory limit.
- In spite of adopting the disinfection process (chlorination), average microbial load (faecal coliform) in discharged water of Chorpani, Chandreswar, Tapovan, Mothrowala I 20 MLD, Mothrowala II 20 MLD, Indiranagar, Jagejeetpur III, and Sarai 14 MLD was observed to be very high (104 to 105 MPN/100ml).
- In all STPs, high microbial load of faecal coliform in inlet water directly or indirectly substantiate the faecal contamination in sewage water.

Annexure II

Consolidated physico-chemical and biological parameters of collected samples

Table 1: Physico-chemical and biological parameters of the samples collected from Telangana

Locations	Sample type	pH	TS (ppm)	TDS (ppm)	TSS (ppm)	COD (ppm)	BOD (ppm)	TKN (ppm)	Ammo-niacal Nitrogen (ppm)	Total Phos-phate (ppm)	Fecal Coliform (MPN/100 ml)
Boduppal	FS	7.1	11085.0	3020.0	8065.0	12750.0	2550.0	817.3	342.2	222.0	430000.0
	Inlet	8.0	2792.7	2600.0	609.3	636.0	135.0	197.6	149.2	9.3	421000.0
	Outlet	**8.2**	**725.0**	**691.3**	**33.7**	**57.3**	**13.3**	**17.2**	**8.6**	**1.1**	14
Bongir	FS	7.1	9569.0	1970.0	7599.0	9400.0	1880.0	394.0	121.1	134.0	9300.0
	Inlet	8.2	1791.0	1673.3	117.7	226.0	49.3	175.9	146.1	6.2	1116.7
	Outlet	8.6	1265.0	1195.0	**70.0**	**49.0**	**11.0**	**6.8**	**2.1**	**0.5**	29
Kamareddy	FS	7.9	30377.7	1864.0	28513.7	41766.7	11328.3	1243.6	295.6	206.0	886666.7
	Inlet	7.7	1917.7	1403.0	514.7	1713.0	350.7	161.0	114.0	10.7	33776.7
	Outlet	7.3	1003.7	862.7	151.0	40.3	11.0	6.0	**1.9**	**0.7**	34
Khajaguda	FS										
	Inlet	6.8	1127.0	1050.5	76.5	1369.5	278.5	59.5	38.5	5.5	835000.0
	Outlet	7.2	912.0	864.5	47.5	88.0	20.5	32.8	26.3	4.4	125500.0
Nalgonda	FS	7.8	48883.5	1575.0	47308.0	48905.0	12643.5	748.1	144.1	106.5	1365000.0
	Inlet	7.5	31888.3	2090.0	29798.3	1441.0	227.3	418.4	47.3	8.6	15716.7
	Outlet	**8.2**	**2120.0**	**1936.7**	**183.3**	**41.0**	**10.7**	**9.3**	**2.3**	**0.9**	20
Nanakamguda	FS	6.7	4846.5	1251.0	3595.5	4553.0	921.0	95.0	29.7	15.3	120018.0
	Inlet	7.6	1081.7	966.3	115.3	1242.7	259.0	43.6	27.7	4.4	530000.0
	Outlet	8.0	879.0	780.7	75.0	74.7	21.3	26.1	9.6	3.0	37434.3
Nirmal	FS	7.4	22000.0	1800.0	20200.0	54350.0	8750.0	914.3	104.6	190.0	110000.0
	Inlet	7.2	1464.5	1270.0	194.5	103.0	23.0	57.7	37.1	5.1	2150.0
	Outlet	7.6	1352.0	1255.0	97.0	27.0	7.5	10.0	2.2	4.6	235.0
Shandnagar	FS										
	Inlet	8.2	1325.3	1220.0	105.3	1305.3	290.7	154.7	106.8	6.1	976.7
	Outlet	8.1	893.0	840.7	52.3	54.7	13.0	10.9	**2.2**	**0.8**	46
Siddipet	FS	8.9	52923.0	1250.0	51683.0	67400.0	17594.0	1134.8	216.6	328.0	11000000.0
	Inlet	8.0	2036.3	1450.0	586.3	1829.7	380.0	353.2	275.9	16.8	67410.0
	Outlet	**6.8**	**1602.3**	**1276.7**	**325.7**	**24.3**	**6.3**	**16.4**	**2.0**	**0.1**	13
Sircilla	FS	7.9	25261.0	1830.0	23431.0	75375.0	17115.5	946.7	155.5	162.0	1570000.0
	Inlet	7.9	1703.3	1218.7	486.0	303.3	64.3	74.8	48.2	5.0	620100.0
	Outlet	**7.8**	**1001.0**	**936.0**	**65.0**	**124.7**	**24.0**	**40.3**	**27.1**	**3.7**	631

Locations	Sample type	pH	TS (ppm)	TDS (ppm)	TSS (ppm)	COD (ppm)	BOD (ppm)	TKN (ppm)	Ammo-niacal Nitrogen (ppm)	Total Phos-phate (ppm)	Fecal Coliform (MPN/100 ml)
Uppal	FS	7.5	2644.0	2000.0	644.0	3410.0	420.0	129.4	99.4	8.2	380000.0
	Inlet	8.4	1925.0	1686.7	238.3	181.3	46.7	115.0	94.9	4.3	32766.7
	Outlet	**7.7**	**1891.0**	**1826.7**	**64.3**	**82.0**	**14.3**	**6.3**	**3.0**	**2.1**	55
Warangal	FS	8.0	27755.5	1965.0	25790.5	65950.0	10691.0	1417.1	263.5	214.0	6700000.0
	Inlet	8.0	923.7	816.7	107.0	351.3	76.0	219.1	185.2	8.7	849766.7
	Outlet	8.3	837.3	800.0	36.7	46.0	**11.3**	**28.3**	**18.9**	**2.5**	13

Table 2: Physico-chemical and biological parameter of the samples collected from Tamil Nadu

Locations	Sample type	pH	TS (ppm)	TDS (ppm)	TSS (ppm)	COD (ppm)	BOD (ppm)	TKN (ppm)	Ammo-niacal Nitrogen (ppm)	Total Phos-phate (ppm)	Fecal Coliform (MPN/100 ml)
Ukkadam, Coimbatore	FS	7.7	2461.7	1756.7	705.0	30090.0	6911.7	240.3	114.3	35.3	403333.3
	Inlet	7.6	1348.3	1042	306.3	768.7	186	58.0	38.7	6.98	580000
	Outlet	8.1	805.7	768.0	37.7	82.0	23.3	17.6	12.9	1.9	4476.7
Periyanaicken-palayam	FS	7.9	3402	1910	1492	31000	8859	173.46	132.43	23	150000
	Inlet	8.3	1684.3	1413.3	271	254.7	64	180.4	149.5	9.5	382143.3
	Outlet	**8.6**	**1465**	**1368.3**	**96.7**	**163.3**	**37.3**	**143.5**	**120.8**	**9.1**	1330
Erode	FS	8	12093.67	1189.7	10910.67	33043.33	7285	586.6	102.9	98.5	620800
	Inlet	7.9	1076	857.7	218.3	301.3	75.7	38.2	26.01	4.3	53000
	Outlet	8.3	823	742.3	80.7	53.3	13.7	4.2	3.2	1.8	886.7
Thuraiyur, Trichy	FS	5.01	4783	2570	2213	37900	9828	211.7	100.03	45	30
	Inlet	8.6	2099	1870	229	334	82	233.9	195.7	8.6	4606.7
	Outlet	10.2	1023.3	913.7	109.7	58.3	15	4.6	**3.10**	**0.3**	30
Panjapur, Trichy	FS	8.0	4059	1753.3	2305.7	25473.33	6715	183.3	107.8	56	2176666.7
	Inlet	7.8	970	842.3	127.7	337.3	83.7	44.7	30.2	5.3	29866.7
	Outlet	8.1	865	831.7	33.3	74.3	19.3	25.09	22.07	4.9	1710
Avanipuram, Madurai	FS										
	Inlet	7.6	1274.3	1013.3	261	732	175	59.7	38.4	5.7	907666.7
	Outlet	8.3	917	878.3	38.7	69.3	17.3	32.4	25.3	1.7	1193.3
Thiruma-ngalam, Madurai	FS	7.6	6596	1955	4141	36225	7382	442.5	207.8	54	226500
	Inlet	280.6	1912	1713.3	198.7	204	49.3	66.6	54.8	5.8	530
	Outlet	**8.7**	**1276**	**1220.3**	**55.7**	**66.3**	**16.3**	**3.0**	**1.2**	**2.6**	14
Vickramasin-gapuram	FS	7.58	83389	1600	81789	95600	28357	2925.3	331.4	200	43000
	Inlet	8.13	986.7	948.7	71.3	338	66.3	70.4	53.2	10.3	11966.7
	Outlet	9.2	485.7	453.3	**32.3**	**54.7**	**14.7**	**11.4**	**8.0**	**1.6**	251
Sengottai	**FS**										
	Inlet	8.4	1232.0	1023.3	208.7	252.00	63.3	139.7	112.50	8.8	56333.3
	Outlet	8.9	1100.7	967	133.7	172	42.7	23.9	12.3	**4.7**	296

Table 3: Physico-chemical and biological parameter of the samples collected from Odisha

Locations	Sample type	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammo-niacal Nitrogen (mg/L)	Total Phos-phate (mg/L)	Fecal Coliform (MPN/100 ml)
Puri	FS	7.2	29717	1231.7	28485.3	20636.7	3730	1488.8	292.1	209.77	670000
	Inlet	7.5	1050	894	156	190.7	54	78.4	64.5	10.97	80077
	Outlet	7.2	842	710	132	90	23.9	29.3	19.5	4.7	177
Balasore	FS	6.8	57619.3	1087	56532.3	74900	4655	2195.3	362.6	255	21100000
	Inlet	7.5	3090.3	1226.7	1863.7	1695	188.5	281.8	209.1	37.03	1616667
	Outlet	7.5	768.7	713.3	55.3	146.3	50	63	37	0.87	72
Baripada	FS	7.3	46736.3	1656.7	45079.7	57880	6230	1715.8	350.8	480.4	38103100
	Inlet	7.7	2508	1363.3	1144.7	1758.7	238	202.3	156.9	28.4	304333
	Outlet	7.6	1204.3	1060	144.3	367.3	90	101.3	81	18.33	5838
Bhubaneswar	FS	7.3	7817	1006	6811	20524	3760	467.9	149.9	71.75	141500
	Inlet	7.3	2053	1080	973	458	83.5	156.1	136.3	23	276500
	Outlet	7.1	918.5	712	206.5	74.5	25.7	56	45.7	10.2	314
Dhenkanal	FS	7.4	4485	1440	3045	3103.5	299	369.5	175.3	30.3	1380000
	Inlet	7.6	1994	1268	726	114.5	57	186.1	43.4	14.55	230046
	Outlet	7.7	1187.5	899.5	288	56	14	35.9	7.9	8.65	61
Berhampur	FS	7.3	46486	1273.3	45212.7	54631.7	2018	1564.4	273	384.03	5200000
	Inlet	7.7	2225	1613.3	611.7	780	217.7	241.2	188.7	23.67	784067
	Outlet	7.7	760.7	583.3	177.3	153.3	27.6	43.5	28.3	5.37	300
Angul	FS	6.9	30658	1446.7	29211.3	61533.3	6312.7	1510.7	302.8	272	1250000
	Inlet	8	2290.7	1540	750.7	322.7	67.3	131.2	104.8	14.7	142000
	Outlet	7.6	1274.7	1160	114.7	162	26.7	41.4	32.4	8.2	16947
Sambalpur	FS	7.4	31578	1698.3	29879.7	41561.7	6565	1667	235.6	149.07	8300000
	Inlet	7.8	1562	1160	402	151.3	21	167.5	112.6	13.77	98667
	Outlet	7.8	330.7	208.7	122	76.3	14.1	17.1	3.9	0.7	9
Rourkela	FS	7.4	37469.3	1659.3	35810	42176.7	5635	1619	295.8	192.43	545333
	Inlet	8	1824	1463.3	360.7	287.3	41	221.6	150.6	16.03	23100
	Outlet	7.7	389	312.3	76.7	89.3	18.2	22.7	6	0.77	5
Asika	FS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Inlet	6.92	1049.3	823	226.3	350.7	114.2	80.4	70.6	6.3	8023.3
	Outlet	6.55	426.7	336.7	90	17	6.1	5.6	1.6	0.1	30
Bhadrak	FS	6.88	11836	1370	10466	52625	10474.8	995.2	266.5	175	1275000
	Inlet	7.79	1277	1073.3	203.7	643.3	191.1	282.4	232.3	14.9	52200
	Outlet	8.07	751.7	668	83.7	105	32.1	22.1	13.9	1.1	32
Chodwar	FS	6.94	4089	1180	2909	6040	1518	355.7	184.2	58	430000
	Inlet	6.95	1284.3	1090	194.3	190.7	56.2	166.1	149.6	11.4	39433.3

Locations	Sample type	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammo-niacal Nitrogen (mg/L)	Total Phos-phate (mg/L)	Fecal Coliform (MPN/100 ml)
	Outlet	8.32	1049.7	996	45.7	43	13.5	12.1	2.7	1	30
Jagatsinghpur	FS	7.2	905	910	1350	21740	6427.5	174.9	121.6	22.7	2515000
	Inlet	6.93	8871.3	997	2444.3	1168.7	370.7	259	148.6	16	4176666.7
	Outlet	7.32	343.3	294.3	49	24.7	7.5	11.9	8.9	1.2	320
Jatni	FS	_	_	_	_	_	_	_	_	_	_
	Inlet	7.38	890	739	181.3	342	101.1	117.8	95.1	13.4	162100
	Outlet	6.98	599.3	553	46.3	91.3	28.5	28.2	17.6	4.4	32
Khordha	FS	6.91	9627	1640	7987	43700	13003	667.4	247.3	86	930000
	Inlet	7.23	1022.7	913.3	109.3	400.7	119.5	148.2	117.9	11.8	368130.7
	Outlet	6.63	652	607.7	44.3	65.7	20.6	24.6	13.5	2.2	200
Nimapada	FS	_	_	_	_	_	_	_	_	_	_
	Inlet	6.84	559	472	87	63	17.5	11.2	4.5	1.9	23180
	Outlet	8.04	478.5	444	33	31.5	9	3.7	1.4	0.1	30
Paralakhe-mundi	FS	7.42	11064	1880	9184	3290	827	761.5	252.4	112	230000
	Inlet	7.35	5378	1245	4133	798.5	210	323	125.5	31.5	2950
	Outlet	7.12	305.5	236	69.5	36	10.5	15.6	1.9	0.5	33

Table 4: Physico-chemical and biological parameter of the samples collected from Rajasthan

Locations	Sample type	pH	TS (ppm)	TDS (ppm)	TSS (ppm)	COD (ppm)	BOD (ppm)	TKN (ppm)	Ammo-niacal Nitrogen (ppm)	Total Pho-sphate (ppm)	Fecal Coliform (MPN/100 ml)
Phulera	FS	7.5	43536.6	2422.3	40673.0	52434.4	5083.0	2137.8	525.9	194.5	2580000.0
	Inlet	8.1	2010.0	1719.0	291.2	373.2	78.6	93.9	62.8	6.9	369.2
	Outlet	**8.5**	**1549.0**	**1427.6**	**121.4**	**148.2**	**23.2**	**36.7**	**9.1**	**4.1**	177
Lalsot	FS	7.2	48796.5	4136.7	32555.0	67837.5	6928.0	2589.1	855.6	501.4	3018250.0
	Inlet	8.0	1956.6	1744.2	212.4	368.0	67.6	228.1	136.9	10.1	20306.0
	Outlet	**8.0**	**1572.6**	**1472.0**	**100.6**	**121.0**	**19.4**	**119.5**	**80.1**	**3.4**	622
Khandela	FS	7.3	22472.0	3486.7	20219.0	54475.0	5323.8	2122.9	602.3	164.3	6175750.0
	Inlet	8.1	1952.4	1694.4	258.0	324.0	65.6	121.7	66.5	5.7	8624.4
	Outlet	9.1	1563.0	**1393.4**	**169.6**	**124.2**	**22.4**	**56.5**	**16.6**	**2.8**	35

Table 5: Physico-chemical and biological parameter of the samples collected from Uttar Pradesh

Locations	Sample type	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammo-niacal Nitrogen (mg/L)	Total Phos-vphate (mg/L)	Fecal Coliform (MPN/100 ml)
Modinagar	FS	7	58892	2740	56152	101700	18340	1928.6	848.1	664	46000000
	Inlet	8	967.5	890	77.5	157	39.5	121.3	100.8	6	13000
	Outlet	8.2	759	733	26	44.5	11.5	60.7	48.8	4.8	30
Loni	FS	7.8	15245	2870	12375	64700	10462.8	1079	443.4	303	2154600
	Inlet	8.1	2761.5	2240	521.5	558	121.5	307.2	142	8.4	118750
	Outlet	7.9	1403.5	1300	103.5	231	47.5	79.4	21.3	5.3	765
Jhansi I (12KLD)	FS	7.8	37347	1670	35677	75166.7	9774.5	1200.5	309.4	311.3	5114333
	Inlet	7.9	1513.3	1004	509.3	185.3	46.9	35.6	22.7	4.6	480000
	Outlet	8.5	788	624.7	163.3	75.3	19.7	15.7	4.3	0.9	2165
Amethi	FS	7.8	9075	2755	6320	8500	1576.2	757.8	336.3	56.6	2300750
	Inlet	7.7	1809	1434.5	374.5	151	42.4	35.6	27.8	7	33500
	Outlet	8.2	1391	1295	96	107	30.1	15.1	6.7	5.3	2400
Bijnor	FS (truck)	8.2	47684	3040	44644	79750	11574.7	767	102.9	534	230000
	FS (Equ. tank)	7.8	64888	1780	63108	100450	14579.1	897	62.7	660	4300000
	Inlet (Leachate)	7.8	2846	1910	936	338	82.4	11.2	4.2	9.4	210000
	Inlet (STP+ FSTP)	7.9	1031	811	220	164	40	16.2	3.3	3.5	2300000
	Outlet	8.4	509	484	25	64	15.6	11.5	4.2	3.3	30
Unnao	FS	7.4	63807.2	1890	57489	164500	10960	2211.8	441.3	509.4	304080
	Inlet	7.7	2980.8	1249	1731.8	486.8	88.8	175.1	111	27.7	2603
	ABR outlet	7.9	1285	1067.8	217.2	132.8	28	64.4	55.3	7.5	1196
	Outlet	8	1126.4	1057.2	69.2	53.6	8.4	30.1	25.4	4.6	69
Bharwara	FS	7.5	55077	1490	62654.5	74000	3786.6	2296.8	499	292.8	1952000
	Co-treated wastewater	7.2	750.2	563.4	186.8	336.4	104.8	89.5	42.4	6	2808600
	Inlet STP	7.6	672.8	558	114.8	253	61.8	76.7	37.6	5.6	957000
	UASB Outlet	7.7	556.6	487	68.8	120.2	32.4	62.1	33.1	3.3	287200
	Outlet Before chlorination	7.6	569.6	519.2	50.4	78.6	18.2	35.2	27.7	2.8	71800
	Outlet After chlorination	7.82	553.8	506.8	47	78.4	12.44	33.348	26.12	2.688	54600
Jhansi II (6KLD)	FS	7.3	33240.7	2090	15400	42919.4	1870.7	1163	233.8	179	20686667
	ABR Inlet	7.3	2240	1413.6	826.4	279.3	40.7	38.3	29.6	6.6	3748444

Locations	Sample type	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammo-niacal Nitrogen (mg/L)	Total Phos-vphate (mg/L)	Fecal Coliform (MPN/100 ml)
	Outlet	7.7	1751.6	1235.2	518.2	144.4	16.7	10.3	5.5	2.8	16593
Chunar	FS	7.1	79352	1984	77368	95366.7	11286.3	1691.5	293.1	246.4	4866667
	Inlet	7.7	1306	1174	132	90.7	29	79.3	67.7	3.8	31100
	Outlet	7.4	1189.3	1112.3	77	59.7	14.7	21.8	14	1.3	3820
Bingawan STP	FS	7.4	27580	2635	35894	27148.7	2648.3	1169.7	389.1	110.3	3171000
	Inlet	7	1183.7	782.3	401.3	494.7	130	86.4	45	7.7	165333
	Outlet	7.7	771.3	679.3	92	93.7	13.2	41.6	32.8	4.7	100666.7

Table 6: Physico-chemical and biological parameter of the samples collected from Madhya Pradesh and Chhattisgarh

Locations	Sample type	pH	TS (ppm)	TDS (ppm)	TSS (ppm)	COD (ppm)	BOD (ppm)	TKN (ppm)	Ammo-niacal Nitrogen (ppm)	Total Phos-phate (ppm)	Fecal Coliform (MPN/100 ml)
Patora	FS	8.0	82593	2080	80513	79475	16916.5	2135.9	381.4	470	2765000
	Inlet	7.9	1359	1180	179	220.7	53	137.1	116.7	6.8	5906.7
	Outlet	8.4	780.7	738.7	42	89	22	29.5	20.2	1.4	117.3
Kumhari	FS	7.4	18614.5	810	17804.5	35542.5	8266.5	923.2	68.3	103.5	5965000
	Inlet	7.5	1024.7	799	225.7	146.7	35.7	51.4	41.6	3.1	19233.3
	Outlet	8.2	714.3	645	69.3	68.7	17	12.7	7.2	0.2	2310
Kalibillod, Indore	Inlet	8.2	6660.7	2809.3	2528.3	304	69.3	22.6	13.3	2.6	77066.7
	Outlet	8.0	2960.3	1852.7	1107.7	119	27.7	8.5	2.1	0.9	4026.7
Ojus	Inlet	6.7	746.5	549.5	197	350	103.9	44.5	32.2	6.4	596500
	Outlet	7.1	490	456	34	19.5	6.5	7.3	1.8	0.115	233
Elanza	Inlet	6.7	1714.5	858.5	855	721	202.3	90.5	64.5	14.8	1665000
	Outlet	7.2	745	676	69	38.5	11.5	11.5	4.1	1.0	14300
St.Alosius	Inlet	7.2	1077.5	770	307.5	144	41.5	36.5	26.8	3.6	21715
	Outlet	7.7	915.5	810.5	105	28	8.6	10.1	1.7	3.3	133

Table 7: Physico-chemical and biological parameter of the samples collected from Uttarakhand

Locations	Sample type	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammo-niacal Nitrogen (mg/L)	Total Phos-phate (mg/L)	Fecal Coliform (MPN/100 ml)
Lakkarghat	Inlet	7.3	682.3	465.3	217	520	79.2	58.8	24.3	7	847333
	Outlet	7.8	455.3	389.7	65.7	48	7.5	20.6	9	0.7	561
Chorpani	Inlet	7.2	869	567.7	301.3	697.7	130	61.8	42.8	8.6	1516667
	Outlet	7.5	580	506.7	73.3	77.7	11.9	30.2	24.6	4.2	374433
Chandreswar	Inlet	7.3	493.7	349	144.7	297.7	59.7	19.6	9.7	2.3	1611433
	Outlet	7.6	359.3	303.7	55.7	46.3	7	3.3	1.2	0.5	11933
Tapovan	Inlet	7.1	1169	783.7	385.3	749.7	194.3	48.2	35.3	8.1	713333
	Outlet	7.8	587.7	474.3	113.3	78	3.8	5.5	1.4	1.6	5767
Mothrowala-I (20)	Inlet	7.3	707.7	544.3	163.3	390.7	59.5	35.6	24.2	5.3	16410000
	Outlet	7.9	520.7	432	88.7	39.7	4.3	9.9	4.5	1.3	25833
Mothrowala-II (20)	Inlet	7.4	638.3	502	136.3	299	59.9	31.9	22.8	4.6	23383333
	Outlet	7.6	512	428.3	83.7	57.3	13.3	3.7	1.9	2.3	3151
Indira Nagar	Inlet	7.4	677	527.7	149.3	405.3	71.2	32.4	23	4.3	38866667
	Outlet	7.8	583.3	518	65.3	30.3	7.9	14.5	12.6	1	36678
Jagjeetpur-I (68)	Inlet	7.3	619.5	398	221.5	368.5	103.5	22	14.7	3.6	680000
	Outlet	7.7	382	328.5	53.5	23.5	3.8	4.2	3.2	0.3	117
Jagjeetpur-II (27)	Inlet	7.2	557	392.5	164.5	425	90	24.8	18.5	4.5	2115000
	Outlet	7.8	383	323	60	103	13	5	2.3	1.1	16
Jagjeetpur-III (18)	Inlet	7.3	573.5	389.5	184	320	93.5	29.7	18.8	4.6	4765000
	Outlet	7.7	419.5	363	56.5	37.5	10	2.7	1.6	2.9	2302
Sarai-I (18)	Inlet	7.2	805	495.5	309.5	606	108	49	23.6	6.2	4765000
	Outlet	7.9	503	415	88	62.5	12	2.8	1.5	0.9	13
Sarai-II (14)	Inlet	7.2	870.5	511.5	359	638	149.5	49.6	24.4	7.2	1350000
	Outlet	7.3	516	470.5	45.5	86	19	22.3	17.6	2.5	460000

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