PERFORMANCE EVALUATION

HOW FAECAL SLUDGE TREATMENT PLANTS ARE PERFORMING

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1 Introduction

In recent years, both government and private bodies have placed a great deal of emphasis on rural and urban sanitation processes to reduce health risks among the Indian population. Several types of on-site technologies such as pit latrines, septic tanks, bio-toilets adapted to public toilets, e-toilets and dry toilets have brought about significant changes in civic life.

Most of the low- and middle-income groups of the country reportedly currently rely on on-site technologies that produce tonnes of untreated faecal sludge every day. When septic tanks or pit latrines are full, the sludge collected from them is largely discharged untreated into open drains, irrigation fields, open lands or surface waters.[1] Untreated faecal sludge discharged into the open environment poses serious public-health risks. The World Bank estimates that poor sanitation contributes to 1.5 million child deaths from diarrhoea every year.

To address the above challenges, several faecal sludge treatment plants (FSTPs) have been set up across the country, while some are in the installation phase. The FSTPs 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.

To understand the efficacy or effectiveness of FSTPs in treating faecal sludge, an intensive study was conducted on 12 diverse technologies of treatment process.

2 Objective

- To analyse the treatment efficiency of the leachate in the FSTPs based on design, working principle, operation and maintenance procedures

Globally, 2.7 billion people rely on un-sewered sanitation systems.[2] This population comprises not only rural inhabitants, but also the majority of urban inhabitants in low- and middle-income countries. Most developing cities have insufficient infrastructure to manage and treat the faecal sludge accumulated in onsite sanitation facilities such as pit latrines and septic tanks.[3] In the absence of a sewerage system, faecal sludge and septage need to be safely managed.

Safe faecal sludge and septage management (FSSM) includes safe containment of excreta in an onsite sanitation system, and regularly emptying and transporting faecal sludge and septage to a FSTP. With increased acknowledgment of the Swachh Bharat Mission and of the importance of faecal sludge management (FSM), FSTPs have begun to be constructed in India. 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.

3 Methodology

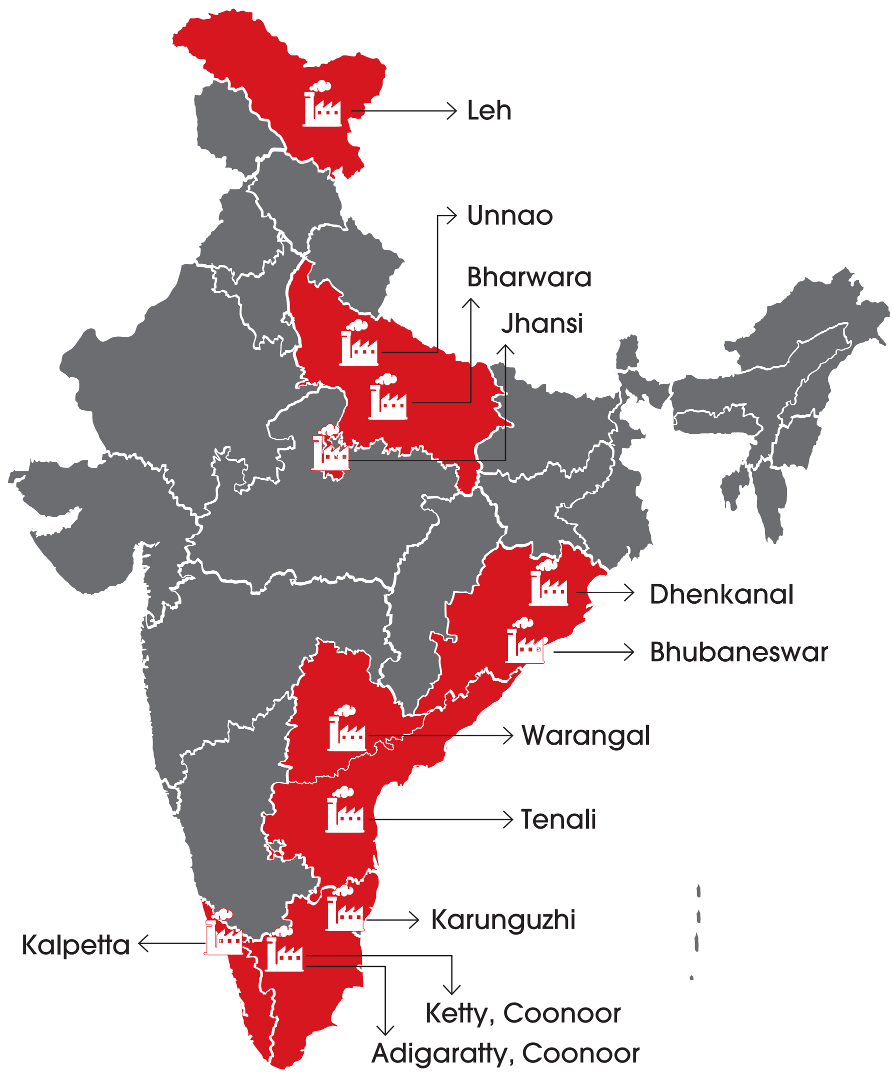
3.1 TECHNOLOGIES ADOPTED FOR THE CURRENT STUDY

Faecal sludge management (FSM) is the collection, transport, and treatment of faecal sludge from pit latrines, septic tanks or other on-site sanitation systems.[4] Faecal sludge is a mixture of human excreta, water and solid wastes (e.g. toilet paper) that are disposed in pits, tanks or vaults of on-site sanitation systems. Faecal sludge that is removed from septic tanks—called septage—is treated in FSTPs before it is discharged to the environment by means of diverse technologies.

The performance efficiencies of selected technologies in the current study is as below:

S. no	FSTP location	Technology	Description	Post treatment
1	Bhubaneswar, Odisha	Decentralized wastewater treatment system (DEWATS)	Settler, anaerobic baffled reactor (ABR) and planted gravel filter (PGF)	No tertiary treatment
2	Dhenkanal, Odisha	Decentralized wastewater treatment system	Unplanted sludge drying bed (USDB), ABR and PGF	Tertiary treatment using sand filter and activated carbon filter
3	Jhansi, Uttar Pradesh	Decentralized wastewater treatment system	Planted sludge drying bed (USDB), ABR and PGF	No tertiary treatment
4	Karunguzhi, Tamil Nadu	Decentralized wastewater treatment system	Unplanted sludge drying bed (USDB) and PGF but without ABR	No tertiary treatment
5	Ketty, Tamil Nadu	Decentralized wastewater treatment system	Planted sludge drying bed (PSDB) and PGF but without ABR	No tertiary treatment
6	Adigaratty, Tamil Nadu	Decentralized wastewater treatment system	Planted sludge drying bed (PSDB) and PGF but without ABR	No tertiary treatment
7	Leh, Ladakh	Decentralized wastewater treatment system	Planted sludge drying bed (PSDB) and PGF but without ABR	No tertiary treatment
8	Unnao, Uttar Pradesh	Decentralized wastewater treatment system	Screw press technology for solid–liquid separation, integrated settler, ABR, PGF	Tertiary treatment using sand filter, activated carbon filter and UV radiation
9	Warangal, Telangana	Package STP and pyrolysis	Anaerobic, anoxic, aeration and sedimentation zones	Tertiary treatment using sand filter, activated carbon filter and chlorination
10	Tenali, Andhra Pradesh	Moving bed biofilm reactor (MBBR)	MBBR, tube settler and clarifier	Tertiary treatment using sand filter, activated carbon filter and chlorination
11	Kalpetta, Kerala	Tiger bio-filter technology	Anaerobic digestion followed by two stage vermin-filtration	Tertiary treatment using sand filter, activated carbon filter and chlorination
12	Bharwara, Uttar Pradesh	STP co-processing	Upflow anaerobic Sludge blanket (UASB), pre-aeration tank, polishing pond	Tertiary treatment using chlorination

Locations of FSTPs for the current study



Source: CSE 2020

3.2 SAMPLING STRATEGY

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. Sampling is carried out to support a study or research project. 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 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.

3.2.1 Seasonal variation

Studies were conducted to capture the seasonal variability of data, and samples were picked to cover winter, summer, autumn and the rainy season. To arrive at a significant outcome, the sampling plan was sometimes extended to more than eight months.

3.2.2 Sampling equipment and consumables

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

For the performance evaluation of an FSTP, at least three bottles of samples were collected from each location as described below:

i. Fresh faecal sludge from tanker or at the inlet of the drying beds or settler—500 ml (faecal sludge)
ii. Influent stream into the anaerobic baffled reactor (ABR) or planted gravel filter (PGF) bed—500 ml (inlet)
iii. Final effluent from the treatment system—1000 ml (outlet)

Composite sampling from the tanker was initiated by assessing the unloading time of septage from the tanker. The slurry removed from the containment was assumed to be stratified into distinct portions within the tanker.

If 'T' is the unloading time and 't' is the time interval between two successive sample collection for 'n' number of samples of equal volume, t = T/(n–1). Usually 'T' is taken as '10 minutes' and 't' = 2.5 minutes and 'n' = 5. Then periodicity of sample collection is as follows:

'0' minutes (at the beginning)
'0 + t' minutes (2.5 minutes)
'0 + 2t' minutes: (5 minutes)
'0 + 3t' minutes: (7.5 minutes)
'0 + 4t' minutes: (10 minutes, at the end)

A composite sample was prepared by mixing equal volumes of the above five samples in a bucket and then a 500ml sludge sample is collected in a clean 500ml plastic bottle. In all circumstances, the sample bottle was first washed with a representative sample twice or thrice, followed by sampling with minimum head space.

3.2.3 Parameters selected for characterization of septage and wastewater

1. pH—APHA 4500-H^+B, 23rd Ed, 2017
2. Total suspended solids—APHA 2540-D, 23rd Ed, 2017
3. Total dissolved solids—APHA 2540-C, 23rd Ed, 2017
4. Chemical oxygen demand (COD—APHA 5220-D, 23rd Ed, 2017
5. Biological oxygen demand (BOD)—Automated BOD analyser

6. Total kjeldahl nitrogen—APHA 4500-N_{org} C
7. Ammoniacal nitrogen—APHA 4500-NH_3 C
8. Total phosphorus—APHA 4500-P E
9. Faecal coliform—USDA, MLG Appendix 2.05

3.3. DATA ANALYSIS AND RESULT INTERPRETATIONS

Public and private raw faecal sludge samples were both taken at the discharge site directly from the trucks. The leachate and final outlet water were collected in the respective locations from the FSTPs. Analyses were conducted according to standardized and well-documented methods and protocols.[5] 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. Results were presented as the mean ± error.

3.4. EXISTING EFFLUENT DISCHARGE STANDARDS AND RECOMMENDATIONS

In India, the major source of water pollution has been observed to be the discharge of untreated sewage and faecal sludge and septage (FSS) into existing waterbodies. There have been frequent revisions to discharge standards over the last 10 years with regard to limits and overall parameters as well as to shifting from one fixed set of standards to another irrespective of end uses over land or discharge to waterbodies. Continuous revision and formulation of discharge standards by the National Green Tribunal (NGT), from stringent in 2015 to relaxed (dilution) in 2017 and back again to stringent standards in 2019, has led to the inconsistencies in performance within the sector.

STPs/FSTPs are recommended to be designed so that they can handle—or eliminate—the increasing load of contaminants in wastewater and so that the effluent from them can comply with the national standard in accordance with end uses of discharged water. Therefore, depending on utilization of effluent water, regulatory norms have been promulgated to safeguard public health and environment as follows:

Table 1: Indian standards over time

S. no.	Parameters	General norms[1] 1986				Draft norms November 2015**	MoEFCC Notification, October 2017**	NGT order 2019** (for mega and metropolitan cities)
		Inland surface water	Public sewers	Land irrigation	Marine coastal areas			
1	BOD [mg/l]	30	350	100	100	< 10	< 30 < 20 (metro cities)	<10
2	COD [mg/l]	250	–	–	250	50	Not more than 50 (for new STP design)	< 50
3	TSS [mg/l]	100	600	200	100 process water 10% of influent cooling water	< 20	< 100 < 50 (metro cities)[2]	< 20
4	TKN [mg/l]	100	–	–	100	< 10	Not more than 10 (for new STP design)	< 10
5	NH3-N [mg/l]	50	50	–	50	< 5	Not more than 5 (for new STP design)	–
6	Dissolved phosphorus [mg/l]	5	–	–	–	–	–	<1
7	Faecal coliform [MPN/100ml]	–	–	–	–	< 100	< 1000	Permissible < 230

Source: NGT 2019, MoEFCC 1986, 2015 and 2017

1. The standards set in 1986 cover 33 parameters, which are not depicted in this table.
2. Metro cities, all state capitals except for the states of Arunachal Pradesh, Assam, Manipur, Meghalaya Mizoram, Nagaland, Tripura Sikkim, Himachal Pradesh, Uttarakhand and Jammu and Kashmir and the Union Territories of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and the Lakshadweep areas/regions.

** Standards applicable for discharge into waterbodies and land disposal/applications, while reuse is encouraged.

4 Result analysis

The test parameters that should be considered for the evaluation of the treatment systems include solids concentration, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nutrients and pathogens. These parameters are the same as those considered for domestic wastewater analysis.

However, it needs to be emphasized that the characteristics of domestic wastewater and faecal sludge are very different. To evaluate the treatment efficiency of the FSTPs we tested and analysed 10 different parameters; four important parameters for each FSTPs are represented here.

(A) FAECAL COLIFORM

Faecal sludge contains large amounts of microorganisms, originating mainly from faeces. These microorganisms can be pathogenic, and exposure to untreated faecal sludge constitutes a significant health risk to humans, either through direct contact or indirect exposure. Faecal sludge needs to be treated to an adequate hygienic level based on the end use or disposal option.

Coliform bacteria populate the intestinal tract, and are pervasive in faeces. Their presence in the environment is therefore used as an indicator of faecal contamination. The standard method of analysing thermo-tolerant faecal coliforms relies on their production of acid and gas from lactose when incubated at 44.5°C

(B) TOTAL SOLIDS

The total solids concentration of faecal sludge comes from a variety of organic (volatile) and inorganic (fixed) matter. It comprises floating material, settleable matter, colloidal material, and matter in solution. Total solids are quantified as the material remaining after 24 hours of drying in an oven at 103–105°C.

(C) CHEMICAL OXYGEN DEMAND

Chemical oxygen demand (COD) is a measure of the total organic compounds that can be degraded by chemical processes. COD represents the oxygen equivalent of organic matter that can be oxidized chemically with dichromate, a powerful chemical oxidant.

(D) BIOCHEMICAL OXYGEN DEMAND

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

PLANT-WISE ANALYSIS
BHUBANESWAR, ODISHA

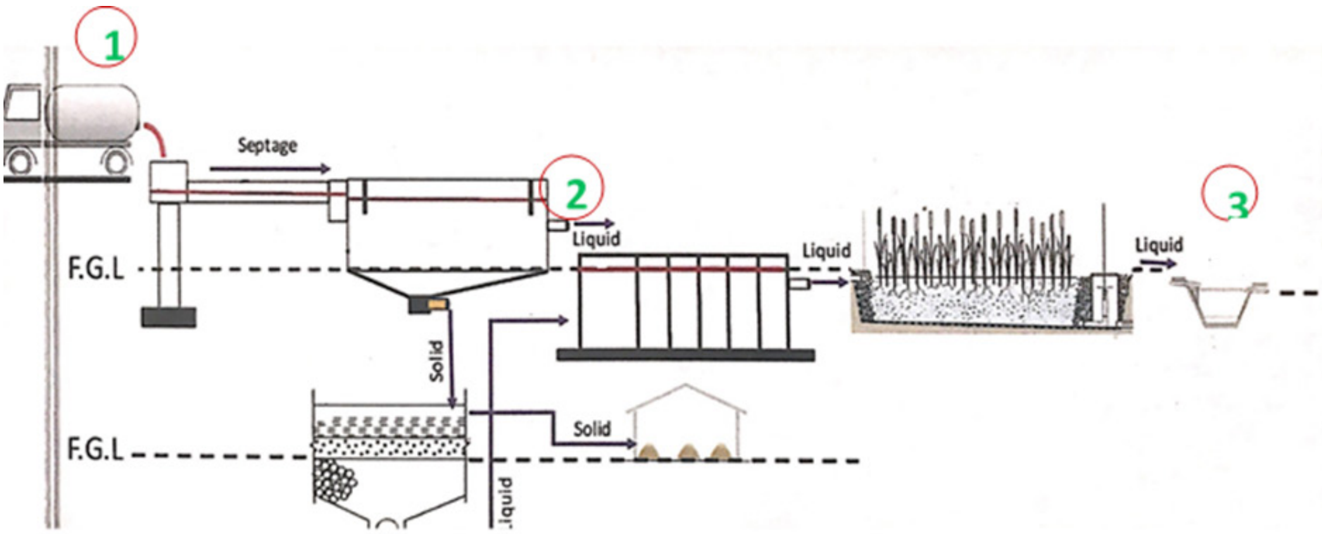
Capacity: **75 KLD**
Operator: **Odisha Water Supply and Sewerage Board (OWSSB)**
Study period: **April–September 2019 (six months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: The Bhubaneswar faecal sludge treatment plant (FSTP) is located in southeast Bhubaneswar, the state capital of Odisha. It was funded by the AMRUT (Atal Mission for Rejuvenation and Urban Transformation) Scheme, and OWSSB (Odisha Water Supply and Sewerage Board) designed it and supervised the construction. The plant started operation in June 2018 and was designed for a capacity of 75 KLD, with possible expansion plan to 150 KLD. It is the first and only FSTP of the city that mainly relies on on-site sanitation systems.

Faecal sludge settling–thickening tanks and dried-sludge storage sheds at the Bhubaneswar FSTP

The treatment consists of two settling-thickening tanks and eight unplanted drying beds. The leachate is treated in two parallel series of anaerobic baffle reactors, anaerobic filters, horizontal flow constructed wetlands and slow sand filters. The effluent is stored in a polishing pond equipped with an aeration pump. The dried sludge is stored in a storage shed.

Process flow and sample collection points



Source: CSE 2020

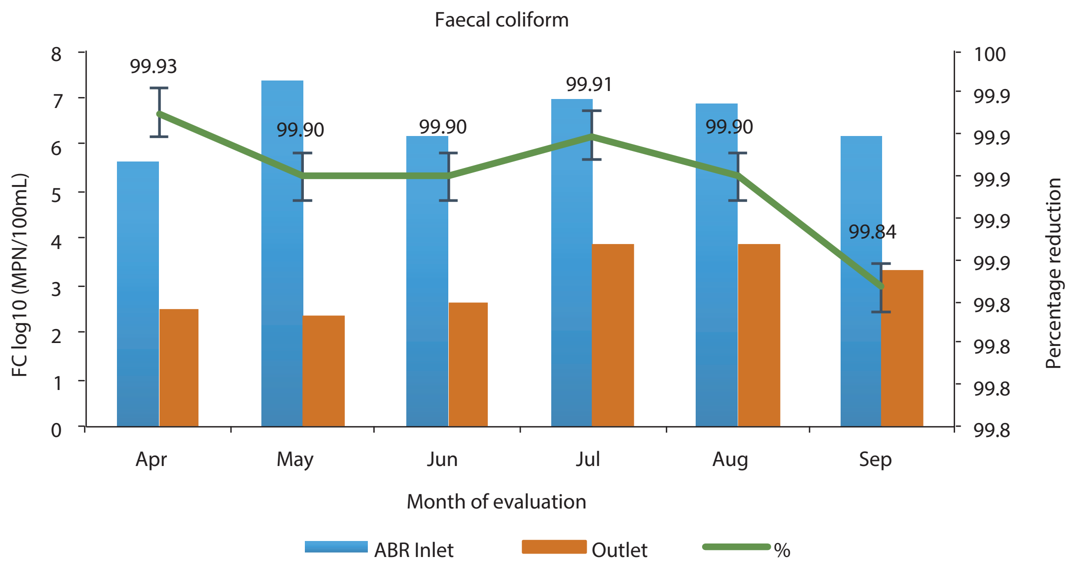
1. Fresh faecal sludge from the tanker
2. ABR inlet
3. Polishing pond

Physicochemical and biological parameters of the samples tested

S. no.	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Apr 2019	Faecal sludge	6.75	10,464	NT	NT	9,800	1,690	198	55.3	28.3	4,300,000
2	Apr 2019	ABR inlet	7.99	403	294	109	248	80	76	71.1	10.3	430,000
3	Apr 2019	Outlet	7.63	354	200	154	89	23	12.2	7.7	0.3	300
1	May 2019	Faecal sludge	6.62	2,250	NT	NT	3260	326	129.6	83.2	21.3	43,000,000
2	May 2019	ABR inlet	6.88	793	663	130	632	85	112.4	111.4	13.6	23,000,000
3	May 2019	Outlet	6.75	332	314	18	55	18	16	3.9	0.4	230
1	Jun 2019	Faecal sludge	6.8	3,191	249	2,942	8,025	325	84.5	8.2	76	2,300,000
2	Jun 2019	ABR inlet	7.1	2,136	979	1,157	414	91	111.5	104.3	4	1,500,000
3	Jun 2019	Outlet	6.8	2,129	378	1,751	49	7	16.6	13.1	3.9	430
1	Jul 2019	Faecal sludge	6.55	17,637	NT	NT	34,300	3,051	684.3	175.7	99.5	7,500,000
2	Jul 2019	ABR inlet	7.26	832	555	277	318	43	100.8	91.7	7.8	9,300,000
3	Jul 2019	Outlet	7.69	485	248	237	97	22	38.4	37.2	3.2	7,500
1	Aug 2019	Faecal sludge	7.64	1,768	NT	NT	7,475	570	190.27	151.49	20.5	23,000,000
2	Aug 2019	ABR inlet	8.08	1,150	914	236	566	88	132.2	124.06	5.48	7,500,000
3	Aug 2019	Outlet	8.32	708	544	164	122	18	69.81	65.81	3.16	7,500
1	Sep 2019	Faecal sludge	7.19	43,886	NT	NT	47,450	2,940	914.36	277.64	149	9,300,000
2	Sep 2019	ABR inlet	7.57	1,583	1,100	483	370	34	130.74	116.33	7.54	1,500,000
3	Sep 2019	Outlet	7.89	575	452	123	40	8	32.03	19.83	3.14	2,300

(A) FAECAL COLIFORM

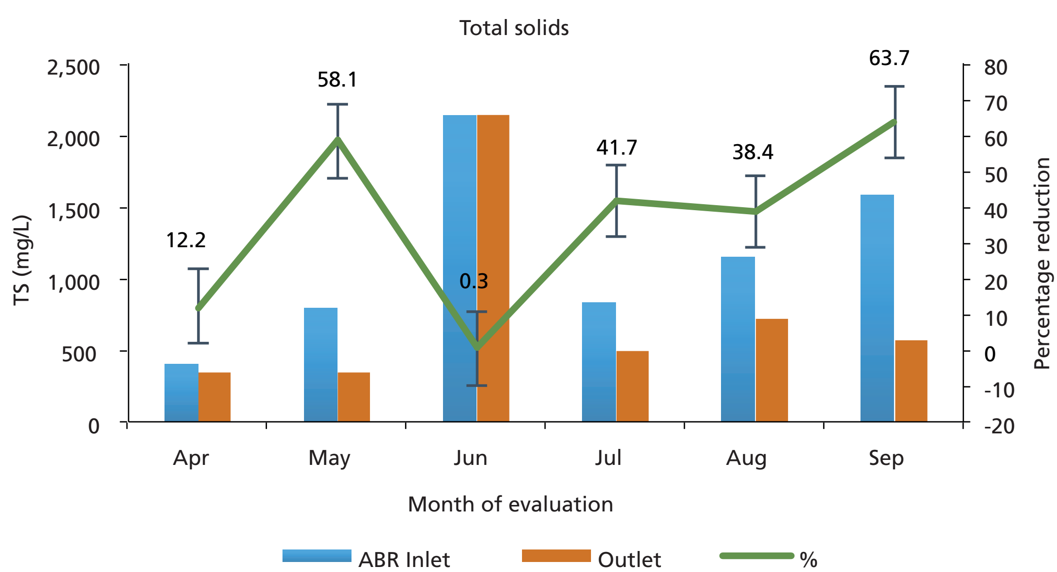
A reduction in faecal coliform to the extent of 2–5 log value was measured in the leachate while it passed through the series of anaerobic baffle reactors, anaerobic filters, and horizontal flow constructed wetlands. An overall reduction of 99 per cent was observed in all the months of evaluation.



Source: CSE 2020

(B) TOTAL SOLIDS

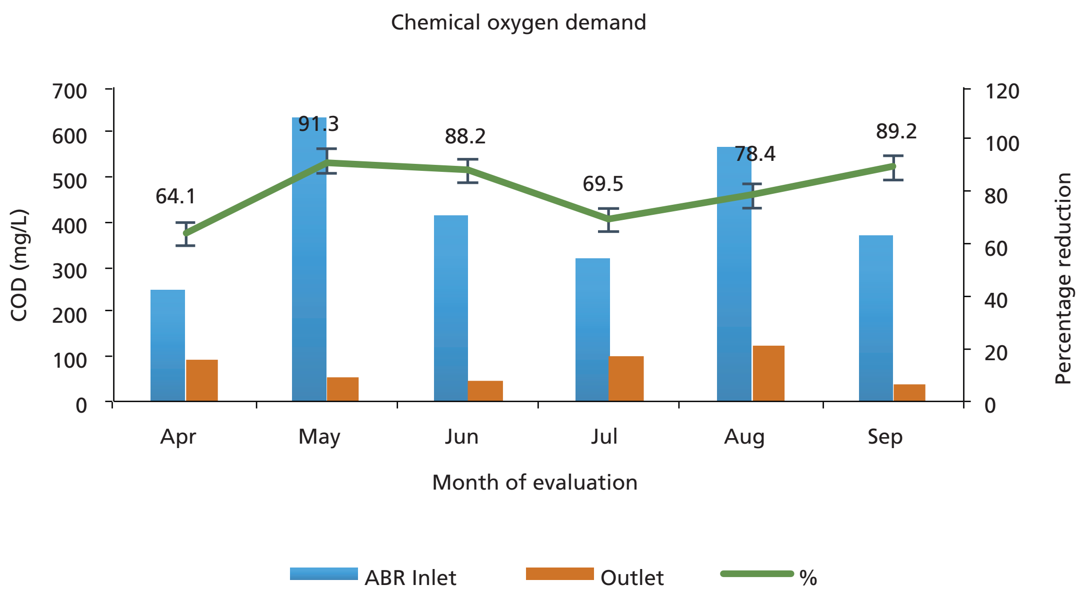
During the six months of evaluation, total solid removal of 0–64 per cent total solid was noted in the system. The overall percentage removal of the system was 36 per cent. This may due to the microalgae growth in the polishing pond, which contributed in the total solids in waterbodies.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

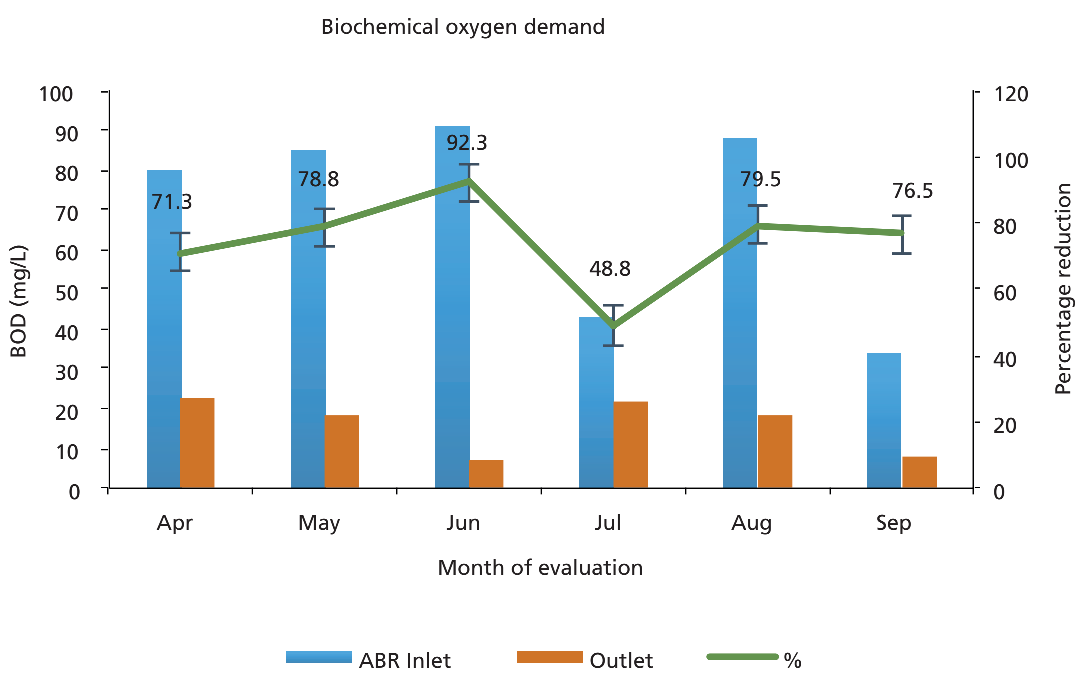
During the evaluation period, chemical oxygen demand (COD) reduced by 64–91 per cent, with an average value of 80 per cent.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD) reduced by 49–92 per cent during the study period of six months, with an average reduction of 75 per cent.



Source: CSE 2020

DHENKANAL, ODISHA

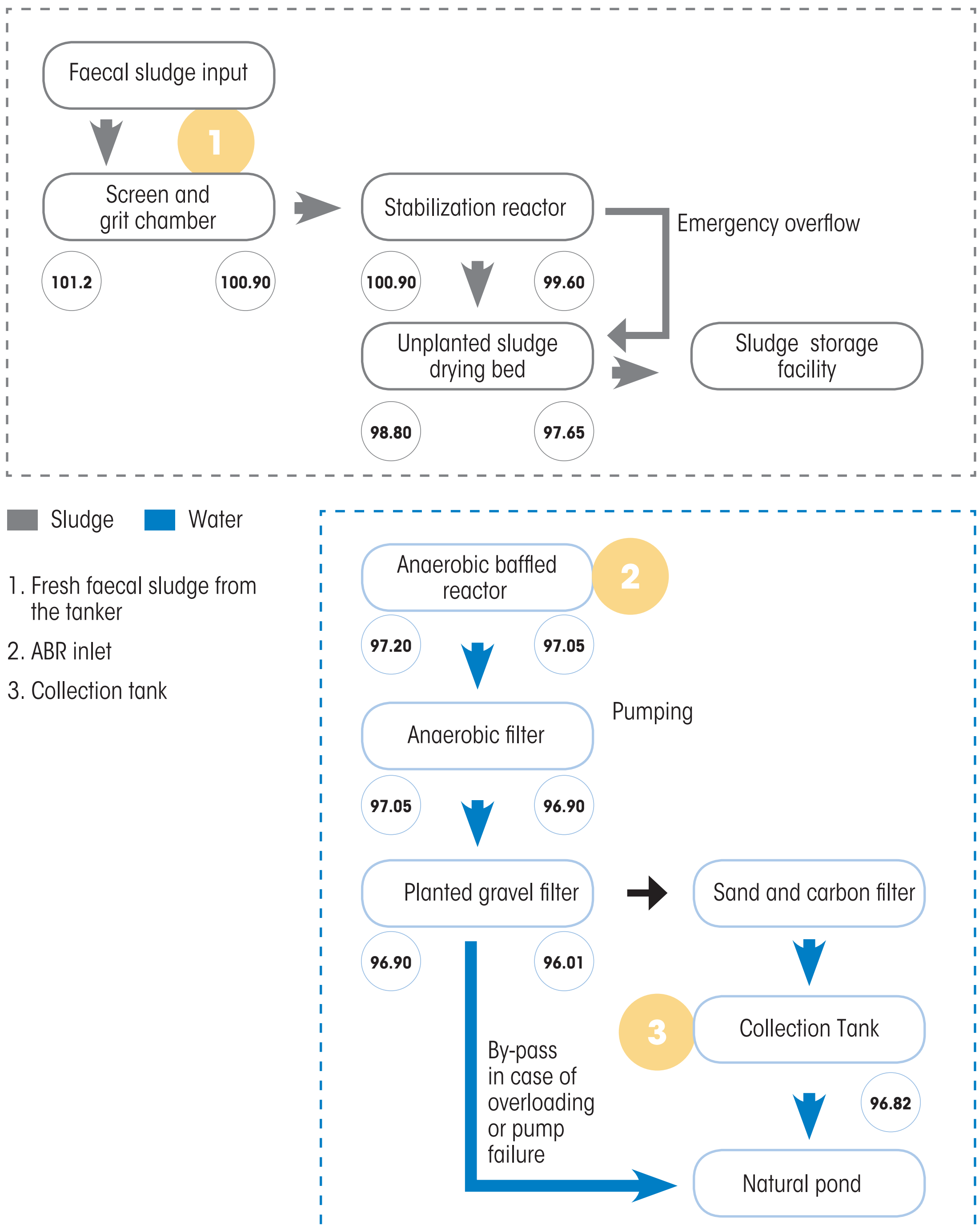
Capacity: **27 kilolitres per day (KLD)**
Operator: **Blue Water Company**
Study period: **April–September 2019 (six months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: The Dhenkanal faecal sludge treatment plant (FSTP) is Odisha's first FSTP to serve the purpose of completing the sanitation value chain. Built by collective action of sanitation alliances with the Dhenkanal Municipality and the government of Odisha, it has a capacity of 27 KLD.

The main treatment steps followed in this FSTP are solid–liquid separation, stabilization, dewatering of sludge and pathogen removal. De-sludge trucks convey faecal sludge to the FSTP. The treatment modules for solid components are the feeding tank (FT) with screen chamber, stabilization reactor, stabilization tank (ST), and unplanted sludge drying bed (SDB) with greenhouse solar drier roof (GHSD). Treatment modules for liquid components include integrated settler, anaerobic baffled reactor with filter chambers, planted gravel filter (PGF), sand and carbon filter, and collection tank. The treatment system also consists of a co-composting unit where the dried sludge from the SDB is composted with municipal solid waste.

Unplanted sludge drying bed at the Dhenkanal FSTP

Process flow and sample collection points



Source: CSE 2020

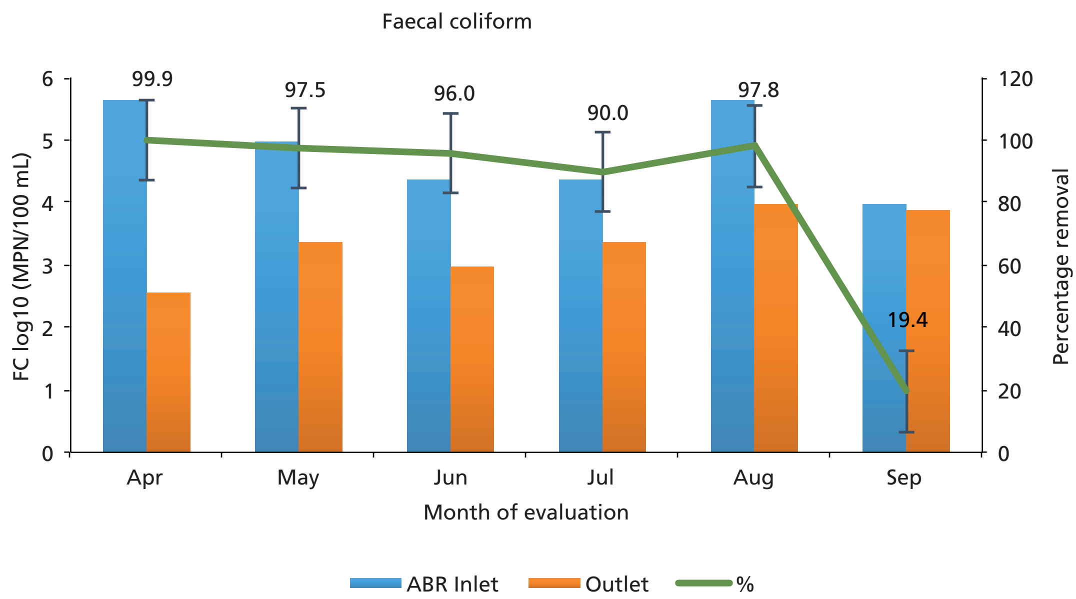
Physicochemical and biological parameters of the samples tested

S. no.	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Apr 2019	Faecal sludge	7.1	22,024	NT	NT	41,600	2512.0	1030.8	192.2	106	11,000,000
2	Apr 2019	ABR inlet	7.7	5,520	1,350	4,170	1,700	49.0	119.1	93.9	1.0	430,000
3	Apr 2019	Post-filtration outlet	7.8	1,381	1,010	371	134	9.0	51.3	47.1	0.5	360
1	May 2019	Faecal sludge	7.1	41,259	NT	NT	64,200	2830.0	739.6	244.6	352	2,300,000
2	May 2019	ABR inlet	6.8	16,856	1,130	15,726	1,810	168.0	43.4	34.6	19	93,000
3	May 2019	Post-filtration outlet	6.9	1,200	1,050	150	30	7.0	34.1	27.6	4.8	2,300
1	Jun 2019	Faecal sludge	7.2	22,750	1,170	21,580	40,000	2,510.0	1,156.1	229.4	197	1,500,000
2	Jun 2019	ABR inlet	7.3	2,938	1,190	1748	362	20.0	88.8	74	13.9	23,000
3	Jun 2019	Post-filtration outlet	6.5	1,484	1,010	474	42	6.0	27.7	26.5	3.9	930
1	Jul 2019	Faecal sludge	7.2	14,344	NT	NT	32,900	2,750	891.1	186.4	161	9,300,000
2	Jul 2019	ABR inlet	7.3	1,532	1,250	282	482	70	48.6	45.4	9.3	23,000
3	Jul 2019	Post-filtration outlet	6.5	960	816	144	39	10	30.5	29.28	6.4	2,300
1	Aug 2019	Faecal sludge	7.81	10,270	NT	NT	25,950	1500	634.81	124.64	75	2,300,000
2	Aug 2019	ABR inlet	8.01	1,571	1,250	321	262	90	68.43	62.61	6.48	430,000
3	Aug 2019	Post-filtration outlet	8.53	961	896	68	91	15	23.87	23.4	3.27	9,300
1	Sep 2019	Faecal sludge	7.44	15,612	NT	NT	3,300	1,900	952.22	221.2	133	1,500,000
2	Sep 2019	ABR inlet	7.45	1,986	1,210	776	188	34	47.17	34.35	6.92	9,300
3	Sep 2019	Post-filtration outlet	7.49	976	768	208	38	8	14.85	12.11	4.35	7,500

Source: CSE 2020

(A) FAECAL COLIFORM

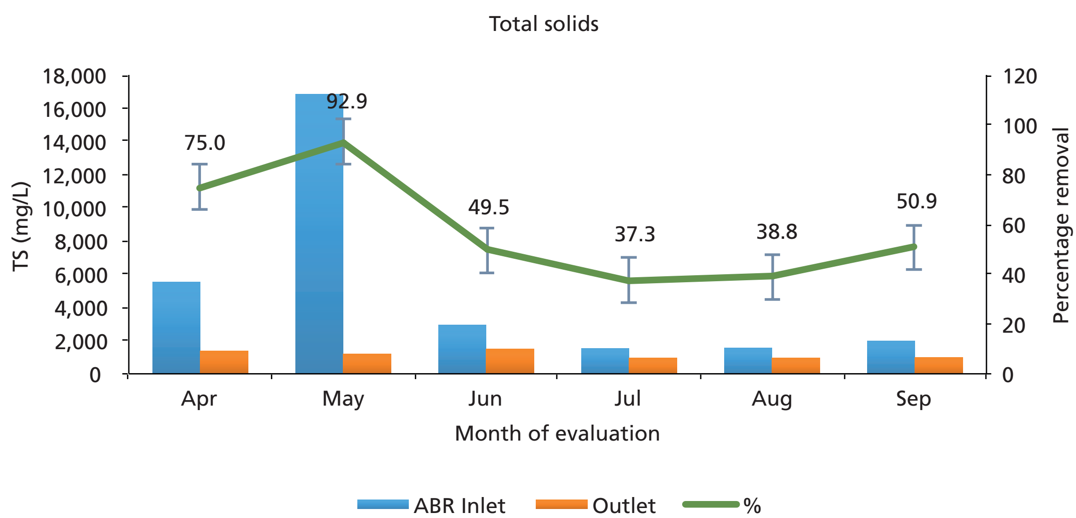
Reduction in faecal coliform to the extent of 1–4 log value was measured in the leachate while it passed through the series of anaerobic baffle reactors, anaerobic filters, and horizontal flow constructed wetlands.



Source: CSE 2020

(B) TOTAL SOLIDS

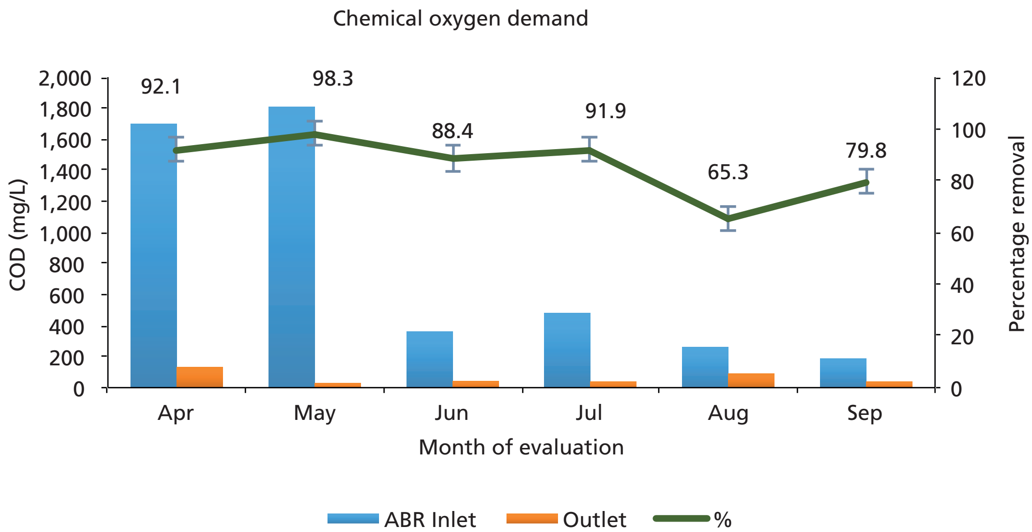
During the evaluation period, total solid removal of 37–92 per cent was noticed in this treatment system, with an average of removal efficiency of 57 per cent.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

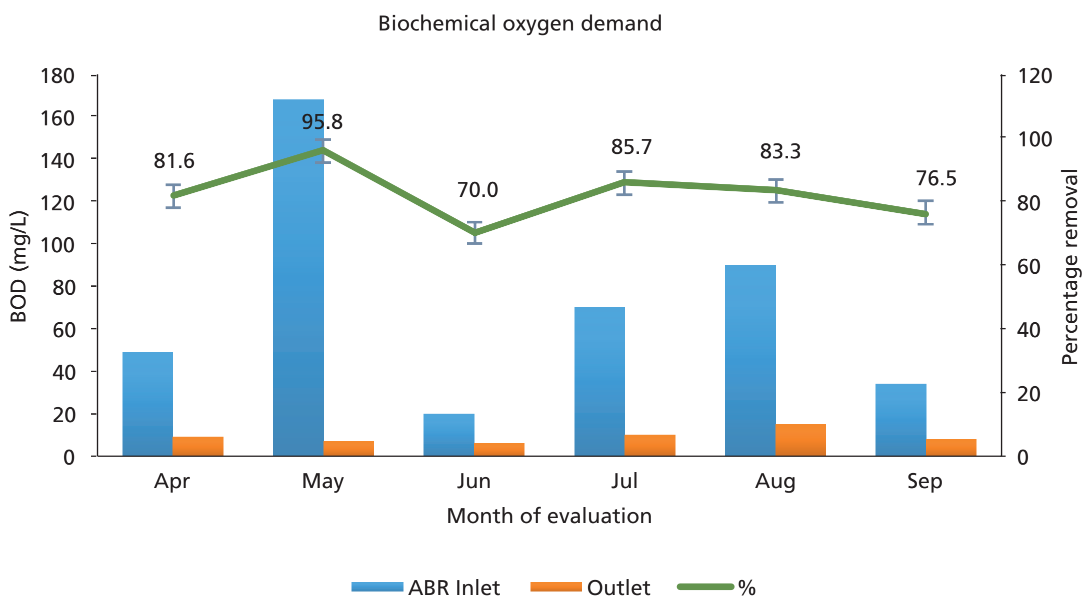
During the evaluation period, a reduction of 65–98 per cent in COD was observed in the treatment plant, with an average reduction of 85 per cent.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

A reduction of 70–95 per cent in BOD values was observed during the evaluation period, with an average removal efficiency of 82 per cent. The final discharge water met the discharge standards (20mg/L) limit.



Source: CSE 2020

JHANSI, UP

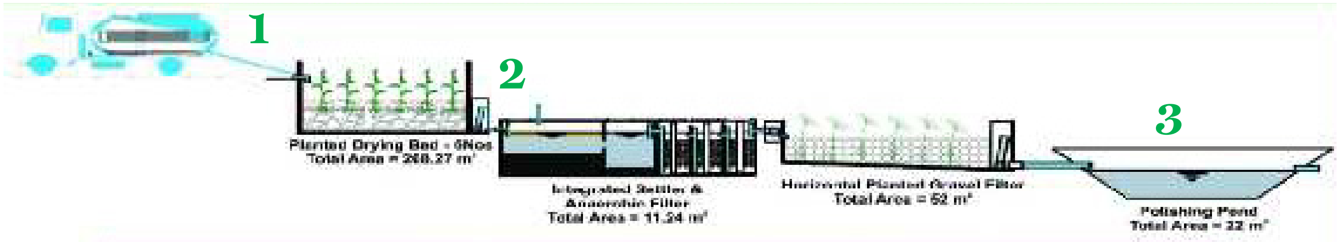
Capacity: **6 KLD**
Operator: **Purna Pro Enviro Engineers Pvt. Ltd, Indore**
Study period: **January–September 2019 (nine months)**
Sample collection and analysis: **Environmental Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: The Jhansi FSTP was designed for a capacity of 6 KLD. 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 percolated water at the bottom is treated separately in DEWATs modules. The percolate from the PDBs is treated in an integrated settler and anaerobic filter. Although most of the solids are retained on the top of the PDB, a small portion enters into the percolate. Solids are separated through sedimentation in the settler before the water enters into the anaerobic filter. The anaerobic filter consists of three chambers in a series in which the wastewater flows through down-take pipes, enabling water to reach the bottom of the tank. Here, the suspended and dissolved solids present in the wastewater undergo anaerobic degradation. As wastewater flows through the filter media, particles are trapped and organic matter is degraded by the biomass that is attached to the filter material. Planted gravel filter is used as an aerobic tertiary treatment unit, where the pollutants (mostly nutrients) present in the wastewater are degraded by wet plants. In order to remove the odour and colour and to enrich the wastewater with oxygen, the wastewater is finally aerated in a polishing pond. The dried sludge is stored separately in a storage shed.

Planted sludge drying bed at the Jhansi FSTP

Process flow and sample collection points



Source: CSE 2020

1. Septage from tanker
2. Planted sludge drying bed outlet/ABR inlet
3. Polishing pond

Physicochemical and biological parameters of the samples tested

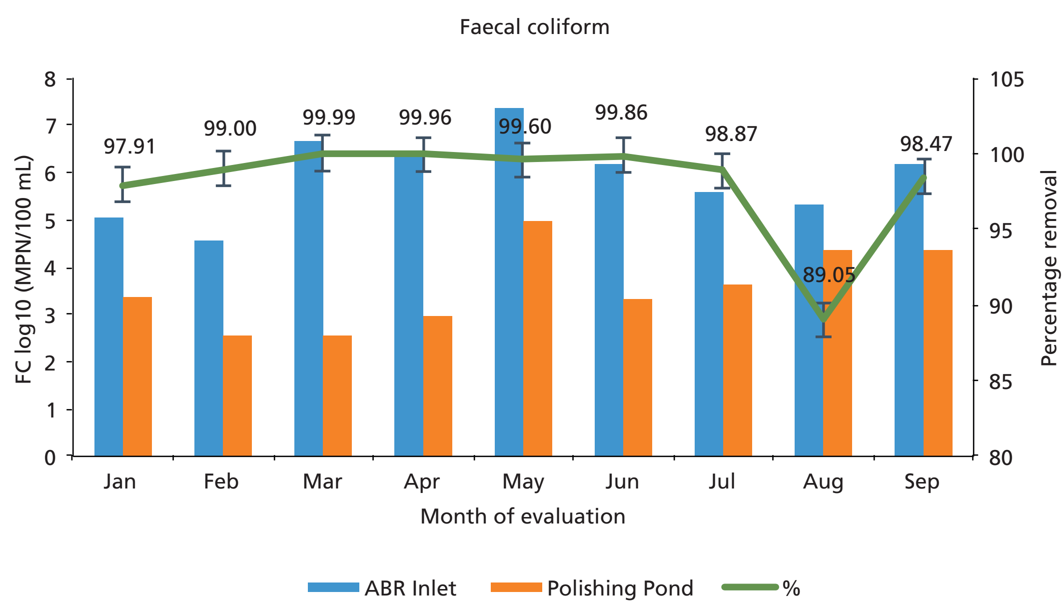
S. no.	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Jan 2019	Fresh faecal sludge	7.8	10,571	–	–	6,600	487	142.8	78.5	7	430,000
2	Jan 2019	ABR inlet	6.5	3,751	1310	2,441	600	110	44.8	21	0.8	110,000
3	Jan 2019	Outlet (polishing pond)	8.2	1,331	706	625	134	13	1.7	0.1	0.05	2,300
1	Feb 2019	Fresh faecal sludge	6.8	48,186	–	–	48,700	1,490	1,467.6	341	198	920,000
2	Feb 2019	ABR inlet	7.8	2,839	1,840	999	304	20	41.6	37.9	8.56	36,000
3	Feb 2019	Outlet (polishing pond)	9.1	2,585	1,790	795	153	5	5.5	0.6	0.14	360
1	Mar 2019	Fresh faecal sludge	6.8	66,340	–	–	94,950	1,164	2,431.5	276.6	240	3,600,000
2	Mar 2019	ABR inlet	7.7	1,863	1,600	263	252	44	74.1	66.1	4.9	4,600,000
3	Mar 2019	Outlet (polishing pond)	7.2	1,569	1,210	359	180	16	3.2	0.1	0.8	360
1	Apr 2019	Fresh faecal sludge	7.2	17,490	2,090	15,400	23,500	665	713.4	269.9	121	2,400,000
2	Apr 2019	ABR inlet	7.4	3,188	1,930	1,258	240	15	19.1	14.6	5.8	2,400,000
3	Apr 2019	Outlet (polishing pond)	7.5	1,641	923	718	51	3	3.5	2.5	0.4	920
1	May 2019	Fresh faecal sludge	6.8	60,872	–	–	52,650	3,340	1,126.9	94.2	329	1.5E+08
2	May 2019	ABR inlet	7.3	1,590	1,310	280	270	31	55.9	49.5	6.4	23,000,000
3	May 2019	Outlet (polishing pond)	7.1	2,221	2,130	91	250	26	11.6	5.8	2.6	93,000
1	Jun 2019	Fresh faecal sludge	7	53,969	–	–	79,100	3,310	2204.4	300.8	131	15,000,000
2	Jun 2019	ABR inlet	6.9	3,288	1,860	1,428	206	13	19.8	13.8	5.6	1,500,000
3	Jun 2019	Outlet (polishing pond)	7.3	3,053	1,740	1,313	122	10	3.5	1	3.2	2,100

S. no.	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Jul 2019	Fresh faecal sludge	6.9	27,654	–	–	45,750	3,310	1520.1	390.2	378	9,300,000
2	Jul 2019	ABR inlet	6.5	1,258	1,050	208	182	31	13.4	5.84	13	380,000
3	Jul 2019	Outlet (polishing pond)	6.7	1,329	1,010	319	45	9	4.9	0.58	5.2	4,300
1	Aug 2019	Fresh faecal sludge	8.15	3,137	–	–	9,525	650	281.0	190.7	59.25	230,000
2	Aug 2019	ABR inlet	7.95	1,424	1,030	394	202	36	27.7	17.96	7.34	210,000
3	Aug 2019	Outlet (polishing pond)	8.5	1,148	848	300	176	22	16.3	3.1	6.3	23,000
1	Sep 2019	Fresh faecal sludge	7.87	10,947	NT	NT	25,500	2420	579.48	162.68	147.5	4,300,000
2	Sep 2020	ABR inlet	8.01	959	792	167	258	66	48.04	39.96	7.26	1,500,000
3	Sep 2021	Outlet (polishing pond)	8.02	887	760	144	189	46	42.12	36.11	6.8	23,000

Source: CSE 2020

(A) FAECAL COLIFORM

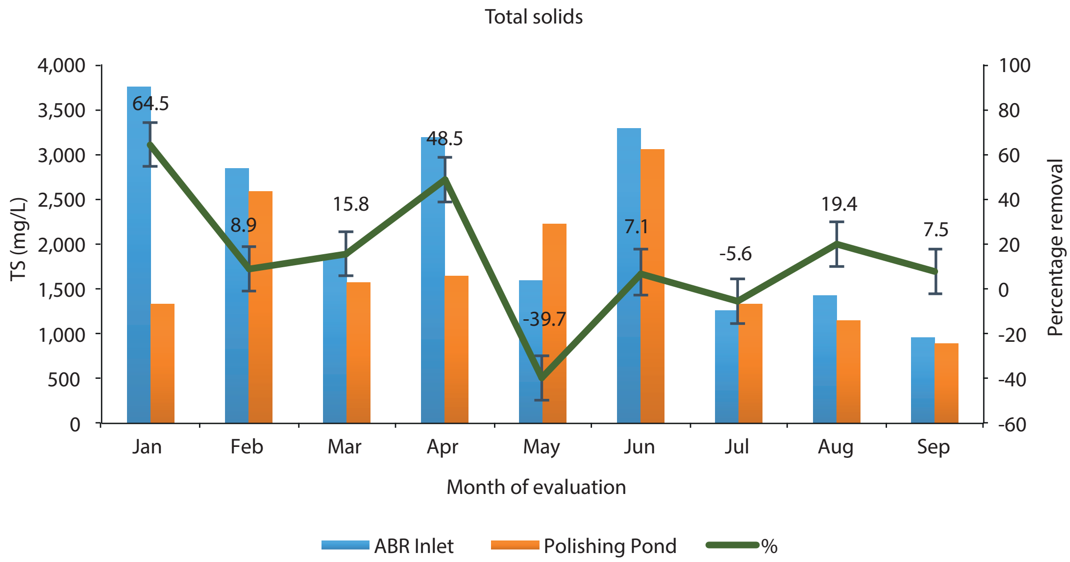
A reduction in faecal coliform to the extent of twice to thrice the log value was measured in the leachate while passing through the series of anaerobic baffle reactors, anaerobic filters, and horizontal flow constructed wetlands. The overall percentage reduction of 89–99 per cent was observed.



Source: CSE 2020

(B) TOTAL SOLIDS

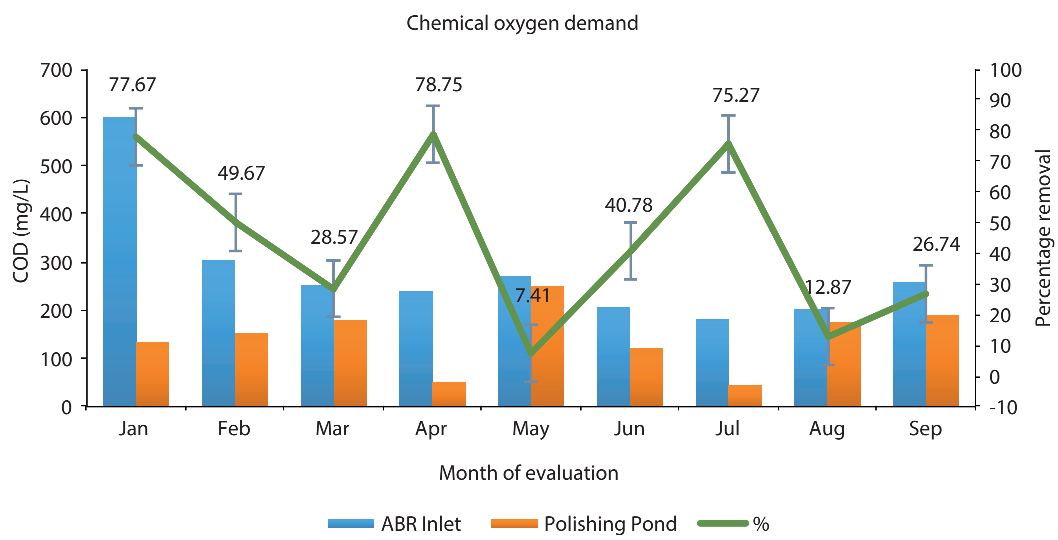
Total solid removal of up to 64 per cent was noted in the system. In many cases, however, the values came very close to zero or negative removal. This may have been due to the growth of microalgae in the polishing pond, which contributed in the total solids in waterbodies.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

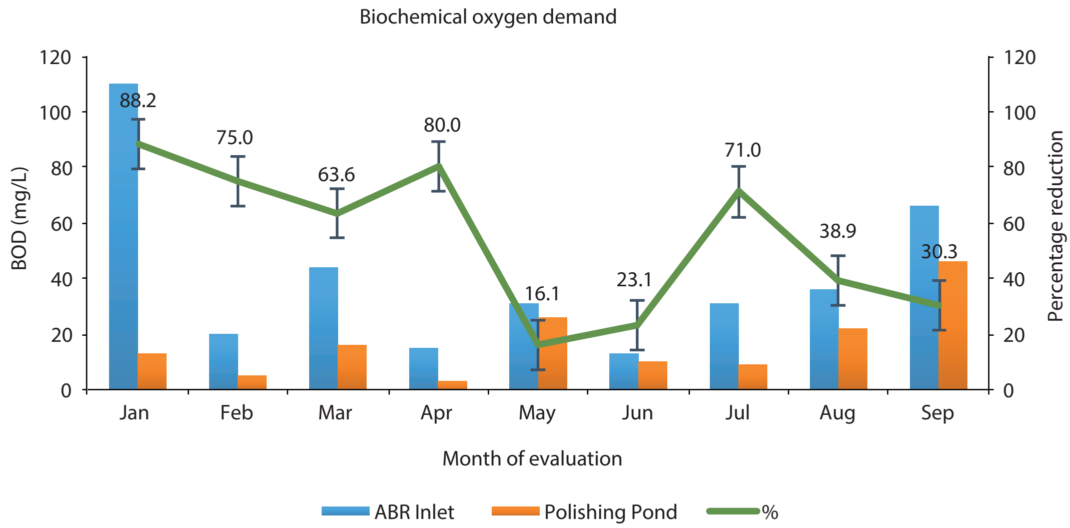
The decrease in COD varied during the evaluation period and was observed at 7–78 per cent, with an average reduction of 48 per cent.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

A reduction in BOD by 16–88 per cent was observed during the evaluation period of nine month, with an overall reduction efficacy of 54 per cent. The treatment system met the discharge standard limit except during one month.



Source: CSE 2020

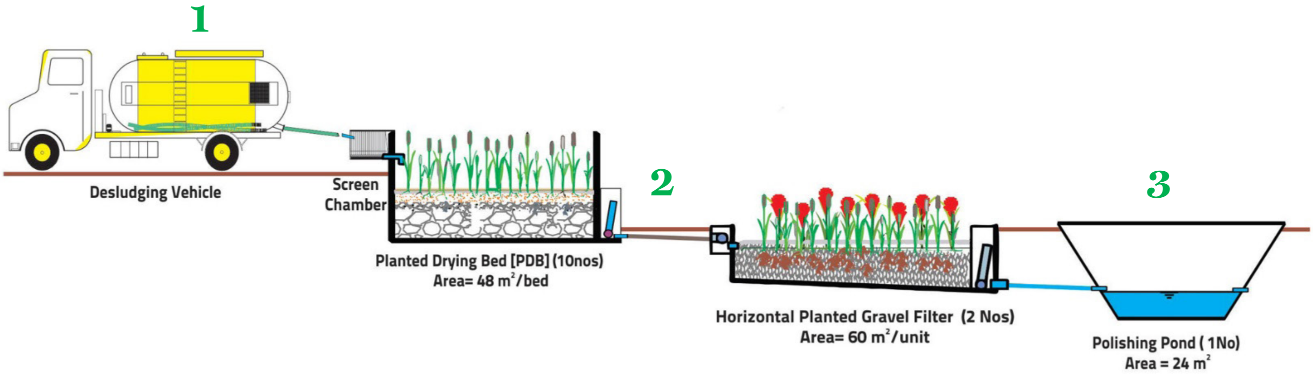
LEH, LADAKH

Capacity: **12 KLD**
Operator: **Blue Water Company**
Study period: **June–November 2019 (four months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description about the treatment system: Planted drying bed technology—used to treat faecal sludge in a high altitude areas—is used in Leh. The Leh FSTP plant has a capacity of 12KLD. The sludge is allowed to dry in the planted drying bed (PDB and the excess water percolates and is treated as it flows through the horizontal planted gravel filter (HPGF). Treated water is finally collected in the polishing pond, where sunlight acts as a solar disinfectant. The sludge accumulated in the PDB is removed and used as organic manure. Operation of the FSTP in Leh remains closed from November to February due to the extreme climatic conditions of the region.

Discharging faecal sludge to planted sludge drying bed at the Leh FSTP

Process flow and sample collection points



Source: CSE 2020

1. Fresh faecal sludge from the tanker
2. Planted sludge drying bed outlet/PGF inlet
3. Polishing pond

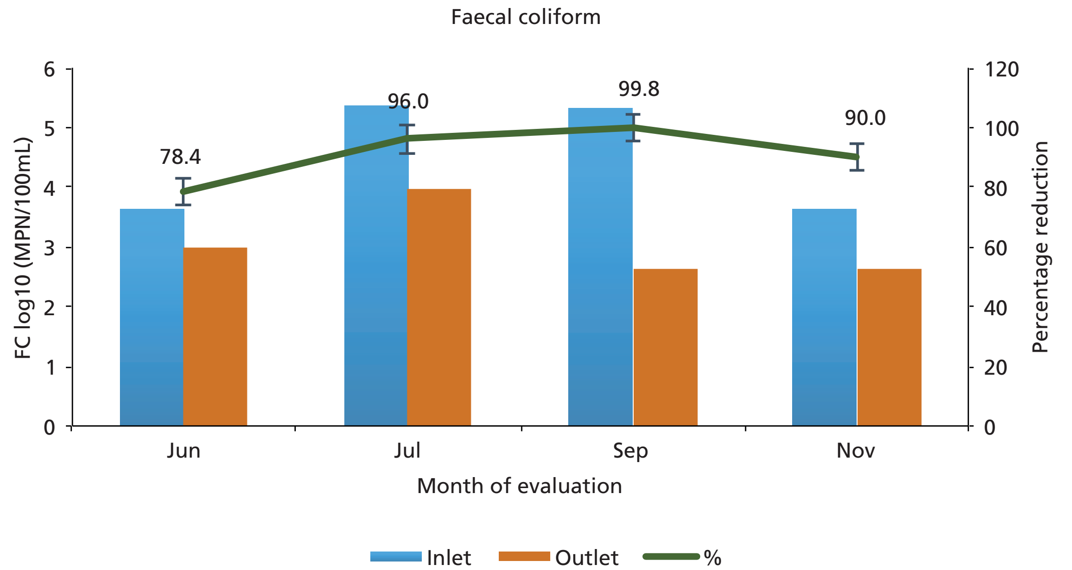
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Jun 2019	Faecal sludge	6.9	35,935	NT	NT	53,000	7,920.0	981.3	107.8	164	9,300,000
2	Jun 2019	Inlet of PGF	5.8	3,539	2,080	1,459	330	55.0	24.2	17.7	4.3	4,300
3	Jun 2019	Outlet	6.9	2,136	1,580	556	196	18.0	40.8	39.6	2.3	930
1	Jul 2019	Faecal sludge	6.5	11,840	NT	NT	25,700	7,070	716.5	264.9	224.5	9,300,000
2	Jul 2019	Inlet of PGF	7.4	4,531	1,900	2,631	354	180	134.2	128.1	13.9	230,000
3	Jul 2019	Outlet	7.6	2,177	1,660	517	225	47	59.4	57.6	5.5	9,300
1	Sep 2019	Faecal sludge	7.16	34,793	NT	NT	57,250	5,403	1,662.75	645.19	250	2,300,000
2	Sep 2019	Inlet of PGF	7.91	2,701	1,860	841	268	95	58.53	38.38	6.32	210,000
3	Sep 2019	Outlet	8.14	2,414	1,750	664	157	73	38.03	32.03	4.17	430
1	Nov 2019	Faecal sludge	7.21	3,804	NT	NT	1,860	184	109.2	70.63	14.6	2,300,000
2	Nov 2019	Inlet of PGF	7.29	2,491	1,750	741	192	37	63.48	31.19	3.8	4,300
3	Nov 2019	Outlet	7.51	1,930	1,740	190	130	25	41.93	37.04	3.2	430

Source: CSE 2020

(A) FAECAL COLIFORM

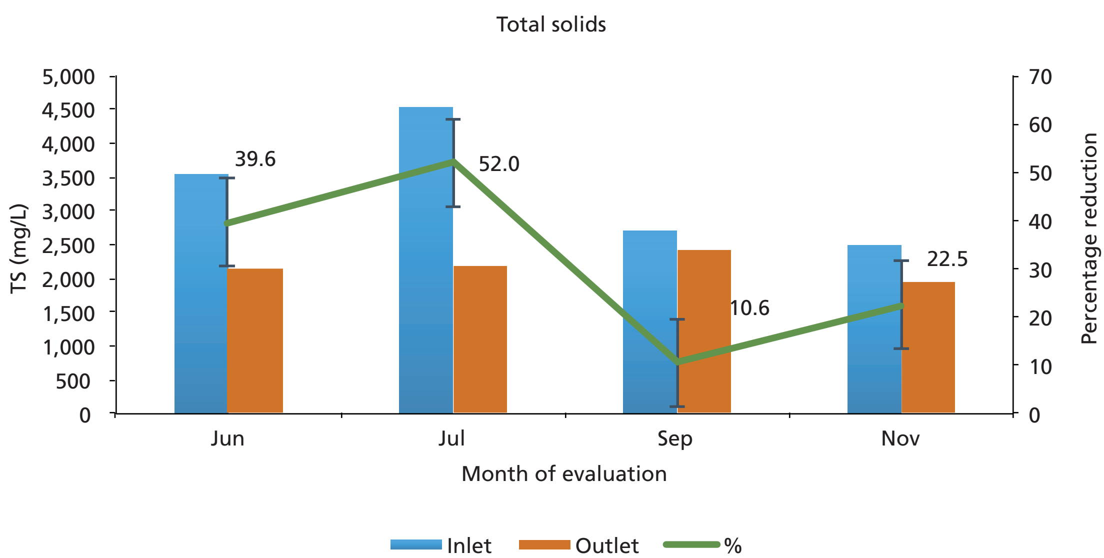
A reduction in faecal coliform to the extent of 1–3 log value was measured in the leachate passing through the horizontal flow constructed wetlands. A coliform removal efficiency of 78–99 per cent was observed in this treatment system.



Source: CSE 2020

(B) TOTAL SOLIDS

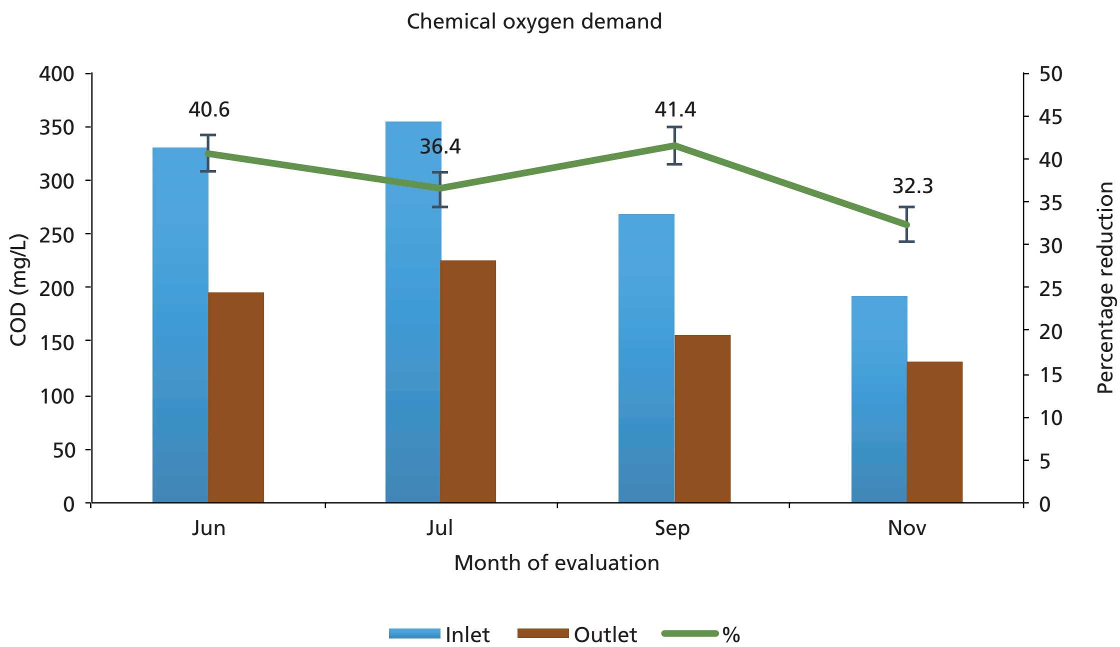
Total solid removal of 10–52 per cent was noticed in the system, with an average removal efficacy of 40 per cent during the study period of four months. The low removal percentage may have been due to the growth of microalgae in the polishing pond, which contributed in the total solids in the waterbodies.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

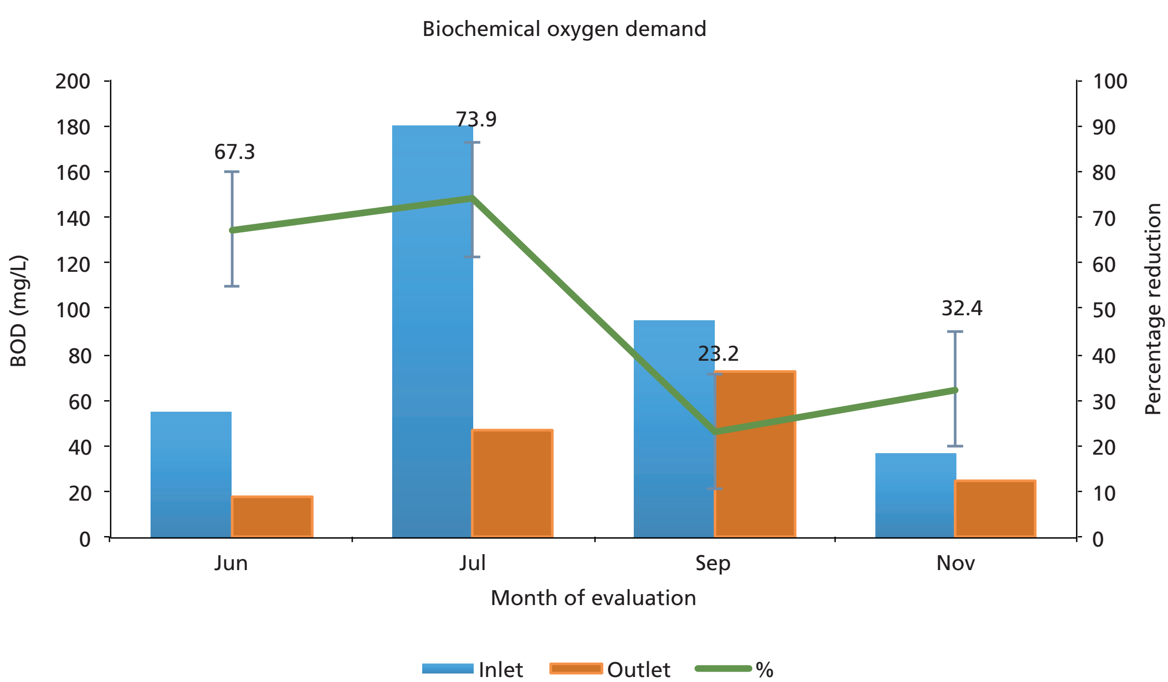
A reduction of 32–41 per cent in COD was observed in the treatment plant during the evaluation period. The average removal efficiency for during the four-month analysis was 38 per cent.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

The BOD value reduction of 23–73 per cent, with an average removal efficiency of 49 per cent, was observed. The final discharge water of the few months' sample was not meeting the discharge standard limit.



Source: CSE 2020

KARUNGUZHI, TAMIL NADU

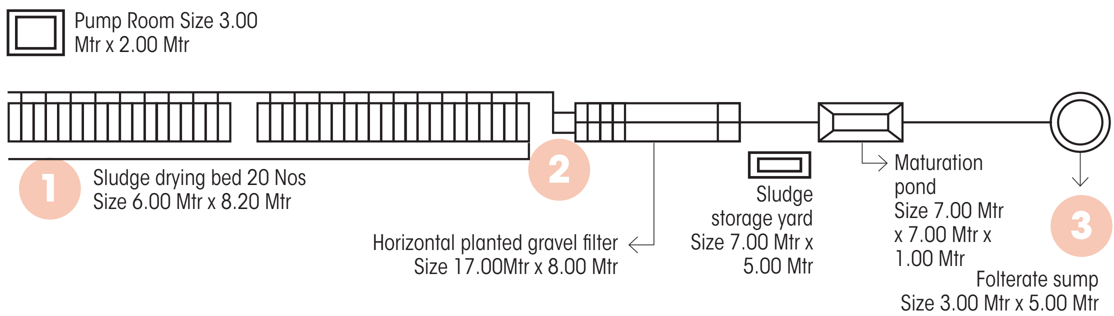
Capacity: **24 KLD**
Operator: **Karunguzhi town panchayat and Indian Institute for HumanSettlements**
Study period: **April–December 2019 (nine months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description about the treatment system: Karunguzhi FSTP, located in between the two urban local bodies (Karunguzhi and Madurantakam, is 80 km south of Chennai, in Tamil Nadu. The Directorate of Town Panchayats (DTP) funded the FSTP, the Tamil Nadu Water Supply and Drainage (TWAD) Board supervised the design and construction, and the municipality of Karunguzhi provided the land. The FSTP was designed for a capacity of 24 KLD and started operation on 10 May 2017. Two municipalities rely entirely on the Karunguzhi FSTP for onsite sanitation.

The treatment process consists of 20 unplanted drying beds, each 6.2 x 8 m. The leachate is treated in a horizontal flow constructed wetland, followed by a maturation pond. The dried sludge is stored in a storage shed for manufacturing of co-compost with municipal agricultural waste.

A series of unplanted sludge drying beds at the Karunguzhi FSTP

Process flow and sample collection points



Source: CSE 2020

1. Fresh faecal sludge from the tanker
2. Sludge drying bed outlet/PGF inlet
3. Filtrate sump

Physicochemical and biological parameters of the samples tested

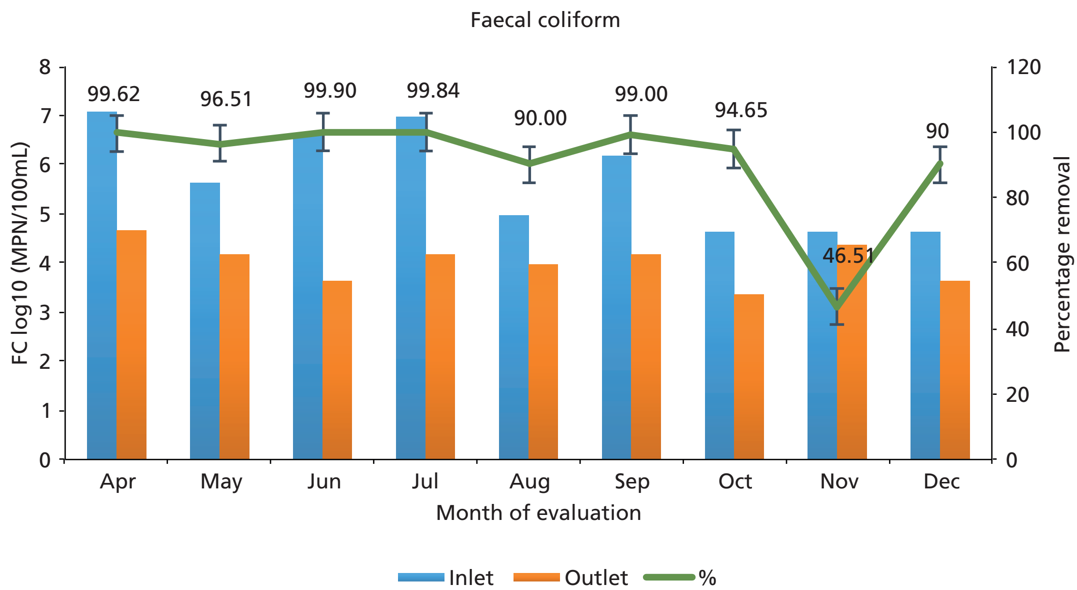
S. no.	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Apr 2019	Faecal sludge	7.4	4,700	NT	NT	8,950	384.0	297	179.6	44	240,000
2	Apr 2019	Inlet of PGF	7.2	3,458	2,100	1,358	1,170	238.0	101.3	71.7	10.2	12,000,000
3	Apr 2019	Filtrate sump	7.5	1,800	1,550	250	150	41.0	82.4	69.7	8.4	46,000
1	May 2019	Faecal sludge	7.8	5,282	NT	NT	2,380	329.0	437	121.8	8.8	93,000
2	May 2019	Inlet of PGF	7.6	3,180	2,250	930	250	27.0	127.5	116	7.2	430,000
3	May 2019	Filtrate sump	8.1	2,997	2,090	907	148	18.0	64.4	58.3	5.3	15,000
1	Jun 2019	Faecal sludge	6.3	2,134	1,530	604	2,305	803.0	142.7	127.1	18.9	15,000,000
2	Jun 2019	Inlet of PGF	6.3	3,437	1,550	1,887	314	96.0	104.8	102.6	13.3	4,300,000
3	Jun 2019	Filtrate sump	6.5	3,015	1,640	1,375	88	14.0	71.3	69.9	5.3	4,300
1	Jul 2019	Faecal sludge	6.6	29,522	NT	NT	45,850	3,940	1,265.8	245.6	254.5	15,000,000
2	Jul 2019	Inlet of PGF	6.95	2,312	1,540	772	1,076	104	93.5	59.6	13.3	9,300,000
3	Jul 2019	Filtrate sump	7.45	1,415	1,140	275	299	32	57.4	50.6	5.3	15,000
1	Aug 2019	Faecal sludge	8.42	2,115	NT	NT	2,865	280	133.07	245.6	19.4	150,000
2	Aug2019	Inlet of PGF	8.37	1,683	1,510	173	180	75	125.21	109.3	9.98	93,000
3	Aug 2019	Filtrate sump	8.39	1,361	1240	121	31	9	25.33	11.14	9.92	9,300

S. no.	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Sep 2019	Faecal sludge	6.28	17,065	NT	NT	19,400	6,600	428.06	122.3	45.75	23,000,000
2	Sep 2019	Inlet of PGF	7.68	2,605	1,520	1,085	624	224	193.35	62.14	5.26	1,500,000
3	Sep 2019	Filtrate sump	8.26	1,217	1,080	137	65	18	71.05	58.63	4.7	15,000
1	Oct 2019	Faecal sludge	7.85	3,307	NT	NT	2,435	267	287.99	242.09	15.8	93,000
2	Oct 2019	Inlet of PGF	7.74	1,259	791	468	90	23	66.39	62.48	4.12	43,000
3	Oct 2019	Filtrate Sump	7.76	769	672	97	64	16	47.46	45.86	4	2,300
1	Nov 2019	Faecal sludge	7.92	3,050	NT	NT	3,365	513	220.4	192.94	14.9	750,000
2	Nov 2019	Inlet of PGF	8.12	1,461	1,180	301	208	41	185.2	160.46	5.8	43,000
3	Nov 2019	Filtrate sump	8.46	1,221	1,140	81	128	26	71.05	65.48	4.1	23,000
1	Dec 2019	Faecal sludge	7.14	2,569	NT	NT	9,058	919	255.96	95.16	10.9	11,000,000
2	Dec 2019	Inlet of PGF	7.24	1,524	1,230	294	170	34	90.27	38.24	4.7	43,000
3	Dec 2019	Filtrate sump	7.8	1,393	1,210	183	86	17	71.05	12.4	2.65	4,300

Source: CSE 2020

(A) FAECAL COLIFORM

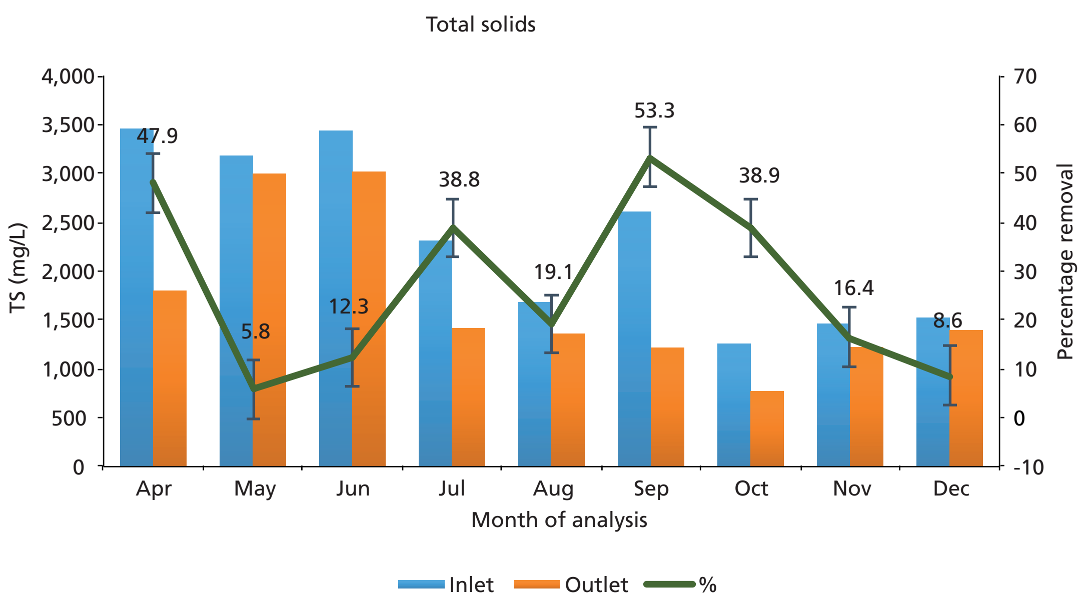
A reduction in faecal coliform to the extent of 1–3 log value was measured in the leachate passing through the horizontal flow constructed wetlands. The overall removal of coliform observed was 46–99 per cent.



Source: CSE 2020

(B) TOTAL SOLIDS

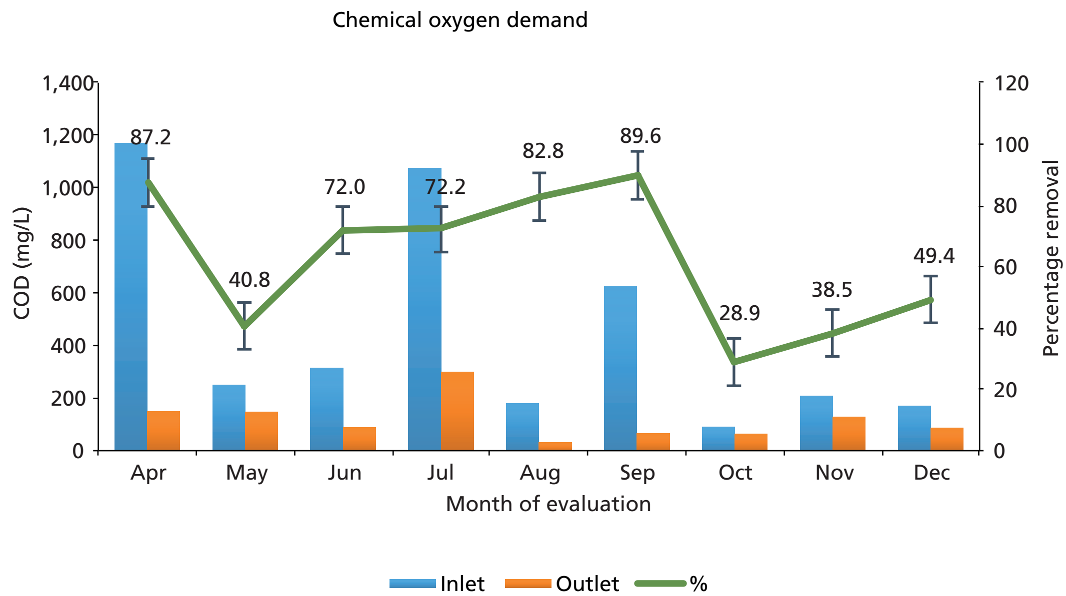
The total solid reduction during the evaluation was observed to be 6–53 per cent, with an average reduction efficacy of 29 per cent. The low percentage removal was due to the growth of microalgae in the maturation pond, which contributed in the total solids in waterbodies and the limited removal of total dissolved solid by the planted gravel filter.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

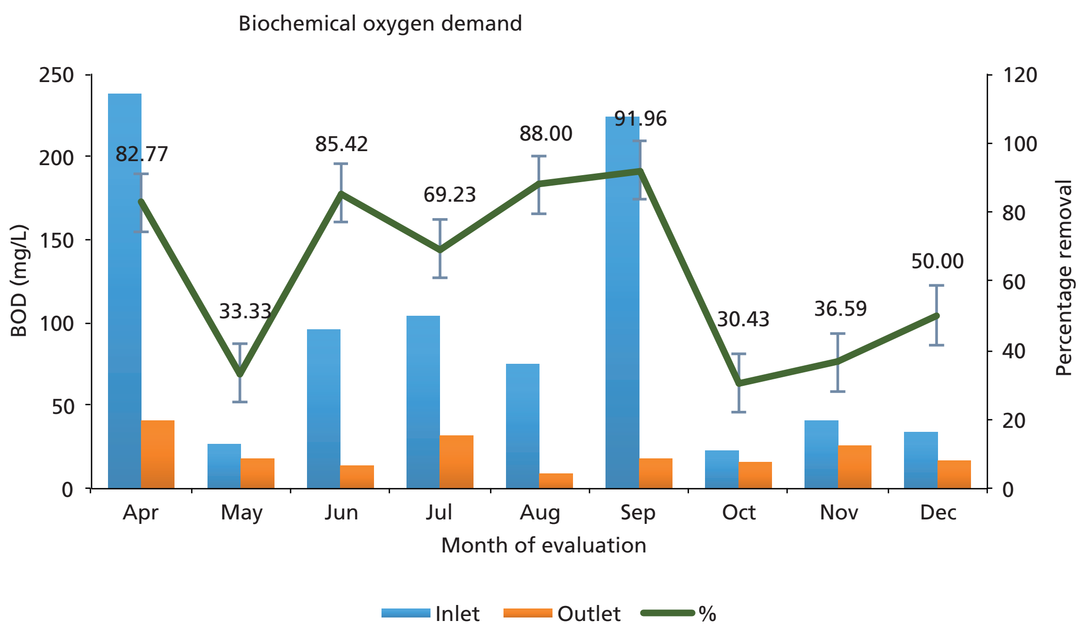
During the nine months of continuous evaluation, COD removal of 29–89 per cent by the treatment system was observed, with an average efficacy of 62 per cent.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

The reduction in BOD fluctuated in the range of 31–91 per cent, with an average efficacy of 64 per cent. The final discharge water met the discharge standard limit except during a few months.



Source: CSE 2020

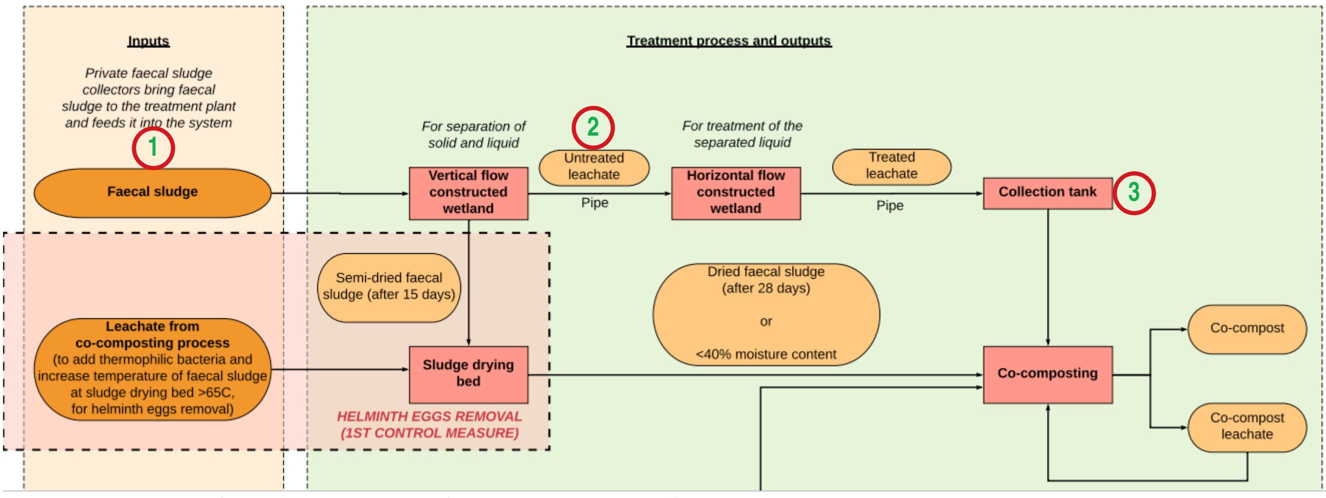
KETTY, COONOOR, TAMIL NADU

Capacity: **1.7 KLD**
Operator: **Rural Development Organization (RDO trust)**
Study period: **May–December 2019 (five months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: The Ketty FSTP is located in Coonoor Municipality, a hill station in the Nilgiri district of Tamil Nadu. It has a capacity of 1.7 KLD. The FSTP has a DWWT system with three planted sludge drying beds for solid–liquid separation, followed by a horizontal flow constructed wetland for treatment of leachate. The effluent is stored in a storage tank. The dried sludge is used for co-composting.

Discharging faecal sludge in the planted sludge drying bed at the Ketty FSTP

Process flow and sample collection points



Source: CSE 2020

1. Fresh faecal sludge from the tanker
2. Planted sludge drying bed outlet/PGF inlet
3. Outlet

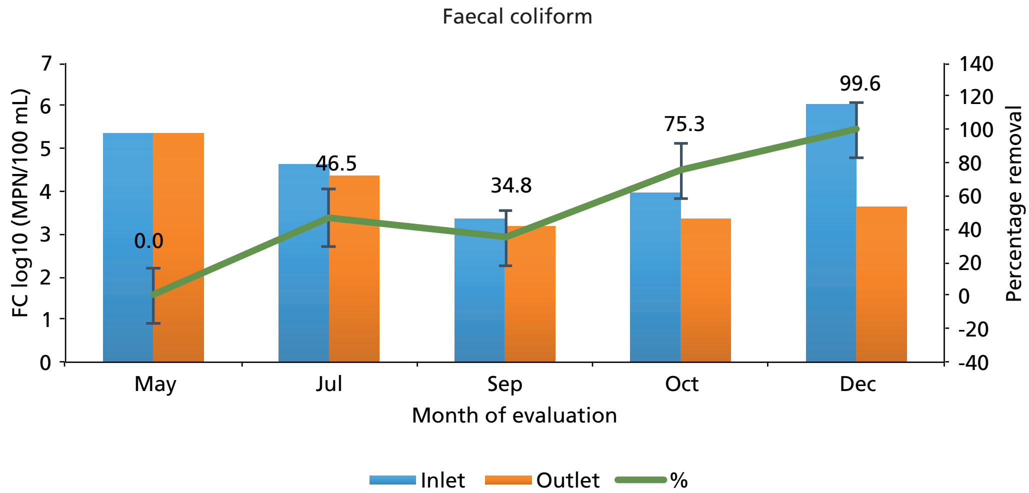
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	May 2019	Faecal sludge	7.67	42,913	–	–	29,200	5,740.0	1,919	580.9	69.9	930,000
2	May 2019	PGF Inlet	7.2	4,340	2,530	1,810	444	75.0	22.7	17.6	5.5	230,000
3	May 2019	Final Effluent	7.26	56,07	2,970	2,637	472	72.0	33.5	32.2	4.8	230,000
1	Jul 2019	Faecal sludge	7.29	27,323	–	–	58,700	4,510	1,865.1	1,001.7	208	9,300,000
2	Jul 2019	PGF inlet	6.48	4,610	2,380	2,230	310	38	22.7	16.4	11.9	43,000
3	Jul 2019	Final effluent	6.34	3,525	2,070	1,455	89	25	11.2	8.4	10.6	23,000
1	Sep 2019	Faecal sludge	7.31	55,002			98,400	6540	2871.23	972.84	259	2,300,000
2	Sep 2019	PGF inlet	7.26	1,655	1190	465	184	35	59.37	50.8	6.54	2,300
3	Sep 2019	Final effluent	7.41	1,486	1,010	476	158	18	44.84	37.97	5.82	1,500
1	Oct 2019	Faecal sludge	7.32	5,378	NT	NT	28,650	7,000	818.27	336.49	165	3,800,000
2	Oct 2019	PGF inlet	7.68	1,513	1,017	496	272	36	155.29	137.17	8.4	9,300
3	Oct 2019	Final effluent	7.29	791	615	176	133	21	67.26	62.96	4.3	2,300
1	Dec 2019	Faecal sludge	7.42	23,337	NT	NT	41,950	5,060	2,938.2	414.3	167.5	24,000,000
2	Dec 2019	PGF inlet	7.44	1,407	1,190	217	314	58	126.9	95.04	8.15	1,100,000
3	Dec 2019	Final effluent	7.56	862	721	141	115	27	103.38	36.05	4.5	4,300

Source: CSE 2020

(A) FAECAL COLIFORM

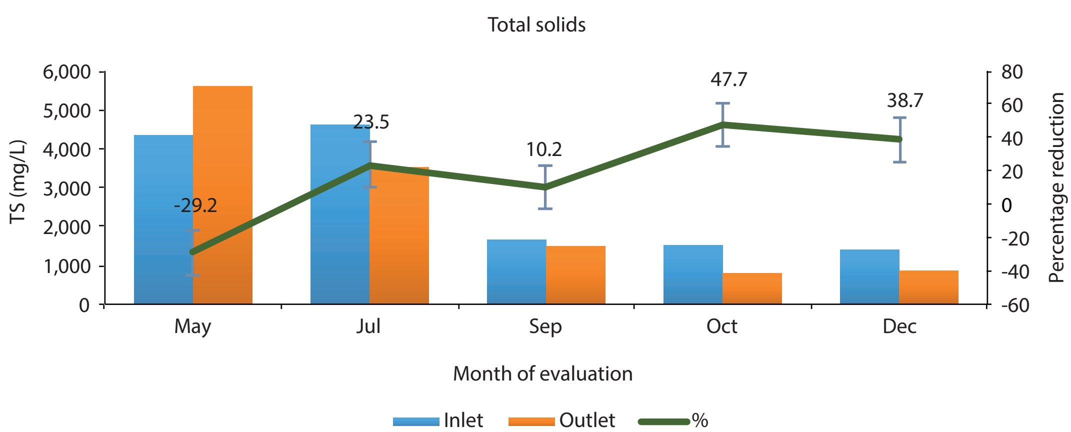
The reduction in faecal coliform to the extent of 0.1–3 log value was measured in the leachate passing through the horizontal flow constructed wetlands. Removal was observed to be from zero to 99 per cent.



Source: CSE 2020

(B) TOTAL SOLIDS

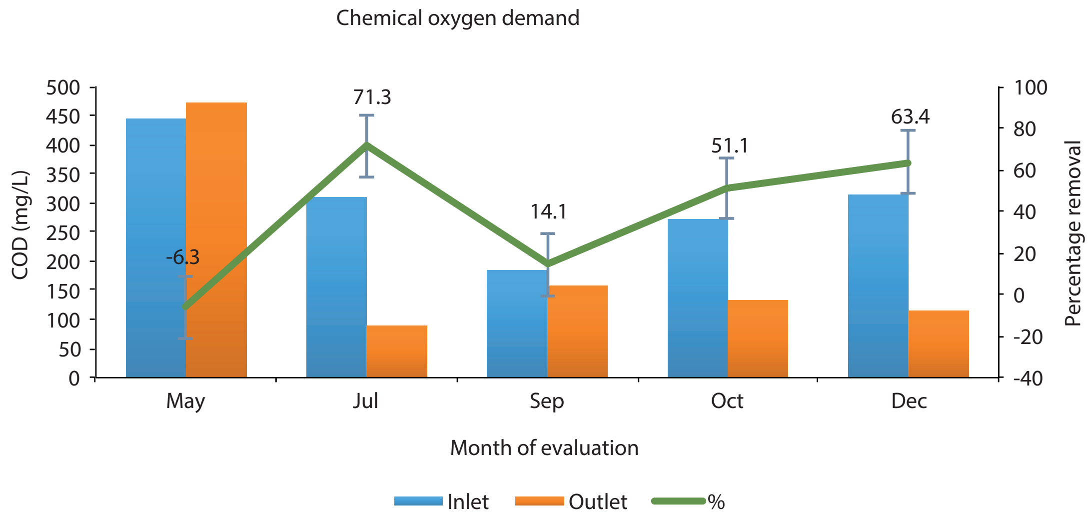
There was up to 47 per cent total solid removal noticed in the system. In the initial month of evaluation, the value showed negative removal. This was because during the evaluation we observed that the outlet water was mixed, i.e. contaminated, with other waste materials and solids.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

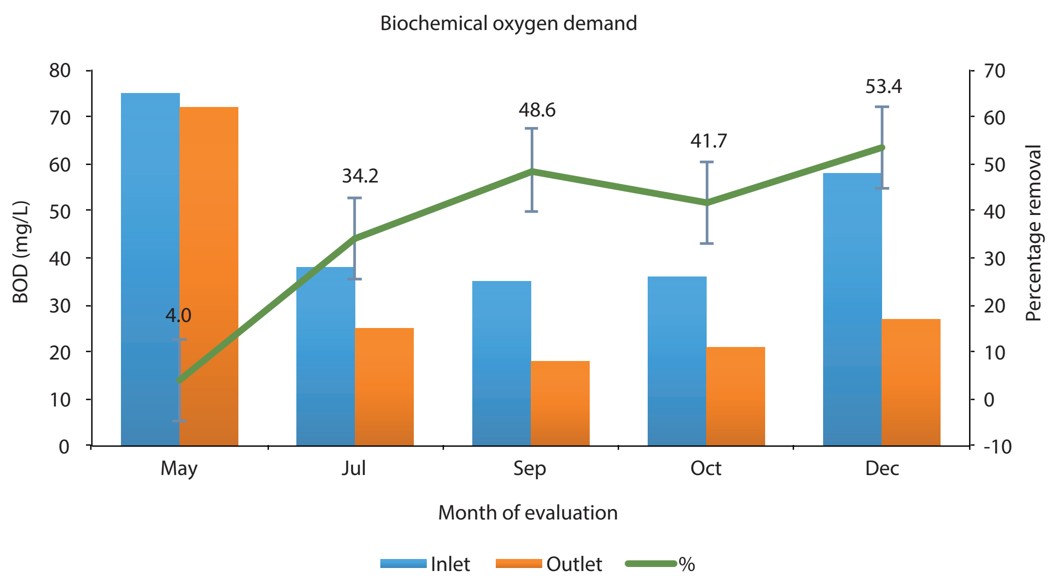
A reduction of –6 to 71 per cent in COD was observed in the treatment plant during the evaluation period, with an average removal efficacy of 49 per cent. The initial month negative value was due to the outlet water being re-contaminated with other waste materials.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

A 4–48 per cent reduction in BOD by the system was observed, with an overall efficacy of 36 per cent. The outlet water did not meet the discharge standards.



Source: CSE 2020

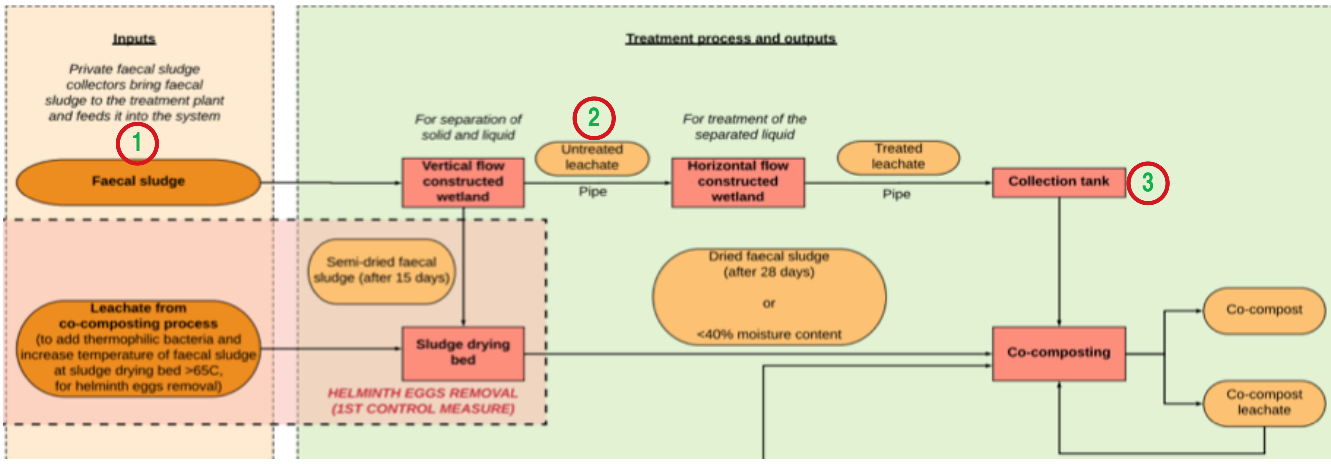
ADIGARATTY, COONOOR, TN

Capacity: **5 KLD**
Operator: **Rural Development Organization (RDO trust)**
Study period: **June–December 2019 (four months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: The Adigaratty FSTP is located in Coonoor Municipality, a hill station in Nilgiri district of Tamil Nadu. It has a capacity of 5 KLD. The FSTP has a DWWT systems with four planted sludge drying bed for solid–liquid separation followed by horizontal flow constructed wetland for treatment of leachate. The effluent is stored in a storage tank. The dried sludge is used for co-composting.

Planted sludge drying bed at the Adigaratty FSTP

Process flow and sample collection points



Source: CSE 2020

1. Fresh faecal sludge from the tanker
2. Planted sludge drying bed outlet/PGF inlet
3. Outlet

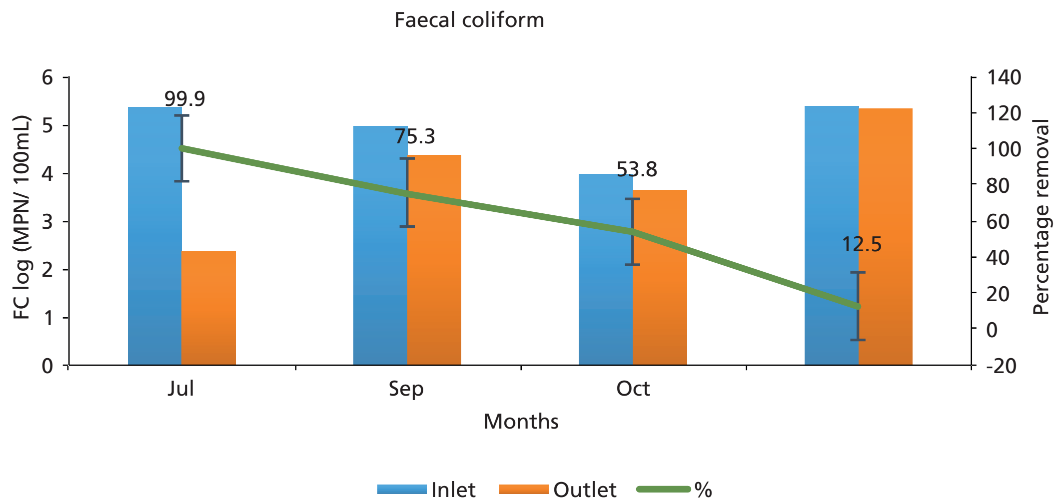
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Jul 2019	Faecal sludge	7.26	66,420	NT	NT	85,600	5,820	3,121.6	643.5	300	930,000
2	Jul 2019	PGF inlet	7.31	2,600	2,420	180	356	55	159	140.2	19.4	230,000
3	Jul 2019	Final effluent	7.74	1,440	1,348	92	212	32	26.4	12.6	16.9	230
1	Sep 2019	Faecal sludge	7.34	55,002	NT	NT	96,600	6,200	3,063.42	1,100.93	264	2,300,000
2	Sep 2019	PGF inlet	7.51	1,973	1,650	323	662	178	463.59	433.75	14.88	93,000
3	Sep 2019	Final effluent	7.76	2,119	1,880	239	271	70	323.23	293.47	7.02	23,000
1	Oct 2019	Faecal sludge	7.13	29,388	NT	NT	48,900	5426	1831.64	571.74	188	230,000
2	Oct 2019	PGF inlet	7.56	2,555	1740	323	210	37	150.84	83.03	6.1	9,300
3	Oct 2019	Final effluent	7.29	866	718	148	113	21	105.12	72.21	5.1	4,300
1	Dec 2019	Faecal sludge	6.98	21,547	NT	NT	36,700	4680	1764.67	398.52	148	11,000,000
2	Dec 2019	PGF inlet	8.13	1,107	930	177	506	137	245.37	33.19	8.5	240,000
3	Dec 2019	Final effluent	7.31	1,003	870	133	140	50	112.29	11.06	3.2	210,000

Source: CSE 2020

(A) FAECAL COLIFORM

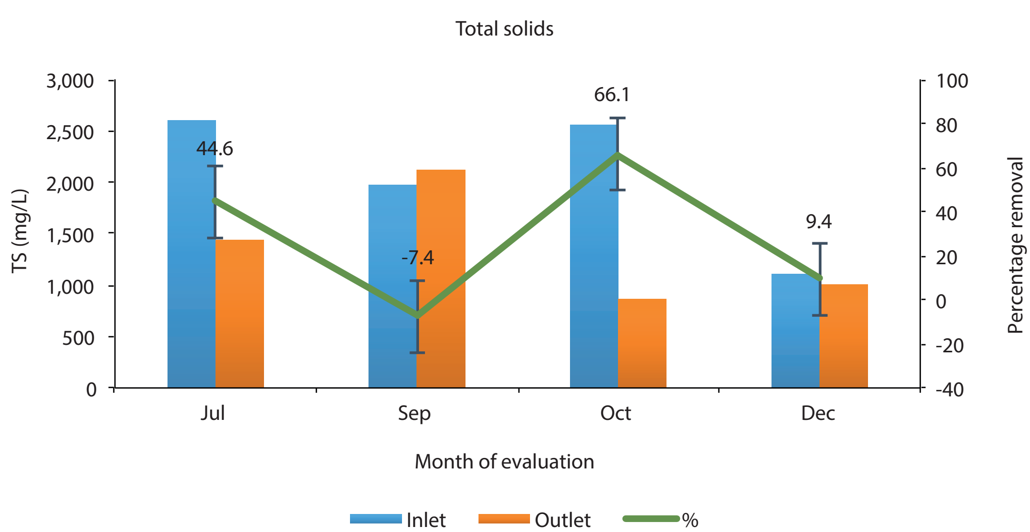
A reduction of faecal coliform to the extent of 0.1–3 log value was measured in the leachate passing through the horizontal flow constructed wetlands.



Source: CSE 2020

(B) TOTAL SOLIDS

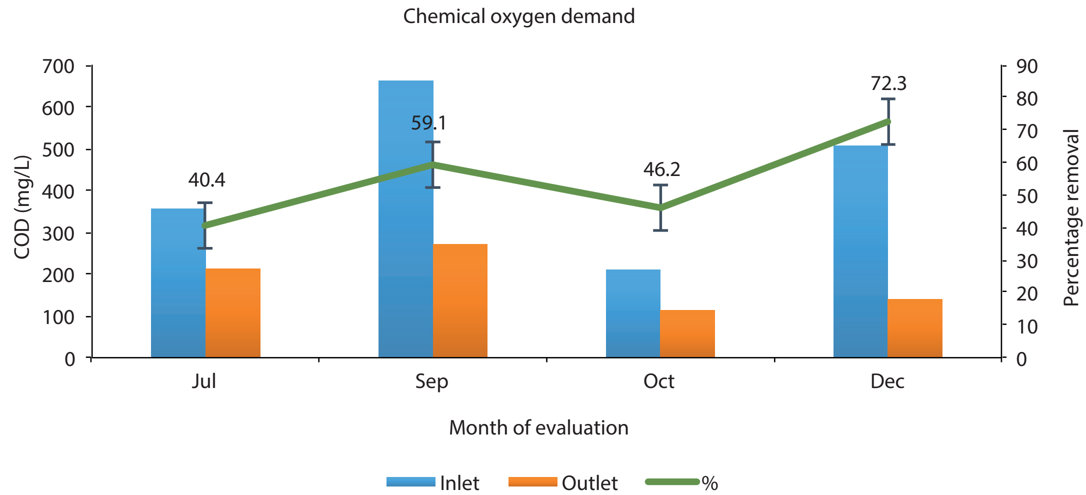
A total solid removal of –7 to 66 per cent was noticed in the system. But in many cases the values came very close to zero or negative removal. This was due to the outlet water being re-contaminated with other waste materials and solids at the site.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

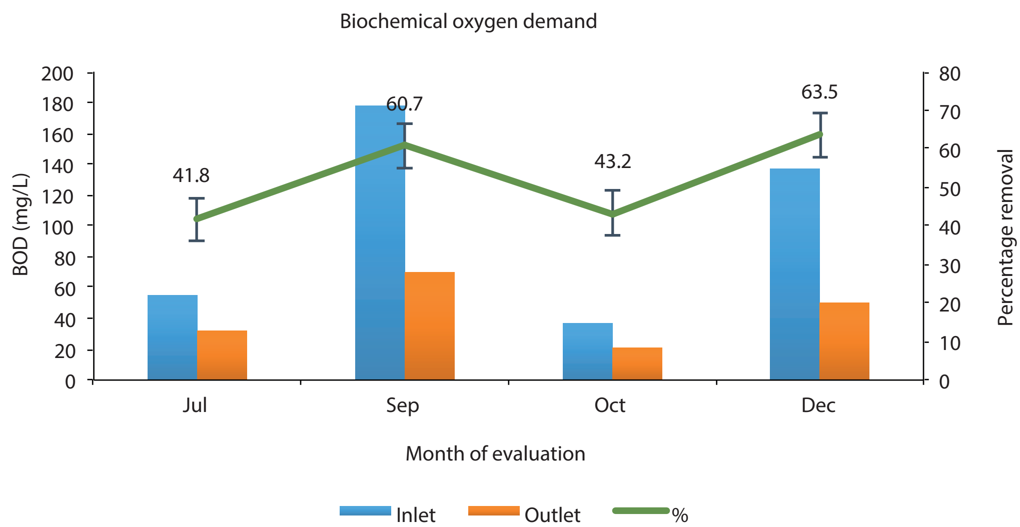
A reduction of 40–72 per cent in COD was observed in the treatment plant.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

A reduction of 41–63.5 per cent in BOD values was observed during the four months of evaluation. The final discharge water did not meet the discharge standards.



Source: CSE 2020

KALPETTA, WAYANAD, KERALA

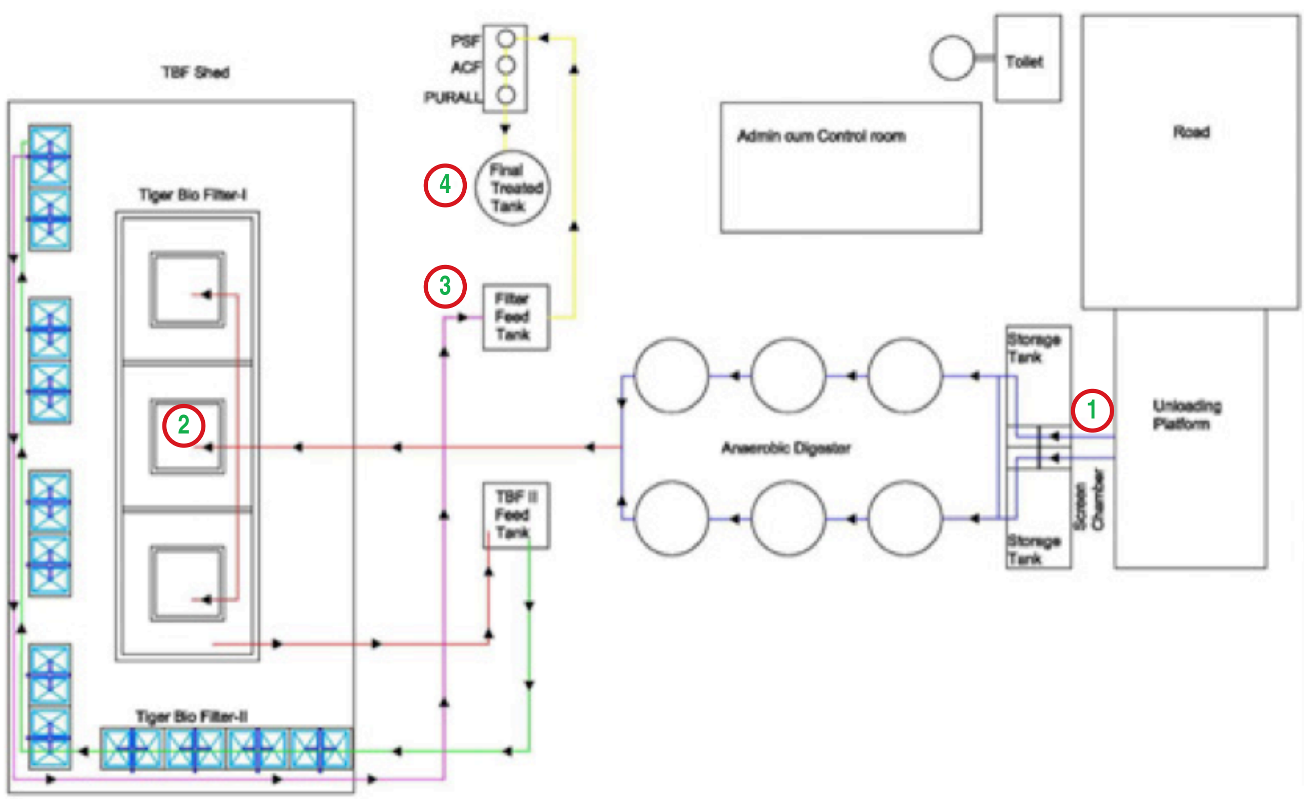
Capacity: **10 KLD**
Operator: **PriMove Infrastructure Development Consultants Pvt. Ltd**
Study period: **August–December 2019 (four months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: Kalpetta is a municipality and the headquarters of Wayanad district in the state of Kerala. The FSTP in Kalpetta municipality is located 5 km from the town on land assigned for solid waste management. The plant is based on Tiger Biofilter technology and has a capacity to treat 10 kilolitres of faecal sludge per day. This technology comprises four stages—anaerobic digestion, vermifiltration-I, vermifiltration-II and tertiary treatment. Earthworms are known to promote digestion of organic waste, which results in the production of vermicompost. In vermifilters, this behavior is combined with filtration to digest the organic matter in septage. The worms need only air, water and organic matter to form a sustainable population in the vermifilter bed.

Tiger biofilter bed at the Kalpetta FSTP

The processing starts at the screening chamber to remove large-size floating matters, plastics etc. from faecal sludge, followed by anaerobic digestion. This is a three-stage process, where micro-organisms breakdown the biodegradable material in the absence of oxygen. These tanks are used to reduce the organic load from faecal sludge. The thickened sludge is then spread on beds comprising earthworms and bacterial culture (Tiger Biofilter-I) that provides a favorable habitat and respiration zone for earthworm growth and reproduction. The beds are used to separate residual solids and liquid stream coming from anaerobic digesters. The trapped solids are consumed by earthworms and converted to vermicompost, thus reducing the organic load. The liquid stream leaves the tank from the bottom and enters into the next stage of processing, Tiger Biofilter-II. The effluent enters the module from the top and exits from the bottom, leaving behind dissolved impurities in media. The trapped solids are consumed by earthworms and converted to vermicompost in the Biofilter-II also. In the next stage, the effluent enters into tertiary treatment zone, where it is passed through a sand filter and an activated carbon filter. In the final stage, disinfection by chlorination is provided to make the effluent safe for human handling and reuse.

Process flow and sample collection points



Source: CSE 2020

1. Fresh faecal sludge from the tanker
2. TBF (Tiger biofilter) bed inlet
3. TBF II outlet
4. Final discharge

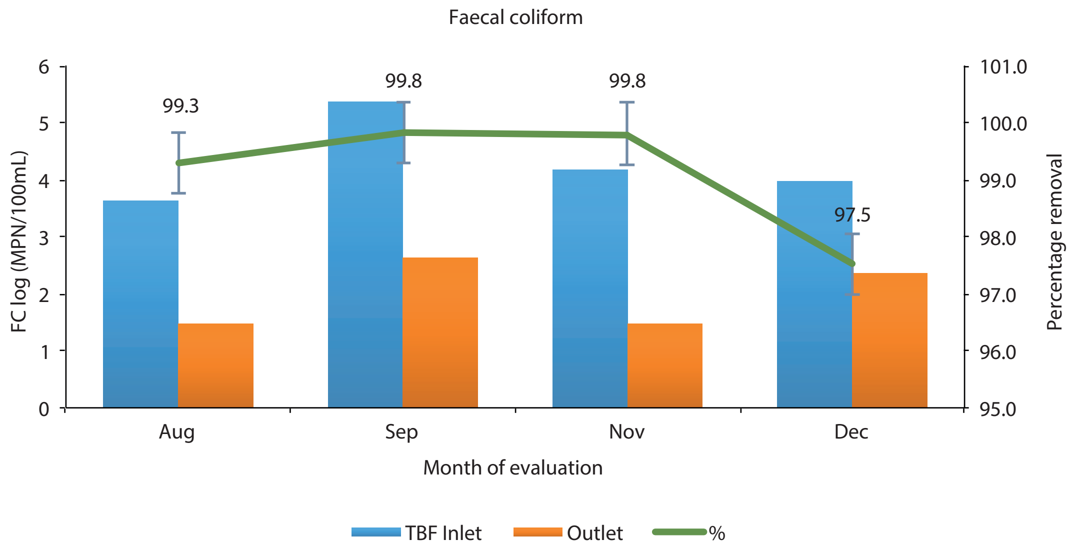
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Aug 2019	Faecal sludge	5.88	21,597	NT	NT	116,700	14,350	2,393.12	894.87	55.5	2,100,000
2	Aug 2019	TBF inlet	7.6	1,374	860	514	172	26	35.74	32.65	7.16	4,300
3	Aug 2019	TBF II outlet	7.54	824	585	239	82	8	15.14	10.88	6.28	2,300
4	Aug 2019	Final outlet	7.54	818	555	264	49	6	11.86	9.48	6.26	30
1	Sep2019	Faecal sludge	7.03	54,461	NT	NT	79,000	15,080	1,782.14	284.4	186	15,000,000
2	Sep2019	TBF inlet	7.21	1,075	792	283	298	118	123.76	104.28	22.15	230,000
3	Sep2019	TBF II outlet	7.92	958	750	208	86	38	25.14	14.27	6.67	93,000
4	Sep2019	Final outlet	8.45	824	680	144	74	36	19.21	10.76	5.48	430
1	Nov2019	Faecal sludge	7.71	33,346	NT	NT	139,425	43,650	2,398.03	303.71	340.5	360,000
2	Nov2019	TBF inlet	8.25	1,480	1,078	402	1,332	289	243.4	211.08	8.5	15,000
3	Nov2019	TBF II outlet	7.35	1,343	1,170	173	40	10	25.62	1.87	4.2	720
4	Nov2019	Final outlet	8.23	1,240	1,190	50	23	6	6.11	1.27	3.8	30
1	Dec 2019	Faecal sludge	6.85	29,617	NT	NT	33,250	2,750	2,294.6	244.6	163.5	230,000
2	Dec 2019	TBF Inlet	7.91	1,783	1,130	653	1,500	145	87.36	34.8	12.5	23,000
3	Dec 2019	TBF II outlet	7.2	522	475	47	98	22	8.4	3.45	3.5	9,300
4	Dec 2019	Final outlet	7.59	343	315	28	36	8	6.1	2.2	2.9	230

Source: CSE 2020

(A) FAECAL COLIFORM

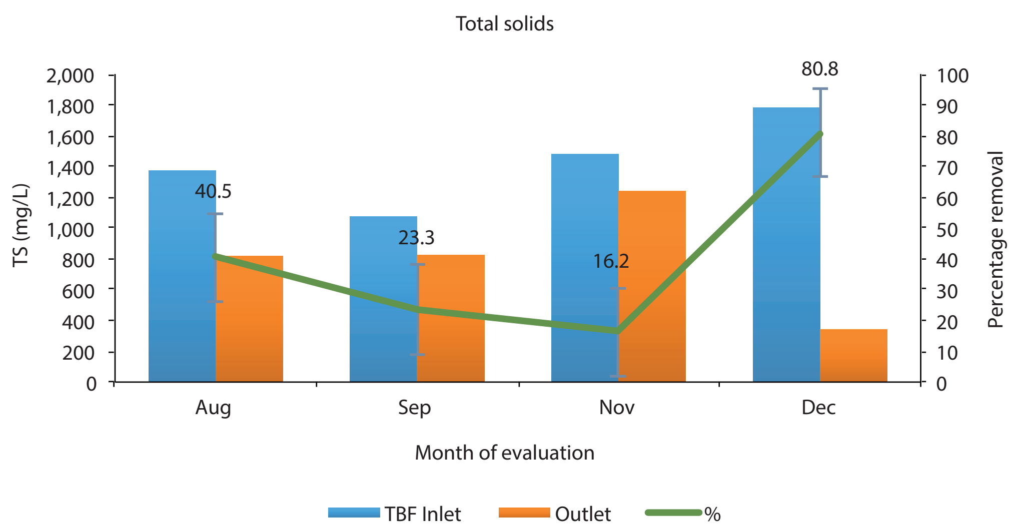
A reduction of 2–3 log value in faecal coliform was observed, with 97–99 per cent removal efficacy while the leachate passed through the series of anaerobic digesters and tiger biofilters and post-treatment modules such as sand filter, activated carbon filter and chlorination.



Source: CSE 2020

(B) TOTAL SOLIDS

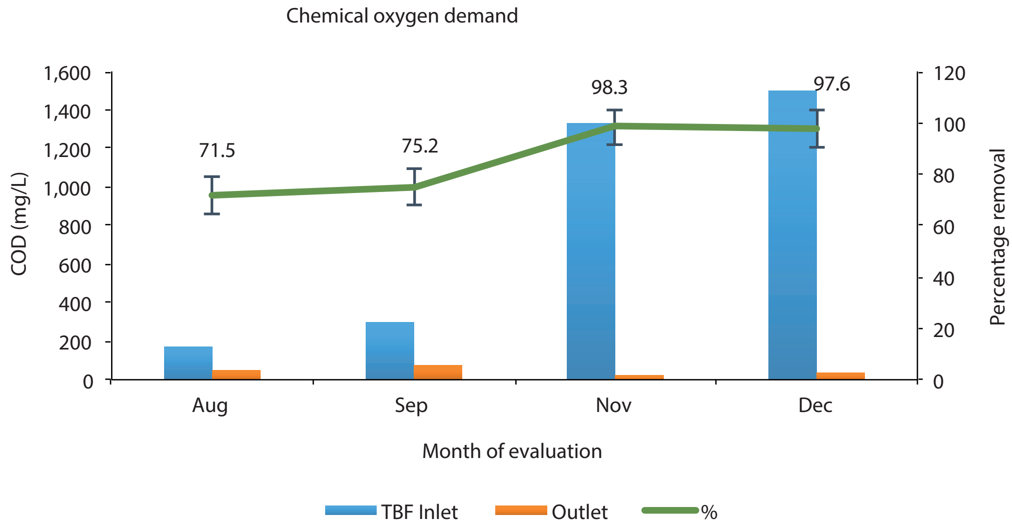
Total solid removal of 16–80 per cent was noticed in the system.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

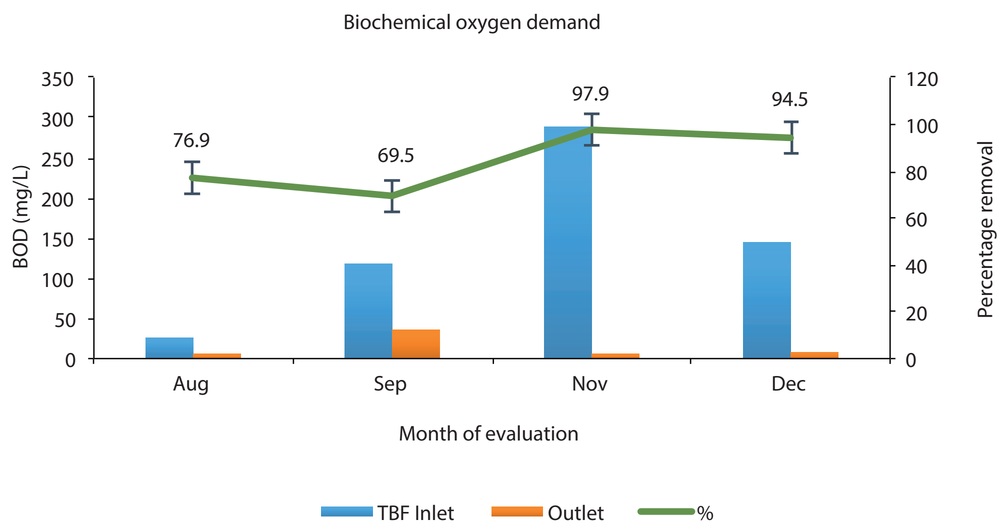
A reduction of 71–98 per cent in COD was observed in the treatment plant.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

During the four months of evaluation, the BOD values reduced by 69–97 per cent, with an average reduction of 84 per cent and the final discharge water meeting the discharge standard limit.



Source: CSE 2020

WARANGAL, TELANGANA

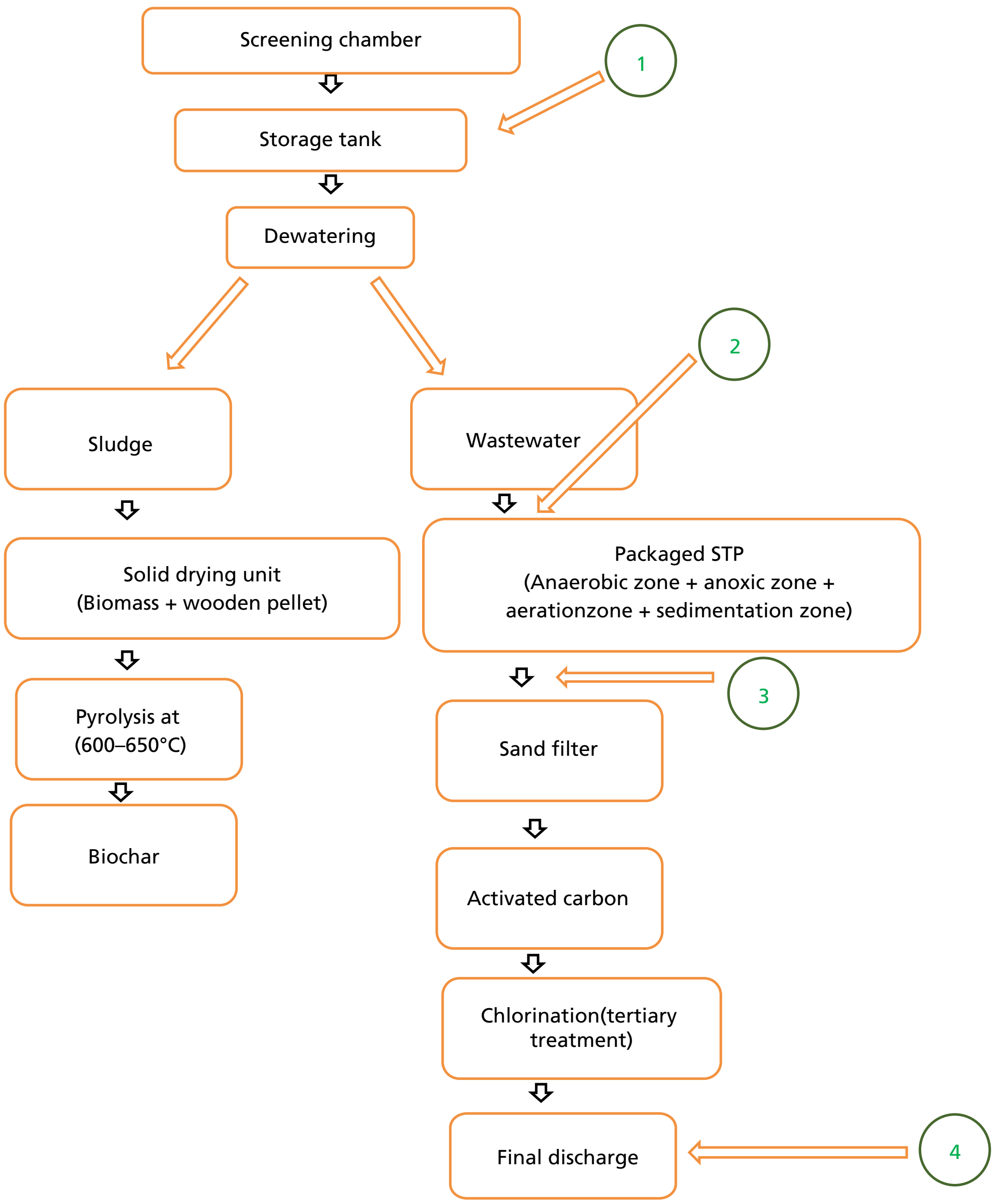
Capacity: **15 KLD**
Operator: **Tide Technocrats Private Limited**
Study period: **October–November 2019 (two month)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description about the treatment system: The FSTP at Warangal was commissioned in 2017, with a capacity of 15 KLD. Different subsystems are integrated together to treat the faecal sludge in successive steps. A pyrolysis-based approach is the treatment mechanism adopted in the plant. This is the thermochemical decomposition of organic material present in dried sludge at elevated temperatures in the presence of controlled oxygen (pyrolysis) to efficiently convert sludge to biochar. It involves killing of pathogens as well as helminths at elevated temperatures to make the end product biosafe.

The system comprises components such as a septage receiving station with screenings and grit chambers, solid–liquid separation, dryer, pyrolizer and heat exchanger. Wastewater from the solid–liquid separator is treated in a separate stream which comprises a package STP with anaerobic, anoxic, aeration and sedimentation zones followed by a sand carbon filter and chlorine treatment.

Package STP for the treatment of leachate at the Warangal FSTP

Process flow and sample collection points



Source: CSE 2020

1. Fresh faecal sludge from the tanker
2. Inlet to packaged STP
3. Outlet from packaged STP
4. Final discharge

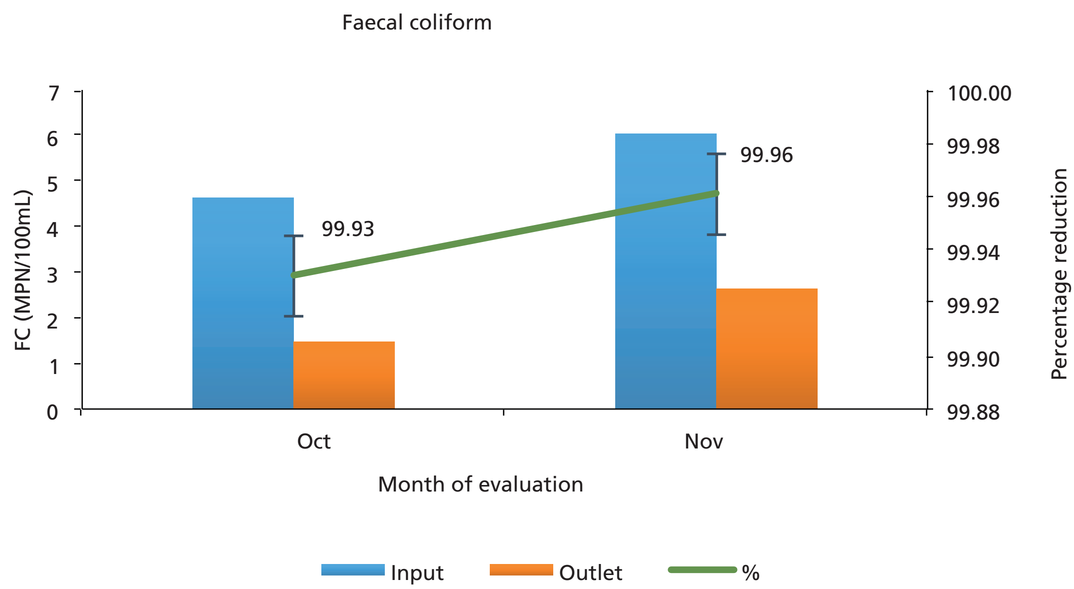
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Oct 2019	Fresh faecal sludge	7.57	24,683	NT	NT	40,700	8,000	1,295.84	337.07	191	4,300,000
2	Oct 2019	Input to packaged STP	7.71	981	780	201	178	74	278.67	256.27	6.1	43,000
3	Oct 2019	Output of packaged STP	7.8	907	775	132	143	29	190.73	167.01	5.2	23,000
4	Oct 2019	Final discharge	8.4	865	768	97	126	23	170.64	158.06	4.3	30
1	Nov 2019	Fresh faecal sludge	7.71	33,346	NT	NT	77,000	7,630	1,220.12	287.91	203	4,300,000
2	Nov 2019	Input to packaged STP	8.25	1,343	1,180	163	420	76	248.68	221.38	6.2	1,100,000
3	Nov 2019	Output of packaged STP	7.36	1,078	990	88	176	41	75.5	61.32	5.1	93,000
4	Nov 2019	Final discharge	8.23	1,040	975	65	134	24	63.48	55.05	4.7	430

Source: CSE 2020

(A) FAECAL COLIFORM

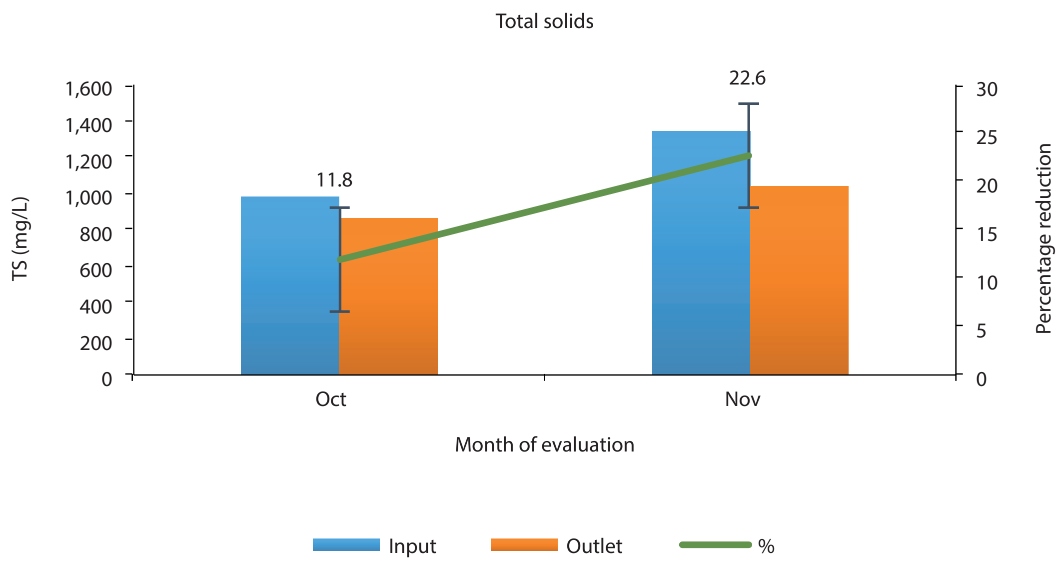
A reduction to an extent of 2–3 log in faecal coliform was observed, with 99 per cent removal while the leachate passed through the series of STP package followed by treatment through sand filter,   activated carbon and finally chlorination.



Source: CSE 2020

(B) TOTAL SOLIDS

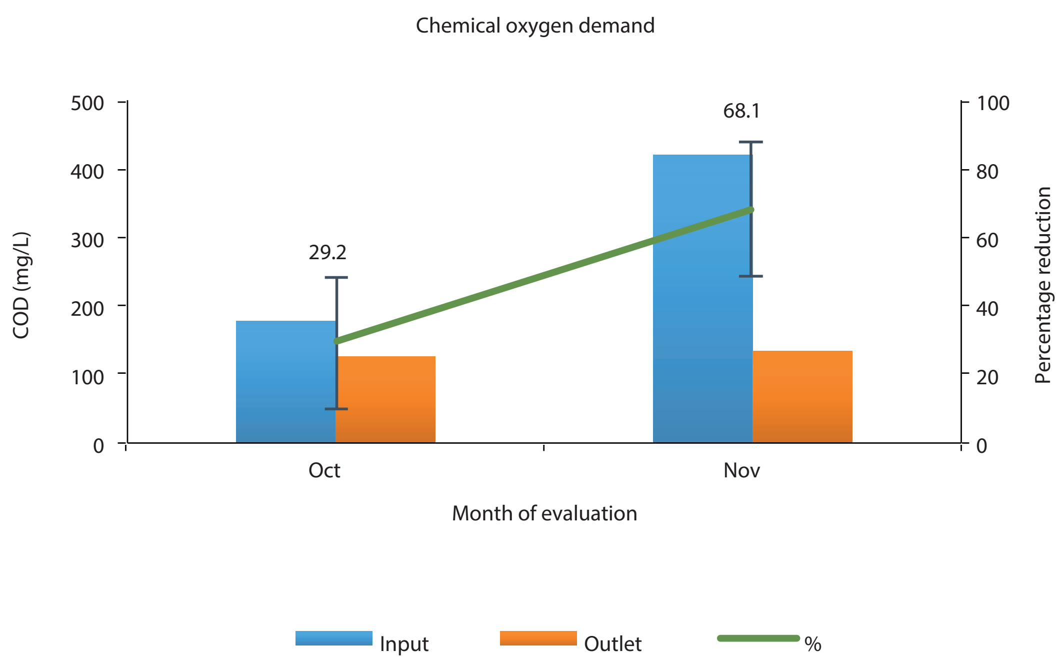
Total solid removal of 11–22 per cent was noticed in the treatment system.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

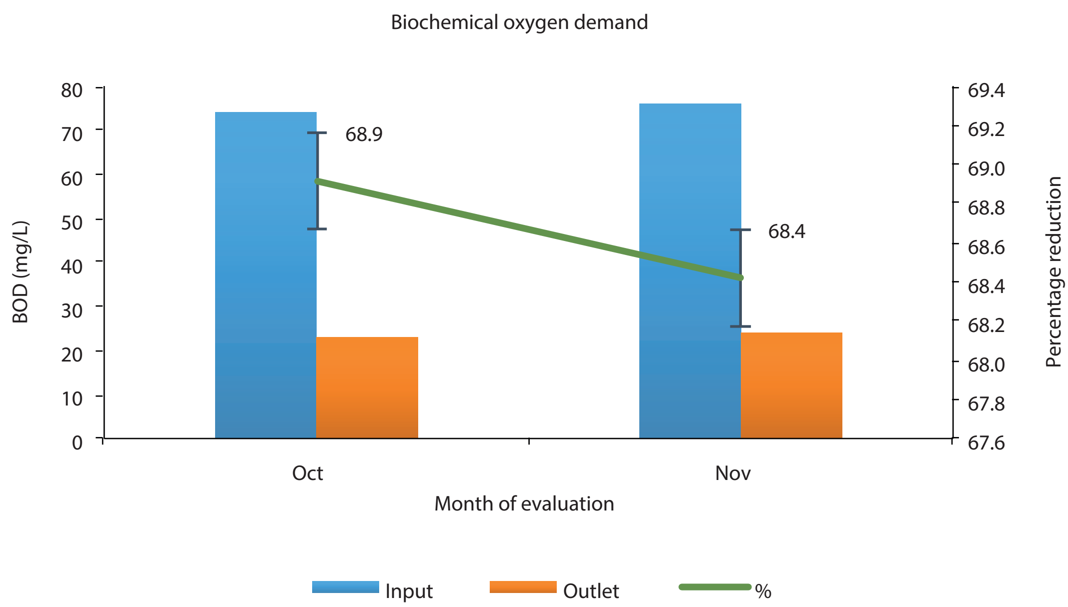
A reduction of 29–68 per cent in COD was observed in the treatment plant.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

The BOD values fell by up to 68 per cent and the final discharge water met the discharge standards.



Source: CSE 2020

TENALI, ANDHRA PRADESH

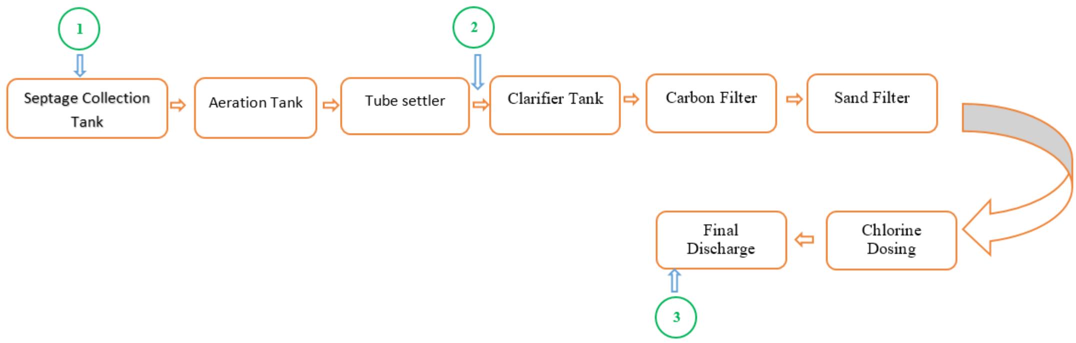
Capacity: **20 KLD**
Operator: **Tenali Municipality. Annual maintenance by G-Tech Engineers**
Study period: **October–November 2019 (two months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: The FSTP at Tenali is based on moving bed biofilm reactor (MBBR) technology. The plant has a capacity of 20 KLD.

MBBR is the simple technology adopted to treat sewage and faecal sludge. Sludge is made to settle by adding flocculants, which aids gravity settling, and the supernatant is pumped to the MBBR unit, followed by tube settler and clarifier, where it undergoes secondary treatment. It is then made to pass through the vertical rapid carbon and sand filter for tertiary treatment. There is no end-to-end solution achieved as only the liquid fraction is treated—solids are not given any attention. Sludge drying beds are absent in the FSTP.

MBBR technology for the treatment of faecal sludge at the Tenali FSTP

Process flow and sample collection points



Source: CSE 2020

1. Fresh faecal sludge from the tanker
2. Tube settler outlet
3. Final discharge

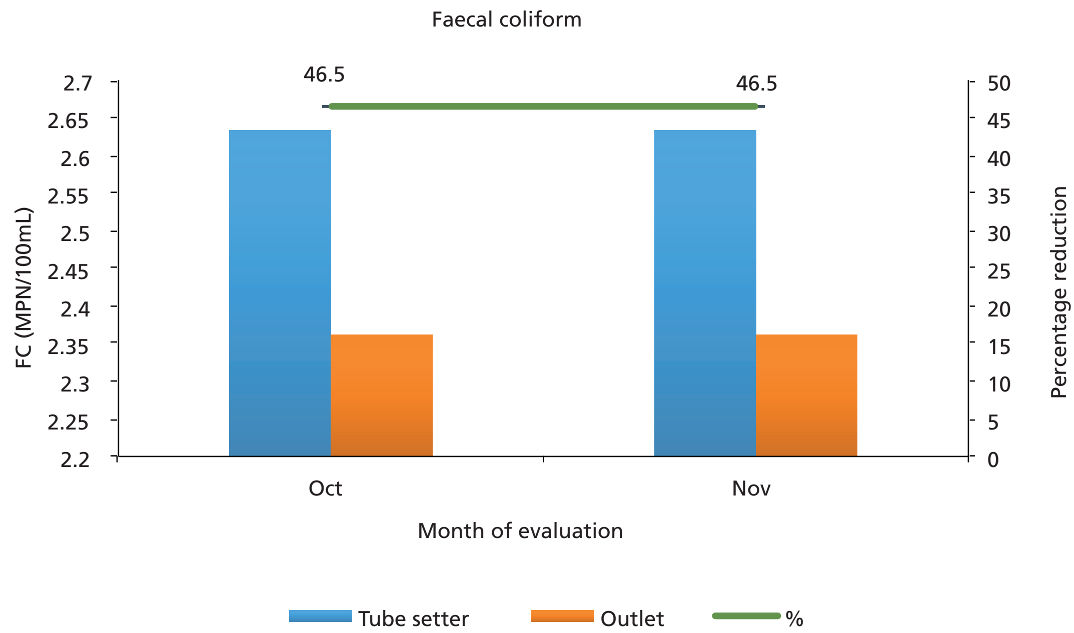
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Oct 2019	Faecal sludge	8.1	32,512	NT	NT	33,600	2,890	978.43	187.26	175	23,000
2	Oct 2019	Tube setter outlet	8.46	3,056	2,080	976	282	80	25.04	2.48	5.5	430
3	Oct 2019	Final outlet	8.49	2353	2,160	193	38	9	15.72	0.52	3.2	230
1	Nov 2019	Faecal sludge	8.22	31,838	NT	NT	25,425	2,950	725.08	131.37	79.5	92,000
2	Nov 2019	Tube setter outlet	8.72	5,061	3,620	1,441	98	25	16.26	9.9	7.8	430
3	Nov 2019	Final outlet	8.42	3,124	2,940	184	56	12	6.11	5.8	4.9	230

Source: CSE 2020

(A) FAECAL COLIFORM

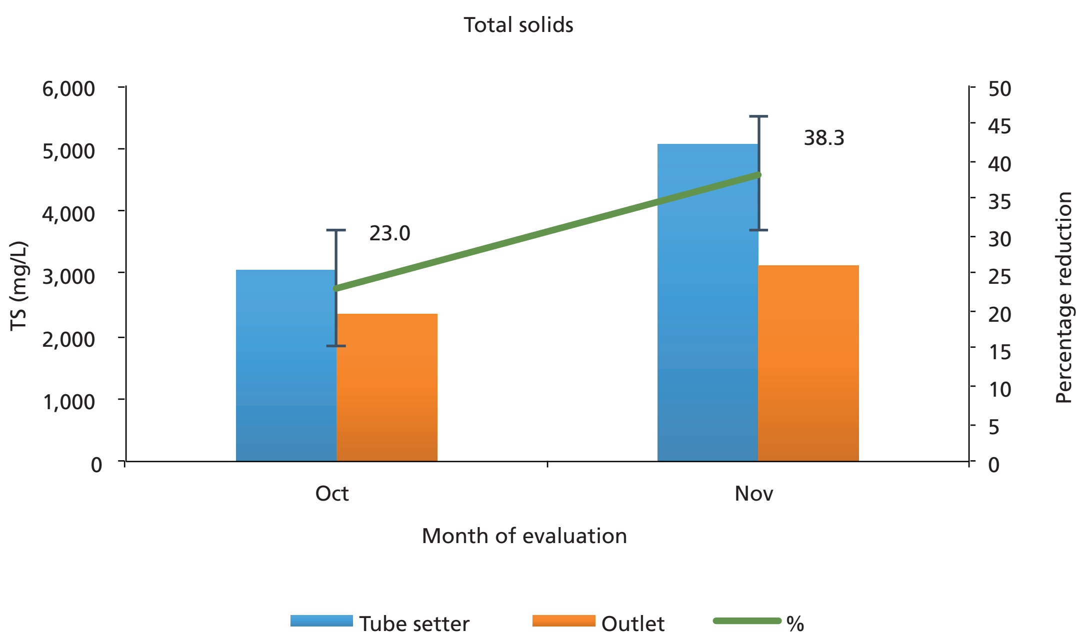
A reduction to the extent of 0.3 log value in faecal coliform was measured in the leachate passing through the series of tube settler, clarifier tank, carbon filter and sand filter. The inlet values itself were very low compared to the inlet samples of the other treatment systems.



Source: CSE 2020

(B) TOTAL SOLIDS

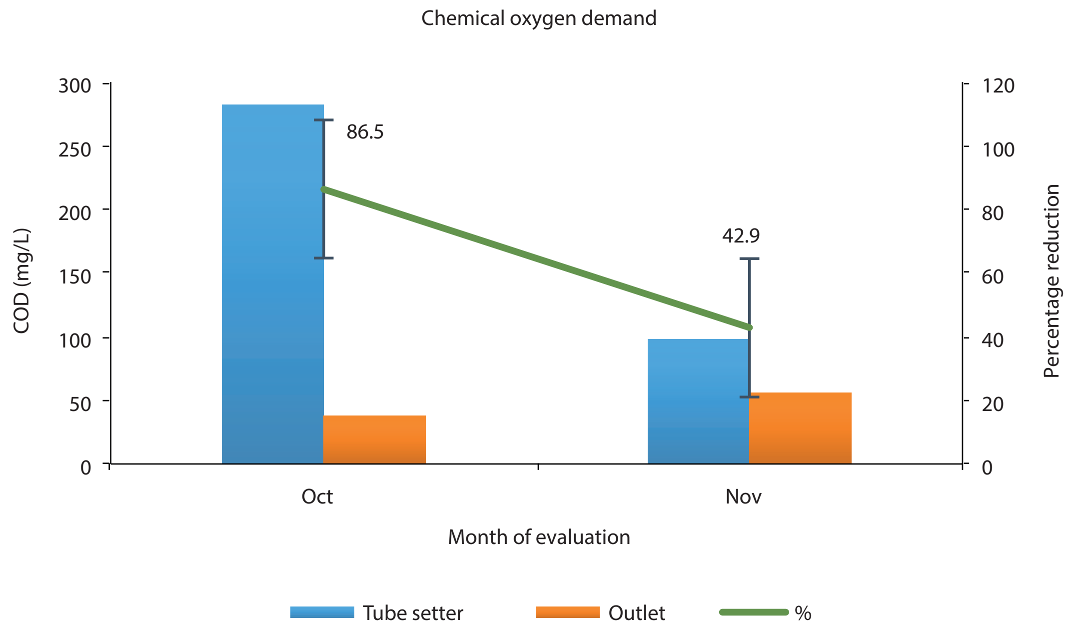
Total solid removal of 23–38 per cent was observed in the system.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

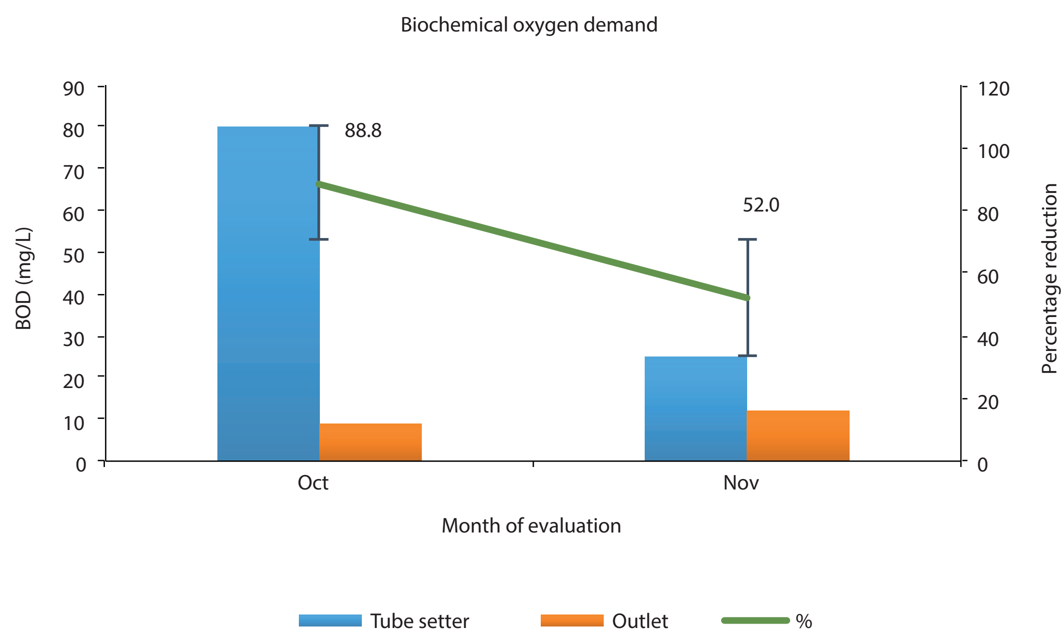
A reduction of 42–86 per cent was observed in the treatment plant in the two months of evaluation.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

The BOD values reduced to 52–89 per cent and met the discharge standards.



Source: CSE 2020

UNNAO, UTTAR PRADESH

Capacity: **32 KLD**
Operator: **Servo Technologies Limited**
Study period: **November–December 2019 (two months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

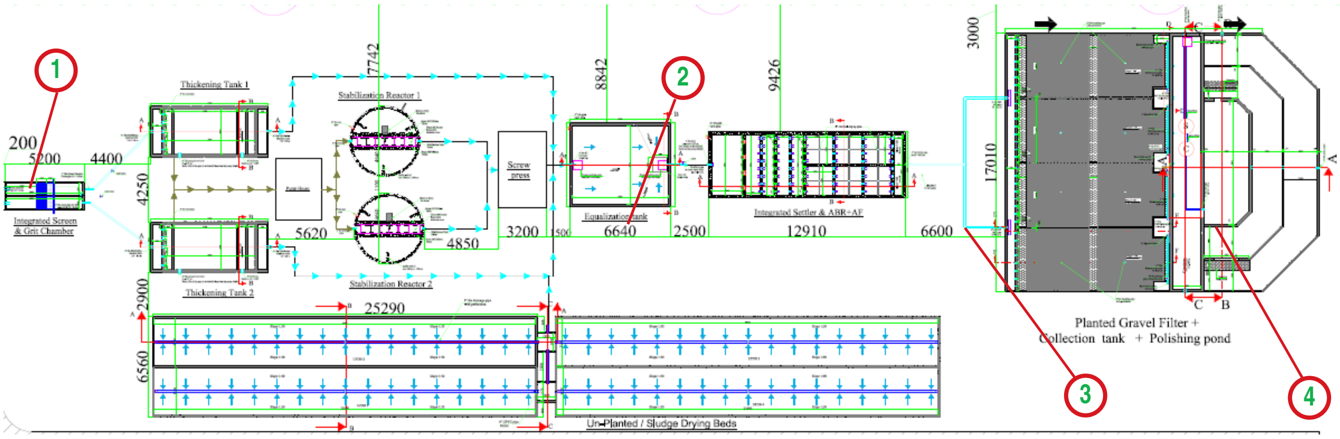
Description of treatment system: The town of Unnao—which lies between Lucknow and Kanpur—is the headquarters of Unnao district in Uttar Pradesh. Sixteen wards in the town are considered to generate faecal sludge that is not covered by the underground drainage system of Unnao.

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 flocculent solids is 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 of wastewater from the screw press in the equalization tank and the water is treated with DEWATS technology, using integrated settler and ABR, anaerobic filters, planted gravel filter, sand, activated carbon filter and, finally, UV treatment.

Unplanted sludge drying bed and sludge thickening tank at the Unnao FSTP

Process flow and sample collection points



Source: CSE 2020

1. Faecal sludge from thickening tank
2. Equalization tank
3. ABR outlet
4. Final outlet

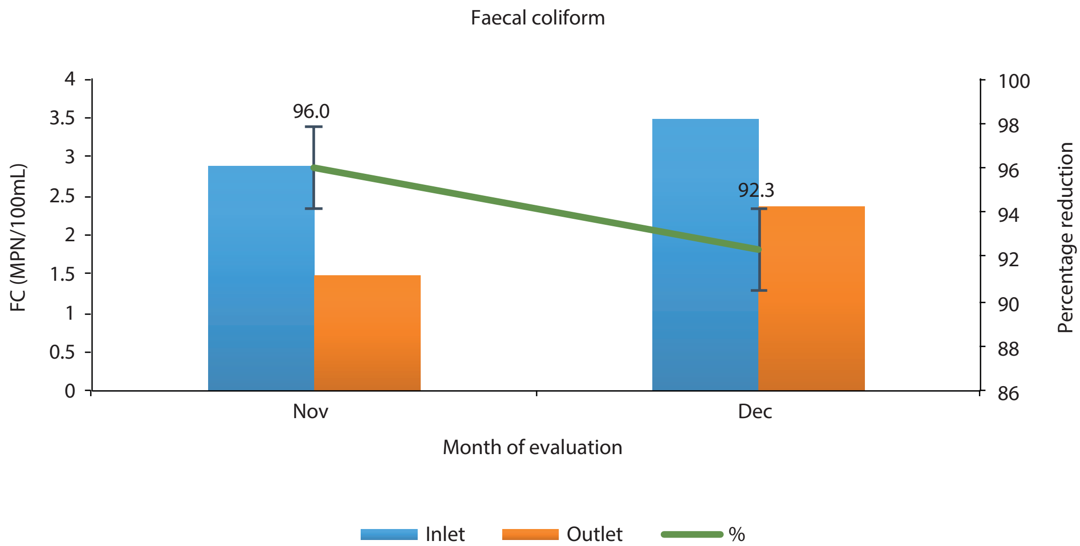
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Nov 2019	Faecal sludge	7.38	84,885	NT	NT	612,500	36,000	2,649.92	412.56	1,075	930,000
2	Nov 2019	Equalization tank	8.03	8,382	1,740	6,642	5,080	2100	285.35	201.3	75	750
3	Nov 2019	ABR outlet	8.65	1,490	1,320	170	222	56	152.88	145.3	7.1	300
4	Nov 2019	Final outlet	8.76	1,172	1,120	52	47	9	33.19	31.7	4.1	< 30
1	Dec 2019	Faecal sludge	7.2	12,207	NT	NT	24,300	2700	713.44	240.51	74	7,400
2	Dec 2019	Equalization tank	7.78	2,741	1,380	1,361	920	170	90.27	70.28	32.1	3,000
3	Dec 2019	ABR outlet	8.11	1,250	980	270	60	16	71.05	60.33	4.21	2,300
4	Dec 2019	Final outlet	7.81	1,058	960	98	40	8	47.46	40.84	2.41	230

Source: CSE 2020

(A) FAECAL COLIFORM

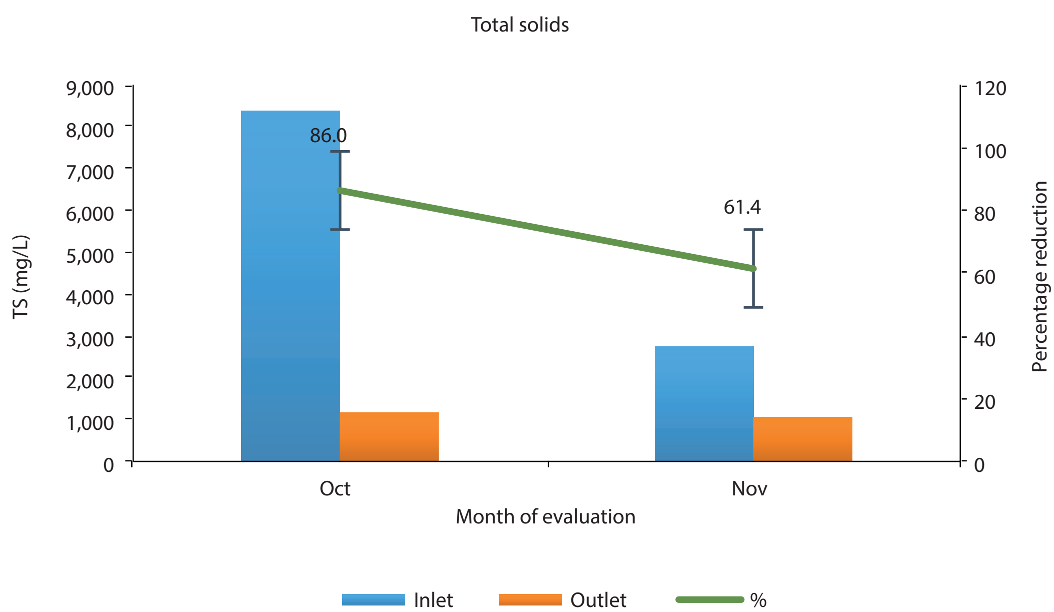
A reduction of 1 log value in faecal coliform was observed, with 92–96 per cent removal efficacy while the leachate passed through a series of anaerobic baffle reactors, anaerobic filters, horizontal flow constructed wetlands, and sand and activated carbon filter followed by UV treatment.



Source: CSE 2020

(B) TOTAL SOLIDS

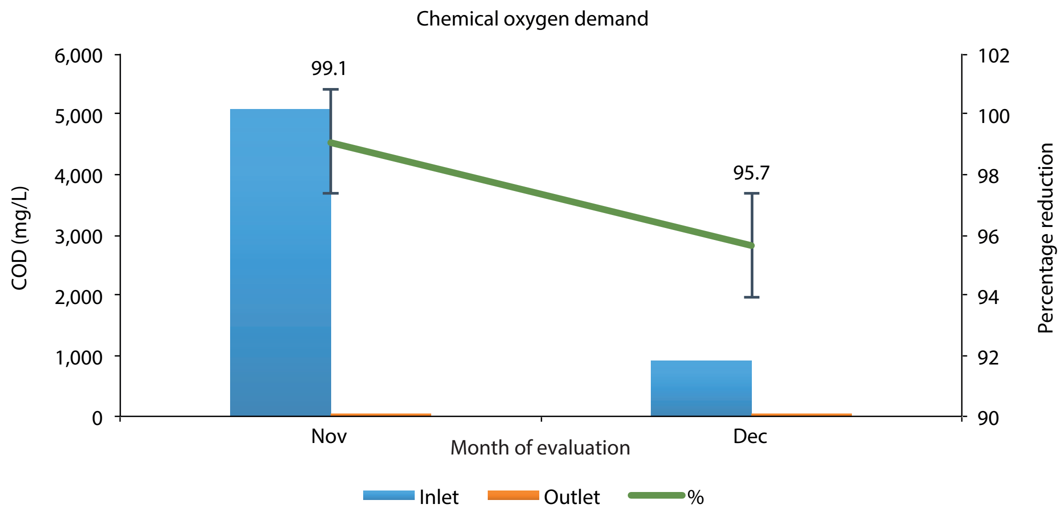
Total solid removal of 61–86 per cent was noticed in the system.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

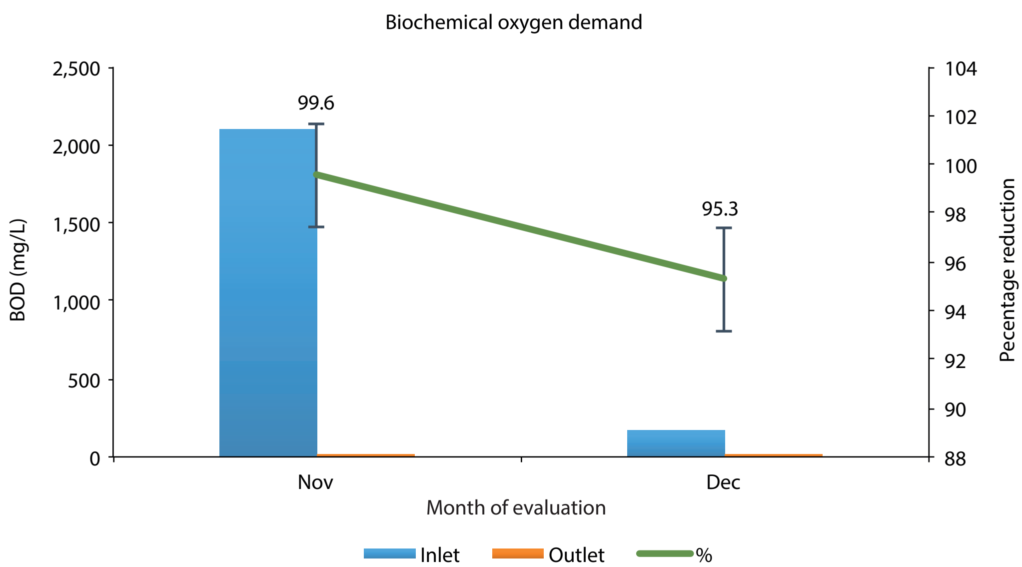
A reduction of 95–99 per cent was observed in the treatment plant.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

A reduction to 95–99 per cent in BOD was observed during the two-month evaluation period and the final effluent water met the discharge standard limit.



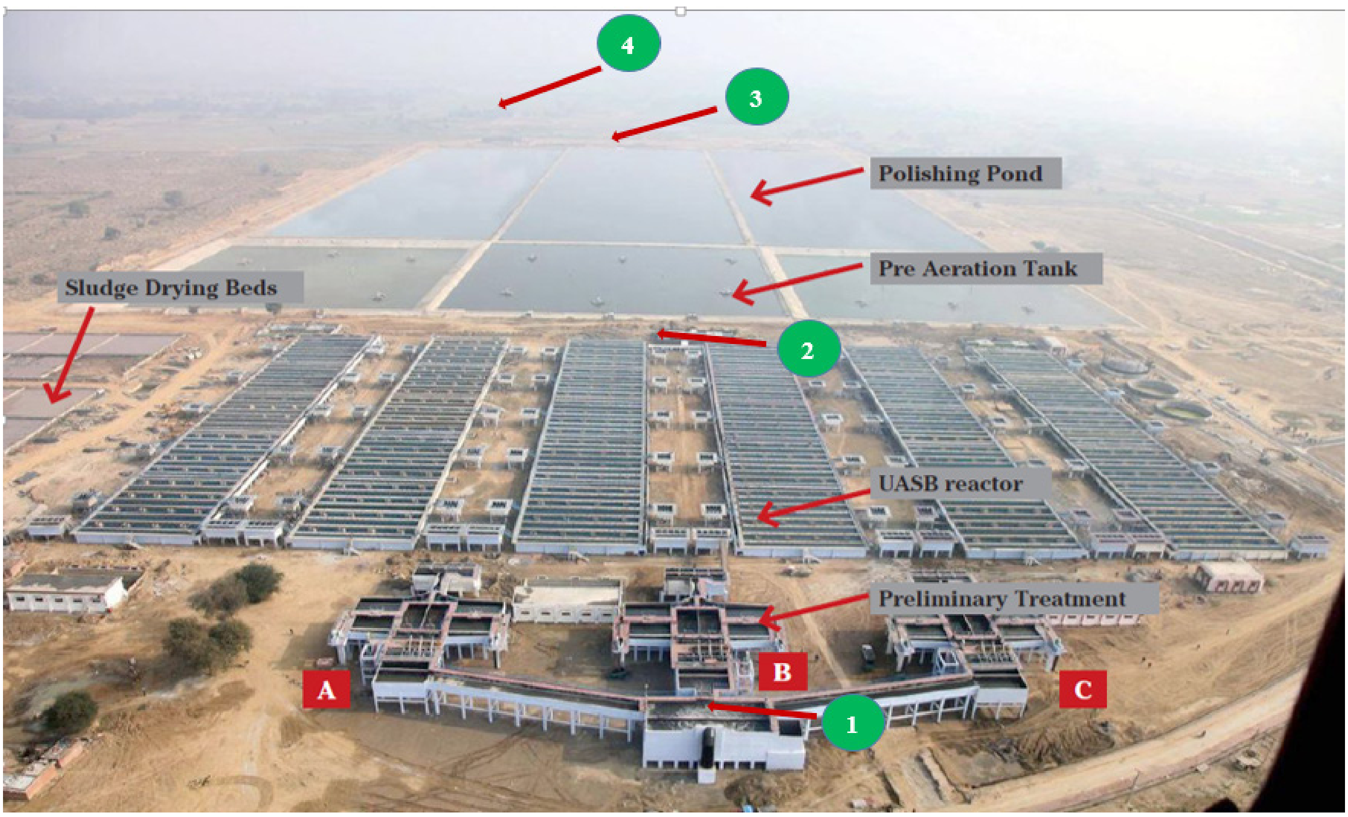
Source: CSE 2020

BHARWARA STP, LUCKNOW (CO-TREATMENT)

Capacity: **345 MLD**
Operator: **SUEZ India Pvt. Ltd**
Study period: **November–December 2019 (two months)**
Sample collection and analysis: **Environment Monitoring Laboratory, Centre for Science and Environment, New Delhi**

Description of treatment system: The Bharwara Sewage Treatment Plant, recognized as Asia's largest STP, is located at Bharwara in Gomti Nagar, Lucknow. The STP, spread over 120 hectares, is based on Upflow Anaerobic Sludge Blanket (UASB) Reactor technology.

The sewage at the inlet of the plant comes from the main pumping station at Gwari. The inlet of the STP is distributed into three distribution streams, A, B and C. Each has a capacity of 115 MLD. From the inlet, the wastewater flows through mechanical screens. Next in line is the grit chamber, which is used to trap inert materials like thermocol, plastic, tetrapack etc. The trapped material is removed from the channel via an outlet at the end of the chamber.

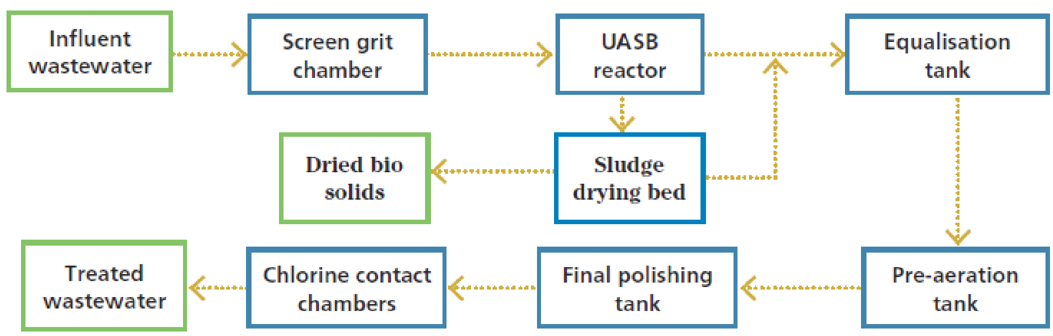


Aerial view of the Bharwara STP with sampling locations

The wastewater then flows to Upflow Anaerobic Sludge Blanket (UASB) reactors. UASB is an anaerobic process that forms a blanket of granular sludge which suspends in the tank. Wastewater flows upwards through the blanket and is degraded by the anaerobic microorganisms. The end product of the process is biogas, which is presently flared into the atmosphere. The sludge generated from the reactor is sent to a sludge pumping station from where it is being pumped to sludge drying beds. 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, where the wastewater is kept for 24–48 hours. From final polishing pond, the treated wastewater is taken to chlorine contact chambers. Here the water is chlorinated, which kills the pathogens in the water. Finally, the water is released from the outlet of the STP to the river Gomti.

The co-processing of faecal sludge in the Bharwara STP is conducted by mixing septage from the tanker with sewage water in pumping stations.

Process flow and sample collection points



Source: CSE 2020

1. Inlet of STP
2. UASB outlet
3. Outlet after polishing pond and before chlorination
4. Outlet after chlorination

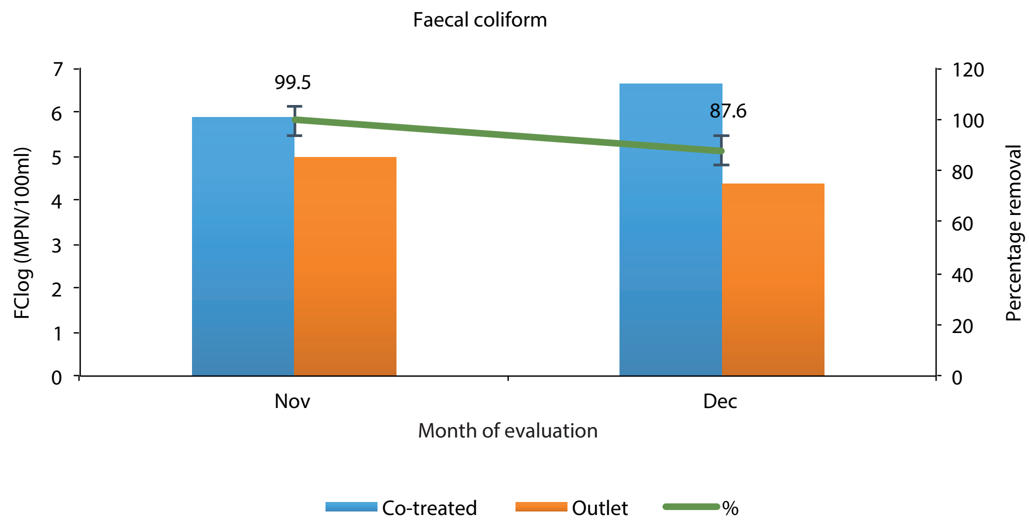
Physicochemical and biological parameters of the samples tested

S. no	Month	Sample location	pH	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	TKN (mg/L)	Ammoniacal nitrogen (mg/L)	Total phosphate (mg/L)	Faecal coliform (MPN/100 ml)
1	Nov 2019	Fresh faecal sludge	7.52	70,075	NT	NT	87,700	4,880	2,580.03	856.73	330	4,300,000
2	Nov 2019	Co-treated wastewater	7.63	820	708	112	422	143	78.04	54.85	6.4	750,000
3	Nov 2019	Inlet STP	7.79	774	672	102	270	89	66.39	38.54	5.8	1,100,000
4	Nov 2019	UASB outlet	8.11	705	602	99	110	46	54.16	32.85	3.9	46,000
5	Nov 2019	Outlet before chlorination	7.75	684	627	57	93	23	42.8	26.26	3.2	93,000
6	Nov 2019	Outlet after chlorination	8.29	589	552	37	92	21	23.59	34.65	3.1	93,000
1	Dec 2019	Fresh faecal sludge	7.3	55,120	NT	NT	76,400	7430	2,114.11	375.69	145	2,300,000
2	Dec 2019	Co-treated wastewater	6.94	672	555	117	256	83	43.97	30.54	6.9	4,300,000
3	Dec 2019	Inlet STP	7.01	785	698	87	530	100	40.18	28.61	6.8	210,000
4	Dec 2019	UASB outlet	7.64	644	569	75	197	51	35.52	33.59	3.5	290,000
5	Dec 2019	Outlet before chlorination	7.31	582	516	66	39	18	36.1	31.54	2.3	43,000
6	Dec 2019	Outlet after chlorination	7.28	572	514	58	53	12	32.9	30.95	2.1	23,000

Source: CSE 2020

(A) FAECAL COLIFORM

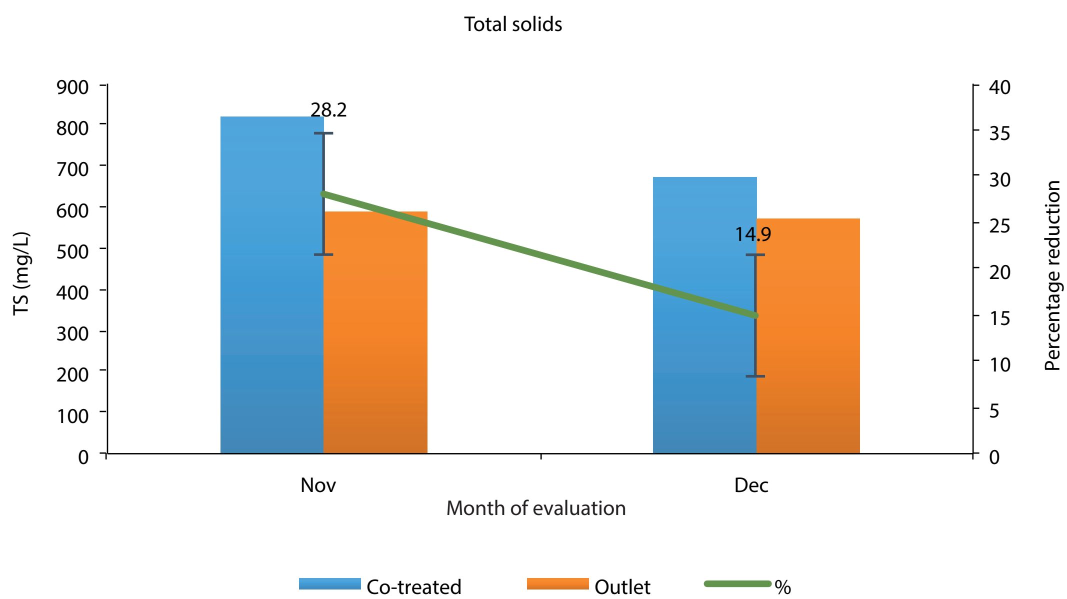
A reduction in faecal coliform to the extent of 1–2 log value was measured in the leachate while passing through the series of flows to the Upflow Anaerobic Sludge Blanket (UASB) reactors, pre-aeration tank, and polishing pond followed by chlorination. An overall reduction of 87–99 per cent of coliform was observed. The chlorination process also seems to have been ineffective because the count before and after chlorination were almost the same.



Source: CSE 2020

(B) TOTAL SOLIDS

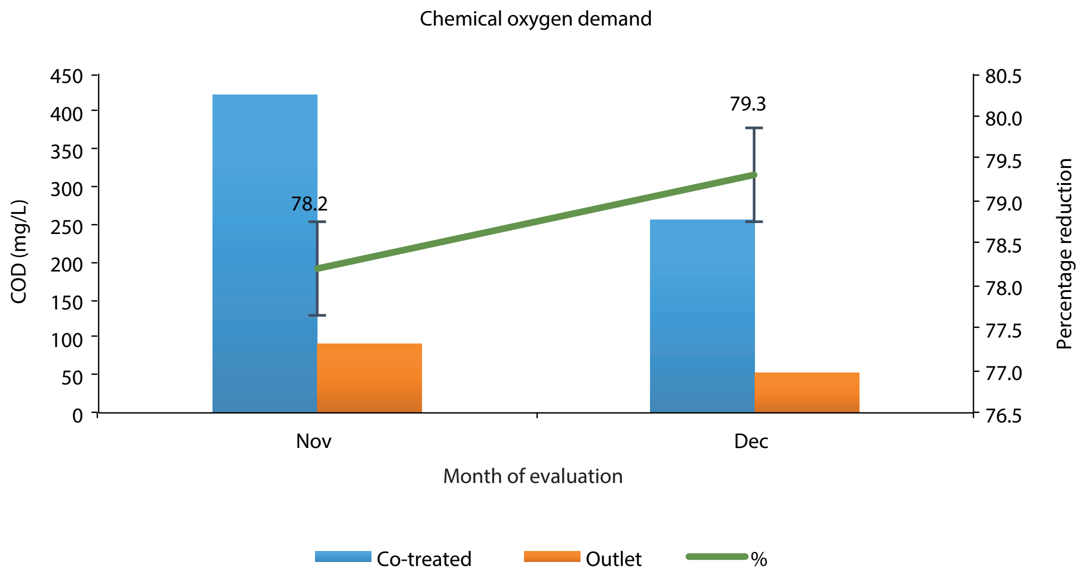
Total solid removal of up to 28 per cent was noticed in the system.



Source: CSE 2020

(C) CHEMICAL OXYGEN DEMAND

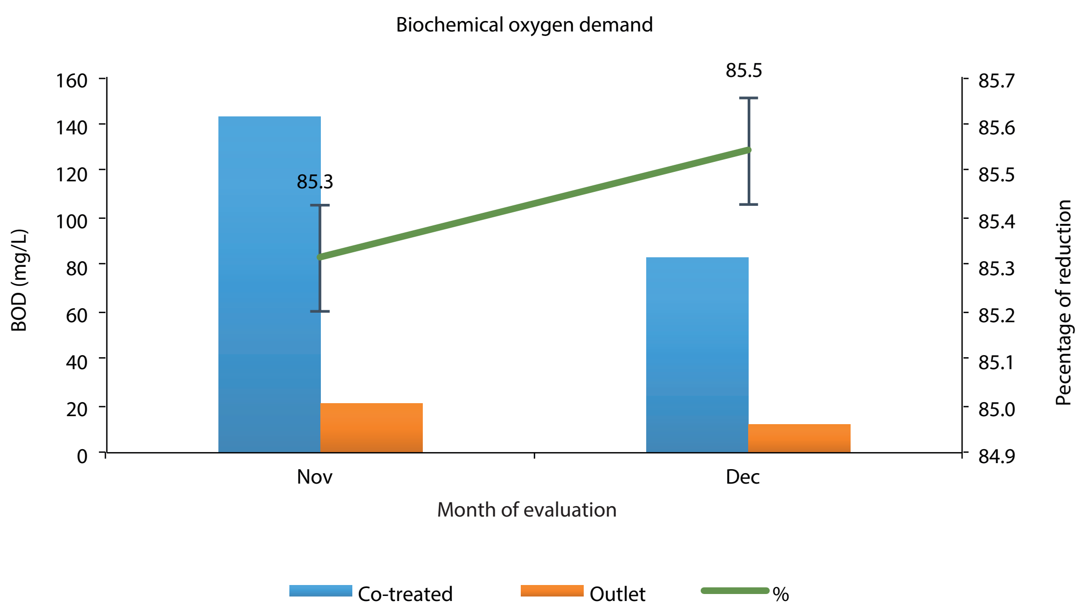
A reduction of 78–79 per cent was observed in the treatment plant.



Source: CSE 2020

(D) BIOCHEMICAL OXYGEN DEMAND

A reduction of 85 per cent in BOD was observed. The discharge water meting the discharge standards.



Source: CSE 2020

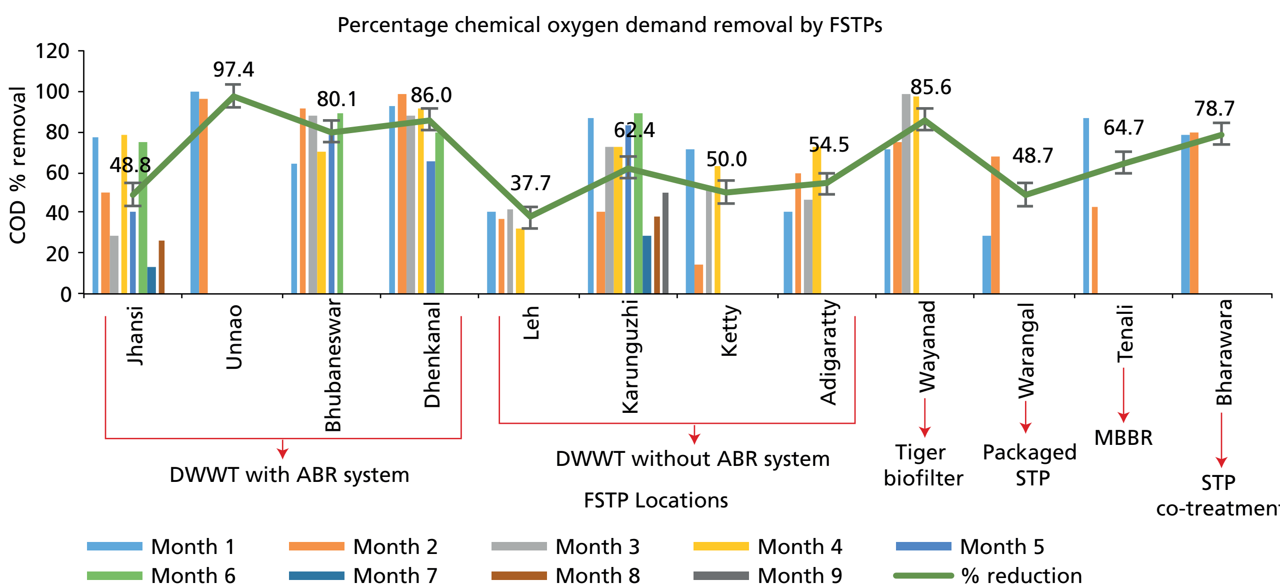
5 Overall performance evaluation of faecal sludge treatment plants

The treatment efficiency of faecal sludge and septage in a total of 11 FSTPs and one STP co-treatment system were subjected to performance evaluations. The study period ranged from two to nine months, depending on the accessibility of the FSTPs. The potential study limitation was for a few FSTPs, the evaluation was conducted only for two months.

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.
The result analysis of the six important parameters are as follows:

5.1 CHEMICAL OXYGEN DEMAND

Chemical oxygen demand (COD) is a measure of total organic compounds that can be degraded by chemical processes. COD represents the oxygen equivalent of the organic matter that can be oxidized chemically with dichromate, a powerful chemical oxidant. The reduction in COD observed in the treatment plants ranged from 38–97 per cent. Treatment plants with an anaerobic baffled reactor or anaerobic digestion modules showed a comparatively high degree of COD removal.

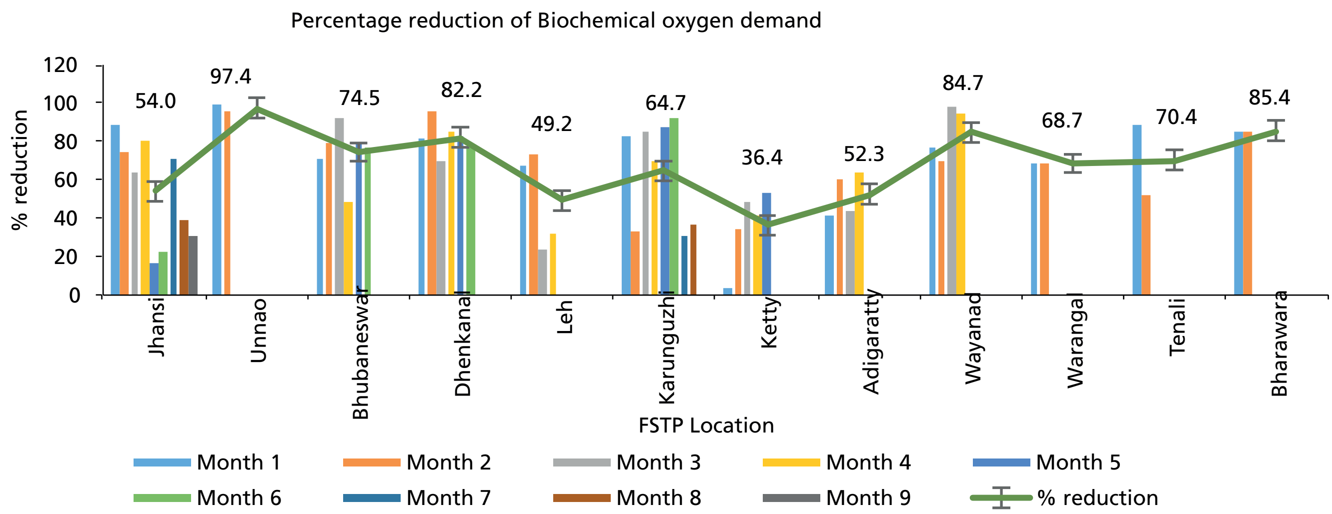


Source: CSE 2020

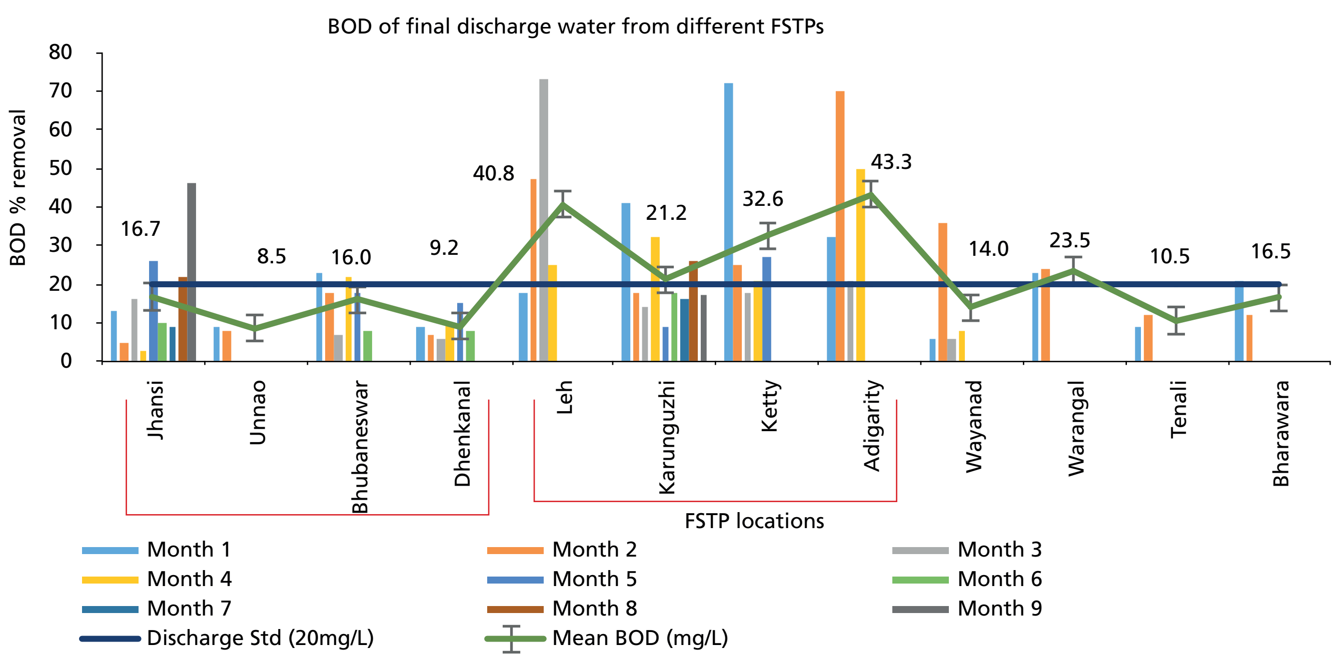
5.2 BIOLOGICAL OXYGEN DEMAND

The oxygen demand of the discharge water is an important parameter to be monitored, as the discharge into the environment can deplete or decrease the oxygen content of waterbodies, resulting in the possible death of aquatic fauna. The oxygen demand is reduced through stabilization, and can be achieved by aerobic or anaerobic treatment.

BOD is a measure of the oxygen used by microorganisms to degrade organic matter. A reduction of 36–97 per cent was observed in the treatment plants (see *Graph: Percentage of reduction of biochemical oxygen demand)*. Treatment plants with the anaerobic baffled reactor or anaerobic digestion modules showed a comparatively high degree of BOD removal and these systems attained BOD levels of discharge water well below the discharge standard values (see *Graph: BOD of final discharge water from different FSTPs*) recommended by the government agencies like the Ministry of Environment, Forest and Climate regulations notified on 13 October 2017.



Source: CSE 2020



Source: CSE 2020

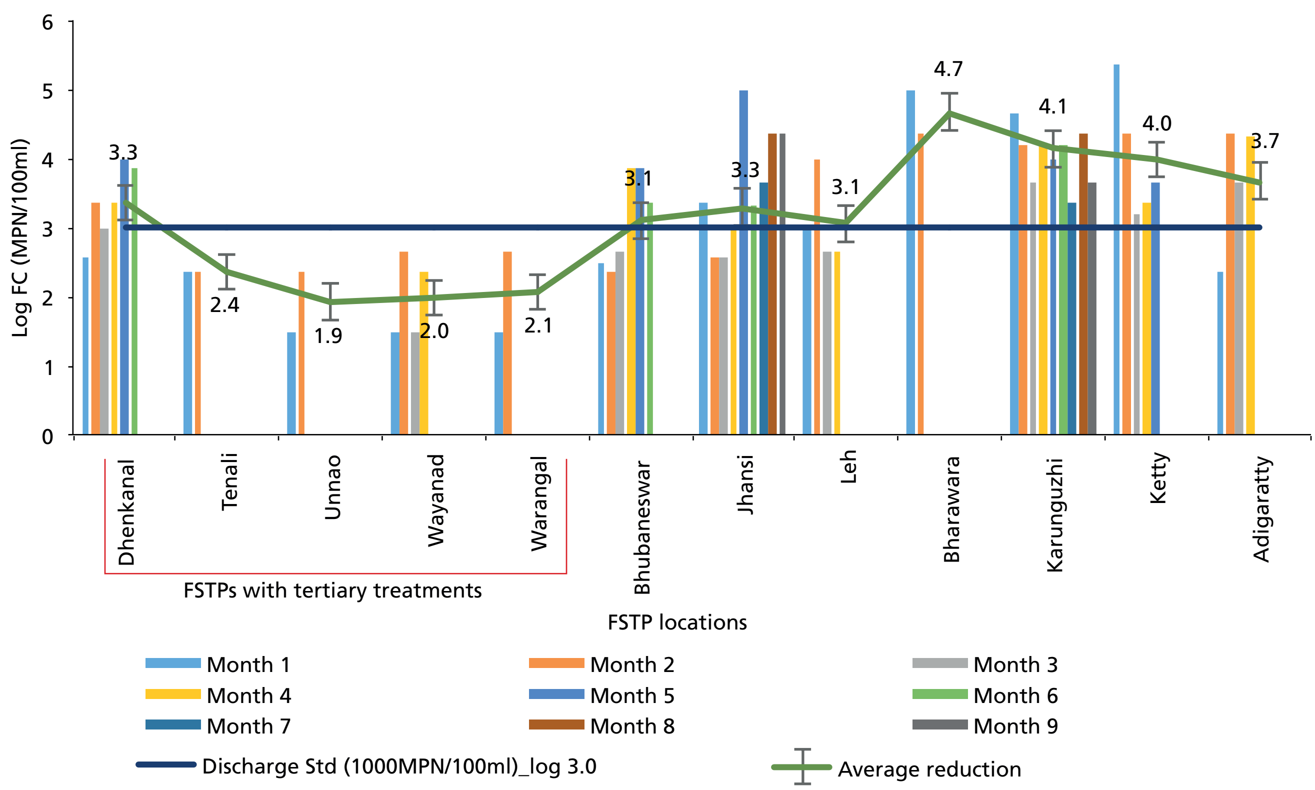
5.3 FAECAL COLIFORM

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. The standard method of analysing thermo-tolerant faecal coliforms relies on their production of acid and gas from lactose when incubated at 44.5°C.

The treatment systems reduced the coliform count in the range of 0–5 log values while the leachate passed through the series of treatment modules. But most of the systems did not meet the discharge standard limits (< 1000 MPN/100 mL) recommended by the Ministry of Environment, Forest and Climate Change and/or NGT, which has a more stringent norms.

It is evident that the FSTPs with tertiary treatment modules like a sand filter, activated carbon filter followed by UV, ozone or chlorination is a good choice to remove the pathogens (coliform) from the discharge water. The FSTPs with these post treatment attained well below the discharge standard limit of faecal coliform by the Ministry of Environment, Forest and Climate regulations notified on 13 October 2017.

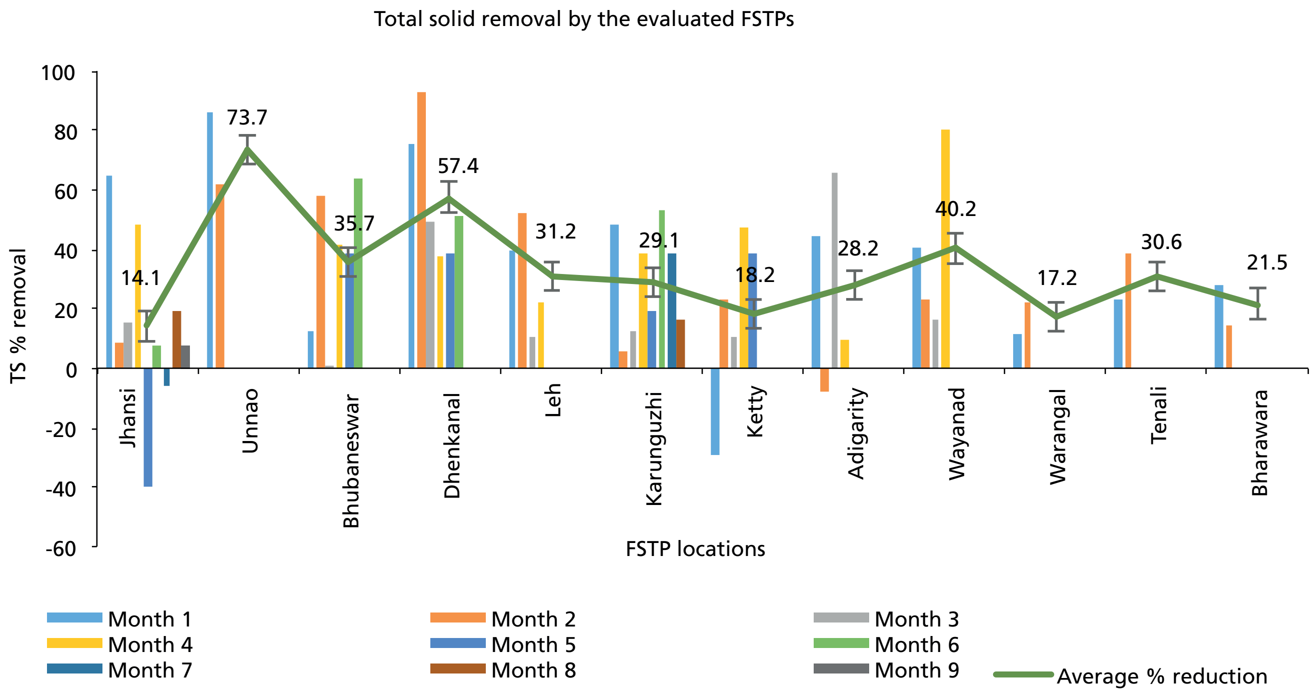
Faecal coliform in final discharge water from the different FSTPs



Source: CSE 2020

5.4 TOTAL SOLIDS

The concentration of total solids in faecal sludge comes from a variety of organic (volatile) and inorganic (fixed) matter, and comprises floating material, settleable matter, colloidal material, and matter in solution. The total solids are quantified as the material remaining after 24 hours of drying in an oven at 103–105°C. There was 14–73 per cent solid removal noticed in the treatment systems. The less percentage removal is noticed in a few FSTPs may be due to the growth of microalga in the polishing pond,[6] which contributed to the total solids in waterbodies. There are negligible total dissolved solids (TDS) removal observed in most of the treatment systems, which also contribute to the less per cent reduction of the amount of total solids.

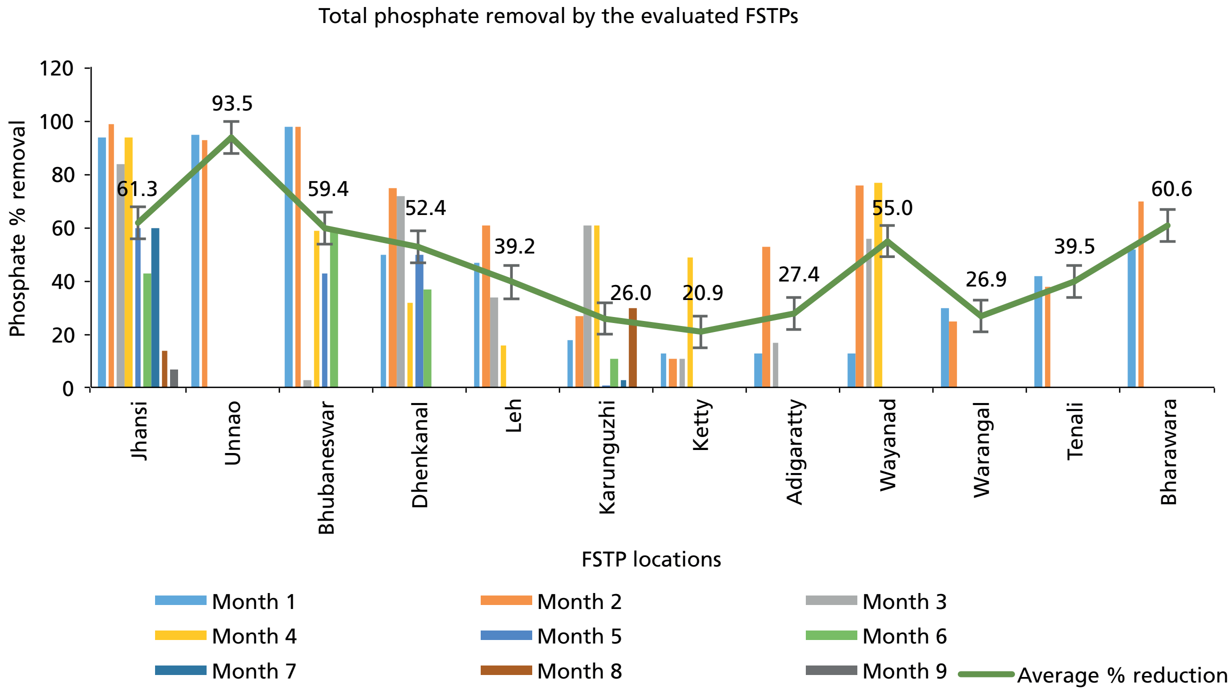


Source: CSE 2020

5.5. PHOSPHORUS

The fate of nutrients during the treatment of faecal sludge is very important as it will determine the end-use opportunities of the sludge and the treatment required for the effluent.

The concentration of phosphorus is also an important parameter to consider, as the total phosphorus concentration in faecal sludge is quite high (e.g. 2–50 times the concentration in domestic wastewater). Phosphorus in faecal sludge will be present as phosphate, the acid or base form of orthophosphoric acid (H_3PO_4 /PO_4-P), or as organically bound phosphate (e.g. nucleic acids, phospholipids and phosphorylated proteins). Of the total phosphorus that is consumed, 20–50 per cent of phosphorus is excreted in faeces. The fate of phosphorus in the various treatment processes will be based on factors such as sorption, precipitation, complexation, sedimentation, mineralization, pH, plant uptake in planted drying beds, and redox potential. Removal of 20–93 per cent total phosphate was noticed in the treatment systems. During biological treatment processes, only about 10–30 per cent of phosphorus is taken up by microorganisms. Phosphorus removal, the primary removal mechanism for phosphorus, appears to be sorption onto the porous media and plant roots. The phosphate removal rate of FSTPs of 20–93 per cent was satisfactory. High removal rate was observed in decentralized wastewater treatment (DWWT) with anaerobic baffled reactor (ABR) and horizontal planted gravel filters systems.

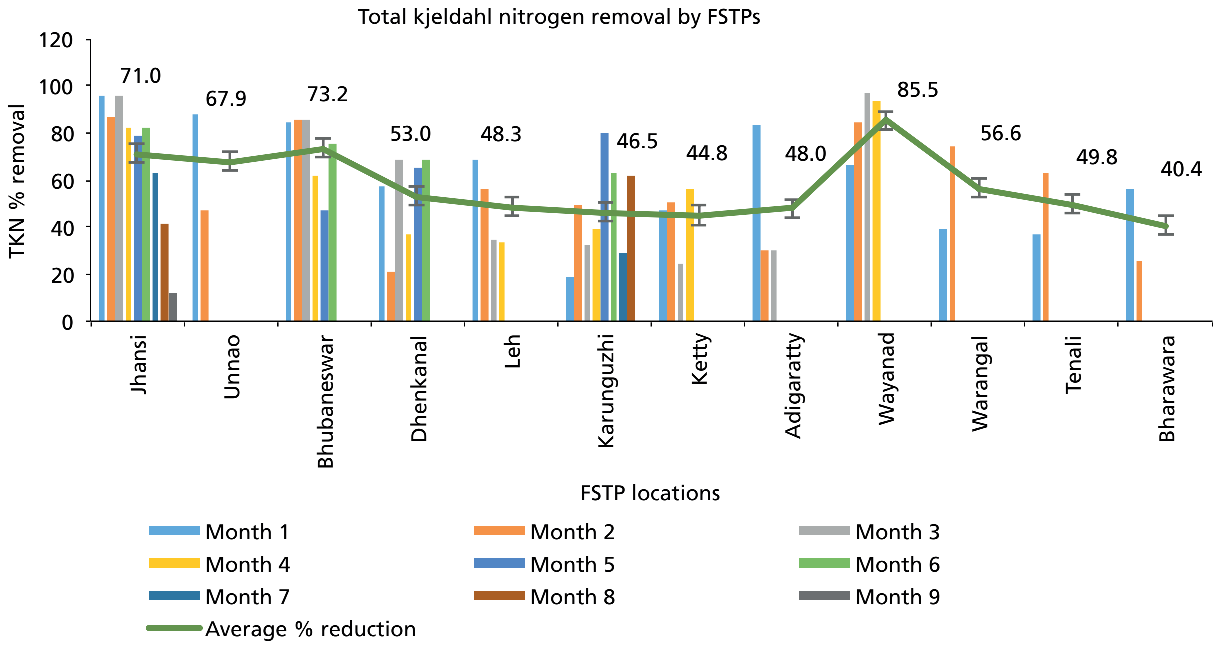


Source: CSE 2020

5.6 TOTAL KJELDAHL NITROGEN (TKN)

Nitrogen is an important parameter to consider in faecal sludge treatment, as the total nitrogen concentrations are typically quite high (e.g. 10–100 times the concentration in domestic wastewater). The nitrogen content in faeces is about 20 per cent as ammonia, 17 per cent as organic nitrogen in the cells of living bacteria, and the remainder as organic nitrogen (e.g. proteins, nucleic acid). Depending on factors such as pH, length of storage, the presence of oxygen, and the type of sludge, nitrogen will be present in a combination of the following forms; ammonium (NH_4-N)/ammonia (NH_3-N), nitrate (NO_3-N)/nitrite (NO_2-N), and organic forms of nitrogen.

Total kjeldahl nitrogen (TKN) is the sum of organic nitrogen and ammonia (NH_3-N)/ ammonium (NH_4-N). It can be determined by the macro-kjeldahl method, the semi-micro-kjeldahl method, or block digestion and flow injection analysis. There was 45–85 per cent TKN removal noticed in the treatment systems. Biological nitrogen removal happens in anoxic environments with the reduction of nitrate to nitrogen gas thereby releasing nitrogen to the air. Nitrogen is mainly removed through nitrification and de-nitrification processes, both of which are increased in the presence of plants, which explains the increased treatment performance of leachate in the planted gravel filter. The removal of TKN was observed in the evaluated FSTPs in the range of 45–85 per cent. High removal rate was observed in the Tiger biofilter system followed by DWWT with ABR systems.



Source: CSE 2020

6 Summary and conclusion

1. This study was conducted with 11 FSTPs and one STP with co-treatment over periods ranging from about two months to nine months of evaluation.

2. The selected FSTPs operated on different working principles.

3. Most of the FSTPs were designed to treat only the liquid portion, after the solid–liquid separation in the initial stage of treatment. The solid part was dried and stored separately or used for co-composting with agricultural waste or vermicomposting.

4. The liquid portion (the leachate) entered through different treatment modules in the FSTPs and the final outlet water was discharged mainly for horticultural purposes.

5. The majority of FSTPs were working on the principle of decentralized wastewater treatment systems (DWWT) with or without anaerobic baffled reactor (ABR).

6. The FSTPs with anaerobic digester/treatment showed higher COD, BOD removal and the final discharge water attained the discharge standard values of the Ministry of Environment, Forest and Climate Change.

7. The faecal coliform values in most of the treated water was very high and not meeting the discharge standard (1000 MPN/100 mL). The FSTPs with tertiary treatment like a sand filter, activated carbon filter followed by UV, ozone or chlorination reduced the faecal coliform count well below the standard discharge value.

8. The removal of total solid (TS) in the majority of the FSTPs was below 50 per cent. This is due to the presence of microalgae in the polishing pond and the removal of TDS is very negligible in all the systems

9. Not much significant variation was observed on the nutrients (phosphate, organic nitrogen and ammonia nitrogen) removal efficacy in the evaluated FSTPs.

10. The newly constructed FSTPs showed good treatment efficiency initially, which is gradually reducing with time. Proper operation and maintenance is essential for steady performance of the FSTPs.

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Faecal sludge treatment plants (FSTPs) are necessary to facilitate safe sanitation. FSTPs in 12 locations with seasonal and geographical diversity in India were evaluated for performance.

In the course of the treatment process, diverse technologies were adopted for solid–liquid separation, followed by successive treatment of wastewater before discharge to the environment. The most commonly used technology was the decentralized wastewater treatment System (DEWATS), where faecal sludge is treated through a settler, anaerobic baffled reactor (ABR), planted gravel filter (PGF) and polishing pond, and treatment initiated with a planted or unplanted sludge drying bed with or without ABR. Where other technologies were used, such as in the Kalpetta FSTP, anaerobically digested faecal sludge was treated through a vermifilter bed to convert sludge to vermicompost. In the Warangal FSTP, after dewatering, the liquid part was treated with a package STP and the sludge underwent thermal degradation (pyrolysis). Similarly, screw press technology was established in the Unnao FSTP for solid–liquid separation of sludge. Co-processing of faecal sludge with sewage water was also monitored in the Bharwara FSTP.

This evaluation provides valuable instructions for urban areas in developing countries and the strategies provide an orientation for stakeholders and decision makers who aim to develop faecal sludge treatment projects. The results help identify operational and maintenance difficulties as well as recommend future expansion to meet increased hydraulic and organic loadings and post-treatment technologies to reduce pathogens, return excreta back to land, use it as fertilizer and reverse the sanitation cycle.

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