Performance Efficiency of Faecal Sludge Treatment Plants (FSTPs) in Maharashtra

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Acknowledgements

Government of Maharashtra focuses on ODF sustainability and ensuring effective collection and treatment of human waste in all cities. Urban Development Department (UDD), GoM developed statewide strategy on faecal waste management and treatment i.e. moving towards ODF++ cities. In this regard, it decided to set up the independent FSTPs 300+ ULBs which are entirely dependent on onsite sanitations systems. With more than 170 operational FSTPs, it was essential to understand the functioning of the FSTPs. This study aims to understand the peformance efficiency of the operational FSTPs in Maharashtra.

The Centre for Water and Sanitation (CWAS) at CEPT University carried out this study in sixteen cities of Maharashtra.

We would like extend our gratidude to various officials at the sixteen municipal councils and corporations, who provided their support in carrying out this study. The testing were conducted at the private NABL accredited laboratories and special mention to Birla Institue of Technology & Science, Pilani, Goa laboratory for testing the dried sludge and compost.

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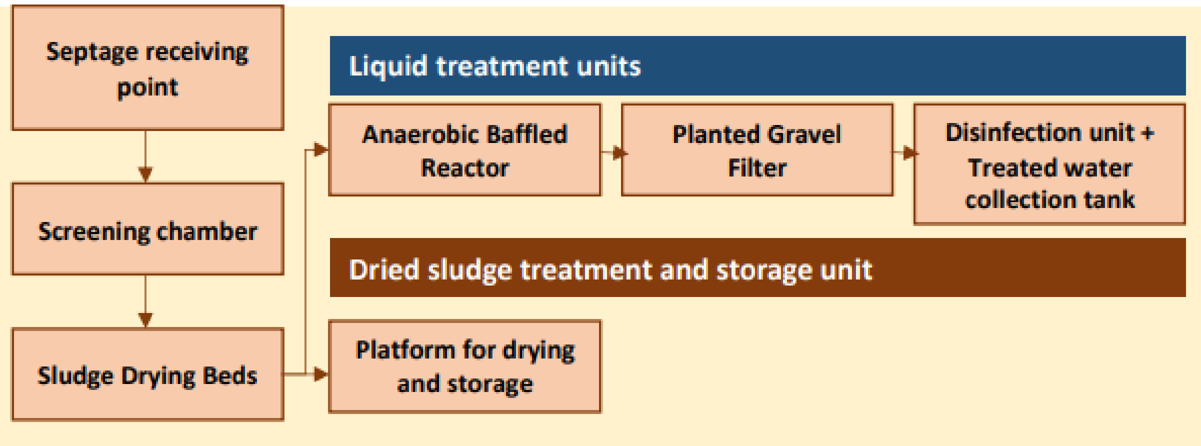
1. Introduction

The state of Maharashtra was declared Open Defaecation Free (ODF) in 2017. Subsequently, it issued a 7-point sustainability charter that included focus on ODF-Sustainability and ensuring effective collection and treatment of human faecal waste in all cities. The state government rolled out a plan to establish nature-based faecal sludge and septage treatment facilities in every city (Government Resolution on FSTP). At present, there are 170+ operational FSTPs across various cities of Maharashtra.

UDD, Government of Maharashtra, in consultation with MJP, decided to implement a cost-effective sludge drying bed-based treatment technology for FSTP. It involves four major modules: namely 1) Sludge Drying Beds (SDB), 2) Anaerobic Baffled Reactor (ABR) 3), Horizontal Planted Gravel Filter (PGF), and 4) Disinfection unit. The facilities have a gravity flow-based system, where septage collected through desludging trucks is discharged to screening chamber from where it flows to different units by gravity (SDB -> ABR -> PGF -> Disinfection Unit -> Reuse/Discharge to environment).

Figure 1 Process flow diagram of FSTP technology



Objective of the study

The study was conducted to understand the performance of the FSTPs operational in Maharashtra. Few cities were selected for this study. The inlet and outlet samples of effluent and treated sludge samples were collected or the study. The main objectives of the study are as follows:

1. To understand the performance of FSTPs
2. To understand the efficiency of each unit at the FSTP
3. To understand the quality of treated sludge

2. Introducing FSTP modules and process description

The technology at FSTP involves four major treatment modules: namely 1) Sludge Drying Beds (SDB), 2) Anaerobic Baffled Reactor (ABR), 3) Horizontal Planted Gravel Filter (PGF), and 4) Disinfection unit.

a) ***Solid treatment by Sludge Drying Beds:*** The septage from the screening chamber is further conveyed to the Sludge Drying Beds which acts as a dewatering and drying unit. It is a simple, permeable bed with sloped base at the bottom holding graded filter media like sand and gravel. When loaded with sludge, the percolate liquid (filtrate) gets out from the bottom of bed through the drainand sludge on the top surface dries by evaporation. This process ideally takes 8-12 days after applying each load during which the beds are used in rotation. Once the moisture content in the sludge reduces to around 30 to 40% , it can be removed and stored on a drying platform for further treatment and safe disposal or reuse.

b) ***Sludge percolate/liquid treatment Liquid treatment Anaerobic Baffled Reactor (ABR) with filters:*** The collected filtrate from the sludge drying beds is treated in liquid treatment units. In the first stage, the liquid passes through an Anaerobic Baffled Reactor (ABR) for reducing its pollutant levels. An ABR is a fixed-bed biological reactor with one or more filtration four chambers in series. As wastewater flows through the filter media, particles are trapped and organic matter is degraded by the active biomass that is attached to the surface of the filter material.

Figure 2 FSTP at Vita Municipal Council

c) **Planted gravel filter (PGF):** Liquid from the ABR is subjected to further treatment in the horizontal planted gravel filter, which is large gravel and sand-filled basin that is planted with wetland vegetation like Canas indica, Phragmites etc. As wastewater flows through the basin, the filter material filters out particles and microorganisms degrade the organics. The filter media acts as a filter for removing solids, provides a fixed surface upon which bacteria can attach, and also acts as a base for the vegetation. Although facultative and anaerobic bacteria degrade most organics, the vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics as well. The plant roots play an important role in maintaining the permeability of the filter media.

d) ***Disinfection unit + treated water collection tank***: The final part of the treatment process includes disinfection unit in the form of an Electro Chlorinator or a Chlorine dosing unit. The treated wastewater from the horizontal planted gravel filter will be further collected in 3000 litres capacity of treated water tank. Chlorination of water is carried out in this unit for disinfection. A pump is installed at the collection tank for disposal or reuse of treated wastewater.

Figure 3 FSTP at Bhadrawati Municipal Council

3. City profiles and sampling methodology

City Profile

16 cities were selected for the various objectives of the study. From 10 cities inlet and outlet samples were collected to understand the performance of FSTPs in March- June 2021. From these 10 cities, two cities were selected for understanding the performance of each unit at the FSTP in April-May 2022. Nine cities were selected for understanding the treatment of sludge at the FSTP. Four cities samples were studied in February 2021 and five cities samples were studied in May 2022. The cities were selected considering the factors of size of cities, FSTP size, technology of FSTPs and more. The cities selected are mainly small and medium cities with population ranging from 19,550 to 97,713, only Satara and Dhule have 2,31,885 and 4,99,998 population respectively.

All the FSTPs are functional with their utilization rate ranging between 20% to 90%. FSTPs at Bhor and Dhule are functioning at its 100% capacity. The treated effluent and the sludge produced at the FSTP are stored in a tank and bags/ platform at the site itself. The by-products are reused for landscaping, gardening, plantation purpose at FSTPs site itself, except for Dhule. Dhule uses its treated effluent for vehicle washing, washing roads, etc.

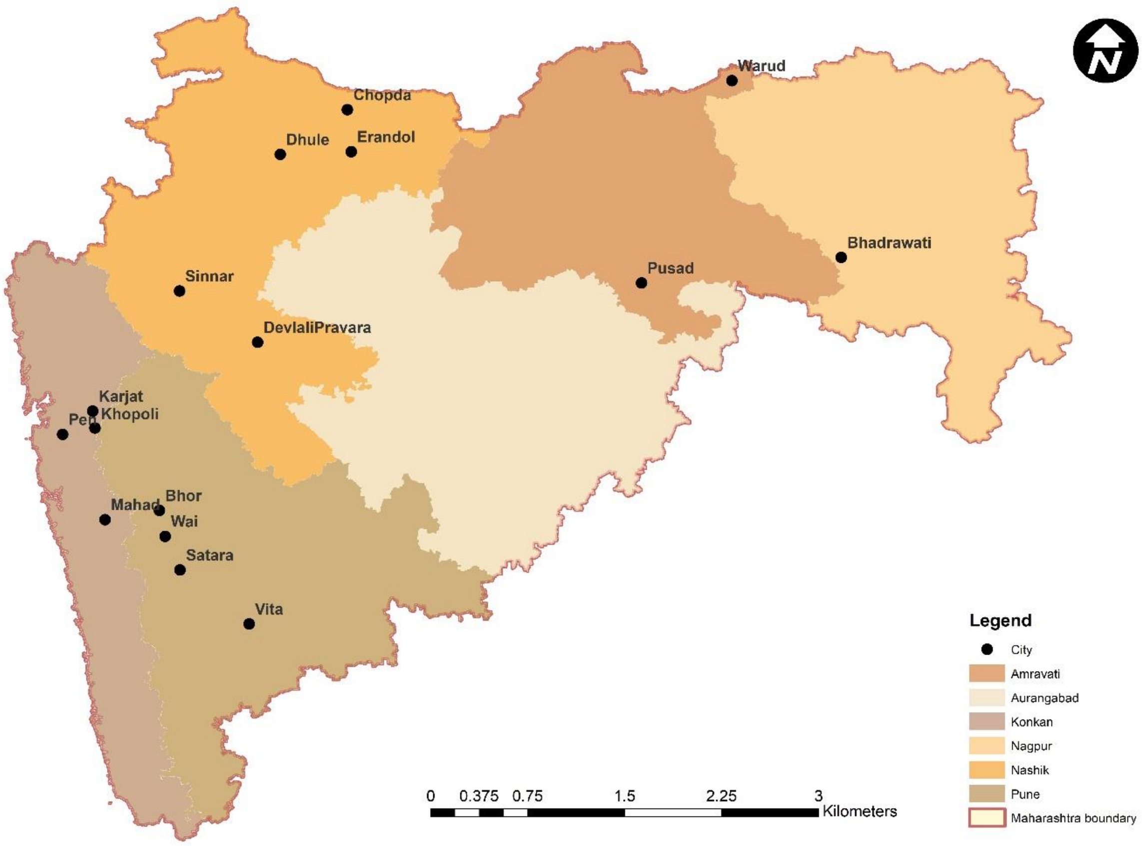
Table 1 City wise details

No.	City Name	Division	Class of ULB	Population	FSTP size (KLD)	FSTP technology	Type of samples collected
1	Dhule	Nashik	M. Corp	499998	20	SDB+ABR+PGF+ CU	Inlet and Outlet
2	Karjat	Konkan	Class C	36030	10	SDB+ABR+PGF+ CU	Inlet and Outlet
3	Mahad	Konkan	Class C	33870	10	SDB+ABR+PGF+ CU	Inlet and Outlet
4	Pen	Konkan	Class C	46558	10	SDB+ABR+PGF+ CU	Inlet and Outlet
5	Pusad	Amravati	Class B	85600	15	SDB+ABR+PGF+ CU	Inlet and Outlet
6	Warud	Amravati	Class B	53100	10	SDB+ABR+PGF+ CU	Inlet and Outlet
7	Bhadravati	Nagpur	Class B	71200	15	SDB+ABR+PGF+ CU	Inlet and Outlet
8	Khopoli	Konkan	Class B	97713	15	SDB+ABR+PGF+ CU	Inlet and Outlet, treated sludge
9	Deolali Pravara	Nashik	Class C	55921	10	SDB+ABR+PGF+ CU	Inlet and Outlet, each unit samples, treated sludge
10	Vita	Pune	Class B	57579	10	SDB+ABR+PGF+ CU	Inlet and Outlet, each unit samples, treated sludge

11	Chopda	Nashik	Class B	90600	15	SDB+ABR+PGF+ CU	Treated sludge
12	Bhor	Pune	Class C	19550	5	SDB+ABR+PGF+ CU	Treated sludge
13	Erandol	Nashik	Class C	39892	10	SDB+ABR+PGF+ CU	Treated sludge
14	Wai	Pune	Class C	50000	70	Pyrolysis	Treated sludge
15	Sinnar	Nashik	Class C	98000	70	UASB+ ABR	Treated sludge
16	Satara	Pune	Class A	231885	20	SDB+ABR+PGF+CU	Treated sludge

SDB- Sludge Drying Bed; ABR- Anaerobic Baffled Reactor; PGF- Phytorid Gravel Filter; CU- Chlorinator Unit

Figure 4 Location map of all 16 cities



The testing of all the samples was conducted by NABL accredited laboratories following the IS standard test procedures or American Public Health Association (APHA) provided test procedure to determine the parameter values. Details are available in Annex-1. Test for various parameters such as BOD, COD, faecal coliform, Nitrates, Total Phosphorous, Total coliforms, Total suspended solids and various pathogens including Helminth eggs were conducted.

Sampling methodology

Sampling methodology of inlet and outlet of effluents for 10 cities

Inlet sample: It is a composite sample which was collected while the desludging vehicle was unloading the septage at the SDB. For each truck one bottled sample is prepared by grabbing samples of equal volume taken directly from the truck at the beginning, middle and end of discharge and then mixed thoroughly. At the end of the day, all the samples collected from each trip made by the trucks at FSTP are mixed thoroughly in a big vessel. The sample from this vessel is considered as the inlet sample at FSTP.

Outlet sample: A grab sample was collected from the chlorination unit of the FSTP for the treated wastewater sample.

Figure 5 Sample collection at FSTP site

Sampling methodology to assess performance of each unit at FSTP for two cities

To understand the performance of each unit of the treatment plant, inlet and outlet samples from each unit of the FSTP were taken. Total five samples were taken from each FSTP- inlet of SDB, inlet of ABR (outlet of SDB), inlet of PGF (outlet of ABR), outlet of PGF and final outlet sample from the chlorination tank. The inlet sample of SDB was collected in the similar way as mentioned in earlier section. Grab samples were collected from the remaining four samples of the FSTP.

Figure 6 Samples collected from each unit at the FSTP site

Sampling methodology for treated sludge for nine cities

Two types of samples were collected from each FSTP. Sample 1- the dried sludge was collected from the Sludge Drying Bed after 14 days of the drying period. A mix of sample was prepared by collecting dried sludge from all four corners and center of the drying bed. Sample 2- the dried sludge which was removed from the sludge drying bed at FSTP is then further kept on the platform where it is dried and stored. The second sample dried sludge from the platform which is dried for a period of one month. It is denoted as Dried sludge pile_one month dry.

A mixture of dried sludge and the compost produced through solid waste treatment were also tried and tested to understand the use of sludge as fertilizer. These samples were collected from Sinnar's FSTP and SWM site.

4. Treatment efficiency of FSTPs

To understand the performance efficiency of the FSTPs, quality monitoring tests were conducted at 10 FSTPs in Maharashtra. One inlet sample (inlet septage) and one outlet sample (treated wastewater) were collected from each FSTP.

Table 2 captures the performance efficiency of the ten FSTPs. It highlights that the almost all the FSTPs have more than 95% removal of BOD, COD, Total suspended solids and Faecal Coliform. Even the phosphorous percentage removal is ranging from 20.6% to 98.5%. The inlet values of BOD of septage ranges from 123 mg/l to 12,000 mg/l.

Table 2 Percentage removal of COD, BOD and Total Nitrogen (TN)

No.	City	BOD removal	COD removal	Faecal Coliform removal	TSS removal	Phosphorous removal
1	Dhule	99.8%	99.8%	97.7%	96.2%	20.6%
2	Deolali Pravara	98.6%	98.0%	-	98.7%	-
3	Karjat	79.5%	79.7%	100%	-	57.9%
4	Khopoli	100.0%	100.0%	100%	99.1%	94.6%
5	Mahad	90.0%	90.9%	100%	99.5%	95.3%
6	Pen	97.2%	97.2%	100%	99.5%	93.9%
7	Pusad	98.7%	98.7%	100%	99.6%	75.3%
8	Warud	94.7%	94.9%	100%	99.8%	98.5%
9	Bhadrawati	99.4%	99.3%	100%	99.0%	67.0%
10	Vita	99.3%	99.4%	100%	98.6%	93.5%

Removal of organic load (BOD and COD) at FSTPs

The BOD and COD in the treated effluent varies from 8-78 mg/l and 25- 224 mg/l respectively, with average values of the BOD and COD being 28 mg/l and 86 mg/l. The efficiency of removal of BOD and COD is 80- 98%, more than 90% of removal is observed in 9 cites. The median of COD to BOD ratio is 2.8. 7 cities have achieved the disposal norms by MoEFCC 2017 of achieving BOD less than 30 mg/l and 6 cities have achieved the disposal norm by NGT, 2019 for COD less than 50 mg/l. Both the units, ABR and PGF in the technology support in removal of BOD and COD efficiently. Only two treated outlet samples showed BOD values more than 30 mg/l i.e. Pusad (74 mg/l) and Warud (78 mg/l).

Figure 7 BOD outlet results

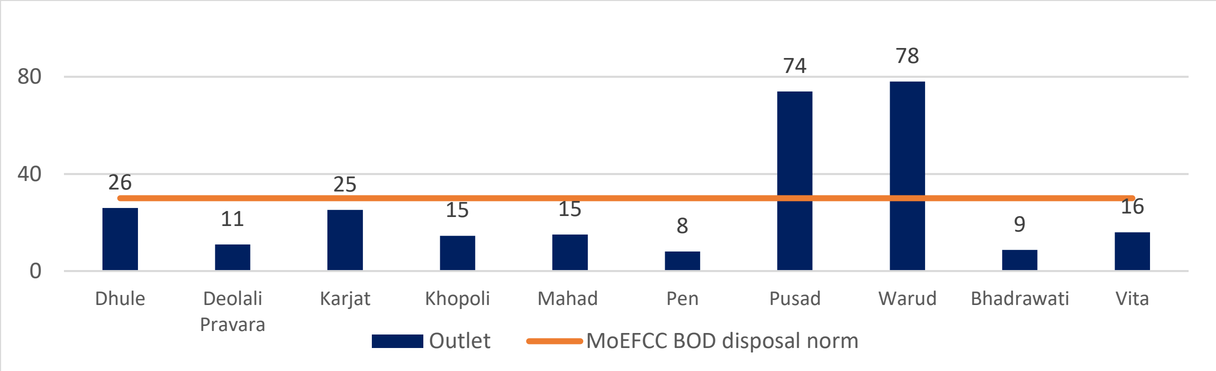
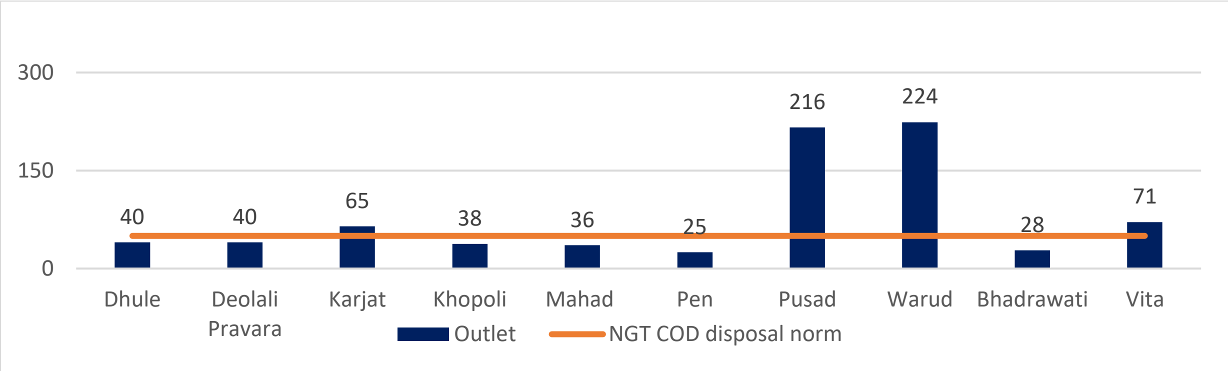


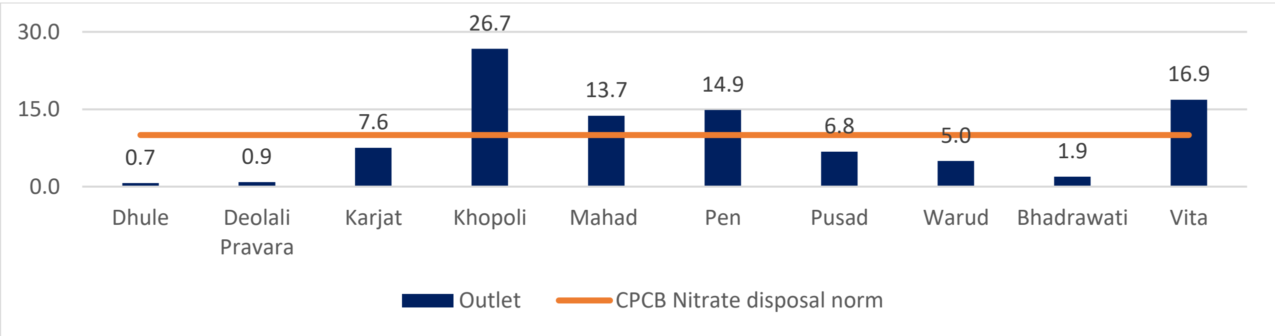
Figure 8 COD outlet results



Removal of nutrients (Phosphorous as PO4 and Nitrates NO3-N) at FSTPs

The norms of disposal for Nitrates by CPCB and for dissolved phosphorous by NGT, 2019 are 10 mg/l and 1 mg/l. The average outlet effluent values for Nitrates and Phosphorus is 9 mg/l and 4 mg/l respectively, ranging from 0.7-26.7 mg/l and 0.2-9.5 mg/l resp. 6 cities have achieved the standards for Nitrates and 9 cities have achieved the standards for Phosphorous.

Figure 9 Nitrate outlet results

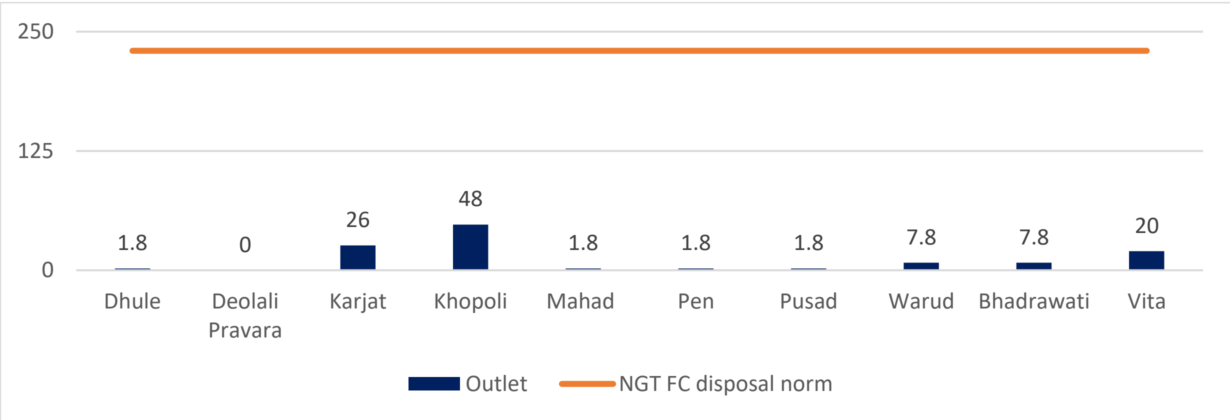


The removal of nutrients like Nitrogen and Phosphorous is significant as they lead to eutrophication process in water. CPHEEO's chapter 5 mentions that, "… these chemicals are well known to contribute to eutrophication in receiving waters, especially stagnant ones" (CPHEEO, 2013, pg. 119). The treated effluent at the FSTP is stored in a tank and reused mainly for plantation or landscaping purposes. The treated effluent is not let into any water bodies.

Removal of pathogens (Faecal Coliforms) at FSTP

The disposal standard for faecal coliform as per the NGT, 2019 is 230 MPN/100 ml. All the ten FSTP's have adhered to the disposal standards with outlet effluent values ranging from 1.8- 48 MPN/ 100 ml. The inlet value of faecal coliforms varies from 10^4-10^5 MPN/ 100 ml. The final part of the treatment process at the FSTP includes disinfection unit in the form of an Electro Chlorinator or a Chlorine dosing unit. As per various studies, proper disinfection through chlorination will help in the removal of faecal coliforms (Mittal, A. and Pant, A., 2007; F. A. Fattouh and M. T. Al-Kahtani, 2002). This improves the efficiency of the FSTP in removal of the faecal coliforms.

Figure 10 Faecal Coliforms outlet values



5. Performance of each unit at FSTP

The overall performance efficiency of the FSTPs was understood in the earlier section. This section captures the performance of each unit at the FSTP. Inlet and outlet samples were collected from each unit at 2 cities, namely Deolali-Pravara and Vita.

The average removal of COD, BOD and total nitrogen (TN) is 94%, 97% and 97% respectively. The functioning of units is good which has shown treated effluent quality complying with the disposal standards provided by CPCB and MoEF&CC, 2017 and few parameters have also matched the NGT, 2019 standards. Gradual reduction of organic load and nutrient load is observed across the units.

Table 3 Overall removal of COD, BOD and Total Nitrogen (TN)

	City	Per cent removal COD	Per cent removal BOD	Per cent removal TN
1	Deolali Pravara	91.1	95.3	88
2	Vita	97.4	98.8	97.6

Performance of Sludge Drying Bed (SDB) unit

The main function of the Sludge Drying Bed is to separate the solids and liquid. The solids contain the major portion of organics. The SDB unit has shown removal of more than 94% for BOD and COD. The total suspended solids are also reduced by 99% from the inlet septage values. The SDB is designed with BOD removal of 40% and TSS removal of 70%. When the sludge is dried at the SDB, they are transferred to the drying platforms where the sludge are further sun-dried which improves the quality of sludge. The section-5 on treated sludge captures the quality of sludge achieved through the FSTPs.

Table 4 Performance of SDB unit

Performance of SDB unit	BOD			COD			TSS		
	Inlet	Outlet	% removal	Inlet	Outlet	% removal	Inlet	Outlet	% removal
Deolali Pravara	8700	480	94%	24288	1295	95%	64890	424	99%
Vita	8400	285	97%	21918	796	96%	28600	212	99%

Performance of Anaerobic Baffled Reactor (ABR) unit

The ABR units across the selected cities have shown an average removal of BOD by 81%. Average 59% of total suspended solids are removed at this unit and more than 70% of total nitrogen is removed at ABR unit. The ABR is designed with 90% efficiency to remove BOD, COD and TSS and 15% treatment efficiency for total Nitrogen. Moderate amount of pathogens will also be reduced in this unit as per design and in practice on an average 99% of faecal coliforms are being removed at ABR unit.

Table 5 Performance of ABR unit

Performance of ABR unit	BOD			COD			TSS		
	Inlet	Outlet	% removal	Inlet	Outlet	% removal	Inlet	Outlet	% removal
Deolali Pravara	480	96	80%	1295	243	81%	424	210	50%
Vita	285	48	83%	796	158	80%	212	70	67%

Performance of Planted Gravel Filter (PGF) unit

The PGF unit is designed with the treatment efficiency of 80% to remove BOD, COD and TSS and reduce high number of pathogens. The PGFs are showing an average removal of 51% of BOD and more than 80% removal of total suspended solids. 40% faecal coliforms are reduced at the PGF unit, the chlorination step also boosts the removal of faecal coliform by 88%.

Table 6 Performance of PGF unit

Performance of PGF unit	BOD			COD			TSS		
	Inlet	Outlet	% removal	Inlet	Outlet	% removal	Inlet	Outlet	% removal
Deolali Pravara	96	62	36%	243	223	8%	210	24	89%
Vita	48	16	66%	158	71	55%	70	15	79%

6. Quality of treated sludge

Ascaris spp and Trichuris app. are the most common type of Helminth eggs which are found in faecal sludge. The inlet characteristics of septage has approximately 4,000 helminth eggs/ml (Strauss, 1996)[1]. To understand the treatment quality of the sludge in regard to presence of pathogens, particularly Helminth eggs and its larvae, treated sludge samples were tested. Two samples of treated dried sludge from nine FSTPs were collected for testing.

Removal of Helminth eggs

The inlet characteristics of septage has approximately 4,000 helminth eggs/ml (Strauss, 1996)[2]. The treated sludge results have viable helminth eggs presence of 4-5 units per gram (i.e. 4-5 units/ml). This indicates that the septage is treated at ~99 percent efficiency at the FSTPs.

5 cities did not presence of viable Helminth eggs and larvae presence. Sinnar's treated sludge and compost mix of sludge and compost did not show presence of viable helminth eggs. "Helminth eggs contained in wastewater, sludge, or excreta may be viable (alive) but not infective. To be infective, the eggs need to develop into larvae, which require a temperature of around 25°C combined with a moisture content of at least 5%".[3]

The dried sludge of Wai and Vita showed presence of helminth eggs and larvae. During the sampling the atmosphere was moist because of the rains in both Wai and Vita, this might be the reason for the survival of helminth eggs. Interestingly, Sinnar SWM compost sample (without mixture of dried sludge) found the presence of larvae that indicates possibility of human feacal waste contamination from used diapers as these were generally dispose to SWM processing site.

To inactivate helminth eggs it is recommended either to raise the temperature (above 40ºC), to reduce moisture (below 5%) or to maintain both of these conditions for an extended period of time.[4] In accordance with this, in the summer months the drying period can be a month and for total removal of helminth and pathogens from sludge, the drying period can be increased for the monsoon and winter seasons.

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[1] Strauss, 1996 cited in "Septage management in urban India: Advisory note" by Ministry of Urban Development, Government of India

[2] Strauss, 1996 cited in "Septage management in urban India: Advisory note" by Ministry of Urban Development, Government of India

[3] Jiménez, B. et. Al. (2017) "Helminths and their role in environmental engineering" Human Helminthiasis

[4] IWA page on Helminth eggs. Retrieved from https://www.iwapublishing.com/news/helminth-eggs on 25th February, 2021.

Table 7 Presence of Helminth eggs in treated sludge

Sample	Helminths Eggs per gram Ascaris spp.		Helminths Eggs per gram Trichuris spp.		Larvae
	Viable[5]	Non-Viable[6]	Viable	Non-Viable	
Wai- Dry sludge pile_one month dry	-	-	5	-	5
Biochar Wai	-	-	-	-	4
Vita- SDB sample_14 days dried	-	-	-	-	-
Vita- Dry sludge pile_one month dry	-	-	3	-	-
Khopoli- SDB sample_14 days dried	4	12	-	-	-
Khopoli- Dry sludge pile_one month dry	-	-	-	-	-
Sinnar - Dried sludge sample	-	4	-	-	-
Sinnar- Compost- Sludge + compost (1:1)	-	-	-	-	-
Sinnar- Compost- Sludge + Compost (1:2)	-	-	-	-	-
Sinnar- Compost- Sludge + Compost (1:3)	-	-	-	-	-
Sinnar - SWM compost sample	-	-	-	-	4
Erandol- SDB sample_8 days dried	-	48.06	-	-	-
Erandol- Dry sludge pile_one month dry	-	-	-	-	-
Chopda- SDB sample_8 days dried	-	-	-	-	-
Chopda- Dry sludge pile_one month dry	-	-	-	-	-
Deolali- SDB sample_8 days dried	-	-	-	-	-
Deolali- Dry sludge pile_one month dry	-	-	-	-	-
Bhor- SDB sample_14 days dried	-	-	-	-	-
Bhor- Dry sludge pile_one month dry	-	-	-	-	-
Satara- Dry sludge pile_45 days dry	-	-	-	-	-

[5] Viable means the larva would be able to hatch from the egg
[6] Non-viable means the eggs would not be able to produce larvae

Use of treated sludge as compost:

For the use of septage as compost, different ratios of septage and compost from SWM waste were mixed to understand the quality of compost obtained. Various elements tests as per the SWM, 2016 rules requirement for compost and pathogens test for Sinnar's sludge and compost mix were tested. In the elements test all the samples complied for most of the parameter. Phosphoruus, Cadmium and Nickle parameters did not comply with the limits set by the advisory. The phosphorous content in the sample is less than required. Cadmium and Nickle values exceed the desired limit of compost mixture. However as per the Advisory of decentralized composting, 2018 - A sum total of nitrogen, phosphorus and potassium nutrients shall not be less than 1.5% in compost-- All the samples comply with this requirement. As the treated sludge sample is Nitrogen rich the value of nitrogen increases when the mixed compost is prepared. Also with the addition of Sludge to compost the content of Nickle is also reducing. Also from the pathogen analysis above, it is observed that the addition of compost to the treated sludge reduces the content of coliforms, e-coli, salmonella, etc in it.

The urban septage management advisory have defined limits[7] for dewatered septage use as fertilizer in agriculture application (The advisory uses USEPA[8], WHO standards). The dried sludge is not complying with the limits provided for faecal coliform, salmonella, e-coli, etc. It is observed that with the addition of compost with the dried sludge, the concentration of pathogens is decreasing. Studies have shown that co-composting reduces the Helminth eggs in Faecal sludge (Gallizzi, K., nd). In the case of Sinnar, the compost mix with 1:3 and 1:2 ratio have less pathogen values. However, these compost mixes have high Cadmium and Nickle value. Compost mix with ratio 1:1 has less Nickel and Cadmium value but higher pathogen values in comparison with 1:2 and 1:3 ratio compost. There is a need to identify which compost mix will be viable for the use of compost for agriculture use. The solid waste, 2016 rules does mention this below the standards table: Compost (final product) exceeding the above-stated concentration limits shall not be used for food crops. However, it may be utilized for purposes other than growing food crops. Thus the compost mixture can be used for landscaping and other purposes.

[7] Fecal coliform less than 1000 MPN/g total dry solids; Salmonella sp. less than 3 MPN per 4 g of total dry solids. Helminth egg concentration of < 1/g total solids and E coli of 1000/g total solids for use in agriculture."

[8] Class A Bio-solids of US EPA

7. Summary

The results show good treatment efficiency of the treatment plants. The parameters such as BOD, COD, faecal coliforms, suspended solids, have shown significant reduction in pollutant loads after treatment. These have complied with the disposal standards provided by CPCB and MoEF&CC, 2017. All the units have shown good performance efficiency. Gradual reduction of nutrient load is observed across the units.

The values of nitrate and phosphate are higher in few of the outlet samples in comparison to the disposal standard. If the treated water is going to get realised into any water body then further treatment must be considered, the water can be utilized for landscape or plantation purposes.

The efficiency of the units at FSTPs get affected due to various reasons such as low and irregular disposal of septage load at the FSTPs, unmaintained units, untrained workers and more. To sustain the performance of FSTPs, it is crucial to make efforts towards regular desludging, training the workers and improving the performance of FSTPs. Usage of PPE and training of FSTP workers is very significant to keep the operations safe at the treatment plant. Regular monitoring of the FSTPs must also be taken up at the state level.

The nature-based technology at FSTPs have shown efficient performance with minimum resources requirement. Similar approach can be adopted across various small and medium cities of India which are dependent on onsite sanitation services.

Annex 1: Testing Methodology

Testing methodology of effluents

To collect and test the samples, nationally accredited laboratories are identified. In phase 1, four laboratories were identified for the work and one laboratory was given the work in phase 2. The laboratories used either IS standard test procedures or American Public Health Association (APHA) provided test procedure to determine the parameter values. Below are the test procedures adopted for testing:

Table A1: Testing methods used by laboratory

No.	Parameters	Testing methods used by Laboratory
1	pH	IS 3025 (Part 11)
2	Total Dissolved Solids	IS 3025 (Part 16)
3	COD	IS:3025 (Pt.58)- 2006/ APHA 23rd Editon, 5220 B
4	BOD3	IS 3025 (Part 44)
5	Total Suspended Solids	IS 3025 (Part 17)
6	Total Phosphorous (as P)	IS:3025 (Pt.31)-1988/ APHA 23rd Editon, 4500-P D
7	Chloride (as Cl)	IS 3025 (Part 32)
8	Nitrates (as NO3)	APHA 23rd Edition, 4500-N03- B
9	Total Nitrogen (as N)	APHA 23rd Editon, 4500-N A
10	Faecal Coliforms	lS:1622/ APHA 23rd Editon, 9221 E
11	Total Coliforms	IS 5401 (Part 1)/ APHA 23rd Editon, 9221 B

Testing methodology for sludge

Helminth eggs analysis was done by using Improved AmBic Method (Pebsworth, Archer, et al; 2012), bacterial pathogens were analyzed using standard spread plating method.

Annex 2: Sludge and Compost Mix- Test results

Table A2: Compost and dried sludge samples test results

		Sinnar Samples					SWM, 2016 compost quality standards
	Test Parameters	**1:3 compost**	**1:2 compost**	**1:1 compost**	**Only compost**	**Dried sludge**	**Organic compost (FCO 2009)**
1	pH	**7.2**	**7.2**	**7.3**	**6.8**	**6.9**	**6.5-7.5**
2	Electrical Conductivity	**1.6**	**1.5**	**1.2**	**1.2**	**2.1**	**4.0**
3	Moisture Content at 108°C %	**5.9**	**6.0**	**6.3**	**27.9**	**7.6**	**15-20**
4	Total Organic Carbon, by weight %	**13.9**	**13.8**	**12.9**	**9.5**	**18.7**	**minimum 12**
5	Ash Content at 815°C %	**39.6**	**41.9**	**41.4**	**48.4**	**44.3**	
6	Carbon Nitrogen Ratio	**8.6:1**	**8:1**	**7.2:1**	**7:1**	**8:1**	**<20**
7	Total Nitrogen (as N), on dry basis %	**1.6**	**1.7**	**1.7**	**1.3**	**2.3**	**minimum 0.8**
8	Total Phosphorus (as P2O5) %	**0.02**	**0.02**	**0.02**	**0.02**	**0.04**	**minimum 0.4**
9	Total Potassium (as K2O) %	**0.5**	**0.5**	**0.5**	**0.48**	**0.1**	**minimum 0.4**
10	Zinc (as Zn)	**374.9**	**480.2**	**658.9**	**686.9**	**921.6**	**1000**
11	Copper (as Cu)	**136.3**	**157.5**	**168.8**	**114.0**	**208.8**	**300**
12	Total Chromium	**26.6**	**19.0**	**20.3**	**14.0**	**32.9**	**50**
13	Cadmium (as Cd)	**8.9**	**8.3**	**7.5**	**4.5**	**3.0**	**5**
14	Nickel (as Ni)	**64.5**	**60.3**	**55.6**	**78.3**	**47.6**	**50**
15	Lead (as Pb)	**52.6**	**46.4**	**36.7**	**34.7**	**34.7**	**100**
16	Iron (as Fe)	**18,282**	**17,399**	**14,047**	**13,463**	**12,552**	
17	Manganese (as Mn)	**297.5**	**378.2**	**390.9**	**287.1**	**513.6**	
	Sum of NPK nutrients	**2.1**	**2.2**	**2.3**	**1.9**	**2.5**	**more than 1.5%**

Annex 3: Test results of 10 cities (Inlet and Outlet results only)

Table A3: Test result of outlet samples of 10 FSTPs

No.	Division	City	FSTP size (KLD)	Sample	pH	BOD (mg/l)	COD (mg/l)	Faecal Coliforms (MPN/100ml)	Total Phosphorous (mg/l)	Nitrates as NO3 (mg/l)	Total suspended solids (mg/l)	Total Coliforms (CFU/100ml)
	Permissible standards as per Moefcc, 2017				5.5-9	<30	<250	<1000	<5	10	100	
	Permissible standards as per NGT				5.5-9	<10	<50	<230	<1.0	-	<20	
	CPHEEO reuse standards for landscaping					20	30	<230	<5	NO3-N 10	<30	
1	Konkan	**Karjat**	**10**	**Inlet**	7.6	123	319	3.9*10^5	7.6	443.5	183	3.5*10^6
				Outlet	4.3	25	65	26	3.2	135.3	214	1600
2	Konkan	**Khopoli**	**15**	**Inlet**	7.0	40320	105280	2.4*10^5	26.7	5000.0	65800	9.2*10^7
				Outlet	7.6	15	38	48	1.4	15.6	590	5.4*10^3
3	Konkan	**Mahad**	**10**	**Inlet**	7.9	151	392	5.4*10^4	13.7	700.0	1584	4.3*10^5
				Outlet	7.6	15	36	<1.8	0.6	42.0	8	<1.8
4	Konkan	**Pen**	**10**	**Inlet**	6.5	289	903	1.6*10^4	14.9	123.0	1580	2.7*10^5
				Outlet	6.2	8	25	<1.8	0.9	97.0	8	11
5	Amravati	**Pusad**	**15**	**Inlet**	7.5	5800	16000	4.8*10^5	6.8	4.4	8700	3.5*10^6
				Outlet	8.2	74	216	<1.8	1.7	43.4	39	<1.8
6	Amravati	**Warud**	**10**	**Inlet**	7.6	1480	4400	1.1*10^6	5.0	8.4	8240	2.8*10^6
				Outlet	7.6	78	224	7.8	0.1	14.4	17	23
7	Nagpur	**Bhadrawati**	**15**	**Inlet**	6.9	1360	4160	4.8*10^5	1.9	<0.5	1150	3.5*10^6
				Outlet	8.0	9	28	7.8	0.6	2.6	11.2	23
8	Pune	**Vita**	**10**	**Inlet**	6.9	2880	9310	110*10^3	16.9	24.3	14030	217*10^3
				Outlet	7.7	16	71	20	1.1	8.3	200	730
9	Nashik	**Dhule**	**20**	**Inlet**	7.7	12000	24000	-	0.7	6.1	1510	-
				Outlet	7.7	26	40	-	0.5	7.4	57	-
10	Nashik	**Deolali Pravara**	**10**	**Inlet**	7.0	788	2000	-	0.9	4.2	1870	-
				Outlet	7.6	11	40	-	1.6	4.4	24	-

Annex 4: Test results of 2 cities (each unit tests)

Table A4: Test result of eah unit of FSTP

No	Sample source	pH	Total Dissolved Solids, mg/l	COD, mg/l	BOD3 at 27°C, mg/l	Total Suspended Solids, mg/l	Total Nitrogen (as N), mg/l	Total Phosphorus (as P), mg/l	Chloride (as Cl), mg/l	Faecal Coliforms, MPN/100 ml
1.1	Deolali Pravara - Inlet Sample From Truck	6.63	2122	24288	8700	64890	595	18	365	6.8 x 10^5
1.2	Deolali Pravara - Inlet Of ABR	7.04	2368	1295	480	424	135	5	375	22 x 10^4
1.3	Deolali Pravara - Inlet Of PGF	7.31	2096	243	96	210	33	1	330	1.8 x 10^3
1.4	Deolali Pravara - Outlet Of PGF	7.78	2200	223	62	24	28	1	317	920
1.5	Deolali Pravara - Storage Tank/after Chlorination Point	8.04	1660	115	23	12	16	1	249	49
2.1	Vita - Inlet Sample From Truck	7.46	2972	21918	8400	28600	395	44	432	2.8 x 10^5
2.2	Vita - Inlet Of ABR	7.35	1672	796	285	212	155	16	166	1.7 x10^5
2.3	Vita - Inlet Of PGF	7.29	1640	158	48	70	31	9	156	5.4 x10^2
2.4	Vita - Outlet Of PGF	7.84	1356	71	16	15	19	5	267	3.5 x 10^2
2.5	Vita - Storage Tank/after Chlorination Point	7.39	164	21	3	< 5	4	1	21	63