Draft Guidance Note on Co-treatment of Septage at Sewage Treatment Plants in India

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Introduction

Septage (or fecal sludge)[1], generated at the time of cleaning and emptying of septic tanks, has significant organic and pathogenic pollutant load, and requires treatment before disposal for a safe and healthy environment. Co-treatment of Septage at Sewage Treatment Plants (STP) is one of the solutions that can be implemented for the treatment of fecal sludge. Co-treatment may be a suitable option in cities and towns with installed sewage treatment plants, and where the plants are not functioning at 100% capacity with spare unutilized capacity available.

In India, CPCB and recent MoUD estimates suggest that STP capacity of ~25,000 MLD (million liters per day) is either installed or under construction across almost 400 cities and towns in the country. Earlier estimates by CPCB on treatment capacity utilization indicated that on average, only two thirds of the installed STP capacity is being utilized in the country, with utilization levels at only 50% in some states. This suggests that there may be significant unused sewage treatment capacity available in cities and towns with STPs. While efforts need to be made to improve sewage collection and improve the capacity utilization at these STPs, in the interim, these plants provide an opportunity for co-treatment of septage. Using conservative estimates for the safe addition of septage, unused capacity at STPs (estimated at about 15,000 MLD) can be used to treat septage generated from about 1.5 - 3 million households, or about 20 - 33% of the households connected to septic tanks across the ~400 cities and towns with STPs where co-treatment may be possible. These estimates demonstrate the potential of co-treatment across the country, however actual implementation and coverage will need to be carefully planned and designed based on the local conditions.

Co-treatment requires addition of fecal sludge either at the STP itself or specific decanting stations located in the city (usually co-located at sewage pumping stations). Co-treatment also requires careful assessment of the incoming sewage load at the STP, as well as the characteristics and quantity of septage in the city. The amount of septage that can safely be added to an STP, without disrupting the treatment system and plant performance, depends on many factors including capacity utilization, pollution load in septage, type and condition of STP. The operationalization of co-treatment also requires careful monitoring of the septage being discharged at the plant and ensuring no mixing of industrial waste. ULBs will need to be encouraged to implement monitoring and oversight systems for managing septage discharge in the sewerage systems.

Research done by international and national organizations has developed guidance on designing and operating co-treating systems. Co-treatment is being practiced at only a few STPs in India, and practical lessons on the implementation of such schemes, though limited,

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[1] Septage is the liquid and solid material that is pumped from a septic tank, cesspool, or such onsite treatment facility after it has accumulated over a period of time. The definition has been taken from the 2017 National Policy on Faecal Sludge & Septage Management, Government of India.

are slowly becoming is available within the country. More guidance on planning and designing of co-treatment systems has been developed by CPHEEO, with supplemental information being planned under the NFSSM Alliance work being led by the Ministry of Housing and Urban Development.

This guidance note discusses the technical, operational and regulatory aspects of septage treatment at STPs highlighting:

- Guidance on design of co-treatment systems
- Challenges, opportunities and successful approaches at each stage of the sanitation value chain (collection, transportation, decanting , treatment and disposal) adopted by select STPs for co-treatment.
- Comparison of the plant co-treatment practice (in terms of septage loading vis-à-vis plant capacity) with the recommended septage loading (per MoUD Septage Management Advisory and other relevant Guidance).
- Regulatory framework prevalent in different states in India

Planning for septage co-treatment

City-Level Diagnostics and Septage Treatment Plan

The first step towards co-treatment of septage at designated sewage treatment plants (STPs) would be to carry out city level sanitation diagnostics to determine various factors to prepare a septage management and treatment plan. This would help determine the amount of septage being generated, septage that is actually collected, number of desludging operators and vehicles, and the current points of septage disposal. Similarly, it is essential to understand the current amount of sewage generated and its treatment at an STP. Roughly, it may be assumed that a 5-member family would generate about 1m^3 of septage per year and that each septic tank would need to be desludged about once every three years.

Thus, if a city has about 100,000 households connected to onsite sanitation systems or septic tanks, then it would need to cater to desludging of about 33,300 septic tanks per year or about 110 septic tanks daily assuming 300 working days in a year. Assuming that each septic tank generates a septage load of about 3 – 4 m^3, the city would need to plan to treat about 330 – 440 m^3 of septage daily (or about 0.33 – 0.44 mld). This would mean about a total of about 100 daily trips by the desludging vehicles to dispose of the collected septage. An excel file tool is readily available with the National Faecal Sludge and Septage Management (NFSSM) Alliance[2] to easily make such calculations after feeding in basic sanitation data about the city. This would give information such as the number of desludging vehicles required, amount of septage to be collected and treated, and the future projects given the rising population and increasing toilet access and coverage due to programs such as the Swachh Bharat Mission.

[2] https://www.washinstitute.org/nfssm.php

It is also important to identify an STP that has spare capacity to handle septage treatment; what are the future sewerage plans for the city and will this spare capacity be soon utilized by increased amount of sewage being generated and collected or will a significant amount spare treatment capacity be available for the next few years at the STP. What is the distance of the STP from neighborhoods that are using septic tanks or other forms of onsite sanitation systems? If the STP is located far away from the septic tanks, then the desludging vehicles may find it very expensive to haul their load over great distances and deliver the septage directly at the STP.

It is important to find out the current performance parameters of the STP in its treatment of sewage. Is it able to meet or nearly meet the current wastewater treatment norms through its treatment process? If not, what mechanisms or actions are possible to for it to enhance its treatment performance. Any addition of septage to the STP influent stream will place additional pollution load, especially related to BOD, nitrification process and total suspended solids. Thus, any addition of septage to a currently ill-performing STP will tend to further worsen its performance and that of discharged treated effluent water.

Modifications to the co-treatment process, such as upfront separation of the solid and liquid fractions of septage before addition at the STP (and treatment of only the liquid stream to the STP and the solids to the solids handling processes) have also been explored by some researchers to address limited treatment capacity available at existing STPs, as well as to lower the impact of septage addition on the existing treatment units when the septage is determined to contain a high pollution load. These aspects should also be assessed as part of the city diagnostic and septage treatment plan to identify the most suitable approach for co-treatment.

Ensuring Disposal of Septage at Designated Treatment Sites

Experience and documentation from the three case studies (Tonca STP, Panaji, Goa; Bingawan STP, Kanpur, Uttar Pradesh; and Nesapakkam STP, Chennai, Tamil Nadu) brings out a clear fact that disposal of collected septage at a designated treatment facility can mainly be ensured through the display of firm commitment by the city authorities to stop disposal of septage into the open environment. Often, a pre-requisite to city commitment and action on septage management will be State commitment and prioritization of septage management supplemented with guidance to cities on planning and adopting the same. Several States in India have initiated the development / notification of policies for septage management, and all such policies describe co-treatment, if possible, as a desirable and viable solution for septage management. Annex A summarizes the policies adopted / being developed by various States in India, with a focus on co-treatment of septage at STPs.

Not only does the city have to promulgate the regulations to end the practice of dumping in the open, but to also have the ability to enforce these regulations through use of regular monitoring, imposition of fines and to offer the desludging operators the facility of disposing of the collected septage at a designated site for treatment.

As in the case of Kanpur, it has helped that in the face of rising resolve of the city government to ensure compliance with environmental and local laws, the desludging operators came together to form a "Committee" that acted as a joint forum for them to negotiate on behalf of all the operators with the city government. The Kanpur Nagar Nigam (KNN) or the Kanpur City Corporation story is highly illustrative (See Table 1) of what may happen when a city becomes firm in its commitment to ensure safe disposal and treatment of septage. Essentially, Kanpur followed an approach summed up in Figure 1 showing the various components of a successful practice.

Figure 1: Process of Commitment, Confrontation, Consultation and Consensus Building leading to a Cleaner City

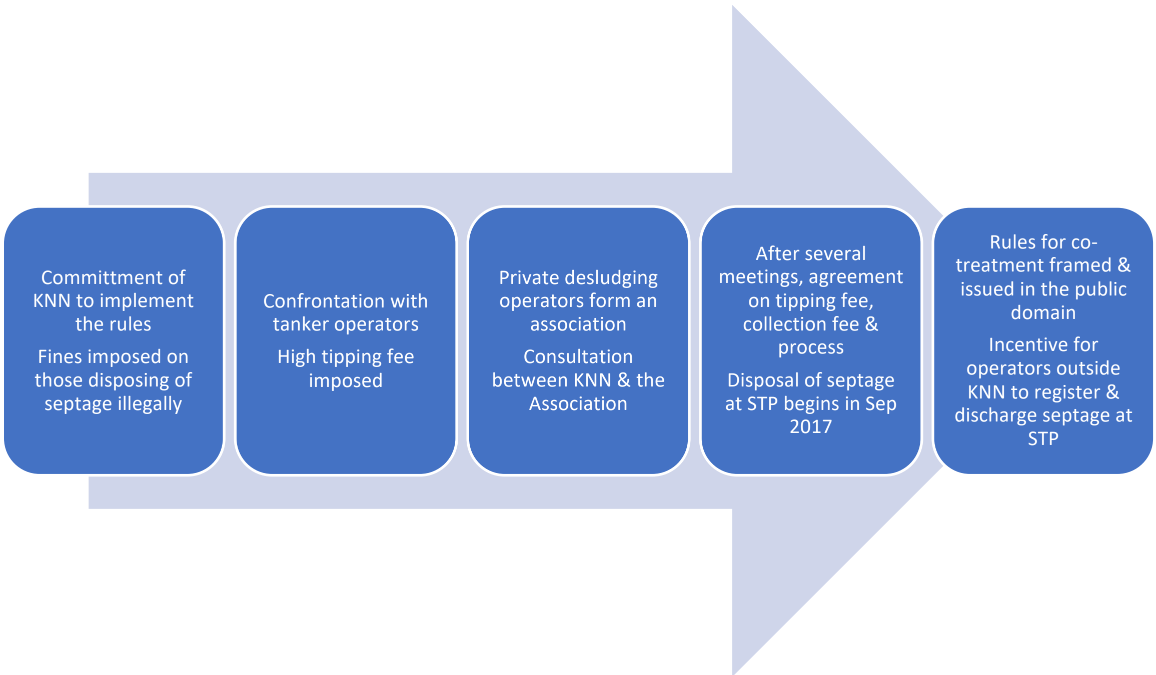


Table 1: Chronology of events in Kanpur leading to co-treatment

Timeline	Action towards planning for septage co-treatment
29.08.2017	Decision was taken by Kanpur Nagar Nigam (KNN) to allow disposal of septage by private desludging operators at the Bingawan STP
31.08.2017	Rate for single trip was fixed at INR 500 per trip. This was objected to by the Kanpur South City Tankers Committee as every truck was likely to make multiple trips in a day and the resultant costs would be prohibitive. The Committee made a representation asking the KNN to consider fixing an all-inclusive monthly charge of INR 1,000-1,500 per month.
11.09.2017	In a meeting chaired by the Additional Municipal Commissioner, KNN it was decided that all private desludging operators would have to register their trucks by paying a registration fee of INR 1,000 (per truck) which is to be renewed annually and pay a user charge of INR 3,500 per month with no ceiling on the number of trips either on a daily or monthly basis.
23.10.2017; issued in newspapers on 19.11.2017	Through a series of meetings, detailed bye-laws for co-treatment have been developed. These were published in newspapers on 19.11.2017 for making the citizens and private desludging operators aware of the same. These have been issued as a notification under

Timeline	Action towards planning for septage co-treatment
	the UP Municipal Act 1959 Section 541 (42) but are yet to be published in the official gazette. • **Registration**: Private operators have to register with the KNN after paying a registration charge of INR 1,000 per truck. This amount is to be paid annually for renewal of registration. • **User Charge**: Private operators have to make a monthly payment of a fixed tipping fee (INR 3,500) for using disposal facilities at the Bingawan STP. There is no upper limit on the number of visits, daily or monthly, by a desludging vehicle. • **Payment:** Payment of registration charge and user charge will be collected by the KNN or any other agency which may be engaged by KNN to collect these charges. The collections thus made have to be deposited in the KNN account within 24 hours. • **Issuing a receipt:** The KNN will issue a receipt for all payments made. The receipt must clearly mention the date, month and duration for which the payment has been made. It is the responsibility of the private operator to safely keep a copy of the receipt and produce it for review as and when required by the municipal authorities. A copy of this receipt has to be shown to the supervisor at the STP while seeking entry. • **Charges for Households:** The private operators can charge households INR 600 for desludging one septic tank[3]. • **Health and Safety of staff:** The private desludging operators must ensure that the staff (driver and helper) use protective gear such as gloves and masks. He must also ensure that they have an identity card. Every tanker must have a mobile number clearly displayed on it. • **Fine for illegal dumping:** If the private operators are found disposing the septage anywhere else except for the STP designated they will be liable to pay a fine. • **Record keeping at STP:** It is mandatory for the STP to maintain a record of the vehicle owner, driver and helper using the decanting facility. A log book needs to be maintained and entry of all trucks using the facility has to be made by the specially employed supervisor.
28.11.2017	As an incentive to private desludging operators the one time registration charge has been waived off by the KNN till 31st March 2018. (Letter No.2296/D/SWA/NSA/17-18). This facility has been extended to attract private operators from peripheral areas of Kanpur UA and to ensure proper treatment of FS collected thereby protecting the environment.

It is important that the city authorities are able to arrive at a mutually acceptable decision with the desludging operators that includes issues such as the registration fee, disposal or tipping fee, collection fee from the households and commercial establishments, process of fee payment and collection, timings of disposal at the STP, documentation required to be maintained by the desludging operators and the STP, quantum of fines to be imposed if an operator is found disposing in the open environment, commitment by the operators to not bring in industrial waste and provisions to ensure the same. If there are more one STP undertaking co-treatment in a city, it is important to designate which operators or collection from which neighborhoods will be disposed of at which STP and also fix an upper limit of the amount of septage that can be disposed of at each STP, given the technical parameters and treatment capacity (such technical information is discussed later on in the document).

[3] Discussions with city officials have revealed that the fee being charged at present ranges from INR 1,000 to 1,500 per septic tank.

Once the regulatory framework and disposal facility are in place in a city, it will lead to creation of an enabling environment for the desludging operators to plan their future operations and begin catering to the needs of the households using onsite sanitation systems. This will help create adequate desludging facilities for the city residents and also healthy competition among the operations to provide the best services and rates to their customers. Further, as the experience of Panaji and Kanpur shows, the septage collected from nearby peri-urban areas is also brought to the STP for disposal; this means a cleaner environment in the nearby areas of the city as well as increased revenues for the STP operator treating this septage (See Table 2).

Table 2: Summary of actions towards planning and design undertaken in each of the STPs reviewed under this study

	Aspect	**Chennai - Nesapakkam**	**Panaji - Tonca**	**Kanpur - Bingawan**
1	Key driver for initiating co-treatment	Discontinue the practice of unauthorized dumping of septage into the city's water ways and storm water drains by the private operators involved in desludging septic tanks	Discontinue the practice of unauthorized dumping of septage into the region's open areas, storm water drains and water ways by private operators involved in desludging septic tanks	Discontinue the practice of dumping of septage into the city's open areas / drains by private desludging operators
2	State level guiding policy framework	GoTN's "Operative Guidelines for Septage Management for Urban and Rural Local Bodies" recommend a decentralized approach to septage management. Clusters of ULBs have been identified for treatment of collected septage at earmarked STPs in the state.	The Goa Public Health (Amendment) Rules, 2010 makes provisions for protecting and advancing public health. Under the Act, some of the measures relate to management of septage including "prohibiting discharge of sewage, poisonous and polluting liquid into water bodies; safe disposal of sullage and sewage"	None
3	City level policy / guidelines / regulations on septage management (specifically co-treatment)	None	None	Bye-laws for co-treatment have been prepared by the Kanpur Nagar Nigam (KNN). Issued as a notification under the UP Municipal Act 1959 Section 541 (42) these were published in newspapers on 19.11.2017 and are yet to be notified in the official gazette
4	Septage quality used for planning	Septage quality was not analyzed while planning.	Septage quality was not analyzed while planning.	Septage quality was not analyzed while planning

	Aspect	Chennai - Nesapakkam	Panaji - Tonca	Kanpur - Bingawan
		Officials shared that septage has a higher BOD and COD values as compared to sewage	While septage characteristics are not monitored and quality data to indicate pollution strength was not available, the prevalent practice of frequent emptying of septic tanks (which could often be as frequently as a few months) is expected to result in a relatively weaker strength septage which is more similar to sewage.	
5	Raw sewage quality	TSS = mg/l; BOD = 380 mg/l; COD = 900 mg/l; Faecal coliform = $4.6X10^7$ MPN/100 ml	SS = 400 mg/l; BOD = 250 mg/l; COD = 462 mg/l; Faecal coliform =$24x10^9$ MPN/100 ml	Data on raw sewage for the period January - August 2017 (prior to co-treatment) shows values well within the design characteristics (BOD 322 mg/l and TSS 418 mg/l). There hasn't been much change in the same post initiation of co-treatment (since Sep 2017)

Implementing Co-treatment of septage at STPs

How much septage can be co-treated?

Treating septage flows in an STP has several significant effects. It may increase the load on both the liquid and solids trains of the STP (depending on the quality of septage), with commensurate increases in operating cost for ensuring adequate aeration and solids handling capacity as well as disposal or utilization costs. The quantity or volume of septage that can be co-treated at an STP depends upon several parameters. Several researchers have developed guidelines to help design and operationalize co-treatment of FS at sewage treatment plants. Annex B summarizes the guidance documents and literature available to help determine safe FS loading rates and design a co-treatment system.

It is prudent, however, to develop realistic site-specific estimates before undertaking co-treatment at the STP. The first step is to understand the details of the STP including its operational performance. Key factors to be kept in mind are the characteristics of sewage arriving at the STP for treatment, spare capacity of the STP, technology and treatment process employed by the STP, and the sewage diurnal flow patterns as well as the difference in seasonal flows.

The second part is to study the characteristics of the septage that is likely to be brought to the STP for treatment. This would mean estimating or analyzing parameters such as total suspended solids, BOD, COD, ammonia nitrogen, total nitrogen and total phosphorus. These factors vary significantly and will determine what the characteristics will be of the mixture of sewage and septage that the STP will now treat (See Table 2).

In Chapter 9[4] of its Manual on Sewerage and Sewage Treatment, the Central Public Health and Environmental Engineering Organization, Government of India proposes a simple method to calculate the combined BOD load of sewage and septage that must be below the maximum load that STP can handle for treatment. Assuming that the BOD for incoming sewage in an STP is 400 mg/l and that of the septage is 3000 mg/l, the septage added equals to 3% of the total designed capacity of the STP, in a 10 mld STP that uses only 65% of its capacity, the calculations for BOD load will be as follows:

Design capacity of the STP	= 10 mld
Actual operating capacity	= 6.5 mld
BOD load in to the STP	= 6.5 mld X 400 mg/l = 2600 kg/day
BOD load from septage	= 0.4 mld X 3000 mg/l = 1200 kg/day
Total resulting BOD load	= 2600 + 1200 = 3800 kg/day
Designed ability of the STP for BOD load	= 10 X 400 = 4000 kg/day

Thus, in this example, it may be possible to accommodate and treat over 0.4 mld (or 400 m^3) of septage with the BOD of 3000 mg/l or less at this STP. But the characteristics of septage and sewage differ based on location and can vary widely. For example, the STP at Tonca, Panaji, Goa receives a substantial amount of septage (almost 5% by volume of the current flows received at the STP) and is still able to treat the same successfully while meeting the environmental norms. Based on the USEPA and MoUD guidance on estimating safe septage addition at an STP, the permitted septage load (based on existing STP capacity utilization and BOD levels of raw sewage and septage as observed in Nesapakkam STP Chennai, Tamil Nadu) is estimated to be ~ 300 m^3/day or about 33 truckloads (@9 m^3 capacity per truck). But the existing septage load at the STP is significantly higher than this, without any adverse impacts on plant performance, which indicates that for such weak strength septage, the safe loading curve may be somewhat different, and requires research to develop the same for the Indian context or a case-by-case basis.

But BOD load is not the only factor to be considered when planning for co-treatment. Based on his work studying co-treatment at the STP in Can Tho, Vietnam, a city of nearly 1.25 million residents, Dave Robbins recommends looking at the treatment efficiency of the STP and the combined load of sewage and septage of different parameters such as BOD, suspended solids

[4] http://cpheeo.nic.in/WriteReadData/Cpheeo_Sewarage_Latest/PartA-HighResolution/Chapter%209.pdf

when calculating the amount of septage that may be added[5]. To estimate the impacts of co-treatment, he suggests the following equations:

- Combined influent concentration of the constituent = (% septage x constituent septage concentration) + (% sewage x constituent sewage concentration)
- % removal or reduction = (influent – effluent) / influent
- Effluent concentration of constituent = (100% - % constituent reduction) x (combined influent constituent concentration)
- Compare effluent concentration to wastewater discharge norms issued by the Central Pollution Control Board

Other researchers have determined criteria and recommendations for co-treatment at STPs implementing specific technologies (such as Waste Stabilization Ponds, Activated Sludge Process and Upflow Anaerobic Sludge Blanket Reactor), and while a listing of compendiums covering these literature references is available in A, a summary of the key recommendations is included in Annex C.

It is important to remember that the quality, and not just the quantity, of the septage, must be evaluated before planning for co-treatment. It must be ascertained beforehand whether the septage and sludge contain any toxic chemicals that can destroy biological communities.

The presence of trash, grit, and trade and industrial sludge can be toxic and impact biological processes. Moreover, co-treatment should not cause consistent compliance issues for the STP. Annex D summarizes examples of fecal sludge co-treatment at a sewage treatment plant (STP) from different countries. While there is limited information available on the practice of co-treatment, and lesser still on the specific experience and design / operation details from sites where the practice of co-treatment is occurring, anecdotal information on challenges and learnings from the experience of septage co-treatment at STPs is summarized in Annexes B, C and D.

Continuing with the above-mentioned example, the combined influent concentration for BOD will = (0.04 X 3000) + (0.96 X 400) = 504 mg/l. If the STP has the ability to remove or reduce BOD concentration by 95%, then the BOD concentration of the effluent will be about 25 mg/l. Assuming the typical figures of TSS to be 7000 mg/l for septage and about 500 mg/l for sewage, the concentration of the combined influent will = (0.04 X 7000) + (0.96 X 400) = 664 mg/l. Thus, if the plant has 90% removal efficiency for TSS, the concentration of TSS in the discharged effluent will be about 66 mg/l. Thus, having prior information on the operating efficiency of the STP with respect to various parameters in addition to knowledge on the characteristics of incoming sewage and septage, can help plan the amount of septage that could be added for co-treatment. However, it may be best to start by adding small amounts of septage and study the impact on the performance of the STP. Then, if the STP is able to successfully treat the combined sewage-septage influent, increase the amount of added septage gradually over time and continue to monitor the performance of the STP; this will

[5] http://www.susana.org/_resources/documents/default/3-2749-7-1488885186.%20et%20alpdf

help determine the optimal amount of septage that could be added to a particular STP. Table 3 provides illustrative characteristics for septage in India but is not representative of the findings under the three case studies in Chennai, Kanpur and Panaji.

Table 3: Illustrative characteristics of septage for Indian conditions

S. No.	Source	Type A	Type B
		Public toilet or bucket latrine sludge	Septage
	Characteristics	Highly concentrated, mostly fresh faecal sludge; stored for days or weeks only	Faecal sludge of low concentration; usually stored for several years; more stabilized than Type A
1.	COD (mg/l)	20 – 50,000	$<$ 15,000
2.	COD/BOD	5:1 to 10:1	5:1 to 10:1
3.	NH_4-N (mg/l)	2 – 5,000	$<$ 1,000
4.	Total solids (%)	$\geq$ 3.5	$<$ 3
5.	Suspended solids mg/l)	$\geq$ 30,000	7,000 (aprox.)
6.	Helminth eggs	20 – 60,000	4,000 (aprox.)

(Source: CPHEEO)[6]

Data from the three STPs studied that are co-treating septage shows that all the three plants are meeting the TSS norms; Nesapakkam, Chennai and Tonca, Panaji meet the BOD norms, while the effluent BOD levels at the Bingawan, Kanpur STP was found to be marginally higher than the prescribed level of 30 mg/l. However, it is important to note that the Kanpur STP., employing Upflow Anaerobic Sludge Blanket (UASB) Reactor technology, has marginally improved its effluent BOD levels since it began co-treating.

The quality of septage will be impacted by many factors including the storage duration in the septic tank, additions such as grease, organic waste from kitchen, local and ambient temperature, design and performance of septic tanks, tank emptying technology and pattern, and common treatment of black and greywater (though not recommended). The Government of India has developed various guidelines for the safe emptying, collection and transportation of septage, and these are discussed briefly in Annex E.

How and when to add septage for co-treatment?

A typical septic tank tends to accumulate grit, rocks and other dense material in its sediment layer over the years. Before the septage can be added for treatment, it is important to remove such solid material. This can be done by the creation of a rock sump, screening process and grit removal chamber for septage.

[6] http://cpheeo.nic.in/WriteReadData/Cpheeo_Sewarage_Latest/PartA-HighResolution/Chapter%209.pdf . However, it is important to note that a wide range of values for parameters such as COD, BOD, suspended solids are seen in the field and local data must be taken into account when planning for co-treatment (See Table 4).

Table 4: Pollution load of septage analysed by different researchers

	The World Bank (2016) - 5 Districts in Dhaka		Bassan et al. (2013)						Kone et al. (2004)				Rashed et al. (2006)	USEPA (1999)	Pradeep e. al. (n.d.)	Ligy et al. (2016)		Ingallinella (2002)
Parameter	**1**[7]	**2**[8]	**3**[9]	**4**[10]	**5**[11]	**6**[12]	**7**[13]	**8**[14]	**9**[15]	**10**[16]	**11**[17]	**12**[18]	**13**[19]		**14**[20]	**15**[21]	**16**[22]	**17**[23]
Total solids (mg/L)	19,420 to 57,272	12,778 to 72,694	8,984	11,820	19,000	,900	14,000	4,500	52,500	12,000	15,350	6,000 - 35,000	3,095	1,132 to 130,475	42,395	2185	3,555	
Suspended Solids (mg/L)	17,868 to 55,484	10,852 to 70,896	7,077										3,068	310 - 93,378		712	1103	5943
COD (mg/L)	300 to 672	480 to 687	7,607	10,725	13,500	7,800	15,700	7,100	49,000	7,800	15,700	4,200	1,243	1,500 to 703,000	59,745	905	1,460	4,243
BOD (mg/L)	118 to 306	266 to 447	1,237		2,240				7,600	840	2,300	750 - 2,600	434	440 to 78,600				754
COD:BOD Ratio	2.01 to 2.54	1.65 to 1.93	7										3					
NH4 - Nitrogen (mg/L)	20 to 1,100	130 to 1,900							3,300	330	415	150	91	3 to 116	1,323	16	32	146
Total nitrogen (mg/L)	30 to 10,700	200 to 1,400			2,100						1,100	190	150	66 to 1,060		94	58	191
Total Phosphorus (mg/L)	170 to 900	120 to 200											13	20 to 760	1,001	77	54	28
Total Volatile Solids (% of TS)			57	48	47	59	NA	70	68	59	73	50	2706	353 - 71,402	15,223	1414	1541	

[7] From Manual emptying
[8] From Mechanical emptying
[9] From FS from septic tanks
[10] Ouagadougou (From discharging trucks)
[11] From Ouagadougou (From septic tanks)
[12] Accra (From Septic tanks)
[13] Dakar (From discharging trucks)
[14] Dakar (from treatment plant receiving channel)
[15] Accra (Ghana) Public Toilet Sludge
[16] Accra (Ghana) (Septage)
[17] Bangkok (Thailand)
[18] Alcorta (Argentina) (Septage)
[19] Albireh Septage
[20] Devanahalli
[21] Chennai - Summer
[22] Chennai - Winter
[23] Argentina

Septage receiving facility

Any STP receiving septage for treatment has to set up the necessary infrastructure for safe disposal by the desludging vehicles. The STP at Bingawan, Kanpur incurred a capital expenditure of about INR 0.8 million towards creating a special receiving area including a manhole for discharge of septage which then mixes with the incoming sewage. Similarly, the Tonca, Panaji STP created a decanting station to allow desludging trucks to discharge septage in a manhole upstream of the STP. Created at a cost of INR 0.14 million, the decanting station is located just outside the plant and has a high boundary wall. The Nesapakkam STP in Chennai presents an interesting case of septage disposal facility, to ensure least discomfort for the nearby residents (See case study in the box).

Disposal of septage at Nespakkam STP, Chennai

A decanting station has been created at the Nesapakkam STP to allow desludging trucks to discharge septage loads. Although located within the STP complex, the decanting facility has a separate entrance which is easily accessible from the main road and is enclosed prohibiting access to the rest of the STP. The trucks are permitted entry between5 am and 5 pm every day except on Sundays and government holidays. The trucks come mostly between 5-8 am and 11-5 pm as they are not allowed to operate in the city during 8-11 am. The decanting station has sufficient space for up to four desludging trucks to decant simultaneously and has ample parking area for another three to four trucks.

The decanting station comprises of a covered receiving tank followed by grit removal chamber and screens. The receiving tank is covered and connected to an odour control air scrubbing unit. Septage from the receiving tank flows into an equalization chamber, then to the trunk sewer line passing outside the decanting facility and flows into the terminal sewage pumping station feeding into the STP. The decanting station also has a CCD monitoring system which is yet to be operational.

The decanting facility (as well as the STP) is located in a residential neighbourhood. The entry to the decanting facility is located directly across a large residential complex. Odour control and aesthetics are therefore key concerns for the plant personnel in order to ensure that there are no objections from the residents. The plant is investing in upgrading the decanting facility to address these concerns and has incorporated the following features into the design:

- Odour control unit connected to the receiving tank
- High compound walls for the decanting facility
- Greenbelt development within the STP (plants which absorb bad odour have been grown)
- Discharge of septage directly into pits connected to the receiving tank to minimize scope for spillage

Ideally, the design of the septage receiving station at the sewage treatment plant should provide for the following elements[24]:

- A hard surface haul truck unloading ramp sloped to a drain to allow ready cleaning of any spillage and washing of the haul tank, connector hoses and fittings. The ramp drainage should be tributary to treatment facilities and should exclude excessive storm water
- A flexible hose fitted with easy connect coupling to provide for direct connection from the haul truck outlet to minimize spillage and help control odours

[24] https://www.ontario.ca/document/design-guidelines-sewage-works/co-treatment-septage-and-landfill-leachate-sewage-treatment-plants

- Electronic metering and billing systems are available to monitor septage received and provide accurate billing information to septage haulers and plant staff. These systems generally consist of a card reader or key pad for controlled access in combination with a flow meter and valve

Puri, Odisha STP: (a) Ramp for desludging trucks to go to the receiving chamber (b) Receiving Chamber
Photos: Mayank Agrawal, KPMG

Bingawan, Kanpur STP: Disposal of septage
Photos: Shikha Shukla Chhabra

Septage disposal at Nesapakkam Chennai STP

- Washdown water with ample pressure, hose and spray nozzle for convenient cleaning of the septage receiving station and haul trucks. The use of chlorinated effluent may be considered for this purpose
- An adequate off-line septage receiving tank should be provided. The tank should be sized to hold twice the maximum daily volume of septage expected on a peak day. Capability to collect a representative sample of any truck load of waste accepted for co-treatment at the plant should be provided. The receiving tank should be designed to provide complete draining and cleaning by means of a sloped bottom equipped with a drain sump. The design should give consideration to adequate mixing. Adequate mixing will ensure uniformity of septage strength and mixing for chemical addition, if necessary, for treatability and odour control

- Screening, grit and grease removal or grinding of the septage as appropriate to protect the STP process units
- Pumps provided for handling the septage should be of the non-clogging design and capable of passing 100 mm (4 in) diameter solids
- Glass-lined pipes are recommended
- Valving and piping for operational flexibility to allow the control of the flow rate and point of septage discharge to the STP
- Safety features to protect the operational personnel

Addition to the liquid stream

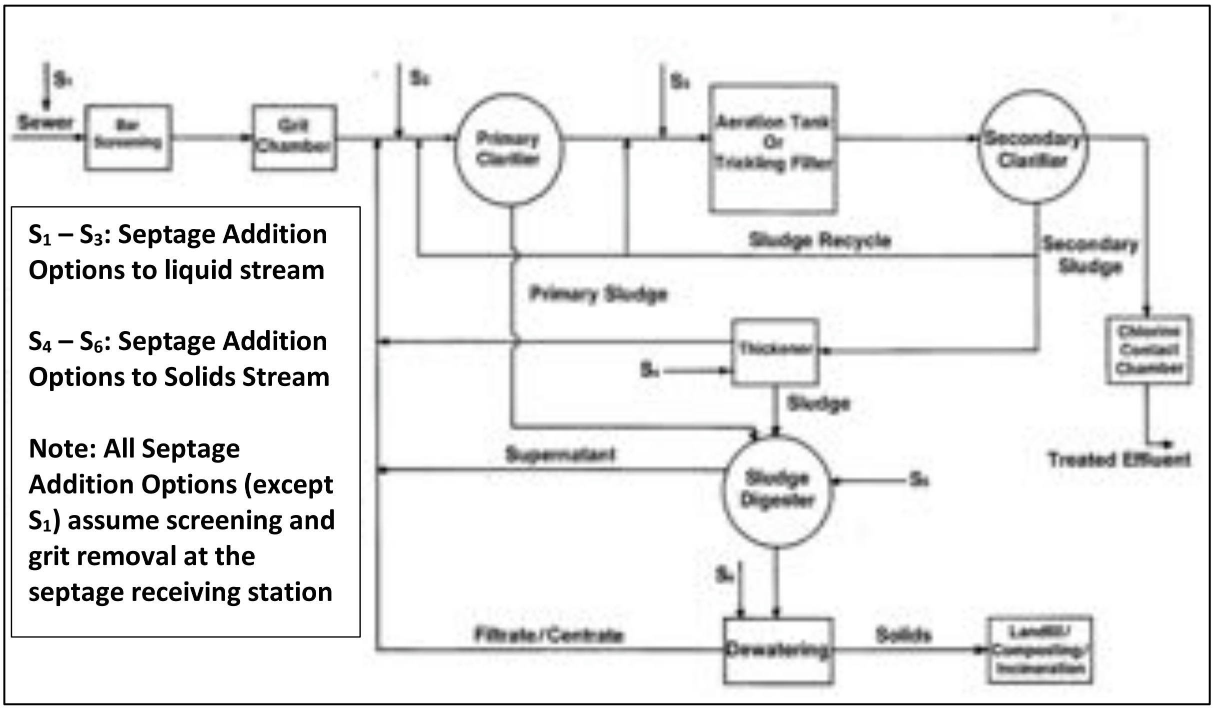
Septage can be added for co-treatment directly to the liquid stream of the STP, either at the STP itself or at a point upstream such as a pumping station or even directly to the sewer where the flow of the sewage is adequate (See Figure 2). But, care must be taken in either case to ensure removal of solid material such as rocks and grit before it is added to sewage. Adding septage at an upstream point or set of points means the desludging vehicles will not have to travel all the way to the STP to dispose of the collected septage. Thus, this kind of facility can be useful in large cities; not only will it be cost-effective for desludging vehicles to travel lesser distance but also it imposes less traffic burden at and near the STP site.

In Chennai, Tamil Nadu, while septage disposal is permitted only at the disposal facility at the STP, the city permits septage discharge at specific sewage pumping stations within the city during monsoon season due to high demand for desludging and therefore higher septage volumes. In Kanpur and Panaji, the septage is discharged directly at the STP site.

It is recommended to add an equalization chamber at the STP for receiving septage; this ensure constant addition of septage to the sewage inflow stream for treatment rather than the possibility of producing hydraulic and biological load carrying capacity due to direct discharge into the liquid stream. If the desludging vehicle discharges directly into the influent liquid stream, little or no control can be exercised over amounts or timings of septage load. This may also result in inadequate mixing of the sewage and septage, and the resultant density currents may interfere with the solids separation process in the primary clarifiers. Inefficiencies in suspended solid removals in the primary clarifiers can cause malfunctioning of the secondary process units. However, if direct or dynamic discharge is the preferred method, then septage may be added upstream of the STP headworks through a manhole. This would result in adequate mixing of the septage and sewage in the sewer lines before arriving at the STP primary clarifiers. The septage must be diluted at least 20 times with the sewage.

For small and medium STPs, the preferred method of septage addition is continuous feed at a rate proportional to the sewage flow; this could lead to addition to a higher amount of septage compared to dynamic loading. Thus, it is important to have both an equalization chamber and a metering process to achieve this method. Ideally, the septage receiving facility should comprise provisions for mixing, odor control, and controlled rate feeding of septage, in addition to the screening and grit removal facilities. At larger STPs, the effects of septage loading are expected to be low and they are also capable of handling shocks better than smaller STPs. Thus, in larger STPs, it may be possible to add small quantities of septage without equalization into an interceptor sewer upstream of the STP[25].

Figure 2: Points of Septage Addition in an STP[26] (Source: US EPA)



Dewatering septage for co-treatment: separate liquid and solid streams

Assuming that septage could also be looked at as a mixture of semi or fully treated settled sludge along with raw sewage, it may also be possible to separate the liquid and solid portions of the septage for treatment. The separated liquid portion is added to the incoming sewage for further treatment while the dewatered solids are added to the digested sludge arising from treatment of sewage at the STP. Septage pre-treatment to separate liquid and solid fractions, which are then processed differently provides a more concentrated sludge for processing and reduces the organic loading to liquid stream processes and the hydraulic loading to sludge processes. Increased operations are required for septage pretreatment at the receiving station.

[25] EPA Handbook on Septage Treatment and Disposal, page 112
[26] EPA Handbook on Septage Treatment and Disposal, page 110

This may be advantageous in certain situations than direct addition to the STP without any pre-treatment, however the plant diagnostic and details septage treatment plan will need to evaluate the suitability of this approach, as well as the implications on capital and O&M requirements from this approach (as these will be higher in case solid-liquid separation is to be practiced than direct addition). This approach may be suited where the incoming septage has a very high BOD or suspended solid strength, which could excessively burden the existing treatment units at the STP, or where there is limited unutilized treatment capacity available at the STP and therefore constraints in terms of the quantity of septage that can be added. A study by Dave Robbins *et al* in Vietnam on Co-treatment of Septage with Municipal Wastewater in Medium Sized Cities in Vietnam concluded that for a given STP and septage mix (based on actual field observations at STPs in Vietnam), while effluent discharge standards would not be met even at 1% addition (by volume) of septage to the STP inlet, incorporating liquid solid separation would enable addition of up to 5% dewatered setpage (liquid fraction) without adversely impacting the effluent quality and meeting applicable discharge standards.

Puri, Odisha STP: (a) Settler cum thickening tank (b) Liquid portion of septage diverted to STP
Photos: Mayank Agrawal, KPMG

Septage, after dewatering, and sludge from STPs can be treated together through co-composting, pyrolysis, etc. Sewage treatment technologies may need to be adapted for liquid stream of septage depending on the quality and pollutant strength of the liquid stream. Some considerations to be kept in mind when implementing liquid-solid separation include the following:

- Liquid stream from solids-liquid separation step will contains high concentration of organics, suspended solids and nutrients than sewage.
- Liquid stream from solid-liquid separation step of septage and faecal sludge has lower potential of organic reduction compared with wastewater due to partial digestion and will require both biological and physical settlement to remove organics.

The solids from dewatered septage may be added at the beginning of the sludge stabilization process as shown in Figure 2. Here, the solid component of the septage may added without equalization but only after screening and de-gritting. The characteristics of septage do not affect the digestion process and the septage becomes biologically digested and stabilized. If the septage is added directly to the sludge dewatering process, then the biological matter of the septage can cause odor and other disposal concerns. If, however, the sludge will be incinerated or composted, then this process may be followed easily.

It is also possible to set up a septage dewatering facility further upstream of an STP (subject to availability of suitable land and the financial viability addressing both the capital investment and O&M costs required under this approach, as discussed earlier); the liquid portion of the septage is added to the sewer lines while the dewatered solids (comprising about 30% of the total septage by volume) may be transported separately for treatment to an STP, municipal solid waste composting facility for addition to the compost or treated at a separate dedicated facility. Adoption of this process may save haulage charges as only the 30% solids have to be transported all the way to an STP or another treatment facility.

There are currently several practiced methodologies for dewatering of septage. One is the process of creating a mechanized facility[27]which could be either fixed or mobile (set upon a truck or other such vehicle). The other is to construct a simple decanting process wherein the septage is added to a settler tank and the solid portion of the septage settle at the bottom. Once the solid sludge has settled, the liquid on top may be diverted to the sewage stream. The settled solids are added to the digested sludge from sewage treatment. The STP in Puri, Odisha used the second method for separating the solid and liquid components of the incoming septage. Some STPs may use a septage or sludge drying bed to do away with the liquid component. Geobags may also be used to dewater the septage as an alternative option to sludge drying beds or the mechanical and decanting processes.

Another possibility, though with little or no practical evidence, is addition of septage, which is not dewatered, directly to the settled sludge from treated sewage. This method reduces the loading to liquid stream processes, and it eliminates the potential for affecting effluent quality. However, there could be an adverse effect on the sludge treatment processes such as dewatering. Adding septage to the sludge handling process may also cause clogging of the pipes and increase wear on the pumps if the septage is not screened and de-gritted in the receiving station. While this is an approach for co-treatment at an STP, there is no practical example of this approach, both from within India and globally, and this approach is expected to create higher operational challenges for STP operators. Hence, this is not a recommended solution.

[27] Two possible methods for dewatering facilities could be seen at: (i) https://www.youtube.com/watch?v=DTSwLouNbCU (ii) https://www.asiapathways-adbi.org/2018/03/minimizing-the-cost-of-fecal-sludge-management-through-co-treatment/

Precautions during co-treatment

Due to higher levels of COD and total nitrogen in septage as compared to sewage, co-treatment can lead increased demand for oxygen during the treatment process. Deficient oxygenation may lead to build-up of nitrite, less nitrification capacity and may also cause sludge foaming/bulking. This can result in ammonia toxicity and be highly detrimental to activated sludge processes or any aerobic treatment process. For example, such a need was felt at the Nesapakkam STP, Chennai which had to increase aeration levels during co-treatment to meet the effluent standards. At this STP, the aeration tanks have four aerators (plus two standbys) to meet the aeration requirements of the treatment process. Each aerator has a capacity of 3,000 m^3 / hr, resulting in total aeration capacity of 12,000 m^3/hr in the plant. Addition of FS to the STP required an increase in the aeration in the tanks. Plant engineers estimated that each truckload of septage (~9 kL) requires an additional 2 kg of air to maintain reactor performance and the desired effluent quality. The installed aeration capacity was sufficient and no additional capital investments were required towards aeration, however, the operational hours for aerators have increased. This increase in the aeration capacity has also resulted in increasing the energy cost of the plant. A similar pattern was noticed at the Albireh Wastewater Treatment Plant, Palestine where additional oxygen was needed to successfully co-treat septage with sewage[28]. However, if the BOD levels of septage are not very high as compared to the incoming sewage for which the STP was designed, then additional aeration may not be required. It may be noted that the higher energy costs incurred due to increased aeration are much less than the tipping fee collected by the STO from desludging vehicles.

The levels of TSS can be a limiting factor in successfully co-treating septage. If the levels of TSS exceed the design capacity, then it can lead to overloading of aeration and secondary settling tanks, solid-liquid separation problems, and a decrease in oxygen transfer efficiency. Thus, caution must be taken to assess the potential amount of septage that can be added without exceeding the designed levels of TSS. Equations shared on pages 10 – 11 can help calculate these amounts. Another expected impact of co-treatment will be generation of higher quantities of sludge. Thus, the STP needs to be prepared for handling, treating and disposal of increased sludge quantities. As mentioned earlier, one approach to address this issue could also include septage pre-treatment and solid-liquid separation before addition at the STP.

The COD to BOD ratios, with and with addition of septage, must be used with caution. As compared to common values observed with wastewater, it has been observed that in some cases septage may not readily be biodegradable (for example, the COD: BOD5 ratio of 5.0 or more indicates that, if degradable, the organics biodegradability is very slow. In contrast, the COD: BOD5 of 1.5 - 3.0 indicates the sludge is biodegradable).

[28] https://journals.ju.edu.jo/DirasatEng/article/view/1430

It is important to assessing the STP nutrient removal process and potential with addition of FS that has higher nitrogen and phosphorous content than carbon. The organic content to nitrogen ratios of FS indicate that organic concentrations are not sufficient for nitrogen removal by denitrification, as they are far below the lowest reported for nitrogen removal[29]. Septage should only be considered for co-treatment in processes that include nitrogen removal if the influent wastewater has COD: TKN or BOD5: TKN in the desirable ratio. Table 5 provides actions in detail undertaken by the three studied STPs for sepage co-treatment.

Table 5: Summary of key actions taken towards implementation / operationalization of co-treatment at the STPs reviewed under this study

S. No.	Aspect		Chennai - Nesapakkam	Goa - Tonca	Kanpur - Bingawan
1	Responsibility and arrangements for collection and conveyance of septage	Collection & conveyance	Collection and conveyance of septage is the responsibility of the private desludging operators	Collection and conveyance of septage is the responsibility of the private desludging operators	Collection and conveyance of septage is the responsibility of the private desludging operators
		Treatment	Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) is overall responsible for the management of STPs and private agencies are contracted to undertake O&M	The Public Health and Engineering (PHE) Department of Government of Goa is responsible for managing the STP. The O&M is being undertaken by a private agency on a contract	UPJN is responsible for the implementation of co-treatment at Bingawan STP. The ULB (KNN) m) has framed the bye laws for co-treatment. KNN also collects the registration fee and tipping fee.
2	Details of Decanting station - design	Design (including capital cost)	The decanting station comprises of a covered receiving tank followed by grit removal chamber and screens. The receiving tank is covered and connected to an odour control air scrubbing unit. Septage from the receiving tank flows into the trunk sewer line passing outside the decanting facility and flows into the terminal Sewage Pumping Station	The decanting station is a very basic set up comprising of a manhole into which the trucks discharge septage. The manhole is just upstream of the STP preliminary treatment works and the septage added to sewage at the manhole enters the STP through the main inlet and passes to the inlet chamber, prior to the preliminary treatment process. There is no equalization / storage tank for receiving	A very basic receiving station has been created with a manhole into which septage can be discharged. The area around the manhole is paved and a gradient has been created to allow any spillage to flow back into the manhole. The septage mixes with sewage being received by the

[29] Henze, M., Comeau, Y. (2008). Wastewater characterization. In: Biological wastewater treatment: principles, modelling and design. Henze, M, van Loosdrecht, M.C.M., Ekama, G.A., Brdjanovic, D. eds. ISBN: 9781843391883. IWA Publishing. London, UK

S. No.	Aspect		Chennai - Nesapakkam	Goa - Tonca	Kanpur - Bingawan
			feeding into the STP. The decanting station also has a CCD monitoring system (which is yet to be operational). **Cost: ~ INR 20 million.**	septage and septage discharge occurs based on the frequency of trucks visiting the STP. **Cost: ~ INR 0.14 million.**	STP through the manhole and a pipe connecting the septage receiving manhole to the inlet chamber of the STP, prior to the preliminary treatment process. **Cost: ~ INR 0.8 million.**
		Operation	Located within the STP complex, the decanting facility has a separate entrance easily accessible from the main road and is enclosed prohibiting access to the rest of the STP. The trucks are permitted entry between 5 am and 5 pm every day except on Sundays and government holidays. The decanting station has sufficient space for up to four desludging trucks to decant simultaneously and has ample parking area for another three to four trucks.	The decanting station can accommodate only two trucks at a time and only one truck can decant at a time. There is no parking available within the decanting station. The trucks are permitted entry between 9 am and 5 pm every day except on Sundays and government holidays. The decanting station also has a small cabin for a supervisor who monitors the entry and exit of trucks and maintains a register in which a record of the trucks using the facility is maintained.	The receiving station is located close to the entrance of the STP. The access to the STP (and the decanting facility) is through a dirt road off the Hamirpur (Naubasta) highway. The trucks are permitted entry between 8 am and 7 pm. A dedicated staff (supervisor) monitors and records the entry (and exit) of tractors and desludging process.
3	Retrofit / modifications undertaken at the STP prior to commencing co-treatment, with expenditure incurred		Increase in aeration capacity: Addition of septage to the STP required an increase in the aeration in the tanks. Plant engineers estimated that each truckload of septage (~9 kL) requires an additional 2 kg of air to maintain reactor performance and the desired effluent quality. The installed aeration capacity was sufficient, however, the operational hours for aerators have increased. This	Mixing of septage with sewage prior to treatment has not resulted in any adverse impact on the STP or necessitated any retrofits or additions to the treatment train or changes in O&M protocols	Implementation of co-treatment did not require any retrofits or additions to the treatment train or changes in O&M protocols at the STP

S. No.	Aspect		Chennai - Nesapakkam	Goa - Tonca	Kanpur - Bingawan
			increase in the aeration capacity has also resulted in increasing the energy cost of the plant. Increase in sludge handling load: Septage addition has resulted in increasing the sludge handling load on the STP, however, existing plant capacity was sufficient to handle the higher loads. Grit Chamber: The grit chamber was designed for peak flows so addition of septage did not require any retrofitting or additions.		
4	Type of STP identifying technology, plant design capacity and current loading	Technology	"Activated Sludge Process" (ASP) Technology.	Cyclic Activated Sludge Technology (C-Tech), an advanced Sequential Batch Reactor (SBR) technology	Upflow Anaerobic Sludge Blanket (UASB) Reactor system
		Plant Design Capacity (in MLD)	117	12.5	210
		Current Loading (in MLD)	100	10	90
		Spare Capacity (in MLD)	17	2.5	120
5	Registration fees and Tipping fees for discharge at STP	Registration Fee	INR 2000 per truck	0	INR 1000 / truck (to be renewed annually)
		Tipping Fee	INR 100 per trip per truck	INR 500 per truck per visit	INR 3500 / truck / month (no ceiling on number of visits)

Monitoring and testing to ensure system performance

Most, if not all STPs, have a monitoring and testing protocol in place for testing characteristics of the influent, effluent and often in between processes. If co-treating, it becomes even more important for an STP to follow a rigorous monitoring and testing protocol that also includes testing of incoming septage. This is crucial for several reasons. Septage characteristics can vary widely based on geography, season and the duration after which a tank has been desludged. These can require proper planning in terms of issues such as when to add septage for co-treatment, how much septage could be co-treated, requirements of additional measures such as increased aeration, and to be able to anticipate increased sludge quantities for treatment and disposal. Testing should also be done to ensure that industrial waste, if brought by the desludging vehicles, does not enter the treatment streams. Often, visual inspection (any color of septage other than brownish/black), different or chemical odor can be used to identify industrial waste in septage. Operators can readily check for pH, conductivity, odour and colour to identify loads that contain commercial or industrial chemicals. When there is doubt, laboratory tests may be performed to identify the presence of industrial chemicals and heavy metals in septage. A protocol needs to be in place to penalize the desludging operators who bring in industrial waste; the Nesapakkam, Chennai STP bars disposal of septage by an operator for one month if industrial waste is found in the septage brought for disposal to the STP. This results in effective loss of business for a month as no STP in Chennai will accept septage from an erring operator during the penalizing period. Table 6 provides a list of monitoring activities undertaken or planned by the three studies STPs.

Table 6: Summary of system performance and monitoring activities being undertaken (or planned) at the STPs reviewed

S. No.	**Aspect**	**Chennai - Nesapakkam**	**Goa - Tonca**	**Kanpur - Bingawan**
1	Past and existing septage disposal practices in the city, and impact of co-treatment	Illegal dumping of septage has been reduced dramatically	Illegal dumping of septage has been reduced dramatically	In the past septage was being dumped illegally which has reduced significantly in Sewage Division II post co-treatment
2	Local sensitivity, risks (including potential toxic or non-compatible wastes being added)	Location of STP in a residential area; potential risk of dumping of industrial wastes	Concern related to dumping of industrial sludge at the STP, however there is no control process in place to monitor or address this practice. Concerns around odor as the plant is surrounded by residential colonies	Given that the sewage arriving at the STP contains about 10% - 15% industrial effluent, dumping of industrial waste at the receiving station for co-treatment is not a great concern. Since the STP is located in the city's periphery there is not much concern about odor.
3	Regular monitoring of septage quality undertaken at the time of deslugding / periodically, and sample size covered for quality testing	Regular sampling and analysis of septage isn't being undertaken. If any septage load is	Regular sampling and analysis of septage isn't being undertaken. There is a concern related to dumping of	Random sampling of septage takes place which is tested at the STP's laboratory. There

S. No.	Aspect		Chennai - Nesapakkam	Goa - Tonca	Kanpur - Bingawan
			suspected to be coming from an industrial source (identified by the plant attendant based on the colour and smell of septage), the decanting is stopped, samples are collected and tested at the laboratory located within the STP complex	industrial sludge at the STP, however there is no control process in place to monitor or address this practice.	are plans to acquire an instant analyzer which will allow immediate testing for specific parameters in the septage prior to discharge at the STP
4	Challenges and opportunities from co-treatment of septage at the STP	Challenges		The officials shared that there is a concern related to dumping of industrial sludge at the STP, however there is no control process in place to monitor or address this practice.	Presence of Solids in septage
		Opportunities	Co-treatment as a septage treatment solution for 0.18 – 0.6 million households annually; regularization of private desludging operators (52); and a source of revenue (the tipping fee have emerged as a revenue source with annual collections of ~INR 6 million).	Co-treatment as a septage treatment solution for 28,000 - 0.14 million households annually; regularization of private desludging operators; and a source of revenue (the tipping fee have emerged as a revenue source with annual collections of ~INR 18 million).	Co-treatment as a septage treatment solution for 27,000 – 0.11 million households annually; regularization of private desludging operators (21); and a source of revenue (the annual registration charge and the monthly tipping fee have emerged as a revenue source for KNN with approximate annual collections of ~INR 0.44 million).
5	City STP operator concerns with co-treatment of septage including technical, institutional and	Technical	Odour control and aesthetics are therefore key concerns for the plant personnel in order to ensure that there are no objections from the residents.	The plant operators, however, had some concerns around higher organic loading of the plant as septage is concentrated organic sludge with high BOD and SS levels. In the future, as higher sewage flows are received at the plant,	Screening to remove solids at the receiving station for septage; Storage facility to provide equalization of septage prior to mixing with sewage; testing of septage prior to discharge at the STP

S. No.	Aspect		Chennai - Nesapakkam	Goa - Tonca	Kanpur - Bingawan
	regulatory challenges.			the loading may become exacerbated and this could become a concern for the plant operators.	
		Institutional	None	None	None
		Regulatory	None	None	None
6	Strategies and implementation approaches adopted by the city / STP to improve co-treatment system and safe decanting and treatment of septage		Increase in aeration capacity by increasing the operational hours for aerators; Upgrading the decanting facility to include a) odour control unit connected to the receiving tank, b) High compound walls, c) Greenbelt development within the STP, and d) Discharge of septage directly into pits connected to the receiving tank to minimize scope for spillage.	Establishing a receiving station for septage; employing a dedicated supervisor for recording the entry and exit of tankers at the receiving station; strict enforcement of the Goa Public Health (Amendment) Rules, 2010	Establishing a receiving station for septage; employing a dedicated supervisor for recording the entry and exit of tankers at the receiving station; strict enforcement of the Municipal Solid Waste Rules by the ULB; and putting in place by-laws for co-treatment.

Annex A: State policies on Septage Management and Co-treatment at STPs

State	Relevance to co-treatment
Punjab: Policy & Guidelines for Septage Management in Punjab March, 2017	Co-treatment of septage along with domestic sewage at a sewage treatment plant (STP), if available, is the most desirable option. Though septage is more concentrated in its strength than domestic sewage, its constituents are similar to municipal wastewater. But care should be taken that the STP should have adequate capacity to accept the septage without hampering the functioning of the sewage treatment plant. The municipality should monitor the incoming wastewater load to the STP and accept the septage if the design norms are not violated with the increased load (on account of the septage). A list of ULBs with their capacity of the STPs and the present flow received at STPs provided in this document. The treatment plants that are under-utilized can serve as treatment plants for septage from nearby ULBs and if the STPs are working close to the design capacity, additional loads due to disposal of septage will necessitate expansion or up-gradation of the STP capacity. If Septage / faecal sludge are to be co-treated with sewage, it will be necessary to construct a Septage /faecal sludge receiving chamber. Chemicals such as lime or chlorine can also be added to the faecal sludge in the storage tank to neutralize it, to render it more treatable, or to reduce odours.
MP: Govt. of Madhya Pradesh State Level Policy (2017) for Waste Water Recycle & Reuse and Faecal Sludge Management (FSM)	Co-treatment of septage along with domestic sewage at a sewage treatment plant (STP) is a feasible and acceptable alternative for septage treatment. Though septage is much concentrated in its strength than the domestic sewage, its constituents are similar to municipal wastewater. Sewage treatment plant should have an adequate capacity in order to accept the septage without hampering the normal functioning of other processes. ● Septage addition to nearest sewer manhole- Septage could be added to a sewer upstream of the sewage treatment plant, and substantial dilution of septage occurs prior to it reaching the sewage treatment plant, depending on the volume of sewage flowing in the sewer. ● Septage addition to STP- Septage could be added to sewage immediately upstream of the screening and grit removal processes. It is economical because of the very simple receiving station design and also allows the wastewater treatment plant staff to have control of the septage discharge
Jharkhand Faecal Sludge & Septage Management Policy, 2017	Co-treatment in waste stabilisation ponds is an established faecal sludge treatment technology
Rajasthan: Draft policy on Faecal Sludge & Septage	Options and broad specifications for Treatment technologies – includes Co-Treatment with STP

Management (FSSM) 2017	
Greater Visakhapatnam Municipal Corporation Faecal Sludge and Septage Management Policy and Operational Guidelines	GVMC will identify suitable location within the city or in its outskirts for disposal of faecal sludge. Possibility of co-treatment with existing sewage treatment plant (STP) will also be looked at considering the quantum of investment involved through CAPEX and OPEX. Where such co-treatment facility is not possible, feasibility of decentralized Faecal Sludge Treatment Plant (FSTP) will be considered. GVMC will assess the possibilities of sludge treatment at the existing STPs in the city or those in the region through appropriate agreements with the STP operators (Part B, section for details of STPs). Proper tests and assessment should be carried out by the STP operators before receiving faecal sludge/septage. It is important to understand the performance of the Sewage Treatment Plant (STP) if at all it is considered for co-treatment. Therefore, the operation and monitoring of the plant shall be taken up on a pilot basis for a month to understand its effect on the plant output parameter, managing sludge lines and addressing the breakdown of the pumps, motors and valves. Waste stabilisation ponds (WSPs) are widely used for the treatment of municipal wastewater. The mechanisms for stabilisation are based on natural processes that occur in aquatic ecosystems. The present study is to scientifically dispose the faecal sludge generated from household level in the city to the existing sewage treatment plant. With these available information, a Detailed Project Report will be prepared, which will discuss the demand estimation, CAPEX, OPEX, recovery of O & M cost, VTO market size and implementation framework to carry out the up-gradation work at selected Sewage Treatment Plant (STP) for disposal of septage.

Annex B: Summary of compendiums / references on septage (FS) co-treatment at STPs

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	FS characterization	Decanting Stations	Co-treatment at STPs	
1	Septage Management in Urban India			Theoretical guidance on components of decanting facility at STP	Provides guidance on co-treatment and estimating permissible load at STPs based on existing capacity utilization and technology.	MoUD (2013)
2	Faecal Sludge Management in Developing Countries: A Planning Manual			**Guidance on siting a decanting / disposal location for FS:** The design must avoid high transport costs for delivering sludge to the facility. **Safe collection:** Appropriate incentive systems should make sure that all collected faecal sludge reaches the plant.	**Siting treatment facility: "**When choosing the treatment sites, it is very important to take into account the resistance or acceptance of the population neighbouring the site or the access roads. Possible negotiations for compensation measures should be held early in the plan. It is important to include surface for possible extensions of the plant and for buffer zones when purchasing or reserving land for sludge treatment. **Safe loading of FS:** "It is necessary to verify if the STP has sufficient capacity to treat the additional pollution load from FS. The most critical parameter is usually suspended solids (SS). Other design parameters are COD, BOD5, NH4-N. **Co-treatment of liquids with sewage:** Effluents from primary FS treatment can be treated together with sewage if a sewage treatment plant is existing or planned. The primary treatment mainly eliminates the suspended solids and the STP can then treat much higher volumes of liquid effluent than of raw FS. This option can be considered when there is existing or planned a sewage treatment plant, and when its capacity is not sufficient to	SANDEC (2002)

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	FS characterization	Decanting Stations	Co-treatment at STPs	
					treat raw FS. It is necessary to verify if the STP has sufficient capacity to treat the additional pollution load from pre-treated FS. The greatest part of suspended solids will be removed in primary treatment. The critical parameters will therefore be BOD5 and COD, further important are remaining SS and NH4-N.	
3	Solids Separation and Pond Systems For the Treatment of Faecal Sludges In the Tropics Lessons Learnt and Recommendations for Preliminary Design		Human Excreta: Per Capita Quantities, Characteristics, Classification and Comparison of FS, Heavy Metal Concentrations in Septage		Three critical variables should be considered when planning to co-treat wastewater and faecal sludge, viz. organic loading rate, solids load and ammonium/ammonia nitrogen concentration. Recommendation for Solids-Liquid Separation Prior to Pond Treatment, design guidelines for settling / thickening. Additional detailed guidance from this reference is included in **Annex C.**	SANDEC (1998)
4	Decentralized Systems Technology Fact Sheet Septage Treatment/ Disposal		Typical FS characteristics for domestic septage		Discusses septage addition at: 1. To Upstream Sewer Manhole: When septage is added to a sewer upstream of the wastewater treatment plant, substantial dilution of septage occurs prior to it reaching the wastewater treatment plant. This method is only feasible with large sewers and treatment plants. It is economical due to the very simple receiving station design. F7However, there is the potential for grit and debris to accumulate in the sewer and for odour problems near the manhole 2. To Plant Headworks: Septage can be added to sewage immediately upstream of the screening and grit removal	USEPA (1999)

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	**FS characterization**	**Decanting Stations**	**Co-treatment at STPs**	
					processes. This method, like the one mentioned above, is economical because of the very simple receiving station design. It also allows the wastewater treatment plant staff to have control of the septage discharge. 3. To Sludge Handling Process: This method reduces the loading to liquid stream processes, and it eliminates the potential for affecting effluent quality. However, there could be an adverse effect on the sludge treatment processes such as dewatering. Adding septage to the sludge handling process may also cause clogging of the pipes and increase wear on the pumps if the septage is not screened and degritted in the receiving station. 4.To Both Liquid Stream and Sludge Handling Processes: Septage can also be pre-treated to separate liquid and solid fractions, which are then processed accordingly. This provides more concentrated sludge for processing and reduces the organic loading to liquid stream processes and the hydraulic loading to sludge processes. Increased operations are required for septage pre-treatment at the receiving station.	
5	Septage Management: A Practitioner's Guide				Guidance on 1. Septage directly mixed with sewage 2. Septage treated with the sludge of an STP. **Key considerations for septage directly mixed with sewage:** **a)** The quality, and not just the quantity, of the sludge, must be evaluated. b) It must be ascertained beforehand whether the septage and sludge contain any toxic chemicals that can destroy biological communities. The presence of trash,	Rohilla et al. (2017)

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	FS characterization	Decanting Stations	Co-treatment at STPs	
					grit, and trade and industrial sludge can be toxic and impact biological processes. c) Consistent compliance of STPs might be an issue **Septage co-treated with STP sludge:** This is a better option because most STPs have land for sludge drying and dewatering. Sludge dewatering sites needs to be improved a bit by designing proper sludge drying beds. To dewater the septage or sludge, Geobags, can be developed as an alternative option to sludge drying bed. The liquid fraction from sludge or septage can be directed to the STPs. This is a much better option than directly mixing septage into the liquid stream of STPs. Septage, after dewatering, and sludge from STPs can be treated together through co-composting, pyrolysis etc. This solution is feasible only in STPs in the vicinity of the target city, otherwise, sludge transportation cost will be prohibitive.	
6	USEPA Guide To Septage Treatment and Disposal	Guidance on septic tank emptying: Types of pumps, procedures for emptying (including precautions), transportation requirements	Typical FS characteristics for domestic septage	Examples of septage receiving stations (typical design), record keeping requirements, example of septage and sludge	See Figure on different approaches and advantages / disadvantages of each. Potential impacts of septage addition: 1. Increasing volume of screenings and grit requiring disposal 2. Increased odour emissions 3. Scum accumulation in clarifiers 4. Increased organic loading to biological processes 5. Increased loadings to sludge handling processes 6. Increased sludge volumes 7. increases housekeeping requirements	USEPA (1994)

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	FS characterization	Decanting Stations	Co-treatment at STPs	
				manifest, O&M checklist,	Guidance on odour control approaches (operational and physio-chemical)	
7	Co-treatment of Faecal Sludge and Wastewater in Tropical Climates		"The formulae and diagrams which were developed by USEPA to determine the allowable rate of septage addition are based on a standard value for BOD concentrations in faecal sludge (7,000 mg/l). However, the quality of FS in many cities of tropical countries varies greatly, particularly where the faecal sludge is composed of a mixture of septage and		Includes operational and design guidance for the co-treatment of faecal sludge in waste stabilisation ponds and in activated sludge sewage treatment plants. For co-treatment in waste stabilisation ponds, FS solids should first be separated by sedimentation or in sludge drying beds. The high ammonia content, especially in fresh faecal sludge, can inhibit algae growth in the facultative ponds. Therefore, when calculating the permissible additional faecal sludge load, ammonia is a relevant design parameter besides BOD. Additional detailed guidance from this reference is included in **Annex C.**	SANDEC (1999)

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	**FS characterization**	**Decanting Stations**	**Co-treatment at STPs**	
			highly concentrated sludge from latrines or from non-sewered public toilets."			
8	Faecal Sludge Management Systems Approach for Implementation and Operation		Includes detailed guidance on FS characterization, and the impact of different water quality parameters on treatability and co-treatment performance. **Use of FS quality parameters in design:** The researchers recommend using COD over BOD to measure organic matter. Advantages of COD over BOD_5 include: (i) a	Types of transfer stations, siting considerations for transfer stations, hazards in handling FS at transfer stations,	Detailed guidance from this reference is included in **Annex C.**	Strauss et al. (2014)

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	FS characterization	Decanting Stations	Co-treatment at STPs	
			rapid analysis (e.g. hours as opposed to 5 days), (ii) more detailed and useful information including all degradable and undegradable organics, and (iii) the potential for the organics balance to be closed (on a COD basis). Of the two COD analytical determination methods, the dichromate method is preferred, as the permanganate method does not fully oxidise all organic compounds			
	Treating Faecal Sludge in Ponds	FS characteristics			Effect of FS TS, VSS, and Ammonia on WSP performance. When treating FS in ponds, be it separately or in	Strauss et al. (2000)

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	FS characterization	Decanting Stations	Co-treatment at STPs	
					conjunction with wastewater, settleable solids must be separated in primary treatment units in order to guarantee an undisturbed treatment of the liquid fraction. Process disturbance by improper design and operation for solids separation has been repeatedly observed The rate of accumulation of settleable solids, hence, the required solids storage volume, is the decisive design criteria for preliminary settling/thickening units or for solids storage compartments in primary ponds. Batch-operated settling/thickening is, in most cases, the technology-of-choice in developing countries, as electro-mechanical installations for continuous sludge removal may not prove sustainable. Primary ponds may constitute an alternative to settling tanks where this proves feasible for reasons of land availability, construction cost and solids removal operations. Such ponds can be designed as deep ponds to comprise a compartment for solids accumulation, with pond emptying intervals of > 1 year. However, the solids removal from the storage compartment may pose great technical difficulties. The handling of bio-solids accumulated in pre-settling tanks or in shallow primary ponds is easier compared with deep primary ponds. The authors hypothesise that rates of up to 600-700 g $BOD/m^3 \cdot day$ might be tolerated in tropical climate as against 300-350 g BOD/m3·day for wastewater ponds.	

S. No.	Study / Document	Aspects covered under the guidance				Reference
		OSS emptying	FS characterization	Decanting Stations	Co-treatment at STPs	
					Although most septage has usually been stored for months or years prior to collection, it has become apparent that, in many cases, it is still conducive to anaerobic degradation. Anaerobic degradation of medium to high-strength FS can be impaired by toxicity due to high ammonia (NH_3) concentrations. NH_3-N threshold levels in the influent to anaerobic ponds in the tropics should not exceed 400-500 mg/l.	

Annex C: Summary of design considerations for co-treatment at select STP technologies

Design considerations for co-treatment

A. **(SANDEC, 1998)**

The problems described in this paper relate to those that may arise when treating combined treatment of FS and sewage in waste stabilisation ponds (WSP). Three critical variables should be considered when planning to co-treat wastewater and faecal sludge, viz. organic loading rate, solids load and ammonium/ammonia nitrogen concentration.

- Organic loading rate: Anaerobic and facultative ponds are sensitive to excessive organic (BOD) loading. In anaerobic ponds, the most serious symptomatic problem resulting from overloading is odour nuisance. In facultative ponds, it will impair the development of aerobic conditions and algal growth. The permissible additional faecal sludge load is dependent on the initial organic load exerted by the wastewater and on the loading rates for which the ponds were originally designed.
- Solids load: Ponds may fill up at undesirably fast rates due to high solids contents in FS. Options for pre-treatment of FS are described in Chapter 4. Separation of the FS solids prior to treating the liquid in wastewater stabilization ponds contributes to optimum WSP performance and to minimising short circuiting and sludge removal operations.
- Ammonia nitrogen: The maximum NH_3 concentration tolerated by the algae in the facultative pond is an additional factor influencing the permissible FS load in a WSP system. Under the conditions prevailing in facultative ponds in tropical climates (T ≥ 25-28 °C; pH 7.5 - 8), ammonia (NH_3) amounts to 2-6 % of the ammonium (NH_4) concentration. If the permissible NH_3-N concentration in facultative ponds is set at 20 mg/l, and assuming that 5 % of NH_4 are NH_3, the maximum NH_4-N concentration of the combined waste in the influent to the facultative pond amounts to 400 mg/l. The bulk of the septage, usually stored for a period of up to several years, does not exhibit very high NH_4-N concentrations.

Fresh FS such as public toilet sludge, however, may contain NH_4-N concentrations of up to 5,000 mg/l.

B. SANDEC (1999)

This guidance includes operational and design guidance for the co-treatment of faecal sludge in waste stabilisation ponds and in activated sludge sewage treatment plants.

1. Excessive organic (BOD) loading rates may lead to overloading of the anaerobic and facultative ponds. This overloading causes odour problems and prevents the development of aerobic conditions in the facultative pond.
2. Ponds may fill up with sludge at undesirably fast rates due to the high solids content of FS.
3. Fresh, undigested excreta and FS contain high NH4 concentrations. These may impair or even prevent the development of algae in facultative ponds.

Preventive measures, such as the addition of a solids separation step ahead of the first pond, and the consideration of a maximum admissible FS load can avoid the aforementioned problems.

Discusses design parameters when co-treating at WSP for:

1. Organic loading rates:
2. Ammonia concentration and toxicity levels (Faecal sludges which have been stored over an extended period, e.g. septage, usually exhibit NH4-N concentrations of 400 mg/l. Fresh FS from unsewered low or zero flush toilets may contain NH4-N concentrations of 5,000 mg/l which would lead to an algae growth inhibition if excessive quantities were mixed. The guidance includes design example to estimate permissible FS loading based on NH3 concentration.
3. Solids accumulation: The high solids concentrations found in most faecal sludge, require pre-treatment of FS by solids-liquid separation, e.g. in batch operated settling/thickening tanks. This will prevent problems from occurring when having to handle large quantities of settled sludge from large primary ponds at intervals of one or more years. The guidance includes design parameters for Sedimentation/thickening tanks and sludge drying beds for solids pre-treatment.

Includes design examples to estimate permissible loading in ASP at various processes – upstream of aeration process and design of critical units, and addition to the sewage sludge stream.

C. Strande et al. (2014)

Co-treatment in WSPs:

1. Waste stabilisation ponds can be used for the co-treatment of wastewater with the effluent following solid-liquid separation of FS in settling-thickening tanks
2. Problems have been reported by researchers when dosing FS after screening directly into the anaerobic pond.
3. Typically, due to the high ammonia concentration and high organic loads and solid content, treating solely FS in WSPs is not recommended, nor is the addition of large quantities

Recommendation:
WSPs can be used for the co-treatment of FS and can treat liquid by-products of other FS treatment technologies, including:

- Leachate from unplanted and planted drying beds. Leachate is low in organic matter compared to domestic wastewater and direct discharge into the facultative pond might be possible as the solid fraction is relatively low. However, the ammonia concentration can still present a problem, and algae and methanogenic inhibition by free ammonia can also occur.
- Effluent from settling-thickening tanks. This was implemented in Argentina as co-treatment with the influent of anaerobic ponds, where tests were conducted for the treatment of the effluent from settling ponds. This solution has also been adopted in Dakar, Senegal, where preliminary solid/liquid separation is done by settling tanks, the effluent is co-treated with wastewater in a WSP, and the thickened sludge is dewatered with unplanted drying beds.

Advantages and constraints of co-treating in WSPs:

- WSPs are simple to build and have relatively low O&M requirements.
- Technology is appropriate for tropical climates given land is available
- FS addition without solids separation could result in high rate of solids accumulation and potential inhibition due to high salt and ammonia concentrations. The removal of sludge that accumulates in the anaerobic ponds may require heavy mechanical equipment.

Co-treatment at STPs:
The authors do not recommend co-treatment of FS with wastewater as a common practice in low-income countries. A co-management option could include co-management of FS with the sludge produced during wastewater treatment.

Challenges with co-treatment:

1. WWTPs are typically not designed for FS loadings, and process disruptions and failures are frequently possible.
2. Common problems with co-treatment of FS in WWTPs range from the deterioration of the treated effluent quality to overloading tanks and inadequate aeration.

Considerations for co-treatment:

1. Transport of FS to STP: Uncontrolled dumping of FS into sewers needs to be carefully regulated and prevented. The considerably higher solids content of FS may lead to severe operational problems such as solids deposition and clogging of sewer pipes. Hence, the first step in designing a co-treatment system includes determining how the FS will be transported to the treatment facility and discharged into the influent stream.
2. Detailed guidance on limiting FS to ensure a) treated water quality; b) adequate aeration capacity and c) adequate sludge management. The researchers observe that accumulation

of TSS is the limiting parameter for the co-treatment of FS. If the increase exceeds the maximum plant capacity, the plant can experience serious operational problems ranging from overloading of aeration and secondary settling tanks (with associated solid-liquid separation problems) to a considerable decrease in the oxygen transfer efficiency (which can lead to insufficient aeration and therefore to oxygen limiting conditions). Modelling results indicated that low FS influent volumes (as low as 0.5% for medium- and high-strength FS and of 2.5% for low-strength) could also overload the plant and exceed the maximum recommended design concentrations for aeration tanks. In addition, the increase in TSS and mixed liquor suspended solids (MLSS) concentrations will also result in increased volumes of waste sludge. There must be sufficient capacity in the sludge handling and disposal/end-use facilities of the plant to deal and cope with the higher sludge volumes generated.

3. FS disposal can also impact oxygen transfer efficiency and therefore aeration requirements of the plant as well as performance of the secondary settling tanks.
4. Dynamic loading of FS at STPs: FS flow rates can be much more dynamic than wastewater because they are not just dependent on diurnal patterns, they are also dependent on factors such as the working schedule of service providers, the customer demand for collection services, and the season. This can result in peak loads during the busiest times that can overload the treatment plant. Results of modelling concluded that, under dynamic conditions, the maximum volumes that can be co-treated in an activated sludge plant without causing any process disruption or (effluent) deterioration sometimes need to be up to 10 times lower than those allowable under steady-state conditions the modelling also tested the impact of dynamic loading during off-peak hours, (discharge during the night) and the potential contribution of primary sedimentation tanks, with little impact on plant performance under dynamic conditions. This illustrates the importance of equalisation tanks to ensure a more even loading, and the need to distribute influent FS evenly through the entire day to approach steady-state conditions.

Co-treatment at STPs with Nitrogen removal

The organic content to nitrogen ratios in typical FS samples presented by the researchers indicate that organic concentrations in FS are not sufficient for nitrogen removal by denitrification. The researchers recommend that FS should only be considered for co-treatment in processes that include nitrogen removal if the influent wastewater has a high COD:TKN or BOD5:TKN ratio (i.e. 12-16 and 6-8, respectively). In contrast, the COD:TP and BOD_5:TP ratios in FS are relatively high, which suggests that there could be sufficient organic matter for biological phosphorus removal

Impact on cost of new STPs

The researchers indicated that while for new STPs can be designed to receive an treat FS, however, the design will probably lead to larger tank volumes, larger settling tanks, and higher installed capacity for aeration and sludge handling, treatment and disposal. For instance, compared to municipal wastewater treatment alone, for 1% FS co-treatment (regardless of the strength), the tank volumes will need to be 300% larger, the aeration capacity at least 200% higher, the secondary settling tanks 5 times larger and the sludge facilities 4 times larger. This will have a considerable impact on plant capital and O&M costs.

Impact of FS treatment in anaerobic treatment systems

Co-treatment of FS and wastewater in anaerobic processes is an alternative for sludge stabilisation, volume reduction and increased dewaterability. Possibilities include Upflow anaerobic sludge blanket reactors (UASB), anaerobic digesters and anaerobic ponds. Anaerobic treatment can offset treatment costs through the production of biogas, which can be used for heating or for the generation of electricity. Pathogen reduction can also be achieved with thermophilic digestion.

The researchers suggest that FS from septic tanks (digested FS) may not be appropriate for anaerobic co-treatment, depending on the level of stabilization it has undergone. In this case, the low concentrations of biodegradable organics in digested FS will lead to low biogas production but high solids accumulation resulting in significant operational costs with limited benefits.

The researchers observe that anaerobic treatment processes are disrupted by overloading of COD, ammonia inhibition, pH variations, and sulphide inhibition. Therefore, these factors need to be carefully monitored, and controlled, to ensure proper operation of co-treatment of FS in anaerobic treatment systems.

1. In UASB reactors, to prevent overloading, the maximum COD or VSS design loading rates must not be exceeded, and reactors must have consistent and uniform feeding
2. For anaerobic co-treatment in digesters, it is recommended that the feeding, including FS, is always lower than one twentieth of the digester volume. This approach would mean a maximum 5% FS loading, regardless of its strength, to prevent overloading or significant reduction in the SRT.
3. Ammonia Inhibition: The anaerobic co-treatment of FS can be inhibited by the high concentrations of ammonia present in FS. The researchers suggest that their volumes need to be limited to no more than 2, 5 and 8% for high-, medium- and low-strength FS, respectively (based on the total nitrogen concentrations expected in co-treatment of wastewater and fresh FS).
4. pH variations: In anaerobic systems, the pH needs to be carefully monitored and kept between 7.0 and 7.5. Monitoring, and if possible adjusting, the alkalinity levels and buffer capacity of the system can help to reduce pH fluctuations and maintain an adequate pH range. Other practices, such as gradual feeding and the controlled addition of external compounds (including charcoal ashes to enhance pathogen removal and nutrient recovery), also need to be carefully performed.

Annex D: Summary of global co-treatment experience

S. No.	Study / Document	Country / Region	Description of co-treatment experience	Level of detail available
1	Regional Siting Of Faecal Sludge Treatment Facilities: St. Elizabeth, Jamaica, Ana Martha Fernandes[30]	Jamaica	Brief reference to practice of co-treatment at 2 existing STPs in St. Elizabeth, Jamaica, however this practice has not been continued due to prohibitive cost of transportation	Brief mention of practice
2	A Review Of Faecal Sludge Management In 12 Cities[31]	Santa Cruz, Bolivia	The private operators transport the FS to a water and sanitation cooperative run (SAGUAPAC) treatment plant. 60% of the waste emptied is transported to treatment but the balance is dumped illegally in the environment. The treatment efficiency is understood to be good and 100% of the sludge delivered is treated and discharged. Only 9% of FS generated from OSS is treated. This cooperative receives and treats sludge from 25 sludge collection services (10,000 m3 / month).	Reference to the practice, and share of FS in the city that is treated at WWTP
3	A Review Of Faecal Sludge Management In 12 Cities[32]	Managua, Nicaragua	50% of the mechanically emptied FS is transported to the water and sanitation provider's (ENACAL) WWTW. The balance is discharged illegally. Six of the 10 known collection companies discharge their faecal sludge at the wastewater treatment plant. Nicaragua's national drinking water and sanitation enterprise, ENACAL, charges them US$0.30/m3. The collection companies generate a monthly sludge volume of 863.51m^3 and	Reference to the practice, and share of FS in the city that is treated at WWTP

[30] Fernandes (2005).
[31] "WSP (2013); Furlong (2017)"
[32] WSP (2013)

S. No.	Study / Document	Country / Region	Description of co-treatment experience	Level of detail available
			fees amounting to US$3,165.16 (ENACAL 2011). These figures suggest that the plant's capacity for the treatment of sludge is probably greater than what it receives.	
4	A Review Of Faecal Sludge Management In 12 Cities[33]	Maputo, Mozambique	Dumping of FS in influent of WWTW is permitted; this is operated by Municipality but operates at only 50% efficiency.	Reference to the practice, and share of FS in the city that is treated at WWTP
5	A Review Of Faecal Sludge Management In 12 Cities[34]	Kampala, Uganda	Dumping of FS in Bugolobi WWTW is permitted; this is operated by NWSC; efficiency is estimated to be 75% (nominal). Faecal sludge that is removed from the plot through manual or mechanical means is disposed of at designated wastewater treatment plants. Operators need a license to transport faecal sludge, but this is seldom enforced	Reference to the practice, and share of FS in the city that is treated at WWTP
6	Faecal Sludge Management In Botswana: A Review Of Current Practices And Policies Using The Case Of Gaborone Low Income Areas[35]	Botswana, Gaberone	The FS sludge from pit latrines is treated with municipal wastewater at the Gaborone Wastewater Treatment plant, 10 km northeast of Gaborone City. Due to limited methods of treatment and disposal of FS from pit latrines, sludge management has become an integral part of the wastewater treatment plants across the country (FS is mixed with sewage at the inlet to the STP).	Reference to the practice and challenges
7	The Status Of Faecal Sludge Management In Eight Southern And	South Africa	Vacuum tanks usually dispose of faecal sludge at the municipal wastewater treatment plants. In a number of municipalities, these plants struggle to meet regulatory requirements.	Plant configuration, size of units, removal efficiencies at each stage of treatment

[33] "WSP (2013); WSP (2012)"
[34] "WSP (2013); WRC (2015)"
[35] Odirile et al. (2018)

S. No.	Study / Document	Country / Region	Description of co-treatment experience	Level of detail available
	East African Countries[36]		In the urban areas of South Africa, faecal sludge is usually added to the wastewater stream where it is subject to co-treatment in wastewater treatment plants, as well as waste stabilisation ponds	
8	Co-treatment of sewage and septage in waste stabilization ponds	Alcorta, Argentina	System of two waste stabilization ponds in series was put into operation in the town of Alcorta. Both wastewater and septage were co-treated in a pond stabilization system with two ponds in series. The vacuum trucks discharge directly into the first pond. Due to high contents of solids of septage, the primary pond had reduced its capacity by half. Construction of two septage ponds was undertaken to address this issue.	
9	Domestic Septage Characteristics and Co-treatment Impacts on Albireh Wastewater Treatment Plant Efficiency	Albireh, Palestine	The study modelled the impact of FS after detailed characterization using a modelling software Albireh city has a central public sewer network of a modified combined system, where part of the collected storm water is mechanically treated at AWWTP site in the storm water tank. Samples were collected from different septage haulers delivering septage from different places in Albireh at different times. ANAwin was used to simulate the impact of septage increment (%) on the unit operation design of the aeration tank including structural and biological design parameters at variable temperatures	

[36] "WRC (2015); WRC (2012)"

S. No.	Study / Document	Country / Region	Description of co-treatment experience	Level of detail available
10	FSM Handbook	South Africa	Two activated sludge WWTPs located in eThekwini, South Africa were receiving low volumes of FS from pit latrines. experienced serious operational problems caused by the high loads of organics, nitrogen compounds and suspended solids	
11	FSM Handbook	Saint Marten, Netherlands Antilles	On the island of Saint Marten, wastewater and septic tank sludge were discharged into the existing Illidge Road WWTP. The plant consisted of an Imhoff tank, buffer tank, secondary settling tank and sludge drying beds. The plant capacity was considerably exceeded by the wastewater flow rate (of at least 65 m3/h) and the high FS volumes that in a typical working day accounted for an equivalent of about 175 m3/day. During retrofit to a Modified Bardenpho (A2O) process design, different scenarios were evaluated through mathematical modelling.	
12	FSM Handbook	Manila, Philippines	Activated sludge systems have recently been chosen in the Philippines as the main biological treatment process for FS treatment. Manila Water's FS operations with septic tank sludge currently utilise a FS treatment with activated sludge in the Manila South septage treatment plant. The plant is able to treat up to 814 m3 per day of FS.	

The following table summarizes the challenges observed and approaches adopted at sites that were co-treating FS at STPs.

S. No.	Study / Document	Country / Region	Challenges	Year of study	Reference
1	Regional Siting of Faecal Sludge	Jamaica	Cost of transportation by trucks was prohibitive	2005	Fernandes (2005)

S. No.	Study / Document	Country / Region	Challenges	Year of study	Reference
	Treatment Facilities: St. Elizabeth, Jamaica, Ana Martha Fernandes				
2	A Review of Faecal Sludge Management in 12 Cities	Santa Cruz, Bolivia		2013; 2017	WSP (2013) Furlong (2017)
3	A Review of Faecal Sludge Management in 12 Cities	Managua, Nicaragua		2013	WSP (2013)
4	A Review of Faecal Sludge Management in 12 Cities	Maputo, Mozambique		2013	WSP (2013) WSP(2012)
5	A Review of Faecal Sludge Management in 12 Cities	Kampala, Uganda	Most of the wastewater treatment plants are designed for wastewater treatment and not faecal sludge. Overloading of plants has been reported at some of the plants	2013	WSP (2013) WRC (2015)
6	Faecal Sludge Management in Botswana: A Review of Current Practices and Policies Using the Case of Gaborone Low Income Areas	Botswana, Gaberone	indiscriminate practice of co-treatment has caused the wastewater treatment plant to malfunction due solids over load.		Odirile et al. (2018)
7	The Status Of Faecal Sludge Management In Eight Southern And East African Countries	South Africa	Part of the problem might be the vacuum tanks that discharge their sludge into the inlet structure of the wastewater treatment plant. This might cause shock loads. There seems to be little experience regarding the treatment process and there are no established strategies to deal with problems. The mechanism of WWT	2015	WRC (2015) WRC (2012)

S. No.	Study / Document	Country / Region	Challenges	Year of study	Reference
			plant failure is not clearly understood. In one case, the removal of secondary solids from the works was limited by the number of truckloads of solids arising from secondary sludge from the plant that could be removed in a month, in terms of operating costs, and the willingness of the receiving landfill to accept the material. Thus when large volumes of fairly dry pit sludge were added to the works, with relatively little addition of biodegradable material, the solids report fairly soon as secondary sludge. The sludge could not be removed at an accelerated rate, and thus was retained in the system for an extended period. It was clearly a case of taking one solids problem and making it into another solids problem. Secondly, the very high load of nitrogen added to the works appeared to inhibit or otherwise deactivate the nitrification capacity of the works, and in this particular case, it took the works several months to recover. Thus while co-treatment in a conventional WWTP seems a convenient disposal route, it is not a sustainable or successful one.		
8	Co-treatment of sewage and septage in waste stabilization ponds	Alcorta, Argentina	Without pre-treatment, the solids loading from FS greatly impacted the available volume in the stabilization ponds, and impacted plant performance. The great difference in total solids between septage and sewage makes it necessary to pre-treat the septage before its	1998	Ingallinella (2002)

S. No.	Study / Document	Country / Region	Challenges	Year of study	Reference
			discharge into conventional treatment. Addition of a sludge pre-treatment unit (sedimentation ponds) helped achieve an effluent that was similar in quality to domestic sewage, and could be co-treated in WSPs.		
9	Domestic Septage Characteristics and Co-treatment Impacts on Albireh Wastewater Treatment Plant Efficiency	Albireh, Palestine	FS co-treatment exerted additional energy consumption due to additional oxygen demand in the oxidation ditches for the biological processes. The daily average energy costs for septage treatment was calculated at US$ 410 per day. The modelling indicated: 1. An increase in the aeration capacity (8-49%) must be achieved to cope with additional loads of both organic carbon and nitrogen; otherwise deficient oxygenation will lead to build-up of nitrite, less nitrification capacity and might cause sludge foaming/bulking. 2. 5-30% of septage addition implies overloading of the system and lead to 7-51% additional volume in the aeration tank. 3. Continuous co-treatment of septage will dramatically affect the issue of non-compliance related to COD and nitrogen.		Ingallinella (2002)
10	FSM Handbook	South Africa	A complete inactivation of the nitrification process was observed in one of the plants, which took several months to recover. The researchers suggested that this was a	2012	Strauss et al. (2014)

S. No.	Study / Document	Country / Region	Challenges	Year of study	Reference
			result of the excessive nitrogen load discharged into the plant and that the aeration capacity was exceeded as a consequence of the high loads discharged At the other plant under study, the high solids overloading made it practically impossible to remove the excess sludge generated as it was equal to the sludge volume produced in a month. Sludge removal was limited by the number of truckloads that could be removed, increasing associated operational costs and even the willingness of the receiving landfill to accept the material.		
11	FSM Handbook	Saint Marten, Netherlands Antilles	Higher concentrations of non-biodegradable compounds and low biodegradability of organics in FS hindered compliance with the effluent limits. Due to the loads of non-biodegradable particulate organic matter and non-biodegradable soluble organic nitrogen from the digested FS, the modelling study suggested that the proposed plant would only be able to comply with most of the discharge limits when the FS volumes comprise of no more than 2.8% of the influent. However, as a consequence of the high nitrogen load and slow biodegradability of biodegradable organics, the study also speculated that the nitrogen limits will probably not be met at the new plant.		Strauss et al. (2014)

S. No.	Study / Document	Country / Region	Challenges	Year of study	Reference
12	FSM Handbook	Manila, Philippines	Currently, the plant handles about 40-50% of its maximum capacity, indicating that there is still room for growth. In addition, the septage management system of the Baliwag water district has decided to build a septage treatment plant that utilises a sequencing batch reactor as a secondary treatment process. These experiences indicate that co-treatment of FS in aerobic biological systems can be feasible and satisfactory if the design is adequate to cope with the FS influent, there is adequate operator capacity and competence, and an appropriate management scheme is implemented.		Strauss et al. (2014)

Annex E: Summary of Guidance on Emptying Septic Tanks and Septage Collection

<table>
<tr><th>Guidance Document</th><th>Key guidance on septic tank desludging</th></tr>
<tr><td>Septage Management in Urban India, Advisory Note by Ministry of Urban Development, Government of India</td><td>
The most satisfactory method of sludge removal is by vacuum tankers.
Though desludging frequencies vary, it is generally recommended to desludge tanks once every two to three years, or when the tank becomes one third full.
A small amount of sludge should be left in the tank to ensure that a minimum level of the necessary microorganisms responsible for anaerobic digestion remain in the tank.
The gas generated due to anaerobic digestion might escape when tank is open for desludging. Hence, it is highly advisable to avoid using fire (or any incendiary material) in these cases.
Because of the delicate nature of septic systems housing microbial processes, care should also be taken not to scrub the septic clean or use chemicals such as detergents etc. to avoid the complete destruction of favourable microbes in the tank.
Before desludging, if the liquid level in the tank is higher than the outlet pipe, this may indicate clogging in the outlet pipe or in the drain. The sludge then may be collected through safe containers or pumping. Before pumping, the scum mat is manually broken up to facilitate pumping. Prior to this, the liquid level in the septic tank first is lowered below the invert of the outlet, which prevents grease and scum from being washed into the drain. After the scum mat is broken up, the contents of the tank are removed.
Normally, the vacuum/suction hose sucks up to a point where 1 to 2 inches (about 2.5 to 5 cm) of sludge remains at the tank bottom to facilitate future decomposition.
The sludge after removal should be transported in a controlled manner to avoid leakage or spillage en route.
</td></tr>
<tr><td>Indian Standard Code Of Practice for Installation of Septic Tanks Part I Design Criteria and Construction (Second Revision), Third Reprint October 1993</td><td>Septic tank design:
Each compartment of a septic tank shall be provided with a rectangular access opening
Every septic tank shall be provided with ventilating pipe of at least 50 mm diameter
It is essential that the floor of the tank be water tight and of adequate strength to resist earth movement and to support the weight of the tank walls and contents.
Septic tank desludging</td></tr>
</table>

Guidance Document	Key guidance on septic tank desludging
	• Half yearly or yearly desludging of septic tank is desirable. Small domestic tanks, for economic reasons, may be cleaned at least once in 2 years provided the tank is not overloaded due to use by more than the number for which it is designed. • A portion of sludge not less than 25 mm in depth should be left behind in the tank bottom which acts as the seeding material for the fresh deposits. • When removal of the sludge is carried out the scum in the first tank should not be disturbed more than necessary, this scum is needed to ensure efficient operation.
CPHEEO Manual on Sewerage	The Manual observes that only about 30% of the settled solids are anaerobically digested in a septic tank. Thus when the septic tank is not desludged for a longer period i.e., more than the design period, substantial portion of solids escape with the effluent. Therefore, for the septic tank to be an efficient suspended solids remover, it should be of sufficient capacity with proper inlet and outlet arrangements. It should be designed in such a way that the sludge can settle at the bottom and scum accumulates at the surface, while enough space is left in between, for the sewage to flow through without dislocating either the scum or the settled sludge. Recommendations on design of septic tanks: • Minimum liquid retention time should be 24 hours, Septic tank may be designed for 1 to 2 days of sewage retention. • The septic tanks are normally rectangular in shape and can either be a single tank or a double tank. In case of double tank, the effluent solids concentration is considerably lower and the first compartment is usually twice the size of the second. The liquid depth is 1-2 m and the length to breadth ratio is 2-3 to 1. • The inlet and outlet should not be located at such levels where the sludge or scum is formed as otherwise, the force of water entering or leaving the tank will unduly disturb the sludge or scum. Further, to avoid short-circuiting, the inlet and outlet should be located as far away as possible from each other and at different levels • All septic tanks shall be provided with watertight covers of adequate strength. Access manholes (minimum two numbers one on opposite ends in the longer direction) of adequate size shall also be provided for purposes of inspection and desludging of tanks. • The floor of the tank should be of cement concrete and sloped towards the sludge outlet. Both the floor and side

Guidance Document	Key guidance on septic tank desludging
	wall shall be plastered with cement mortar to render the surfaces smooth and to make them water tight. Recommendations on emptying of septic tanks • The mechanical vacuum tankers should be used to empty the septic tanks. Alternately, where space is not a constraint, a sludge-pipe with a delivery valve to draw the sludge as and when required, should be installed at the bottom of the tank to empty its contents into a sump, for subsequent disposal on land or sent for further treatment. • Yearly desludging of septic tank is desirable, but if it is not feasible or economical, then septic tanks should be cleaned at least once in two - three years, provided the tank is not overloaded due to use by more than the number of persons for which it is designed.
Guidelines for Septage Management in Maharashtra, February 2016	While desludging the following norms should be followed: **1.** The septic tanks should not be fully emptied; small amount of sludge of around 1 to 2 inches should be left in the septic tank to facilitate decomposing of incoming faecal waste. 2. No fire or flame should be used near the septic tanks as there may be inflammable gases inside septic tanks 3. Proper safety gears should be used by the operator while desludging / emptying the septic tanks **4.** Septage transportation vehicle operators (whether from ULB or private sector) should be well trained and equipped with protective safety gears, uniforms, tools and proper vacuum trucks, to ensure safe handling of sewage/septage.