



Desk Study on Co-treatment of Wastewater and Faecal Sludge



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Abstract – This knowledge document is an effort intended to capture some of the key aspects on co-treatment design – treating domestic wastewater and faecal sludge (FS)/septage together, internationally and within India through literature review and elicitation of expert opinion. Some insights are drawn for assessing co-treatment feasibility and design for Indian context.

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Prepared By:



CONTENTS

List of Figures	5
List of Tables	6
List of Abbreviations	7
1 Introduction	9
2 Quality of Faecal Sludge from a Co-treatment perspective	11
2.1 Interpretations	12
2.1.1 FS vs Sewage Concentrations.....	13
2.1.2 Design Parameters	13
3 Sewage Treatment Plants - from a Co-treatment perspective	15
3.1 Design Criteria for STP	15
3.2 Sizing of STP.....	15
3.3 Treatment Technologies:	16
3.3.1 Activated Sludge Process	16
3.3.2 Sequencing Batch Reactor	17
3.4 Approaches to addition of FS to STPs	18
3.5 STP Operations from a Co-treatment perspective	19
4 Quantity estimation for Co-treating FS in STP	23
4.1 Quantity estimation based on USEPA guidelines	23
4.2 Quantity estimation based on Guidelines for septage addition (Germany)	24
4.2.1 Guidelines	24
4.2.2 Design considerations	25
4.2.3 Method 1 – Population equivalent approach	25
4.2.4 Method 2 – Septage addition based on plant utilization	27
4.3 Quantity estimation based on Dave Robbins study	28
4.3.1 Guidelines	28
4.3.2 Design considerations	28
4.4 Quantity estimation based on CPHEEO guidelines on FS load estimation	29
4.4.1 Guidelines	29
4.4.2 Design considerations	29
4.5 Quantity estimation based on FSM book	30
4.5.1 Guidelines	30
4.5.2 Design considerations	31
4.5.3 Co-treatment of FS with municipal wastewater treatment plant	31
4.6 Quantity Estimation - Summary	34

5	Conclusions.....	35
6	Areas of exploration.....	38
7	References	39

LIST OF FIGURES

Figure 1. Schematics of ASP technology	17
Figure 2: Schematic of process stages in the SBR Treatment	18
Figure 3: Co-treatment using Direct Addition at the STP, for illustration only	19
Figure 4: Co-treatment option using solid-liquid separation method, for illustration only	19
Figure 5. Graph showing the allowable septage volume to be added to municipal treatment plant per German guidelines (U.S. EPA., 1984)	25
Figure 6. Graph showing allowable rates of equalised septage to an existing treatment plant (U.S. EPA., 1984)	27

LIST OF TABLES

Table 1: Characteristics of faecal sludge as reported in different studies/ literature.....	11
Table 2. Characteristics of Sewage as per (CPHEEO, 2013)	13
Table 3: Comparison on Strength of FS vs Sewage specific to India	13
Table 4. Fractionation of sewage, fresh and digested FS (Strande et. al, 2014)	14
Table 5: Design consideration of Sewage characteristics to STP	15
Table 6: Characteristics and design parameters of ASP systems (CPHEEO, 2013).....	17
Table 7: Showing the key implications on STP due to co-treatment.....	20
Table 8: Characteristics of Septage considered in the U.S. EPA., (1984)	25
Table 9: Quantity of Estimation based on USEPA	26
Table 10: Calculation of septage addition based on plant utilisation	27
Table 11: FS characteristics from Hanoi (Robbins et. al, 2017)	29
Table 12: Estimated quantity of FS based on (CPHEEO, 2013) recommendations	30
Table 13: FS characteristics considered for simulation study	31
Table 14: Quantity of FS addition at average flow and Peak flow (Strande et. al, 2014)	33
Table 15: Quantity of FS estimated allowable in STP based on strength (Dongal, 2013).....	33
Table 16: Estimated quantity of FS that can be treated in STP based on various studies.....	34

LIST OF ABBREVIATIONS

ASP	Activated Sludge Process
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPHEEO	Central Public Health and Environmental Engineering
CSE	Centre for Science and Environment
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
IIHS	Indian Institute of Human Settlements
Kg/d	Kilogram per day
LPCD	Litres per capita per day
MBBR	Moving Bed Biofilm Reactor
Mg/L	Milligram per litre
MLD	Million Litres per day
MSW	Municipal solid waste
NFSSM Alliance	National Faecal sludge and Septage Management Alliance
NH ₃ -N	(Ammonia) Nitrogen
NH ₄ -N	(Ammonium) Nitrogen
NO ₃	Nitrate
SBR	Sequencing Batch Reactor
SCBP	Sanitation Capacity Building Platform
SS	Settleable Solids
STP	Sewage Treatment Plant
TKN	Total Kjeld Hal Nitrogen
TP	Total Phosphate
TS	Total Solids
TSS	Total Suspended Solids
UASBR	Up flow Anaerobic Sludge Blanket Reactor
USEPA	United States Environment Protection Agency
VS	Volatile Solids

EXECUTIVE SUMMARY

Co-treatment is widely discussed as an alternative approach to treat Faecal Sludge (FS)/septage using spare capacity in existing Sewage Treatment Plants (STP) ; however its design aspects have not received due consideration. This knowledge document is an effort intended to capture some of the key aspects on co-treatment design in the Indian context through literature review and practitioner experiences. Chapter 1 sets the context for this knowledge document, starting with the key questions guiding this study: 1) How much FS to co-treat in an STP? , 2) How to add FS? , 3) Where to add the FS for co-treatment, and 4) When is the right time to add FS in an STP? To address these questions, we did a deep dive into topics including FS and sewage, STP design and operation. Documented guidelines on addition of FS to STPs were also studied and implemented.

Chapter 2 considers the first challenge for co-treatment, especially the widely varying characteristics of FS and sewage. FS is context dependent and can vary with diet, source, storage duration, type of onsite containment, climatic conditions, septic tank performance and desludging pattern. Key literature sources were considered, and it was found that FS can be 10 to 100 times more concentrated than the sewage. Considering specific datasets for parameters like Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) from specific areas in India, FS is **50-60** times more concentrated than sewage. Given the higher COD demand of FS over wastewater, and the higher non-biodegradable soluble fraction of COD, it is argued that COD should be considered to quantify the amount of FS to be added for co-treatment.

Chapter 3 considers STP design criteria like influent sewage parameters (CPHEEO, 2013 and designer criteria), sizing of STP based on hydraulic flows and treatment technologies (aerobic systems like Activated Sludge Process (ASP) and Sequencing Batch Reactor (SBR) being most common in Indian context). Two key approaches to adding FS to STP have been found in the literature and pilots: Direct Addition (Adding FS at FSTP head works/ wet well at required dilution) and Solid Liquid Separation (Separation of liquid and solid, and addition to liquid stream and sludge handling facility respectively). Literature and practitioner reports of problems encountered during co-treatment are listed, including influent characteristics, sludge characteristics and handling and contractual issues.

Chapter 4 presents and applies five methods to determine the maximum quantity of FS that can be co-treated in an existing STP namely: U.S. EPA. Hand book: Septage Treatment and Disposal (U.S. EPA., 1984), Guidelines for septage addition (Germany)- (U.S. EPA., 1984), Approaches and quantity Estimation: Dave Robbins (Robbins et. al, (2017), CPHEEO Manual (CPHEEO, 2013) and Linda Strande's FSM book (Strande et. al, 2014). FS for co-treatment was quantified for a STP of 50 MLD capacity running at 50% capacity utilization and specified boundary conditions. Calculations for with these methods yields FS loading ranging from 0.25% to 3% based on the method used. While these calculations suggest that co-treatment using direct addition is feasible, it is noteworthy that these guidelines are designed with certain assumptions and a careful attention to a context is needed.

Chapter 5 summarises the key takeaway of co-treatment through direct addition to existing and Greenfield STPs, as well as addition of FS at pumping stations. Areas for further exploration, especially to better understand solid-liquid separation are listed.

1 INTRODUCTION

Over the last few years, through the efforts of the Ministry of Housing and Urban Affairs (MOHUA), National Faecal Sludge and Septage Management (NFSSM) Alliance and various state governments, tremendous awareness has been generated on the need for Faecal Sludge Management (FSM) in India. This has resulted in various initiatives along the FSM value chain, with a major focus on setting up of Faecal Sludge Treatment Plants (FSTPs). While more FS treatment plants are a necessity, efforts have also been put in to see how existing infrastructure can be utilized for treatment of FS. Utilizing existing infrastructure for treatment of FS has gained attention because of - issues associated with identifying and **getting permissions for land** for a new Faecal Sludge treatment plant and the **resultant delays**, the **costs associated with investing in new infrastructure** exclusively for FSTPs, **underutilization of existing infrastructure**.

Some of the approaches to treat FS by utilizing existing infrastructure include - Co-treatment in existing Sewage treatment plants (STPs), Co-composting with Organic Solid Waste, Co-Digestion (Bio methanation along with organic Municipal Solid Waste (MSW)).

Out of these options, given the number of the STPs currently in India and their under-utilization¹, co-treatment of FS at STPs has become an extremely relevant and important area to focus on. There are documented examples of co-treatment of FS at STPs in India – namely Tonca in Panaji², Bingawan in Kanpur³, Nesapakkam in Chennai⁴, Trichy Waste Stabilization pond⁵. Guidelines have also been prepared by IIHS and CPHEEO, (2013) with the IIHS co-treatment guidelines⁶ document focusing on various operational aspects and infrastructure to be put in place and the CPHEEO, (2013) document laying out guidelines on load calculations⁷ for co-treatment. However, there has been little emphasis on the design aspects of co-treatment which can guide a practitioner on the following key questions when it comes to co-treatment

- 1) How much FS to co-treat in an STP?
- 2) How to add FS?
- 3) Where to add the FS for co-treatment
- 4) When is the right time to add FS in an STP?

This document attempts to answer the above questions through

¹ According to CPCB report dated 12th September 2017 (<http://cpcb.nic.in/status-of-stps/>), the actual capacity utilization of STPs is only 72.2%

² Study conducted by CSE on Tonca STP published in website (<https://www.cseindia.org/co-treatment-at-tonca-stp-panaji-8640>)

³ Study conducted by CSE on Bingawan STP published in website (<https://www.cseindia.org/co-treatment-at-bingawan-stp-kanpur-8641>)

⁴ Case study : https://www.fsmttoolbox.com/assets/pdf/143_Chennai_Nesapakkam_STP_case_study.pdf

⁵ Case study published in SCBP co-treatment training module: <https://scbp.niua.org/training-modules/module-co-treatment-septage-and-sewagedraft>

⁶ Checklist prepared by IIHS for evaluating the feasibility options for Co-treatment in existing STPs <http://muzhusugadharam.co.in/wp-content/uploads/2018/05/Checklist-for-Assessment-of-STPs-for-Co-treatment-of-Fecal-Sludge-2017.pdf>

⁷ Chapter 9 on onsite sanitation in the CPHEEO manual, discuss about load calculation for addition of septage in the existing STPs http://cpheeo.gov.in/upload/uploadfiles/files/engineering_chapter9.pdf

- 1) Desk study of some of the widely known and published literature on co-treatment and Faecal Sludge Treatment.
- 2) Consultations with STP designers, operators and officials in charge of managing wastewater utilities to capture their understanding with respect to the key questions.

In the process of answering these questions, some of the key aspects that drive co-treatment design were identified – which include

- Characteristics of FS
- Characteristics of Sewage
- Design of STPs
- Operations of STPs
- Documented approaches and guidelines on addition of FS to STPs
- Documented guidelines for quantity estimation of FS that can be added to STPs

Based on the above key aspects and how they influence co-treatment design, key conclusions and areas for exploration are drawn for the Indian context with the intention to help practitioners approach co-treatment design in a more nuanced manner.

2 QUALITY OF FAECAL SLUDGE FROM A CO-TREATMENT PERSPECTIVE

Faecal sludge comprises of all liquid and semi-liquid content that accumulates in on-site sanitation (OSS) installations. Some examples of OSS are un-sewered public and private latrines or toilets, aqua privies and septic tanks (Strande et. al, 2004). Parameters that are typically considered for characterisation of FS are the same as wastewater and include solids concentration, COD, BOD, nutrients, pathogens, and heavy metals. FS is normally several times more concentrated in terms of organics, nutrients and solids in comparison to wastewater. In order to co-treat FS in STPs, information on the quality and quantity of FS is essential. This section compiles the characteristics of FS considered by some of the major literature/ studies and compares them with characteristics of FS from India.

Heinss et.al. (1998), have shown the difference in characteristics of FS and sewage with reference to a specific country. FS characteristics differ widely according to source of the sludge (public toilet, household, pit, and septic tank), location (from household to household, from city to city, from country to country). Based on CDD Society's field observations in various towns⁸, FS from pits are found to be more concentrated than those from septic tanks. This is because of longer retention time/ emptying period of sludge and hence accumulation of high amount of unbiodegradable soluble organics over the time. Further it is observed that solids are accumulated in pits due to seeping of water content into the ground resulting in high solids concentrations. On the other hand, septic tanks those constructed as per the standards with soak away arrangements are designed to be emptied at regular intervals and are likely to have less concentrated sludge.

Sludge in septic tanks of public toilets fills up very quickly due to more number of users. Hence such septic tanks will have more of a fresh sludge with high COD, BOD and TSS concentrations. Hence, sludge from septic tanks of public toilet will be partially digested as compared to FS from a household septic tanks. Table 1 shows the characteristics of faecal sludge collected from FS studies conducted in various countries/cities having various sanitation contexts.

Table 1: Characteristics of faecal sludge as reported in different studies/ literature

Sl. No.	Source/ Country	Parameters (mg/l)						
		COD	BOD	TSS	TS	VS	TKN	TP
1	U.S. EPA. Handbook- (U.S. EPA., 1984)	15,000	7,000	15,000	40,000	25,000	700	250
2	FSM Book- Public toilet- (Strande et. al., 2014)	50,000	7,600		35,000	22,000	3,400	450
3	FSM Book- Septic tank- (Strande et. al., 2014)	10,000	2,600		30,000	9,500	1,000	150
4	Dave Robbins- Hanoi- (Robbins et. al., 2017)	30,526	16,033	21,173			1,285	202
5	Devanahalli, India- Lab results, CDD Society	23,900	3,750	16,700	34,560	19,965		

⁸ Devanahalli, Sircilla, Bheemili, about 20 towns in Tamil Nadu, about 10 towns in Rajasthan

Sl. No.	Source/ Country	Parameters (mg/l)						
		COD	BOD	TSS	TS	VS	TKN	TP
6	Sircilla, India- Lab results, CDD Society	32,000		15,700	25,000	17,000		
7	Tide technocrats, India- (Kumar et. al, 2017)	21,954	16,321		29,927	16,741	307	12
8	Chunar, India- Lab results, CSE, Delhi	21,936	4,470		44,760		1,573	166
9	IIT Chennai, India- (Krithika et. al, 2017)	1,576		1,216	3,096			110
10	PSI, Patna, India- Lab reports, PSI, Patna, India	6,804	3,448	3,670				
11	Accra- Public toilets- (Heinss et. al, 1994)	49,000	7,600	52,500				
12	Accra- Septage- (Heinss et. al, 1994)	7,800	2,600	35,000				
13	Kampala, Uganda- (Heinss et. al, 1994)	24,962		19,140				
14	Manila, Philippines- (Heinss et. al, 1994)	37,000	3,800	72,000				
15	Albireh, Palestine- (Al-Sa'ed et. al, 2006)	1,243	434	3,068				
16	Burkina Faso (Septic tanks)- (Bassan et. al, 2013)	7,607	1,453	7,077				
17	Burkina Faso (Pit latrines)- (Bassan et. al, 2013)	12,437	1,480	10,982				

Nonetheless, the varying characteristics in the tables presented above still emphasize that FS characteristics also may vary from city to city context, city to rural and even further household to household level, which can be related to following factors⁹:

1. Storage duration
2. Source of the FS (Residential/Public toilet/Commercial establishments)
3. Type on onsite containment
4. Climatic conditions
5. Performance of septic tank
6. Desludging technology and pattern

2.1 INTERPRETATIONS

Compilation of FS characteristics given in table 1, are collected from studies conducted by various organisations shows the variability of FS with respect to above-mentioned factors. FS has much

⁹https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/FS_Quantification_Characterisation/Characterization_FS_Ouaga.pdf

higher BOD and COD values than sewage characteristics given in Table 2 which is stated as in CPHEEO, (2013)

What is interesting to observe is that the values from Devanahalli, Sircilla, those compiled by Tide Technocrats (from 10 cities) and even for Chunar to an extent, especially total solids (TS), Volatile Solids (VS), Total Suspended Solids (TSS) and Chemical oxygen demand (COD) are in a similar range to those quoted in the literatures, considering especially in U.S. EPA., (1984), Robbins, D. (2017) and Strande et. al, (2014)

2.1.1 FS vs Sewage Concentrations

The table below presents the characteristics of Sewage according to CPHEEO Manual.

Table 2. Characteristics of Sewage as per (CPHEEO, 2013)

S. No	Source	COD (mg/l)	BOD (mg/l)	TSS (mg/l)	TKN (mg/l)
1	Sewage	425	250	375	50

Table 3 below shows strength ratios for BOD and COD determined for samples from four different sources. FS characteristics from Devanahalli and Sircilla were obtained as an average from more than 90 and 70 samples respectively.

Table 3: Comparison on Strength of FS vs Sewage specific to India

Source	COD of FS	BOD of FS	COD Ratio	BOD Ratio
Devanahalli, Karnataka- Lab results, CDD Society	23,900	3,750	56:1	15:1
Sircilla, Telangana- Lab results, CDD Society	32,000		71:1	
Chunar, Uttar Pradesh- Lab results, CSE, Delhi	21,936	4,470	49:1	18:1
Tide Technocrats- (Kumar et. al, 2017)	21,954	16,321	48:1	65:1

Based on Faecal sludge characteristics shown in Table 1, it is evident that – across various parameters - FS can be several times concentrated than the sewage. While it is important to acknowledge the wide variation, it can also be seen that considering values from various literature in Table 1 and the four sources in the table 3 above, the ratio of FS to Sewage is more in the range of **50-60** times especially for COD and BOD¹⁰ (considering sewage characteristics from Table 2). FS characteristics from Devanahalli, Sircilla, Chunar and Tide Technocrats' study have been chosen since the values of key design parameters are relatively higher and a system that can handle higher concentrations can also handle lower concentrations but not vice versa

2.1.2 Design Parameters

According to CPHEEO, (2013) STPs in India are designed to remove BOD with an influent concentration of 250 mg/l and COD to BOD ratio of 2. From table 1, it can be found that COD to BOD

¹⁰ An upper limit has been considered since any co-treatment design that can account for a higher concentration of FS will automatically handle FS of a lower concentrations.

ratio of FS is in the range of 2- 7. This is due to presence of high unbiodegradable over bio-degradable organics in FS. Table 4 shows the break-up of the different fractions of organics in wastewater and FS.

Existing STPs can treat the biodegradable fraction of COD in sewage (both soluble and particulate) through primary and secondary treatment stages. The STPs can remove unbiodegradable fraction (only particulate) in the form of sludge. The unbiodegradable-soluble fraction does not get treated and exits from the STP as effluent. In the case of sewage treatment, 6% of unbiodegradable soluble fraction of COD would leave the STP as effluent. While co-treating FS, unbiodegradable soluble fraction will be in the order of either 3 or 9% more, depending on whether it is fresh or digested FS. Comparing the COD concentrations of sewage and FS, unbiodegradable soluble fraction of the FS will be high and will be the limiting factor while co-treating, since this fraction will exit the STP as effluent.

Hence, **COD may be considered as the limiting factor while quantifying the amount of FS to be added for co-treatment** and by doing so, comparatively lower values of BOD will also be addressed.

Table 4. Fractionation of sewage, fresh and digested FS (Strande et. al, 2014)

COD fractionation- Wastewater		
Total COD (mg/l)		
Biodegradable (mg/l)	Unbiodegradable (mg/l)	
24%	6%	Soluble organics (from lab)
57%	13%	Particulate organics
COD fractionation- Fresh faecal sludge		
Total COD (mg/l)		
Biodegradable (mg/l)	Unbiodegradable (mg/l)	
2%	3%	Soluble organics (from lab)
69%	13%	Particulate organics
COD fractionation- Digested faecal sludge		
Total COD (mg/l)		
Biodegradable (mg/l)	Unbiodegradable (mg/l)	
13%	9%	Soluble organics (from lab)
31%	47%	Particulate organics

3 SEWAGE TREATMENT PLANTS - FROM A CO-TREATMENT PERSPECTIVE

STP is an important asset to the city and is important to understand how an STP is designed and operated before undertaking co-treatment at any given existing STP. In this chapter we will discuss the design criteria, sizing of STP, technologies of wastewater treatment and different approaches for addition of FS at STP. Finally the implications of co-treatment on STP are captured - based on various literature, our interactions with senior utility engineers.

3.1 DESIGN CRITERIA FOR STP

The first step to be considered in design of an STP (or consider an existing STP for co-treatment) is to consider effluent characteristics that need to be met. CPHEEO, (2013) manual specifies the parameters that needs to be considered for designing a STP. The table below presents the sewage characteristics that are considered by CPHEEO, (2013) and STP designers/practitioners. It can be observed that the designers tend to take higher values than CPHEEO to have buffer capacities handle fluctuations in the incoming load.

Table 5: Design consideration of Sewage characteristics to STP

Parameters	CPHEEO Guidelines (mg/l)	STP Designer (mg/l) ¹¹
pH	-	6.8 - 7.4
BOD	250	300
COD	425	600
TSS	375	350
VSS	262.5	200
Total Nitrogen	50	75
Total Phosphate	7.1	7

3.2 SIZING OF STP

STPs are sized after considering the projected population and the Dry Weather Flow (DWF) that is generated in the catchment area of the city. CPHEEO, (2013) specifies a design period between 10 – 15 years for STPs. Hence, depending on when the STP was commissioned and the households it has been connected to from its catchment, there will be different levels of utilization of the STP. For daily functioning of STPs, the following flows associated with STPs are considered:

- a) **Peak flow:** According to CPHEEO, (2013), when the peak factor exceeds 3 by a wide margin, it is advisable to equalize the sewage flow before feeding to the STP units. According to one of the utility engineers from Bangalore water boards, most peak flow occurs during the peak hours (Morning 8 AM-1 PM) which contributes to the

¹¹ Based on Interaction with senior Utility Engineer

maximum flow of the day. Apart from the morning peaks, another peak may be towards end of the day which will be treated overnight in the STP. All of the hydraulic and organic load of the STP are expected to be used up for the peak flow in cases where equalization is not provided. Peak factor is typically considered 2.5 times the dry weather flow.

- b) **Average flow:** This can also be interpreted as average hourly flow rates. This flow occurs through the afternoon and till the evening.
- c) **Low flow:** This flow mostly occurs during the night time as the flow tapers off and could be as lower than 25% of the average hourly flow rates.

Depending on the size of the STP, sizing criteria for wet well¹² or equalization tanks¹³ are laid out by CPHEEO, (2013). But, all STPs may not have a wet well or equalization tank. Smaller STPs tend to have equalization tanks since their ability to handle shock loads is limited.

3.3 TREATMENT TECHNOLOGIES:

According to a report by CPCB¹⁴, out of all the STPs in India, 64% are operational, 10% are non-operational, 18% are under construction and 8% are proposed. Further, It was also found that the maximum STPs have Activated Sludge Process (ASP) based treatment technology and lately, SBR based technology is also being widely used for sewage treatment. Hence, the section below will focus largely on ASP and SBR treatment processes.

3.3.1 Activated Sludge Process

ASP is a biological wastewater treatment system which offers a secondary level of treatment. Here the wastewater is aerated and mixed well so that the naturally occurring heterotrophic bacteria oxidises the organics present in the wastewater converting them into a biomass/ sludge. Further, the sludge is separated by settling the mixed slurry and there by treating the wastewater. This sludge is then wasted or recirculated as an activated sludge back for aeration so that there is enough amount of heterotrophic bacteria present for oxidising the organics present in the new stream of wastewater entering the system.

There are two variations of this process namely,

- (a) Conventional process for removal of BOD and SS alone
- (b) Incorporation of biological nitrification and denitrification for removal of nitrogen in the same process.

Over the years, several modifications to the conventional system have been developed to meet specific treatment objectives. The aeration process employs specific organic loading and aeration time, high mixed liquor suspended solids (MLSS) concentration and low food to micro-organism

¹² Wet wells are the holding sump for gravity-flow sewer systems. As sewage enters the **wet well** and the water level rises, pumps are engaged to pump out the sewage to a forced main, or the sewage is lifted to a higher grade to continue the gravity flow to the outlet point.

¹³ Equalization (EQ) Basins are designed to provide consistent influent flow to downstream processes by retaining high flow fluctuations. Due to the additional retention time, aeration and mixing is required in equalization basins to prevent the raw wastewater from becoming septic and to maintain solids in suspension.

¹⁴ "Inventorization of sewage treatment plants, 2015"

(F/M). Because of long detention in the aeration tank / oxidation ditch, the MLSS undergo considerable endogenous respiration and get well stabilized and in these cases, limited quantity of excess sludge is produced which does not require separate digestion and can be directly dried on sand beds or mechanically dewatered. A typical ASP is shown in the figure 2 below (CPHEEO, 2013).

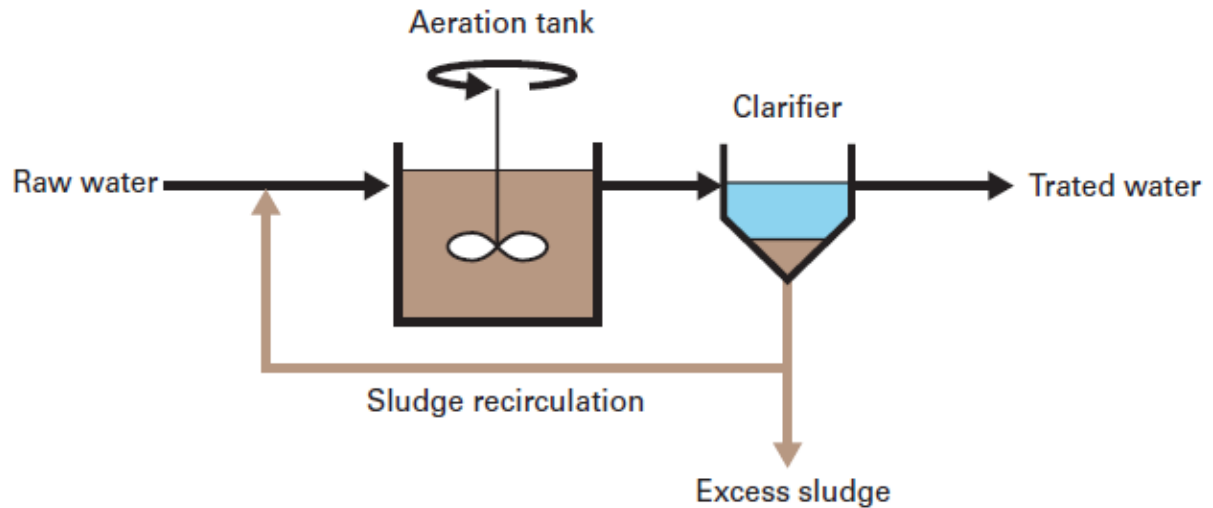


Figure 1. Schematics of ASP technology

According to CPHEEO manual, following are the design parameters for designing ASP based STP:

Table 6: Characteristics and design parameters of ASP systems (CPHEEO, 2013)

Process type	Values	Unit
MLSS	1500-3000	mg/l
F/M	0.3-0.4	Ratio
HRT	4-6	Hours
SRT	5-8	Days
BOD rem	85-92	%
Kg O ₂ /Kg BOD rem	0.8-1.0	ratio

3.3.2 Sequencing Batch Reactor

SBR is a variant of ASP technology to treat wastewater. SBR is a batch process where four different stages of treatment process is carried out in a single reactor. These stages are Fill, React, Settle and Decant. Here surplus amount of oxygen is pumped for aeration and mixing of wastewater to oxidise all the organic matter and form biomass. Further the biomass is settled to decant the supernatant. All these processes are carried out in a single tank. However there will be multiple reactor to operate the STP for 24 hours.

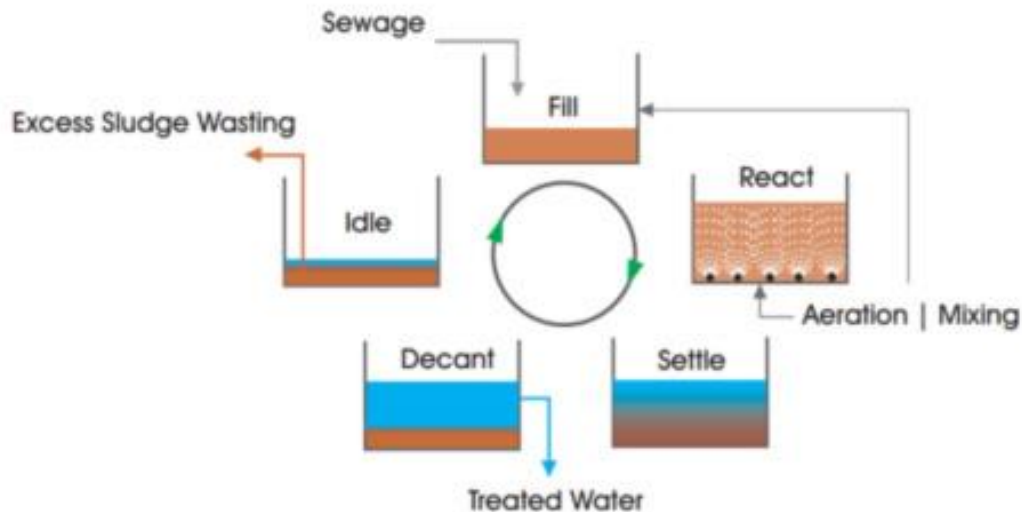


Figure 2: Schematic of process stages in the SBR Treatment

3.4 APPROACHES TO ADDITION OF FS TO STPs

FS can be added in different places at STP. U.S. EPA., (1984) gives a detailed explanation on potential locations for adding FS. Broadly, the following two methods are widely considered for addition of FS to STPs.

- **Direct Addition** -Faecal sludge collected from the OSS will be added to the FSTP at the head works or in the wet well of the STP to achieve the desirable dilution, which brings down the concentration of resultant liquid to inlet sewage characteristics
- **Solid Liquid Separation Method** – After solid-liquid separation, the liquid portion of FS will be added into the liquid treatment stream of STP directly and solids portion which needs further treatment and will be treated in solid handling facility of the STP

For addition at the liquid stream directly, there is a need for equalisation which can be achieved by adding the FS into:

- I. Existing wet well (if there is enough volume) followed by primary clarification
- II. Adopt a dosing tank similar to a wet well/ equalisation tank depending on the dilution rate

For addition at solid stream, FS could be directly added into an existing sludge thickening tank/ new tank commissioned for handling FS and further processing liquid and solid streams separately.

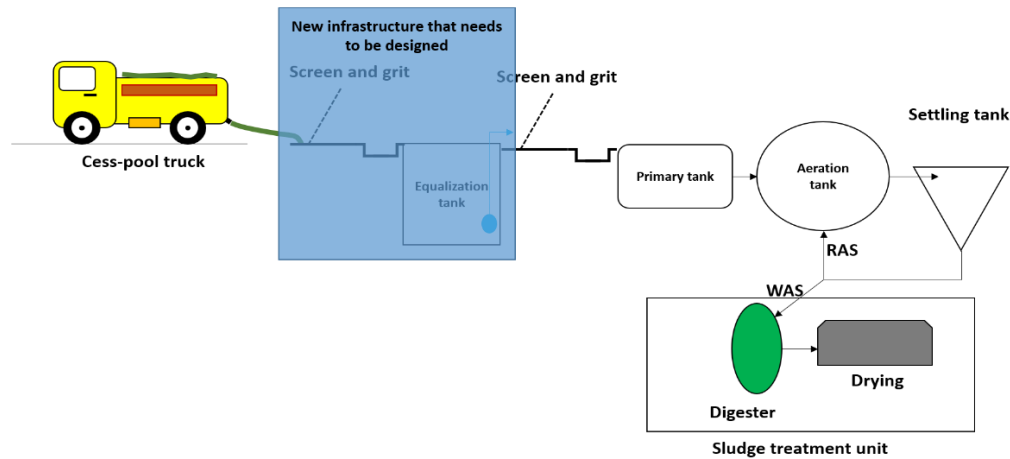


Figure 3: Co-treatment using Direct Addition at the STP, for illustration only

Finally, for both solid and liquid streams, FS can be added to a thickening tank with a required retention time. Here the solid stream can further undergo dewatering or stabilisation and the supernatant can undergo treatment in the existing primary and secondary systems.

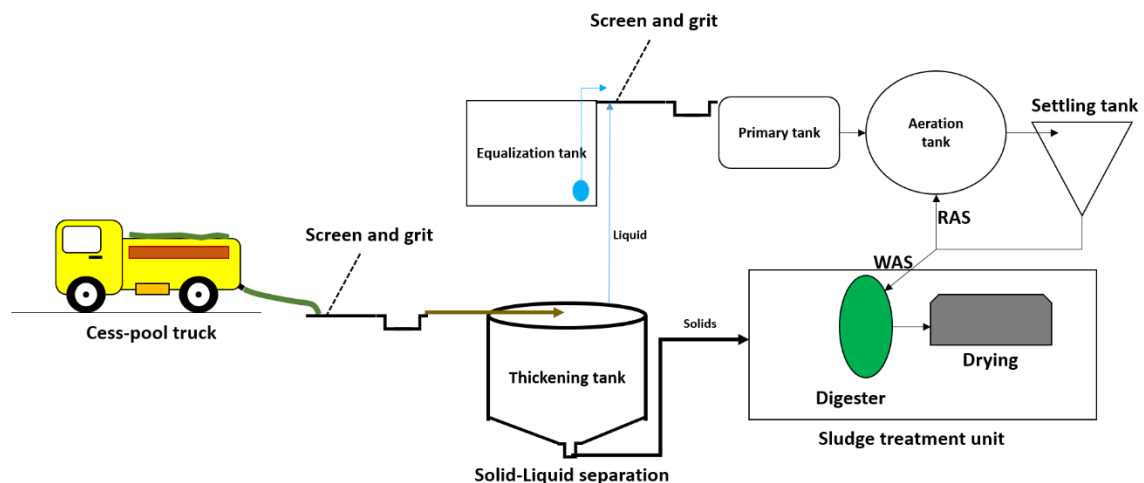


Figure 4: Co-treatment option using solid-liquid separation method, for illustration only

U.S. EPA., (1984) provides guidelines to estimate the quantity of FS on the STPs having ASP with and without primary treatment, Aerated lagoons and Packaged treatment systems. It does not discuss on any anaerobic treatment systems and the additional cost / infrastructure that might be required for setting up a solid- liquid separation units for FS at the existing STPs.

3.5 STP OPERATIONS FROM A CO-TREATMENT PERSPECTIVE

As discussed in chapter 2, due to high variations in the quality of FS and sewage, the challenge is in co-treating without hampering the operation of the existing STP. Strande et. al, (2014) has reported multiple case studies, where the Activated Sludge treatment Plants in eThekweni, South Africa & Saint Marten, Netherlands Antilles had serious operational issues due to unplanned and improper co-treatment.

Case Study of STPs in eThekweni, South Africa – *"In spite of the apparent relatively low volumes of FS from pit latrines, two activated sludge WWTPs located in eThekweni, South Africa experienced serious operational problems caused by the high loads of organics, nitrogen compounds and suspended solids (Wilson and Harrison, 2012)."*¹

Case Study on Saint Marten, Netherlands Antilles – *"Although the high concentrations of solids, organics and nitrogen compounds in FS attract most attention, the higher concentrations of unbiodegradable compounds and low biodegradability of organics can also hinder compliance with the effluent limits."*

Similarly, various literature and studies have described the issues that could occur due to addition of FS to an existing STPs in an unplanned manner. A summary of the issues is listed below:

Table 7: Showing the key implications on STP due to co-treatment

Key Implication or Issues	Source	Issues	Comments
High concentrations of COD and TN	Strande et. al, (2014) & U.S. EPA., (1984)	When co-treating FS in an existing STP, the COD and TN concentrations in the aeration tank and at the outlet will increase proportionally. This is due to quality and quantity of FS that is added which reduces the efficiency of the treatment process.	Presence of soluble unbiodegradable COD and TN will reduce the treated effluent quality because they cannot be removed or treated by either physio-chemical or biological processes. Hence the quantity and quality of the FS needs to be assessed closely in order to meet the required treatment standards. Identifying the source of FS is one way of understanding FS quality.
Increase in Oxygen demand	(Henze et. al, 2008) & (Turovskiy et. al, 2006)	Addition of FS in to an existing STP can result in a severe increase in the oxygen demand due to the high concentrations of biodegradable COD and TN. Oxygen requirement for COD removal is 1.2 kg oxygen per kg of COD and for Nitrification, 4.6 kg of oxygen per kg of Ammonia is required.	FS contains high concentrations of COD and TN. When the FS is co-treated, the oxygen demand of the STP will increase. Hence, organic concentrations of FS should be studied before undertaking co-treatment and the system needs to be retrofitted in order to meet the required treatment standards.

			Again, understanding of the source of FS can act as a proxy for understanding the organic loads.
Surplus sludge production	Strande et. al, (2014)	Due to high organics present in the FS, more biomass will be produced in the treatment reactor which will result in surplus amount of solids. If the TSS exceeds the maximum limit, the treatment plant can experience serious operational problems ranging from overloading of aeration and secondary settling tanks to a considerable decrease in the oxygen transfer efficiency in the aeration tank.	Dilution of FS based on COD may most likely ensure the organic load as well as solids entering the STP would not exceed the design load. Limiting the rate at which FS is added into the system will be an appropriate measure to avoid excess sludge production.
Difference in sludge quality	Senior Utility Engineer	The sludge handling units in STP are designed for handling sewage sludge from primary clarifier with solids concentration ranging from 2-4.5% and solids concentration in activated sludge ranging from 0.4 to 1.5%. Introducing the separated solids of FS will overload the sludge handling units and result in reduction of the efficiency. Hence additional sludge handling units at STP will be required for accommodating the solids from co-treatment infrastructure.	Based on the FSTP operations experience of CDD Society from Devanahalli FSTP, solids concentration after solid-liquid separation of FS would range from 5-6% (50,000-60,000 mg/l). Hence due care should be taken while loading the solids fraction of FS into the sludge handling facility of STP.
Need for Sludge handling facility		In India, it is acknowledged that solids handling is not an area of strength for the STPs. Due to space constraints a lot of STPs are devoid of drying beds. Also, the existing equipment to handle solids are not properly operated and	Mechanical solids handling units like screw press or centrifuge can be explored as an option for the STPs which don't have space for putting in place passive systems like drying beds

		maintained leading to issues with handling and disposal of sludge.	These units require less space and the dewatered solids can be relatively easily handled within the STP. However, the capital and operational expenditures are likely to be higher for such systems.
Contractual Issues		Given that most of the STPs are operated under a contract through a private operator, the operator might not be interested in taking up additional task of co-treatment given the complexities it is expected to add to the process. Further, if a new service provider is appointed for the task, there may not be efficient co-ordination between the operators which may affect the treatment efficiency of the plant.	Confidence building measures need to be taken up to convince the existing operators that through additional infrastructure and necessary control mechanisms, STPs will be able to safely treat FS also.

From the above listed implications on STP due to co-treatment of FS, there is a need for a step by step approach for checking the feasibility of co-treatment. It will include a complete study on:

- a) The existing STP, its catchment area, design consideration, current situation
- b) Adopted modules, utilisation and performance

Further, the quality check and quantity estimation of FS that is proposed to be co-treated in the STP needs to be undertaken. In the next section, quantification of FS using different methods adopted in various literature or studies is discussed through a sample example.

4 QUANTITY ESTIMATION FOR CO-TREATING FS IN STP

Efforts have been made in several studies to understand and determine the maximum quantity and different methods of FS that can be added to an existing STP. Objective of this section is to identify these different methods and to compare them which would largely affect the STP. Following are the literatures/ study that is considered for this desk study:

- 1) USEPA Hand book on Septage Treatment and Disposal (U.S. EPA., 1984)
- 2) Guidelines for septage addition (Germany)- USEPA (U.S. EPA., 1984)
- 3) Approaches and quantity Estimation: Dave Robbins (Robbins et. al, 2017)
- 4) CPHEEO Manual- November 2013 (CPHEEO, 2013)
- 5) Chapter 9: FSM book - Co-treatment of FS with municipal wastewater treatment plant – Linda Strande: Strande et. al, (2014)

An example (sample calculation) is assumed in order to determine the quantity of FS that can be co-treated based on the methods found from the above studies. Quantification of FS was determined for the following boundary conditions:

- 1) STP Capacity: 50 MLD
- 2) Town Population: 5,00,000 persons
- 3) Current utilized capacity of STP: 25 MLD (50 %)
- 4) STP design parameters:
 - a. Inlet BOD – 300 mg/l
 - b. Inlet COD – 600 mg/l
 - c. Inlet TSS – 350 mg/l
- 5) STP Technology – ASP for C (carbon removal)
- 6) Faecal sludge characteristics:
 - a. Inlet BOD – 6,500 mg/l
 - b. Inlet COD – 15,000 Mg/l
 - c. Inlet TSS- 20,000 mg/l

FS quantification was carried out for the above assumed scenario is calculated based on different methods. These are discussed further in this sections below.

4.1 QUANTITY ESTIMATION BASED ON USEPA GUIDELINES

United States Environmental Protection Agency (U.S. EPA., 1984) has developed a handbook on review of available design, performance, operation and maintenance, cost, and energy information pertaining to receiving, treatment and disposal of septage. Co-treatment of septage in an existing STP is stated as one of the options for septage treatment.

According to U.S. EPA., (1984) septage is the liquid and solid material pumped out from a septic tank or cesspool when it is cleaned. Inorder to treat the septage, following treatment options are mentioned: Land disposal, Co-treatment, Independent treatment. Further, there are three ways of carrying out co-treatment, they are:

- a. Addition of septage into a liquid stream (upstream or at various points within the plant)
- b. Addition of septage in the solid stream
- c. Addition to both liquid and solid stream

Also, U.S. EPA, (1984) considers two major factors that governs the quantity of septage that a plant can handle. They are:

- a. Quantity and nature of flow in the STP
- b. Aeration and solids handling capacity and organic loading of the plant.
- c. Due to high variability of the septage and presence of unwanted solid waste, proper handling and pre-treatment should be provided at the receiving station.

4.2 QUANTITY ESTIMATION BASED ON GUIDELINES FOR SEPTAGE ADDITION (GERMANY)

4.2.1 Guidelines

Guidelines for septage addition which U.S. EPA, (1984) has stated in their co-treatment report and considered it as the key points that needs to be followed for developing a co-treatment approach.

- a. The municipal treatment plant must have a biological treatment step designed for minimum 10,000 persons
- b. The biological step must have enough excess capacity to treat the additional organic load from the septage
- c. During periods with high hydraulic load on the plant (rainfall/ infiltration) no septage must be added
- d. Effluent quality requirements for the plant must be adhered to at all times. During normal operation this can be achieved by estimating maximum volumes of septage that can be added to the plant
- e. The septage volume determined must be added in at least two batches with several hours in between, and outside the normal peaking periods at the plant
- f. The septage must be diluted at least 20 times with the municipal wastewater
- g. Detention basins for septage must be used in those cases where the septage arrival volumes exceed the allowable volume that can be added to the plant in one batch. The same is true if the trucks arrive at the plants too often to allow the necessary time between discharges of each truck load
- h. If the septage can be added from a detention basin during several hours and outside peaking periods at the plant, the volumes estimated can be multiplied by a factor of 4
- i. The septage must be added upstream from the plant screen
- j. The addition of septage must be managed by the treatment plant operators
- k. Quantities and time of discharge must be recorded

In order to quantify the amount of septage that could be added to a treatment plant, following graphs were suggested. These graphs were developed based on the field experiences from Germany and the US.

4.2.2 Design considerations

The study on co-treatment of FS in STPs were conducted based on the FS characteristics shown in table 8 below. STPs in US, Europe and Canada mostly depends on Aerobic treatment systems and in this study feasibility of co-treatment options are explored for the following technologies.

1. Activated sludge process (ASP) with primary treatment
2. Activate Sludge process (ASP) without primary treatment
3. Aerobic lagoons
4. Packaged aerobic treatment systems

Table 8: Characteristics of Septage considered in the U.S. EPA., (1984)

Parameters (mg/l)						
COD	BOD	TSS	TS	VS	TKN	TP
15,000	7,000	15,000	40,000	25,000	700	250

4.2.3 Method 1 – Population equivalent approach

Quantity of FS that can be treated in the STP located in a certain locality is calculated using the graph by considering the design capacity of the plant with respect to number of users and the current utilisation rate. An example calculation that was made using the graphs provided in the U.S. EPA., (1984) German guidelines are given in Table 8. Figure 3, show the graph developed for estimating quantity of FS that can be added into the STP based on the population equivalent. The graph is plotted with allowable quantity of septage S (m³/day) in y-axis and population served in 'A' (persons) by the STP in X-axis.

The Quantity of FS that can be added into the STP is determined with the help of two sets of data

1. A – Population equivalent of the town (persons) considered for estimating the capacity of STP
2. a – Current population equivalent connected to the STP

By applying the above mentioned in the formula in the graph, allowable capacity of Septage is determined. The estimated values are validated by drawing the intercept lines with help of trend curve for different 'a' value.

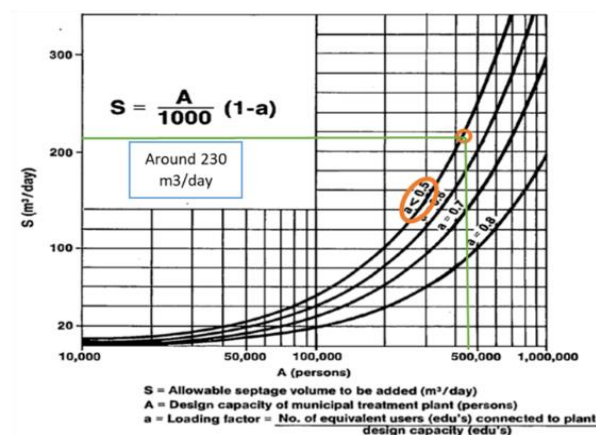


Figure 5. Graph showing the allowable septage volume to be added to municipal treatment plant per German guidelines (U.S. EPA., 1984)

Table below shows the sample calculations for when the treatment plant is utilized at 50% and 90% of its hydraulic capacity respectively. We find that 0.46% and 0.09% of the FS can be added at 50% and 90% hydraulic capacity respectively.

Table 9: Quantity of Estimation based on USEPA

Assumptions for Example Calculation			
Description	Values	Values	Unit
Capacity	50	50	MLD
Sewage characteristics:			
Design BOD inlet Conc	300	300	mg/l
DESIGN TSS inlet Conc	350	350	mg/l
Design Population of the STP	462963	462963	persons
Overall BOD reduction Efficiency	50%	90%	%
Treatment option selected	Activated sludge process with Primary Treatment		
FS characteristics:			
BOD in	6500	6500	mg/l
TSS in	20000	20000	mg/l
Example - Calculation as per German guidelines			
Capacity	50	50	MLD
Q	50000	50000	KLD
Q	5,00,00,000.00	5,00,00,000.00	L
LPCD	135	135	LPCD
WW @ 80% generation	108	108	LPCD
A	4,62,963	4,62,963	persons
A	0.50	0.90	
1-a	0.50	0.10	
A/1000	462.96	462.96	
S	231	46	KLD
Overall septage capacity added	0.46%	0.09%	

4.2.4 Method 2 – Septage addition based on plant utilization

Design considerations and guidelines for this approach are similar to those mentioned in section 4.2.2 above. This particular approach uses the graph shown below in figure 6, which is obtained through plotting existing STPs' current utilization rate in percentage on Y-axis and the allowable quantity of septage in percentage of plant design capacity in X-axis. Trend lines for four different aerobic treatment technologies are derived from the experiences from various treatment plants in US, Europe and Canada.

In the graph below, estimation of quantity of septage added were found by drawing an intercept line from the corresponding plant utilization rate (i.e. annual average flow at present) towards the technology of the chosen STP. As we assumed earlier, estimation of septage quantity is made for a 50 MLD STP (ASP with primary treatment) operating at 50 % of it capacity and it is estimated that septage quantity of 1.4% of the total plant capacity can be cotreated which is shown in table 10.

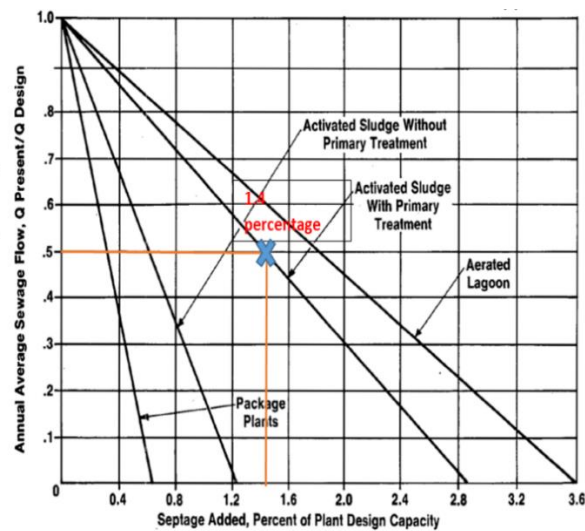


Figure 6. Graph showing allowable rates of equalised septage to an existing treatment plant (U.S. EPA., 1984)

Table 10: Calculation of septage addition based on plant utilisation

Current Capacity of the plant	50	50	MLD
Plant utilization rate	50%	90%	%
% of septage (from graph)	1.4%	0.4%	%
Volume of septage	0.7	0.175	MLD

4.3 QUANTITY ESTIMATION BASED ON DAVE ROBBINS STUDY

4.3.1 Guidelines

Dave Robbins has developed a framework for estimating the quantity of FS that can be added to the city's existing sewage treatment plant in Can Thoi, a city in Vietnam.

Study suggest that for the new sewerage projects, proper planning can enable co-treatment by appropriately sizing the STPs to handle the additional loading from FS. For existing plants, evaluating the capacity of the STPs to receive faecal sludge is needed to ensure that effluent quality standards can still be met. WWTPs are not designed for the BOD or solids loading that would come with faecal sludge, hence the need for dewatering or liquids-solids separation before the liquid is released into the treatment system.

Dave Robbins has conducted co-treatment studies in Can Thoi, Vietnam and Kwa, Singapore. In his studies, the need for pre-treatment of FS before it can be added to the WWTP was highlighted. Factors such as volume of FS received and the quantity of liquid fraction of FS that can be added into the WW stream based on the current capacity of the Wastewater treatment plants (WWTP) are critical to take into account for each specific case where co-treatment is to be implemented.

4.3.2 Design considerations

Estimating the impact of co-treatment on the WWTP and estimation of the quantity of the FS that can be added to the WWTP will depend on the following factors:

1. Quantity of FS received / generated in a day
2. Number of trucks arriving at the WWTP for discharging
3. FS characteristics or quality data
4. Design capacity of WWTP
5. Current operational capacity of the WWTP
6. Characteristics of WW influent
7. Effluent Discharge standard of the WWTP (Design organic load, Hydraulic load)
8. Combined influent characteristics of the WW& FS

Based on the above factors, Dave Robbins has developed the formula to estimate the quantity of FS that can be added to a WWTP.

- $(\% \text{ FS} \times \text{constituent FS concentration}) + (\% \text{ influent} \times \text{constituent influent concentration}) = \text{combined influent concentration of the constituent}$
- $(100\% - \% \text{ constituent reduction}) \times (\text{combined influent constituent concentration}) = \text{effluent concentration of constituent}$
- Compare effluent concentration to regulations on domestic wastewater discharge.

What the formula above does not take into consideration is that there is no available organic capacity in an STP if it is working at 100% load. There is a possibility that the STP might be overloaded organically after addition of FS. Table 11 shows the FS characteristics considered by Dave Robbins for his study from the Hanoi city.

Table 11: FS characteristics from Hanoi (Robbins et. al, 2017)

Parameters (mg/l)				
COD	BOD	TSS	TKN	TP
30,526	16,033	21,173	1,285	202

The Liquid stream can be used directly into the treatment stream without much effort, but the study suggests to include a mechanical dewatering unit as solid-liquid separation stage and introducing the supernatant from the dewatering unit into the STP. But the framework developed for estimating quantity of FS for co-treatment did not consider the plant utilization rate as a factor. Hence the calculation with assumed cases were not discussed elaborately.

Major conclusions to be noted from this study include that the testing of co-treatment should start by adding the liquid fraction of the settled FS, because this is the weaker fraction. All the trials and monitoring can begin with a FS/WW proportion of 2% and work upward to about 5% of the total WWT plant capacity. The effluent quality concentrations, specifically those listed in the Government regulations and / or standards, should be monitored during the augmentation. Also operating personnel should pay special attention to nutrient concentrations as this could be a potential limiting factor. Mechanical dewatering will likely be required when FS volumes exceed 2% and can be very handy in terms of achieving around 85% TSS removal and 45% BOD removal.

4.4 QUANTITY ESTIMATION BASED ON CPHEEO GUIDELINES ON FS LOAD ESTIMATION

4.4.1 Guidelines

CPHEEO, (2013) details about FS in on-site sanitation chapter (p 9-41 to 9-53). Most sections of the chapter are adopted from U.S. EPA., (1984) hand book on septage handling which is elaborated in the first chapter. There are no specific guidelines for co-treatment, but the spare capacity at the existing STP is considered as the basic criteria for determining the feasibility for co-treating septage. It is assumed that the septage volumes will not be significantly equal in quantity compared with the STP capacity. It is stated that even if FS quantity received is as high as 5% of the plant capacity, it is still possible to add FS as long as the BOD load is not exceeding the design load.

4.4.2 Design considerations

Co-treatment of FS into an existing STP is shown as two options in the manual:

- Addition to the liquid stream of the STP
- Addition to the solid's treatment of the STP

According to the manual, it may be possible to accommodate septage as long as the actual flow to STP does not increase. However, over a period of time, if both the sewage volumes and septage volumes will increase, it is not easy to use this option as a permanent measure. At the same time, if spare capacity is available, then it is wiser to opt for co-treatment instead of rushing into a dedicated septage treatment facility. Yet another option will be to augment or upgrade the STP capacity, which is by far simpler and so far as the liquid stream is concerned. The characteristics of FS were referenced from the U.S. EPA., (1984) handbook and the following example in Table 12 is provided using load

calculation method given in manual, but here calculations have been **made based on the COD load rather than using BOD load**. Following case is worked out to evaluate the quantity of FS that can be loaded to an existing STP and table 12 shows that for a treatment plant operating at 50 % capacity, quantity of FS that can be added into the STP on daily basis is calculated to be 228 KLD (0.46% of plant capacity).

Table 12: Estimated quantity of FS based on (CPHEEO, 2013) recommendations

Wastewater treatment plant			Faecal sludge		
Inflow	50	MLD	Max inflow (based on COD)	314	KLD
COD _{in}	600	mg/l	COD _{in}	23900	mg/l
TSS _{in}	300	mg/l	Allowable COD load/day	7500	kg/d
Plant utilisation	50	%	Allowable COD load/ hour	682	Kg/h
Maximum COD load	30000	kg/d	Max inflow (based on TCOD)	29	KL/h
Existing COD load	15000	kg/d	Max inflow/ 15 min	7.1	KL/15 min
Operational hours	22	h	Max inflow/ day	228	KLD
Designed Hourly inflow (peak hours)	2.27	ML/h	Max inflow /day	0.23	MLD
Hourly COD load	1363.64	kg/h	Percentage quantity of FS	0.46	%
Actual hourly inflow	1.14	ML/h			
Actual Hourly TSS load	681.82	kg/h			

4.5 QUANTITY ESTIMATION BASED ON FSM BOOK

4.5.1 Guidelines

In this section, feasibility of co-treatment and the relative implications on addition of FS to the STP were analysed through a mathematical modelling (Biowin) of an activated sludge treatment plant with an installed capacity of 100,000 p.e. (20,000 m³/d) treating medium strength municipal wastewater and performing biological nitrogen removal. Further, steady and dynamic state flow modelling was carried out for low, medium and high strength FS addition. Following are some of the key considerations recommended for the aeration based STPs that need to be taken into account before co-treatment approach is adopted:

1. Required effluent standards: To estimate the minimum effluent COD and TN concentrations to verify the compliance with the required effluent standards.
2. Maximum TSS concentrations in aeration tanks: To calculate the maximum expected TSS to evaluate if the aeration tanks will be overloaded.
3. Maximum sludge production: To evaluate if the sludge handling and disposal facilities have the capacity to deal with the increase in sludge waste generation.
4. Maximum installed aeration capacity: To estimate the aeration requirements based on the increase in oxygen demand and decrease in oxygen transfer efficiency.

5. For existing plants, the DO concentration needs to be carefully monitored to maintain a concentration of at least 2 mgO₂/L.
6. Secondary settling tanks: To determine the minimum surface area required for the operation of the settling tanks for the observed sludge settleability (in terms of the sludge volume index -SVI- or any other similar parameter).
7. Existence and performance of equalisation tanks. To allow an even discharge of FS to the sewage plant for the longest period possible (e.g. over 24 h).
8. For new WWTPs that expect to receive certain volumes of FS or that are *a priori* designed to co-treat FS, the previous aspects can be used and applied to adapt the design depending upon the discharge volumes, type and strength of the FS.

Key considerations for feasibility of co-treatment in anaerobic system are:

1. Anaerobic systems being the most robust, but still need care on the rate of feeding of FS into the system.
2. Feeding should be done gradually and if possible, continuously to avoid shock loads.
3. FS co-treatment in UASB reactors, the maximum OLR of design (including both wastewater and FS) must not be exceeded in order to avoid the overloading of the system.

Further implication of the adding FS into the aerobic and anaerobic STPs were discussed in sections below.

4.5.2 Design considerations

The study was based on simulation software under a controlled and uncontrolled environment (i.e. steady state and dynamic state) in STPs with aerobic technology. FS characteristics collected for different containment types were considered for estimating the allowable quantity of FS for co-treatment in existing STP shown in table 13.

Table 13: FS characteristics considered for simulation study

Parameters (mg/l)							
Source of FS	COD	BOD	TSS	TS	VS	TKN	TP
Public toilet	50,000	7,600		35,000	22,000	3,400	450
Septic tank	10,000	2,600		30,000	19,500	1,000	150

4.5.3 Co-treatment of FS with municipal wastewater treatment plant

4.5.3.1 Co-treatment with Aerobic systems:

A mathematical modelling was conducted by Bipin Dangol using a Biowin software of an activated sludge treatment plant with an installed capacity of 100,000 p.e. (20,000 m³/d) (Dangol, 2013). The treatment plant is designed to treat medium strength municipal wastewater along with biological nitrogen removal and is operational in its full capacity.

I. Influent COD and TN concentrations

It was found from the simulation that the influent concentrations would increase drastically (10-100 times) by introducing 1% high strength FS at the inlet of the treatment plant. Due to presence of un-

biodegradable soluble fraction of COD and TN in FS, this sets as the limit for the allowable volumes of FS that can be introduced to the treatment plant.

II. Oxygen demand

Due to addition of FS, there will be increase in the oxygen demand in the aeration tank. From the simulation it was found that addition of 1% high strength or 2% medium strength FS could shoot up the oxygen demand to 200%. However, there is a need to check the additional aeration capacity that the plant may have to offer.

III. Impact on secondary settling tanks

It was observed that by addition of 1-2% of high and medium strength FS, either fresh or digested, can result in an increase in required settling tank area by 300%. However, if 5 to 10% of low strength FS is added, the area requirement would go up by 200%.

According to the simulation results, here the factors effecting addition of maximum FS volume in order to co-treat in an existing STP:

- A. Total Suspended Solids accumulation in the reactor- Preferably TSS<6 g/L
- B. Aeration capacity and efficiency
 - a. Sufficient installed capacity to cover new Oxygen requirement
 - b. Cope with decrease in aeration efficiency
- C. Enough alkalinity available for N removal (Alk_{eff} of at least 50 mg Alk/L (after 7.14 mg Alk consumed/mgFSA)
- D. Minimum required A_{SST} (minimum Area required for Secondary settling tank) after FS addition
- E. Meet effluent standards

4.5.3.2 Co-treatment with Anaerobic systems:

The co-treatment of FS and wastewater in anaerobic processes is an alternative for sludge stabilisation, volume reduction and increased dewaterability. Possibilities include up flow anaerobic sludge blanket reactors (UASB) 10.3% by the number of STP and 10.6% of the total installed capacity as per the report "Status on sewage treatment in India¹⁵" by CPCB, 2005. 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 (Metcalf&Eddy, 2003).

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. Each of these factors is explained below, and also how they affect appropriate FS loading rates. UASB reactor can handle feedings of up to 7.5% by volume of low strength fresh FS (1,500 m³/d equivalent to the organic load of up to 180,000 p.e.), but only 0.25% high strength fresh FS due to the high COD content (10 tankers of 5m³ per day but with an organic load equivalent to approximately 139,000 p.e.). This means that the 100,000 p.e. UASB system, as well as other UASB plants of different capacities, could handle low strength FS but are prone to overloading with high strength FS. Table

14 below shows the percentage of FS that can be added to STP stream under steady state (Operating at the constant influent concentration throughout the simulation) and dynamic state (STP operating at the constantly varying as per the site condition constantly at different patches of the day). It shows that maximum quantity of FS addition is possible at steady state than the dynamic state (i.e. Average flow is better for FS addition than the Peak flow) (Strande et. al, 2014). Table 14 shows the corresponding quantities of FS allowable for co-treating FS of different categories.

Table 14: Quantity of FS addition at average flow and Peak flow (Strande et. al, 2014)

Faecal sludge type and strength	% FS quantity – under steady state	% FS Quantity – Under dynamic condition	Approximate ratio between maximum allowable faecal sludge volumes under steady-state to dynamic conditions
DIGESTED FS			
Low-Strength FS	3.75	0.64	6.0
Medium-Strength FS	0.375	0.375	1.0
High-Strength FS	0.25	0.25	1.0
FRESH FS			
Low-Strength FS	0.375	0.125	3.0
Medium-Strength FS	0.25	0.025	10.0
High-Strength FS	0.125	0.025	5.0

Finally, the findings mention that requirements and limitations of Co-treatment depend on two factors which are:

- Technology of the STP – Both aerobic and anaerobic technology has their own retrofitting requirements on infrastructure.
- Type of flow – maximum FS addition can be achieved at the average or steady flow condition. Under the dynamic flow or peak flow condition quantity of FS that can be treated is limited.

Table 15: Quantity of FS estimated allowable in STP based on strength (Dongal, 2013)

Faecal sludge type and strength	% FS quantity – under steady state	Quantity of FS in MLD (50 MLD @50% Utilization)
DIGESTED FS		
Low-Strength FS	3.75	0.94
Medium-Strength FS	0.375	0.094
High-Strength FS	0.25	0.062
FRESH FS		
Low-Strength FS	0.375	0.094
Medium-Strength FS	0.25	0.062
High-Strength FS	0.125	0.031

4.6 QUANTITY ESTIMATION - SUMMARY

The table 16 below provides a summary of the quantity estimated through the various approaches discussed in this section where a specific scenario of an STP of 50 MLD capacity running at 50% utilization has been considered.

Table 16: Estimated quantity of FS that can be treated in STP based on various studies.

FS quantification for co-treatment	U.S EPA, (1984) German Guidelines	U.S. EPA, (1984) US Guidelines	Dave Robbins Method	CPHEEO, (2013) – Load calculation	(Dangol, 2013) – for digested FS
	0.46 % Or 230 KLD	1.4 % or 700 KLD	2% or 1 MLD	0.46 % or 228 KLD	0.25 % - 3% 62 KLD - 950 KLD

It can be observed that the percentage loading ranges from as low as 0.25% to as high as 3% based on the method used. For a 50 MLD plant, the minimum of 0.25% would correspond to 125 KLD. If it had to be quantified in terms of truck loads (assuming a 3 KLD truck which is typically the least capacity and also the most used in India based on various field observations) – the minimum of number of truck loads is 42. Based on various FSM surveys conducted by CDD Society, 42 truckloads from households are more likely to be generated in larger towns with population greater than 5 lakhs. Towns of population in the range of 1 lakh may generate average of about 4-5 truckloads of FS in a day. Hence, it might be possible that given the current household desludging regimes in various cities (infrequent/ demand based rather than scheduled desludging is the norm) the quantity of FS that might arrive at an STP in relation to what an STP may be able to accommodate (based on its utilization) is likely to be much lesser, making co-treatment a very attractive option.

As far as the approaches referred to in this section are concerned, it is important to note that the methods adopted for arriving at the quantity are different. The guidelines have been developed based on information from specific STPs, specific sludge characteristics and cities/countries and thus might not apply to every STP. The correct approach to take would be to analyse every STP as a standalone system and determine its co-treatment potential rather than trying to calculate volume of FS based on percentage and thumb rules.

5 CONCLUSIONS

Co-treatment of FS with sewage in STPs seems feasible and should be explored. Various studies referred to earlier in this document while documenting the issues and challenges, do present ways and necessary precautions to be taken before taking up co-treatment. The conclusions below throw light on how co-treatment feasibility can be explored in different situations and what factors are to be taken into account for determining quantum of FS to be added and what arrangements need to be ensured before addition of FS into the STP.

- **FS characterization** is the first important step to be followed, where quality of FS likely to be collected in the catchment area of the STP needs to be understood. This will determine the co-treatment potential of FS and sewage in a STP.
 - Key parameters to be assessed are COD, BOD, TSS, TS, VS, TKN and TP.
 - FS parameters from western countries should not be thoughtlessly applied to Indian cities.
- **FS Quantification – FS addition as a percentage of the STP capacity - this approach should be avoided.**
 - As an approach, quantifying FS to be added as a percentage of STP capacity should be avoided
 - To arrive at the capacity of FS that can be co treated in a STP, COD may be used as limiting factor for load calculation.
 - STP Design parameters, treatment technology, utilization of the STP, performance of STP and flow variations do play a role in how much FS can be co-treated. This should be arrived at, on a case-case basis, for every STP.
 - The septage load calculations in CPHEEO, (2013) (*also illustrated in section 4.4 of this document based on COD as limiting factor*) guidelines present a lucid way of estimating the quantity of FS that can be added based on unutilized Hydraulic and Organic load of an STP.
- Irrespective of the type of approach used for co-treatment – there needs to be **proper screening mechanisms** to avoid solid waste, grit entering the STP. Also, required are **discharge platforms/ receiving station** so that it is easy for the trucks to discharge FS without having to queue up for long durations.
- **Co treatment approaches:**

The document has covered two major approaches to co-treatment – Direct Addition and Solid-Liquid Separation.

Based on the unutilized COD load and the quantity of FS likely to be collected in the catchment area of the STP, following conclusions can be drawn.

If unutilized COD load (estimated on daily basis) is X and the total COD load of FS estimated to be co-treated (estimated on daily basis) is Y

Criteria	Approach to Adopt
Y is less than 25% of X	Direct Addition Approach should be the preferred choice
Y is between 25-50% of X	Follow Direct Addition approach – but in an incremental manner – i.e. increase the FS to be co-treated STP in a phased manner and closely monitor results. Solid/Liquid separation approach may be considered if it is expected that the FS collection in catchment area is likely to increase drastically or STP utilization could increase in the next 1-2 years.
If Y is greater than 50% of X	Solid/Liquid separation approach is recommended

➤ **Direct Addition of FS into the STP.**

- ï There needs to be infrastructure in place to collect and dose the FS into the STP inlet at the required rate of dilution to match the influent characteristics of the STP.
- ï In cases where the STPs already have an existing wet well or equalization tank, the dosing may happen into the wet well or equalization tank.
- ï **FS dosing: Understanding of the sewage flow pattern into the STP** is important to identify the optimal dosing intervals that will maximize FS treatment capacities without adversely affecting the STP operations. **Dosing of Faecal Sludge at required levels of dilution during steady state flows** (outside the peak flows duration) may be the best approach for addition of FS into STP
- ï [The German Guidelines referred to in section 4.2 of](#) this document in the U.S. EPA, (1984) seems to have articulated all the major aspects when looking at Direct Addition approach. Their recommendations may be adopted as it is except for the amount of dilution required. The chapter on co-treatment from the FSM Handbook also suggest similar precautions to be taken for co-treatment of FS in STPs.
- ï While the German guidelines state that at least 20 times dilution should be looked at, based on the ratios of various parameters in the table (refer FS vs Sewage characteristics table in section 2) **50-60 times dilution based on COD is recommended.**

➤ **Solid-Liquid separation of FS for treatment at an STP.**

- ï Any appropriate FS dewatering technology, for separation of solid and liquid components of FS can be considered to generate a supernatant/liquid separation, as close to the quality influent sewage
- ï Separated solids from FS needs to be treated or disposed as per the prescribed norms either by utilizing the existing or by setting up new sludge handling facilities

- **Addition of Faecal Sludge at intermediary pumping stations of an STP.** Pumping stations are likely to be closer to the catchment area, thus reducing the distances over which FS needs to be transported. But the pumping stations too should have to be fitted with the required infrastructure like screening chambers followed by suitable direct addition or Solid Liquid separation approaches.
 - ï **If the flow arrangement from the pumping station to the STP is through gravity,** adding FS at the pumping station **could be risky** because there is a chance that the solids might settle in the pipelines, even after requisite dosing or solid liquid separation arrangements.
 - ï **If the flow arrangement from the pumping station to the STP is through pressure flow,** adding FS at the pumping station **should be explored**, after putting in place required dosing or solid liquid separation mechanisms.
 - ï **Addition of FS at manholes** may also be explored, after due consideration of required screening and dosing arrangements. Typically, finding an area to accommodate such a system around a manhole might be difficult.
- **When considering co-treatment as part of new STPs that are being planned,** i.e. where it is known that STP is expected to handle a specified amount of Sewage as well as FS from the beginning, **direct addition might be the preferred way.** This is because, typically STPs will not achieve 100% utilization immediately after being operationalized thus leaving scope for utilization of the unused organic loading over a period of time. Only when it is expected that STPs will run at full capacity or closer to full capacity from the inception, Solid-Liquid separation may be considered. More importantly, solids loading can be estimated in advance and required solids handling facilities can be provided.
- The costs of liquid treatment in an FSTP are typically between 10-20% of the total costs (*based on CDD Society's experience in FSTP designing*). When co-treatment is taken up instead of co-location (i.e. having separate STP and FSTP in same vicinity), **cost savings to the tune of 10-20% can be envisaged.** This needs to be explored.

6 AREAS OF EXPLORATION

- **Trying out various Solid/Liquid separation mechanisms** that can bring the liquid quality closer to STP inlet design, while keeping the capital as well as operational expenditures low. A majority of the current understanding of various Solid/liquid separation mechanisms is from an Activated Sludge perspective rather than a Faecal Sludge perspective.
- Most of the studies **have focused on ASP based systems**. The FSM book has references to UASB systems as well. We are probably richer in knowledge as regards ASP based systems, but in India where a good chunk of STPs are also based on SBR, we do not have enough literature on impact of co-treatment on STPs that use SBR technology.
- The existing case studies of co-treatment in India are strong on understanding operations, quantity of FS coming into the STP, revenue models and regulatory frameworks. More details on the quality and source of the FS would have helped in understanding co-treatment better from a design perspective.
- **Before undertaking co-treatment design, understanding the source of FS is very necessary.** For example, if the quality of the FS is closer to high strength wastewater – which is the case when a lot of commercial establishments may empty their containment systems once-twice in a week at least¹⁶ and this is fed into the nearest STPs on a regular basis, the amount of FS that can be co-treated can be high. On the other hand, if the most regular source is pits which were desludged more than 10 years ago, this will place limitations on quantities and influence design.

¹⁶ Case of Mylasandra STP in Bangalore is an example, where samples were collected from multiple trucks visiting the STP. The values of the FS from most of the trucks corresponded to high strength wastewater.

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