DESIGN MODULE
FOR
CO-TREATMENT OF FAECAL SLUDGE AND SEPTAGE WITH SEWAGE IN SEWAGE TREATMENT PLANT

PART C: WORKBOOK
TITLE
Design Module for Co-Treatment of Faecal Sludge and Septage with Sewage in Sewage Treatment Plant
(Part C: Workbook)

PUBLISHER
National Institute of Urban Affairs, New Delhi

RESEARCH PROJECT
Sanitation Capacity building Platform (SCBP)

GRAPHIC DESIGN
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CONTENT
The module has been developed with the collaborative effort of NFSSMA partner organisations under Training Module Review Committee (TMRC) anchored by NIUA.

<table>
<thead>
<tr>
<th>Editor</th>
<th>Authors</th>
<th>Contributor and reviewer</th>
</tr>
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<tr>
<td>National Institute of Urban Affairs (NIUA)</td>
<td>National Institute of Urban Affairs Ecosan Services Foundation</td>
<td>National Faecal Sludge and Septage Management Alliance (NFSSMA)</td>
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</tbody>
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DESIGN MODULE
FOR
CO-TREATMENT OF
FAECAL SLUDGE AND SEPTAGE
WITH SEWAGE IN
SEWAGE TREATMENT PLANT

PART C: WORKBOOK

Collaborative Effort Under Training Module Review Committee (TMRC)
About National Faecal sludge and Septage Management Alliance (NFSSMA)

The ‘NFSSM Alliance’ was formed with a vision to “Create an enabling environment which amplifies scaling of safe, sustainable and inclusive FSSM through knowledge, partnerships and innovative solutions by 2024.”

Convened by Bill and Melinda Gates Foundation in 2016, the Alliance is a voluntary body that aims to:

- Build consensus and drive the discourse on FSSM at a policy level, and
- Promote peer learning among members to achieve synergies for scaled implementation and reduce duplication of efforts.

The Alliance currently comprises 28 organizations across the country working towards solutions for Indian states and cities. The Alliance works in close collaboration with the Ministry of Housing and Urban Affairs (MoHUA) and several state and city governments through its members to support the progress and derive actions towards mainstreaming of FSSM at state and national level. The NFSSM Alliance works on all aspects of city sanitation plans to regulatory and institutional frameworks across the sanitation value chain. The NFSSM Alliance working in collaboration with the Ministry of Housing and Urban Affairs has been instrumental in the drafting of India’s First Policy on FSSM launched in 2017. This resulted in 19 out of 36 states and UTs adopting guidelines and policies for FSSM in India.

The strength of the Alliance lies in its diverse membership, which includes research institutes, academic institutions, think-tanks, quasi-government bodies, implementing organizations, data experts, consultants, and intermediaries. This enabled a multi-disciplinary view of urban sanitation, with members building on each other's expertise. The alliance has had enormous success in championing FSSM as a viable solution to the Government of India by broadly focussing on:

1. Influencing and informing policy.
2. Demonstrating success through innovation and pilots.
3. Building capacities of key stakeholders across the value chain.

The collaborative continues to work towards promoting the FSSM agenda through policy recommendations and sharing best practices which are inclusive, comprehensive, and have buy-in from several stakeholders in the sector.

- ASCI
- Athena Infonomics
- BBC Media Action
- BMGF
- Borda
- CEPT University
- CSTEP
- CDD
- CPR
- CFAR
- CSE
- Dasra
- EY
- GIZ
- IHSS
- ISCI
- MWM
- KPMG
- NIUA
- PSI
- RTI International
- Tide Technocrats
- UMC
- UNICEF
- USAID
- WASHi
- Water Aid
- World Bank Group
About Training Module Review Committee (TMRC)

To ensure quality control in content and delivery of trainings and capacity building efforts, a Training Module Review Committee (TMRC) was formed with the collaborative effort of all Alliance partners. TMRC which is anchored by National Institute of Urban Affairs (NIUA), has the following broad objectives:

- Identification of priority stakeholders and accordingly training modules for Capacity Building
- Development of a Normative Framework – For Capacity Building at State Level.
- Standardization of priority training modules – appropriate standardization of content with flexibility for customization based on State context.
- Quality Control of Trainings – criteria for ensuring minimum quality of training content and delivery.
- Strategy for measuring impact of trainings and capacity building efforts.
# About the Training Module

<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Co-Treatment of Faecal Sludge and Septage with Sewage in Sewage Treatment Plant (Part C: Workbook)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>This module gives the participants hands-on knowledge about designing a co-treatment system including assessment of existing STP capacities and available treatment technology options. With the announcement of SBM-U 2.0 and AMRUT 2.0, continuation of NMCG and the recommendations of the 15th Finance Commission, this module provides participants a detailed understanding for adopting co-treatment, which is a key component under septage management in these national missions.</td>
</tr>
<tr>
<td><strong>Target Audience</strong></td>
<td>Officials with engineering background and professional experience in wastewater and septage management such as technical faculties from nodal training institutes, technical officials/engineers from state govt, parastatal bodies and ULBs; consultants from TSU/PMUs and sector partners.</td>
</tr>
</tbody>
</table>
| **Learning Objectives** | The module aims to convey the following learnings:  
1. Understand the working principles of Sewage Treatment Plant  
2. Understand how to conduct feasibility assessment of existing sewage treatment plants (STPs) to evaluate co-treatment potential and quantify the amount of FSS that can be co-treated  
3. Know the approaches for adding faecal sludge in a STP for co-treatment along with the design of additional components such as septage receiving station  
4. Gain insight into the operation and maintenance as well as mitigation measures for different treatment units in a STP |
| **Structure of the module** | The training module is based on case methodology where in the sessions will be combined with exercises based on real-life cases. This helps to trainees to apply the knowledge grasped during the session and reinforce it further.  
The module is divided into three parts:  
Part A: This contains the slides used during the session in the presentation format.  
Part B: This is a comprehensive compilation of the all the session briefs and further reading material which helps to strengthen the learning.  
Part C: This contains the exercise developed for training based on the real-life cases |
| **Duration** | In this face-to-face training format, this training is conceptualized for two days without site visits and can be adopted for including the site visits depending upon the city where it is being conducted. |
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SI units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name of Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Volume</td>
<td>cubic meter or kilo litre</td>
<td>m³ or KL</td>
</tr>
</tbody>
</table>

CONVERSION TABLES

Length

<table>
<thead>
<tr>
<th></th>
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<th>centimeter (cm)</th>
<th>meter (m)</th>
<th>kilometer (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 millimeter (mm)</td>
<td>1</td>
<td>0.1</td>
<td>0.001</td>
<td>0.000001</td>
</tr>
<tr>
<td>1 centimeter (cm)</td>
<td>10</td>
<td>1</td>
<td>0.01</td>
<td>0.00001</td>
</tr>
<tr>
<td>1 meter (m)</td>
<td>1000</td>
<td>100</td>
<td>1</td>
<td>0.001</td>
</tr>
<tr>
<td>1 kilometer (km)</td>
<td>1000000</td>
<td>100000</td>
<td>1000</td>
<td>1</td>
</tr>
</tbody>
</table>

Mass

<table>
<thead>
<tr>
<th></th>
<th>milligram (mg)</th>
<th>gram (g)</th>
<th>kilogram (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 milligram (mg)</td>
<td>1</td>
<td>0.001</td>
<td>0.000001</td>
</tr>
<tr>
<td>1 gram (g)</td>
<td>1000</td>
<td>1</td>
<td>0.001</td>
</tr>
<tr>
<td>1 kilogram (kg)</td>
<td>1000000</td>
<td>1000</td>
<td>1</td>
</tr>
</tbody>
</table>

Time

<table>
<thead>
<tr>
<th></th>
<th>second (s)</th>
<th>min (m)</th>
<th>hour (h)</th>
<th>day (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 second (s)</td>
<td>1</td>
<td>1/60</td>
<td>1/3600</td>
<td>1/86400</td>
</tr>
<tr>
<td>1 min (m)</td>
<td>1000</td>
<td>1</td>
<td>1/60</td>
<td>1/1440</td>
</tr>
<tr>
<td>1 hour (h)</td>
<td>3600</td>
<td>60</td>
<td>1</td>
<td>1/24</td>
</tr>
<tr>
<td>1 day (d)</td>
<td>86400</td>
<td>1440</td>
<td>24</td>
<td>1</td>
</tr>
</tbody>
</table>

Volume

<table>
<thead>
<tr>
<th></th>
<th>litre (L)</th>
<th>cubic meter (cum, m³) or kilo litre (KL)</th>
<th>million litre (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 litre (L)</td>
<td>1</td>
<td>0.001</td>
<td>0.000001</td>
</tr>
<tr>
<td>1 cubic meter (m³) or kilo litre (KL)</td>
<td>1000</td>
<td>1</td>
<td>0.001</td>
</tr>
<tr>
<td>1 million litre (ML)</td>
<td>10,00,000</td>
<td>1000</td>
<td>1</td>
</tr>
</tbody>
</table>
DESIGN MODULE FOR CO-TREATMENT OF FAECAL SLUDGE AND SEPTAGE WITH SEWAGE IN SEWAGE TREATMENT PLANT
1. Foundation
In order to understand the design of treatment units, it is important to be well versed with the terminologies, their definitions and their significance.

1.1 Design capacity
The design capacity of the treatment plant is defined as the volume of liquid that a plant can treat in a day. For example, “The design capacity of the STP is 18 MLD” means, that the STP can treat 18 ML of sewage in a day. Please note this does not necessarily mean that the STP is operational for 24 hours during the day.

1.2 Flow rate
Flow rate (also known as hydraulic loading rate) is defined as the volume of liquid flowing per unit time. For example, “The design flow rate for the 18 MLD STP with 20 h of operation is 900 m³/h” means the STP is designed to treat 900 m³ of sewage in 1 h.

However, the flow rate of the STP is not constant and changes with time during the day. This is known as the diurnal variation of flow. Typically, an STP faces two peaks of flow in a day, once during morning between 0800 – 1200 hours and the other during evening between 1900 – 2300 hours. This is defined as the peak flow rate. Please note that the peak flow rate is always higher than the average flow rate. The peaking factor (multiplication factor) is determined by the population connected to the sewerage network. Higher the population, lower is the peaking factor.

1.3 Mass concentration
Mass concentration (also commonly known as concentration) is defined as the mass of constituent in a unit volume of the liquid. For example, “BOD of the sewage is 300 mg/L” means there is 300 mg of BOD in 1 L of the sewage. Similar to the changing flow rate of influent to the STP, the concentration of the influent sewage also keeps on changing.

1.4 Mass load
Mass load (also commonly known as load) is defined as the mass of the constituent. For example, “The BOD load of 1 ML treated sewage as per the treated wastewater discharge standard for STP is 20 kg.” This means that 1 ML of treated sewage with a concentration of 20 mg/L discharged into a surface water body will add 20 kg of BOD to the surface water body.

1.5 Loading rate
Loading rate is similar to the flow rate. It is defined as the mass (or volume) of the constituent applied per unit time to a treatment unit. Thus, the loading rate can be classified as organic (or solids) loading rate and hydraulic loading rate. For example, “The gravity thickener in the STP is designed for the solids loading rate of 5,000 kg TSS/d” means the thickener can handle a load of 5000 kg TSS on a daily basis.

1.6 Problem statement
A moderately sized town has access to a good water source using which the ULB is providing a water supply of 135 LPCD to its population. The ULB conducted a detailed survey and stakeholder consultation for assessing the situation and understanding the feasibility of wastewater management and FSSM. The current generation of wastewater was estimated to be 1 MLD whereas the collection of the faecal sludge and septage was approximately 10 KLD.
Table 1: Characteristics of sewage and septage

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Sewage</th>
<th>Septage</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>mg/L</td>
<td>250.00</td>
<td>7000.00</td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td>425.00</td>
<td>40,000.00</td>
</tr>
<tr>
<td>TSS</td>
<td>%</td>
<td>0.04%</td>
<td>1.50%</td>
</tr>
</tbody>
</table>

Given the condition that the ULB does not have any financial and land constraints, please explain whether setting up a sewage treatment plant (STP) is recommended or not?

**SOLUTION**

\[
\text{Pollution load} \left( \frac{kg}{d} \right) = \text{Pollution concentration} \left( \frac{mg}{L} \right) \times \text{Volume generation}
\]

Hint: TSS of 1.5% = 15 g/L
SECTION 02

SEWAGE TREATMENT PLANT
2. Sewage treatment plant (STP)
A semi-urban city is experiencing urbanization due to the development of an IT hub in its peri-urban region. As a result, the ULB is unable to keep pace with the implementation of sewerage network in the fringe areas of the town.

The city had built and commissioned an 18 MLD STP 7 years ago. The following data was used to calculate the design capacity of the STP.

2.1 Design criteria
The ULB is supplying water at the rate of 135 LPCD to the consumer and has managed to connect 96,000 population to the STP. Due to byelaws and their stringent enforcement, the remaining households are connected to septic tanks. The majority of the population in the adjacent ULBs are also dependent on septic tanks.

Table 2: Design criteria for the STP

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Design period</td>
<td>15</td>
<td>Years</td>
</tr>
<tr>
<td>2</td>
<td>Projected population</td>
<td>1,66,000</td>
<td>no.</td>
</tr>
<tr>
<td>3</td>
<td>Water consumption</td>
<td>135</td>
<td>LPCD</td>
</tr>
<tr>
<td>4</td>
<td>Wastewater generation</td>
<td>80</td>
<td>% of water consumption</td>
</tr>
</tbody>
</table>

2.2 Design parameters
The consultants who were engaged by the ULB for preparing the DPR had based the assumption on the Central Public Health and Environmental Engineering Organization (CPHEEO) Manual on Sewerage and Sewage Treatment (2013).

Table 3: Standard design parameters for the STP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Design concentration</th>
<th>Discharge Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>mg/L</td>
<td>250.00</td>
<td>20.00</td>
</tr>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>425.00</td>
<td>100.00</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>375.00</td>
<td>50.00</td>
</tr>
</tbody>
</table>

2.3 Treatment chain
The STP has two treatment chains – one for handling the sewage (liquid) and the other for handling the sewage sludge (solids). The figure below shows the two treatment chains in the STP. The top chain is the liquid treatment chain and the bottom one is the solids treatment chain.
2.4 Details of the treatment units

The following table gives details of treatment unit in the liquid treatment chain and solid treatment chain:

<table>
<thead>
<tr>
<th>Table 4: Dimensions of the treatment units at STP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary clarifier</strong></td>
</tr>
<tr>
<td>Number</td>
</tr>
<tr>
<td>Diameter</td>
</tr>
<tr>
<td>Depth</td>
</tr>
</tbody>
</table>

| **Activated Sludge Process (ASP) reactor**   | **Dimension** | **Unit** |
| Number                                       | 3.00          | no.      |
| Length                                       | 15.00         | m        |
| Breadth                                      | 15.00         | m        |
| Depth                                        | 5.20          | m        |
2.5 Efficiency of treatment units

Table 5: Efficiency (%) of the treatment units at the STP

<table>
<thead>
<tr>
<th>Treatment Unit</th>
<th>Dimension</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary clarifier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS removal efficiency</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>BOD removal efficiency</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td><strong>Secondary clarifier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS removal efficiency (with respect to TSS_{in} to the clarifier)</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td><strong>Gravity thickener</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS removal efficiency</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td><strong>Anaerobic digester</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS removal efficiency</td>
<td>35%</td>
<td></td>
</tr>
</tbody>
</table>
2.6 Sludge characteristics

Table 6: Characteristic of sludge generated at the STP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Primary sludge</th>
<th>Secondary sludge</th>
<th>Thickened sludge</th>
<th>Digested sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid content [%]</td>
<td>4.00%</td>
<td>0.60%</td>
<td>8.00%</td>
<td>6%</td>
</tr>
<tr>
<td>Density [kg/m³]</td>
<td>1010</td>
<td>1001</td>
<td>1010</td>
<td>1020</td>
</tr>
</tbody>
</table>

2.7 Sludge production

Table 7: Sludge production rate at the STP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Primary sludge</th>
<th>Secondary sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume [m³/h]</td>
<td>1.20</td>
<td>4.60</td>
</tr>
<tr>
<td>Solid loading rate [kg/h]</td>
<td>48.00</td>
<td>27.00</td>
</tr>
</tbody>
</table>
SECTION 03

PRE-FEASIBILITY ASSESSMENT
DESIGN MODULE FOR CO-TREATMENT OF FAECAL SLUDGE AND SEPTAGE WITH SEWAGE IN SEWAGE TREATMENT PLANT
3. Pre-feasibility Assessment

3.1 Problem statement
In order to curb the indiscriminate disposal of faecal sludge and septage into surface water bodies, the ULB wishes to utilize the current STP for co-treatment of faecal sludge and septage with sewage. You are appointed as a consultant by the Water Supply and Sewerage Board (WSSB) to carry out a rapid assessment of the STP for checking the feasibility of co-treatment of faecal sludge and septage with sewage at the STP. A meeting is convened by the WSSB where you have to present the following data:

- Current utilization of the volumetric capacity of the STP.
- Current utilization of the loading capacity with respect to BOD, COD and TSS.

Composite sampling was carried out in order to assess the characteristics of the influent sewage. Similarly, in case of septage, multiple samples were taken and sent for analysis to the lab. The tables below provide the results from the lab analysis.

Table 8: Influent sewage characteristics at the STP

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Influent concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>182.00 mg/L</td>
</tr>
<tr>
<td>COD</td>
<td>305.00 mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>157.00 mg/L</td>
</tr>
</tbody>
</table>

Table 9: Faecal sludge and septage characteristics collected in the city

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>7000.00 mg/L</td>
</tr>
<tr>
<td>COD</td>
<td>20000.00 mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>15000.00 mg/L</td>
</tr>
</tbody>
</table>

3.2 Solution

3.2.1 Volumetric utilization
Using information given in section 2.1, calculate the volumetric utilization.

\[
Volumetric\ utilization\ [MLD] = \frac{Connected\ Population\ [no.] \times \ Water\ consumption\ [LPCD] \times \ Wastewater\ generation\ [%]}{Design\ capacity\ [MLD]} \\
\]

Volumetric utilization = _____________ MLD

\[
Volumetric\ utilization\ [%] = \frac{Current\ utilization\ [MLD]}{Design\ capacity\ [MLD]} \times 100 \\
\]

Volumetric utilization = _______ %
3.2.2 Load utilization

Using information given in section 2.1, calculate the design load.

\[
\text{Design load } \left( \frac{kg}{d} \right) = \text{Design capacity [MLD]} \times \text{Design concentration } \left( \frac{mg}{L} \right)
\]

**Table 10: Design load of the STP**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Design capacity [MLD]</th>
<th>Design concentration [mg/L]</th>
<th>Design load [kg/d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Load utilization } \left( \frac{kg}{d} \right) = \text{Volumetric utilization [MLD]} \times \text{Influent concentration } \left( \frac{mg}{L} \right)
\]

**Table 11: Load utilization of the STP**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Utilization [MLD]</th>
<th>Influent concentration [mg/L]</th>
<th>Load utilization [kg/d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Load utilization } [\%] = \frac{\text{Load utilization } [kg/d]}{\text{Design Load } [kg/d]} \times 100
\]

**Table 12: Load utilization (%) of the STP**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Design load [kg/d]</th>
<th>Load utilization [kg/d]</th>
<th>Load utilization [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.3 Co-treatment feasibility

\[
\text{Unutilized load } \left[\frac{kg}{d}\right] = \text{Design load } \left[\frac{kg}{d}\right] - \text{Load utilization } \left[\frac{kg}{d}\right]
\]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Design load [kg/d]</th>
<th>Load utilization [kg/d]</th>
<th>Unutilized load [kg/d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Using information given in the section 3.1, calculate the faecal sludge and septage (FSS) handling capacity.

\[
\text{Septage handling capacity } [\text{KLD}] = \frac{\text{Unutilized load } [\frac{kg}{d}]}{\text{Septage Concentration } [\frac{mg}{L}]}
\]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unutilized load [kg/d]</th>
<th>Concentration [mg/L]</th>
<th>Handling capacity [KLD]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constraining parameter is ____________.

**INFERENCEx:**
Write your inference here from the findings and observations from the above section of the exercise.
SECTION 04

DETAILED ASSESSMENT
4. Detailed Assessment

4.1 Problem statement
The WSSB decided to go ahead with carrying out the detailed assessment of the STP in order to understand the implications of the co-treatment on the operation and maintenance cost of the STP. This would enable them to draft better terms for the maintenance contract with a private operator.

As a consultant, your job is to carry out a detailed assessment and provide recommendations for co-treatment of faecal sludge and septage with sewage at the STP.

4.2 Solution
The addition of equalization tank or a receiving sump at the inlet of the STP is mostly to ensure a continuous flow of sewage into the STP. The optimization in area requirements and improvement in treatment efficiency of STP are some of the additional benefits of providing an equalization tank. This depends on the hours of operation of STP. In this case, the STP was designed for 20 hours of operation in a day. This means that the 18 MLD sewage will be treated in 20 hours in a day (and not 24 hours!).

In order to maximize the potential of co-treatment, let’s assume that the STP will be operated for 20 hours during the co-treatment of faecal sludge and septage with sewage.

4.2.1 Flow rate
Calculate the design and actual flow rate.

\[
\text{Flow rate} \left[ \frac{\text{cum}}{\text{h}} \right] = \frac{\text{Design Capacity or Utilized Capacity [MLD]}}{\text{Operation hours [h]}}
\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Quantity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design flow rate</td>
<td></td>
<td>m³/h</td>
</tr>
<tr>
<td>Actual flow rate</td>
<td></td>
<td>m³/h</td>
</tr>
</tbody>
</table>

4.2.2 Loading rate
Calculate the organic loading rate and solids loading rate based on the information provided in sections 2.2 and 3.1.

\[
\text{Loading rate} \left[ \frac{\text{kg}}{\text{h}} \right] = \text{Flow rate} \left[ \frac{\text{cum}}{\text{h}} \right] \times \text{Concentration} \left[ \frac{\text{mg}}{\text{L}} \right]
\]
Table 16: Organic and solids loading rate at the STP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flow rate [m³/h]</th>
<th>Concentration [mg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design</td>
<td>Actual</td>
</tr>
<tr>
<td>BOD</td>
<td>250.00</td>
<td>182.00</td>
</tr>
<tr>
<td>COD</td>
<td>425.00</td>
<td>305.00</td>
</tr>
<tr>
<td>TSS</td>
<td>375.00</td>
<td>157.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Loading rate [kg/h]</th>
<th>Unutilized Loading [kg/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design</td>
<td>Actual</td>
</tr>
<tr>
<td>BOD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2.3 Faecal sludge and septage (FSS) load
Calculate load of FSS assuming, one truck load of FSS is added to the sewage every hour.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration [mg/L]</th>
<th>Truck capacity [KL]</th>
<th>Truck decanted [no./h]</th>
<th>Truck load [kg/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>7,000.00</td>
<td>3.00</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>20,000.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td>15,000.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2.4 Addition of faecal sludge and septage (FSS)
There are two options for co-treating FSS with sewage at an STP: (1) addition of FSS in the sewage (liquid) stream, and (2) addition of FSS in the sewage sludge (solid) stream.

In case of option one, there is a further option of direct addition in the receiving sump and addition after solid-liquid separation. This mainly depends on the utilization of design capacity and the availability of land area within the plant premises. In this section, we will explore the option of addition after solid-liquid separation and addition of septage in the solid stream.

At this stage, a safety factor needs to be considered in order to accommodate any change in the quality of the influent sewage or septage. In this case, a safety factor of 20% is assumed.

If direct addition of FSS is to be done in the receiving sump, then the feasible load that can be added per hour is 2 truckloads with COD as the constraining parameter.

4.2.5 Solid-liquid separation
Let us assume a settling thickening tank is provided having an efficiency of 60%. For every truck emptied in the settling thickening tank, part of the solids are settled in the tank as thickened sludge and the rest of the solids are retained in the liquid phase.
Consider the approximate values for the BOD and COD of the supernatant based on the TSS content of the supernatant and corresponding ratio (BOD: TSS and COD: TSS) of the FSS.

**Calculate the suspended solids (SS) load in supernatant and thickened sludge stream.**

\[
SS_{load\ in\ supernatant\ stream} \left( \frac{kg}{h} \right) = SS_{load} \left( \frac{kg}{h} \right) \times \text{Efficiency} \left( \% \right)
\]

SS load in supernatant stream = ________ kg/h

\[
SS_{load\ in\ supernatant\ stream} \left( \frac{kg}{h} \right) = SS_{load} \left( \frac{kg}{h} \right) \times \left( 1 - \text{Efficiency} \left( \% \right) \right)
\]

SS load in supernatant stream = ________ kg/h

**Calculate the volume of thickened sludge.**

\[
\text{Volume of sludge} \left( \frac{cum}{h} \right) = \frac{SS_{load\ in\ sludge} \left( \frac{kg}{h} \right)}{\text{Dry solid content} \left( \% \right) \times \text{Sludge density} \left( \frac{kg}{cum} \right)}
\]

Volume of thickened sludge = ________ m³/h

\[
\text{Volume of supernatant} \left( \frac{cum}{h} \right) = \text{Volume of septage} \left( \frac{cum}{h} \right) - \text{Volume of thickened sludge} \left( \frac{cum}{h} \right)
\]

Volume of supernatant = ________ m³/h

**Calculate the solid content in the supernatant.**

\[
\text{Solid content} \left( \% \right) = \frac{SS_{load\ in\ supernatant} \left( \frac{kg}{h} \right)}{\text{Volume of supernatant} \left( \frac{cum}{h} \right) \times \text{Density of water} \left( \frac{kg}{cum} \right)}
\]

Solid content = ________ %

Solid content = ________ mg/L

In case of FSS, the organic pollutants are correlated to the total suspended solids. Hence, removal of TSS in the FSS also reduces the COD and BOD in the supernatant.

Consider the approximate values for the BOD and COD of the supernatant based on the TSS content of the supernatant and corresponding ratio (BOD: TSS and COD: TSS) of the FSS.
### Table 17: Characteristics of supernatant from settling thickening tank

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration [mg/L]</th>
<th>FSS</th>
<th>Supernatant</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>7,000.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>20,000.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td>15,000.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 4.2.6 Supernatant load

Using the information from 4.2.5, calculate the load of supernatant.

### Table 18: Organic and solids load of supernatant from settling thickening tank

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration [mg/L]</th>
<th>Supernatant volume [m³/h]</th>
<th>Supernatant load [kg/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 4.2.7 Feasible truck load

\[
\text{Feasible truck load} \left[ \text{no./h} \right] = \frac{\text{Unutilized loading} \left[ \text{kg/h} \right]}{\text{Supernatant load} \left[ \text{kg/h} \right]}
\]

### Table 19: Feasible truck load for co-treatment of FSS with sewage at the STP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unutilized loading [kg/h]</th>
<th>Supernatant load [kg/h]</th>
<th>Feasible truck load [no./h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thus, for safer treatment the constraining parameter is identified and corresponding truck loads are taken for further calculation. Thus, in this case, the feasible truck loads are _______ no./h.

It can also be inferred that because of solid-liquid separation, the STP can handle almost _____ times the load when compared to direct addition of faecal sludge and septage in the receiving sump.
4.3 Addition after solid-liquid separation

In this section, a detailed assessment of all the treatment units will be done upon addition of supernatant and thickened sludge from settling thickening tank into the sewage (liquid) stream and gravity thickener, respectively.

4.3.1 Primary clarifier

Using the information from sections 4.2.6 and 4.2.7, calculate the total solids loading rate and hydraulic loading rate to the primary clarifier after addition of supernatant to the liquid stream.

\[
\text{Solids loading rate} \left[ \frac{kg}{h} \right] = \text{Solids loading rate of sewage} \left[ \frac{kg}{h} \right] + \left\{ \text{Feasible truck loads} \left[ \frac{no.}{h} \right] \times \text{Supernatant load} \left[ \frac{kg}{h} \right] \right\}
\]

Solids loading rate = __________ kg/h

\[
\text{Hydraulic loading rate} \left[ \frac{cum}{h} \right] = \text{Hydraulic loading rate of sewage} \left[ \frac{cum}{h} \right] + \left\{ \text{Feasible truck loads} \left[ \frac{no.}{h} \right] \times \text{Supernatant volume} \left[ \text{cum} \right] \right\}
\]

Hydraulic loading rate = __________ m³/h

This hydraulic loading rate is assumed to be constant for the subsequent liquid treatment units.

FEASIBILITY CHECK!

The hydraulic loading rate should be lower than the design flow rate. This usually holds true provided there is no mistake in the calculations done before.

Calculate the TSS concentration.

\[
\text{TSS concentration} \left[ \frac{mg}{L} \right] = \frac{\text{Solids loading rate} \left[ \frac{kg}{h} \right]}{\text{Hydraulic loading rate} \left[ \frac{cum}{h} \right]}
\]

TSS concentration = __________ mg/L

FEASIBILITY CHECK!

The TSS concentration should be lower than 1000 mg/L. Primary clarifier is designed for flocculant settling of solids assuming that the solids loading rate will be below 1000 mg/L.
Using the information given in section 2.5, calculate primary sludge generation in kg/h and m³/h.

\[
\text{Primary sludge generation} \left( \frac{kg}{h} \right) = \text{Solids loading rate} \left( \frac{kg}{h} \right) \times \text{TSS removal efficiency} \% 
\]

Primary sludge generation = __________ kg/h

Using the information given in section 2.6, calculate the primary sludge generation rate.

\[
\text{Primary sludge generation} \left( \frac{cum}{h} \right) = \frac{\text{Primary sludge generation} \left( \frac{kg}{h} \right)}{\text{Solid content} \% \times \text{Sludge density} \left( \frac{kg}{cum} \right)} 
\]

Primary sludge generation = __________ m³/h

Using the information from sections 4.2.6 and 4.2.7, using the calculations done for solids loading rate on primary clarifier kindly calculate the BOD loading rate.

BOD loading rate = ____________ kg/h

BOD_{in} = ____________ mg/L

Using the information from section 2.5, calculate the BOD_{out} from the primary clarifier.

\[
\text{BOD}_{out} = \text{BOD}_{in} \times (1 - \text{BOD removal efficiency}) 
\]

BOD_{out} = ____________ mg/L

4.3.2. ASP Reactor

Using information from section 2.4, calculate the design BOD (S₀) for ASP reactor.

Volume of the reactor (V) = __________ m³

Design hydraulic load (Q) = __________ MLD

Standard design criteria for an ASP Reactor: F/M ratio = 0.45 /d and MLSS (X) = 3500 mg/L

\[
\text{So} \left[ \frac{g \text{BOD}}{L} \right] = \frac{F \left[\frac{1}{d}\right] \times V \left[\text{cum}\right] \times X \left[\frac{mg}{L}\right]}{Q \left[\frac{\text{cum}}{d}\right]} 
\]

Design BOD (S₀) = ____________ mg/L

**FEASIBILITY CHECK!**

The BOD_{out} of a primary clarifier (i.e. BOD_{in} of the ASP reactor) should be less than the design BOD of the ASP reactor. During the operation of plant, the operator will have to adjust the return flow...
Calculate the hydraulic retention time.

**Design HRT [h]** \(= \frac{V \text{ [cum]}}{Q \text{ [MLD]}}\)

Design HRT = __________ h

**Actual HRT [h]** \(= \frac{V \text{ [cum]}}{\text{Hydraulic loading rate [cum h]}}\)

Actual HRT = __________ h

**FEASIBILITY CHECK!**

The actual HRT should be more than the design HRT for an ASP reactor. This ensures that the aeration capacity of the reactor is sufficient to handle the incoming BOD load and to maintain the BOD removal efficiency of the ASP reactor.

### 4.3.3 Secondary Clarifier

Using the information given in sections 2.4 and 4.3.2, calculate the solids loading rate (solids loading per day per unit area of the clarifier).

**TSS_{in}** concentration [mg/L] = MLSS in ASP reactor = __________ mgTSS/L

Area of the clarifier = __________ m²

**Solids loading rate** \(\frac{\text{kg TSS}}{d \times \text{sqm}}\)

\[\text{Solids loading rate} = \frac{\text{TSS}_{\text{in}} \times \text{Hydraulic loading rate} \times \text{Operation hours [h]}}{\text{Area of clarifier [sqm]}}\]

Solids loading rate per unit area of clarifier = __________ kgTSS/d/m²

**FEASIBILITY CHECK!**

The solids loading rate per day per unit area of a secondary clarifier should be lower than 120 kgTSS/d/m². This ensures that the TSS removal efficiency of the clarifier is not affected and sludge wash-out does not take place.

Using information given in sections 4.1, 4.3.1 and 4.3.3, calculate the surface loading rate (hydraulic loading per day per unit area of the clarifier).

**Surface loading rate** \(\frac{\text{cum}}{d \times \text{sqm}}\)

\[\text{Surface loading rate} = \frac{\text{Hydraulic loading rate} \times \text{Operation hours [h]}}{\text{Area of secondary clarifier [sqm]}}\]

Surface loading rate per unit area of the clarifier = __________ m³/d/m²
FEASIBILITY CHECK!

The surface loading rate per day per unit area of a secondary clarifier should be lower than 30 m³/d/m². This ensures that the TSS removal efficiency of the clarifier is not affected and sludge wash out does not take place.

Using information provided in section 2.5, calculate \( TSS_{\text{out}} \) of the secondary clarifier.

\[
TSS_{\text{in}} \left[ \frac{kg}{h} \right] = TSS_{\text{in}} \left[ \frac{mg}{L} \right] \times \text{Hydraulic loading rate} \left[ \frac{cum}{h} \right]
\]

\[
TSS_{\text{out}} \left[ \frac{kg}{h} \right] = TSS_{\text{in}} \left[ \frac{kg}{h} \right] \times \text{TSS removal efficiency} \left[ \% \right]
\]

\[
TSS_{\text{out}} = \text{__________} \text{kg/h}
\]

\[
TSS_{\text{out}} \left[ \frac{mg}{L} \right] = \frac{TSS_{\text{out}} \left[ \frac{kg}{h} \right]}{\text{Hydraulic loading rate} \left[ \frac{cum}{h} \right]}
\]

\[
TSS_{\text{out}} = \text{__________} \text{mg/L}
\]

FEASIBILITY CHECK!

The \( TSS_{\text{out}} \) for a secondary clarifier should be less than the discharge standards as mandated by the state pollution control board or the design outlet parameter of the STP.

Calculate the sludge wastage in the secondary stage of STP.

Secondary stage of the STP refers to a combination of the ASP reactor and the secondary clarifier. The sludge waste is equal to 0.50 kg/kgBOD removed in the secondary stage.

\( BOD_{\text{in}} \) to the ASP reactor = \( BOD_{\text{out}} \) of primary clarifier = \text{__________} \text{mg/L}

\( BOD_{\text{out}} \) of the secondary clarifier = 20 mg/L.

\[
BOD \text{ removed} \left[ \frac{kg \ BOD}{h} \right] = (BOD_{\text{in}} - BOD_{\text{out}}) \left[ \frac{mg}{L} \right] \times \text{Hydraulic loading rate} \left[ \frac{cum}{h} \right]
\]

\[
\text{Sludge wastage} \left[ \frac{kg}{h} \right] = BOD \text{ removed} \left[ \frac{kg}{h} \right] \times 0.50 \left[ \frac{kg}{kg \ BOD} \right]
\]

\[
\text{Sludge wastage} = \text{__________} \text{kg/h}
\]

\[
\text{Sludge wastage} \left[ \frac{cum}{h} \right] = \frac{\text{Sludge wastage} \left[ \frac{kg}{h} \right]}{\text{Dry solid content} \left[ \% \right] \times \text{Sludge density} \left[ \frac{kg}{cum} \right]}
\]

\[
\text{Sludge wastage} = \text{__________} \text{m³/h}
\]
4.3.4 Gravity Thickener
Using information from section 2.4, calculate the following:

Area of the gravity thickener = ___________ m²

Volume of the gravity thickener = ___________ m³

Solids loading rate [kg/h] applied to the gravity thickener is equal to the sum of primary sludge production [kg/h], sludge wastage from secondary stage [kg/h] and thickened sludge from the settling thickening tank [kg/h]. Multiply the above number with operation hours [h] to get solids loading rate in [kg/d].

Solids loading rate = ___________ kg/d

Similarly, calculate hydraulic loading rate [m³/d].

Hydraulic loading rate = ___________ m³/d

Calculate the solids loading rate (solids loading per day per unit area of the gravity thickener).

\[
\text{Solids loading rate} \left[ \frac{kg \ TSS}{d \times sqm} \right] = \frac{\text{Solids loading rate} \left[ \frac{kg \ TSS}{d} \right]}{\text{Area of gravity thickener} \ [sqm]}
\]

Solids loading rate per unit area of gravity thickener = ___________ kgTSS/d/m²

FEASIBILITY CHECK!

The solids loading rate per day per unit area of a gravity thickener should lie between 25 kgTSS/d/m² and 80 kgTSS/d/m². If the solids loading rate is less than 25 kgTSS/d/m², then the return flow of the effluent from anaerobic digester needs to be adjusted. This ensures that the TSS removal efficiency of the gravity thickener is not affected and sludge wash-out does not take place.

Move to the next step as the adjustment is done later.

Calculate the surface loading rate (hydraulic loading per day per unit area of the gravity thickener).

\[
\text{Surface loading rate} \left[ \frac{cum}{d \times sqm} \right] = \frac{\text{Hydraulic loading rate} \left[ \frac{cum}{d} \right]}{\text{Area of gravity thickener} \ [sqm]}
\]

Surface loading rate per unit area of the gravity thickener = ___________ m³/d/m²

FEASIBILITY CHECK!

The surface loading rate per day per unit area of a gravity thickener should lie between 20 m³/d/m² and 30 m³/d/m². If the surface loading rate is less than 20 m³/d/m², then the return flow of the effluent from anaerobic digester needs to be adjusted. This ensures that the TSS removal efficiency of the gravity thickener is not affected and sludge wash-out does not take place.
Move to the next step as the adjustment is done later.

Calculate the hydraulic retention time (HRT) of gravity thickener.

\[
HRT \ [d] = \frac{\text{Volume of the gravity thickener} \ [\text{cum}]}{\text{Hydraulic loading rate} \ [\text{cum/d}]}
\]

HRT = ___________ d

FEASIBILITY CHECK!

The HRT of a gravity thickener should be less than 1 day i.e. 24 hours. This ensures that the conditions in the gravity thickener do not turn septic and issues related foul odor do not arise in the STP.

ADJUSTMENT

Adjusting the return flow of the effluent from the anaerobic digester automatically adjusts the solids loading rate, the surface loading rate and the HRT of the gravity thickener.

The operator needs to calculate the return flow based on the dimensions of gravity thickener and the design criteria (solids loading rate and surface loading rate).

\[
\text{Solids loading} \ \left[\frac{kg}{d}\right] \\
= \text{Area of the gravity thickener} \ [sqm] \\
\times \text{Design solids loading rate} \left[\frac{kg \ TSS}{d \times sqm}\right]
\]

\[
\text{Hydraulic loading} \ \left[\frac{cum}{d}\right] \\
= \text{Area of the gravity thickener} \ [sqm] \\
\times \text{Design surface loading rate} \left[\frac{cum}{d \times sqm}\right]
\]

Thus, after adjusting the return flow of the effluent:

Solids loading to the gravity thickener = ___________ kg/d

Hydraulic loading rate to the gravity thickener = ___________ m³/d

Using the information from section 2.5, calculate the production of thickened sludge from the gravity thickener.

\[
\text{Mass of thickened sludge} \ \left[\frac{kg}{d}\right] \\
= \text{Solids loading to gravity thickener} \left[\frac{kg}{d}\right] \times \text{TSS removal efficiency} \ [%]
\]
Mass of thickened sludge = ___________ kg/d

Using the information from section 2.6, calculate the volume of the thickened sludge.

\[
\text{Volume of thickened sludge} \left[ \frac{\text{cum}}{d} \right] = \frac{\text{Mass of thickened sludge} \left[ \frac{\text{kg}}{d} \right]}{\text{Solid content} \% \times \text{Sludge density} \left[ \frac{\text{kg}}{\text{cum}} \right]}
\]

Volume of thickened sludge = ___________ m³/d

4.3.5 Anaerobic Digester
Using the information from section 2.4, calculate the following:

Area of the anaerobic digester = ___________ m²

Volume of the anaerobic digester = ___________ m³

Solids loading = mass of the thickened sludge = ___________ kg/h

Hydraulic loading = volume of the thickened sludge = ___________ m³/d

Calculate the detention time of anaerobic digester.

\[
\text{Detention time} \ [d] = \frac{\text{Volume of the anaerobic digester} \ [\text{cum}]}{\text{Hydraulic loading} \ [\frac{\text{cum}}{d}]}
\]

Detention time = ___________ d

FEASIBILITY CHECK!

The recommended value for detention time of an anaerobic digester is 30 days at a minimum temperature of 25 °C. This provides enough time for the sludge to get digested and produce maximum methane gas.

Calculate the solids volumetric load.

\[
\text{Solids volumetric loading} \left[ \frac{\text{kg TSS}}{d \times \text{cum}} \right] = \frac{\text{Solids loading} \left[ \frac{\text{kg}}{d} \right]}{\text{Volume of the anaerobic digester} \ [\text{cum}]}
\]

Solids volumetric loading = ___________ kgTSS/d/m³

FEASIBILITY CHECK!

The solids volumetric loading for an anaerobic digester should be between 1 kgTSS/d/m³ and 2 kgTSS/d/m³. This ensures that the performance efficiency of the digester is not hampered.
The anaerobic digester produces two effluent streams: (1) liquid stream from the top of the digester, and (2) digested sludge stream from the bottom of the digester. The liquid stream is returned to the gravity thickener or the inlet of the STP and the digested sludge stream is sent to the dewatering unit/s.

Using the information from section 2.5, calculate the production of digested sludge from the anaerobic digester.

\[
\text{Mass of digested sludge} \left[ \frac{kg \ TSS}{d} \right] = \text{Solids loading to anaerobic digester} \left[ \frac{kg}{d} \right] \times \text{TSS removal efficiency [%]}
\]

Mass of digested sludge = ______________ kgTSS/d

Using the information from section 2.6, calculate the volume of the digested sludge.

\[
\text{Volume of digested sludge} \left[ \frac{cum}{d} \right] = \frac{\text{Mass of digested sludge} \left[ \frac{kg}{d} \right]}{\text{Solid content [%]} \times \text{Sludge density} \left[ \frac{kg}{cum} \right]}
\]

Volume of digested sludge = _____________ m³/d

4.3.6 Sludge Dewatering

At this stage, the dewatering of the digested sludge is done using a mechanical equipment such as centrifuge, screw press or belt press. The aim of this stage is to increase the solid content of the sludge up to 25%.

To increase the efficiency of the mechanical dewatering equipment, adjustments are done to the operating parameters such as:

- Centrifuge: RPM and feeding rate.
- Screw press: Feeding rate and the tension in the spring of the compaction plate.
- Belt press: Feeding rate and tension in the belt.

Apart from this, the operator needs to adjust the dosage of the polymer to condition the sludge so that the mechanical dewatering equipment gives highest efficiency.

Calculate the dosage of polymer.

Dose 10 g polymer/kgTSS of sludge

\[
\text{Dosage} \left[ \frac{kg}{d} \right] = \text{Mass of digested sludge} \left[ \frac{kg \ TSS}{d} \right] \times 10 \left[ \frac{g}{kg \ TSS} \right]
\]

Dosage = _____________ kg/d
4.4 Addition in sewage sludge stream

By adding the septage directly in the sewage sludge (solid) stream, the primary and secondary sludge production will not change significantly. Using information from section 2.7, please fill the following data:

Primary sludge generation = ____________ m³/h & ____________ kg/h

Secondary sludge generation = ____________ m³/h & ____________ kg/h

4.4.1 Gravity Thickener

Using information from section 4.3.4, please fill the following:

Area of the gravity thickener = ____________ m²

Volume of the gravity thickener = ____________ m³

Following assumptions are based on the design criteria:

Design solids loading rate = 52.50 kg/d/m²....................... (average of 25-80 kg/d/m²)

Design surface loading rate = 25 m³/d/m²......................... (average of 20-30 m³/d/m²)

Calculate the design solids and hydraulic loading.

\[
\text{Design solids loading} \left(\frac{kg}{d}\right) = \text{Area [sqm]} \times \text{Design solids loading rate} \left(\frac{kg}{d \times \text{sqm}}\right)
\]

\[
\text{Design hydraulic loading} \left(\frac{\text{cum}}{d}\right) = \text{Area [sqm]} \times \text{Design surface loading rate} \left(\frac{\text{cum}}{d \times \text{sqm}}\right)
\]

Design solids loading = ____________ kg/d

Design hydraulic loading = ____________ m³/d

Calculate current solids and hydraulic loading before addition of the septage.

Current solids and hydraulic loading are only due to primary and secondary sludge generated in the STP. Use the given sludge generation rate above and multiply it with operations hours to get the current solids loading rate [kg/d] and hydraulic loading rate [m³/d].

Current solids loading rate = ____________ kg/d
Current hydraulic loading rate = _____________ m³/d

The solids load of one 3 KL truck load of FSS with TSS content of 15,000 mg/L is 45 kg/truck load.

Assuming 20% as a factor of safety, calculate the unutilized solids loading rate.

\[ Unutilized \ solids \ loading \ rate \ \left( \frac{kg}{d} \right) = Solids \ loading \ rate \ \left( \frac{kg}{d} \right) \times (1 - safety \ factor) \]

Unutilized solids loading rate = _____________ kg/d

Calculate the feasible truck load.

\[ Feasible \ truck \ load \ \left( \frac{no.}{d} \right) = \frac{Unutilized \ loading \ \left( \frac{kg}{d} \right)}{Septage \ load \ \left( \frac{kg}{truck \ load} \right)} \]

Feasible truck load = _____________ no./d

Calculate the actual solids and hydraulic loading after addition of FSS in sewage sludge stream.

\[ Actual \ solids \ loading \ \left( \frac{kg}{d} \right) = Current \ solids \ loading \ \left( \frac{kg}{d} \right) + \left\{ Feasible \ truck \ load \ \left( \frac{no.}{d} \right) \times Septage \ load \ \left( \frac{kg}{truck \ load} \right) \right\} \]

Actual solids loading = _____________ kg/d

\[ Actual \ hydraulic \ loading \ \left( \frac{cum}{d} \right) = Current \ hydraulic \ loading \ \left( \frac{cum}{d} \right) + \left\{ Feasible \ truck \ load \ \left( \frac{no.}{d} \right) \times Septage \ volume \ \left( \frac{cum}{truck \ load} \right) \right\} \]

Actual hydraulic loading = _____________ m³/d

Calculate the solids loading rate per unit area of the gravity thickener.

\[ Solids \ loading \ rate \ \left( \frac{kg \ TSS}{d \times sqm} \right) = \frac{Actual \ solids \ loading \ rate \ \left( \frac{kg \ TSS}{d \times sqm} \right)}{Area \ of \ gravity \ thickener \ [sqm]} \]

Solids loading rate per unit area of gravity thickener = _____________ kgTSS/d/m²

FEASIBILITY CHECK!

The solids loading rate per day per unit area of a gravity thickener should lie between
25 kgTSS/d/m² and 80 kgTSS/d/m². If the solids loading rate is less than 25 kgTSS/d/m², then the return flow of the effluent from anaerobic digester needs to be adjusted. This ensures that the TSS removal efficiency of the gravity thickener is not affected and sludge wash out does not take place.

Calculate the surface loading rate (hydraulic loading per day per unit area of the gravity thickener).

\[
\text{Surface loading rate} = \frac{\text{Hydraulic loading rate}}{\text{Area of gravity thickener}}
\]

Surface loading rate per unit area of the gravity thickener = ___________ m³/d/m²

FEASIBILITY CHECK!

The surface loading rate per day per unit area of a gravity thickener should lie between 20 m³/d/m² and 30 m³/d/m². If the solids loading rate is less than 20 m³/d/m², then the return flow of the effluent from anaerobic digester needs to be adjusted. This ensures that the TSS removal efficiency of the gravity thickener is not affected and sludge wash out does not take place.

Move to the next step as the adjustment is done later.

Calculate the hydraulic retention time (HRT) of the gravity thickener.

\[
HRT = \frac{\text{Volume of the gravity thickener}}{\text{Hydraulic loading rate}}
\]

HRT = ________ d

FEASIBILITY CHECK!

The HRT of a gravity thickener should be less than 1 day i.e. 24 hours. This ensures that the conditions in the gravity thickener does not turn septic and issues of foul odour do not arise in the STP.

ADJUSTMENT

Adjusting the return flow of the effluent from the anaerobic digester automatically adjusts the surface loading rate of the gravity thickener.

The operator needs to calculate the return flow based on dimensions of the gravity thickener and the design criteria (solids loading rate and surface loading rate).

\[
\text{Hydraulic loading} = \frac{\text{Area of the gravity thickener}}{\times \text{Design surface loading rate}}
\]
Thus, after adjusting the return flow of the effluent:

**Hydraulic loading rate to the gravity thickener = __________ m³/d**

Calculate the production of thickened sludge from gravity thickener.

\[
\text{Mass of thickened sludge} \left[\frac{kg}{d}\right] = \text{Solids loading to gravity thickener} \left[\frac{kg}{d}\right] \times \text{TSS removal efficiency [%]}
\]

Mass of thickened sludge = __________ kg/d

\[
\text{Volume of thickened sludge} \left[\frac{cum}{d}\right] = \frac{\text{Mass of thickened sludge} \left[\frac{kg}{d}\right]}{\text{Solid content [%]} \times \text{Sludge density} \left[\frac{kg}{cum}\right]}
\]

Volume of thickened sludge = __________ m³/d

#### 4.4.2 Anaerobic Digester

Using the information from section 2.4, fill the following:

Area of the anaerobic digester = __________ m²

Volume of the anaerobic digester = __________ m³

Solids loading = mass of the thickened sludge = __________ kg/h

Hydraulic loading = volume of the thickened sludge = __________ m³/d

Calculate the detention time of anaerobic digester.

\[
\text{Detention time} [d] = \frac{\text{Volume of the anaerobic digester} [cum]}{\text{Hydraulic loading} \left[\frac{cum}{d}\right]}
\]

Detention time = __________ d

**FEASIBILITY CHECK!**

The recommended value for detention time of an anaerobic digester is 30 days at a minimum temperature of 25 °C. This provides enough time for the sludge to get digested and produce maximum methane gas.

Calculate the solids volumetric load.

\[
\text{Solids volumetric loading} \left[\frac{kg \ TSS}{d \times cum}\right] = \frac{\text{Solids loading} \left[\frac{kg}{d}\right]}{\text{Volume of the anaerobic digester} [cum]}
\]
Solids volumetric loading = \[\text{___________ kgTSS/d/m}^3\]

FEASIBILITY CHECK!

The solids volumetric loading for an anaerobic digester should lie between 1 kgTSS/d/m³ and 2 kgTSS/d/m³. This ensures that the performance efficiency of the digester is not hampered.

The anaerobic digester produces two effluent streams: (1) liquid stream from the top of the digester, and (2) digested sludge stream from the bottom of the digester. The liquid stream is returned to the gravity thickener or the inlet of the STP and the digested sludge stream is sent to the dewatering unit/s.

Using the information from section 2.5, calculate the production of digested sludge from the anaerobic digester.

\[
\frac{\text{Mass of digested sludge [kg TSS]} }{\text{d}} = \frac{\text{Solids loading to anaerobic digester [kg]} \times \text{TSS removal efficiency [%]}}{

\text{Mass of digested sludge = ____________ kgTSS/d}

Using the information from section 2.6, calculate the volume of digested sludge.

\[
\frac{\text{Volume of digested sludge [cum]}}{\text{d}} = \frac{\text{Mass of digested sludge [kg]} \times \text{Solid content [%]} \times \text{Sludge density [kg/cum]}}{

\text{Volume of digested sludge = ____________ m}^3/\text{d}

4.4.3 Sludge Dewatering

At this stage, the dewatering of the digested sludge is done using a mechanical equipment such as centrifuge, screw press or belt press. The aim of this stage is to increase the solid content of the sludge to up to 25%.

To increase the efficiency of the mechanical dewatering equipment, adjustments are done to the operating parameters such as:

- Centrifuge: RPM and feeding rate.
- Screw press: Feeding rate and the tension in the spring of the compaction plate.
- Belt press: Feeding rate and tension in the belt.

Apart from this, the operator needs to adjust the dosage of the polymer to condition the sludge so that the mechanical dewater equipment gives highest performance efficiency.

Calculate the dosage of polymer.
Dose 10 g polymer/kgTSS of sludge

\[
\text{Dosage} \ [\text{kg/d}] = \text{Mass of digested sludge} \left(\frac{\text{kg TSS}}{\text{d}}\right) \times 10 \left(\frac{\text{g}}{\text{kg TSS}}\right)
\]

Dosage = _________________ kg/d

**INFEERENCE:**
Write your inference here from the findings and observations from the above section of the exercise.

**4.5 Summary**
The exercise covered in this workbook gives us an insight into the following aspects of co-treatment of faecal sludge and septage (FSS) with sewage in a sewage treatment plant (STP):

• Solid-liquid separation allows higher volume of faecal sludge and septage to be handled at the STP as compared to the direct addition of FSS in the sewage stream.

• The settling thickening tank also provides homogenization of FSS with supernatant thereby reducing the risk of process upset in the STP due to co-treatment.

• Addition of FSS to the sewage stream affects the liquid treatment chain as well as the sewage sludge treatment chain. Thus, the monitoring of the STP operation becomes very critical. In this case, the operator needs to be technically sound.

• Addition of FSS to the sewage sludge (solid) treatment chain in an STP have either insignificant or no impact on the liquid treatment chain of the STP.

• In case of addition to sewage sludge (solid) stream, proper care needs to be taken regarding ammonia concentration and pH of the FSS. These parameters are very important for the functioning of an anaerobic digester and monitoring becomes critical in this case.

• Co-treatment of FSS with sewage in an STP provides a good opportunity to handle waste generated from onsite sanitation systems with minimal investment in terms of capital and operational expenditure.
About NIUA
NIUA is a premier national institute for research, capacity building and dissemination of knowledge in the urban sector, including sanitation. Established in 1976, it is the apex research body for the Ministry of Housing and Urban Affairs (MoHUA), Government of India. NIUA is also the strategic partner of the MoHUA in capacity building for providing single window services to the MoHUA/states/ULBs.

About SCBP
The Sanitation Capacity Building Platform (SCBP) is an initiative of the National Institute of Urban Affairs (NIUA) to address urban sanitation challenges in India. SCBP, supported by Bill & Melinda Gates Foundation (BMGF) is an organic and growing collaboration of credible national and international organisations, universities, training centres, resource centres, non-governmental organisations, academia, consultants and experts. SCBP supports national urban sanitation missions, states and ULBs, by developing and sourcing the best capacity building, policy guidance, technological, institutional, financial and behaviour change advise for FSSM. SCBP provides a unique opportunity for:

- Sharing and cross learning among the partner organisations, to pool in their knowledge resources on all aspects of urban sanitation capacity building;
- Developing training modules, learning and advocacy material including key messages and content, assessment reports and collating knowledge products on FSSM. Through its website (scbp.niua.org), SCBP is striving to create a resource centre on learning and advocacy materials, relevant government reports, policy documents and case studies;
- Dissemination of FSSM research, advocacy and outreach to State governments and ULBs.

Its strength is its ability to bring together partners to contribute towards developing state sanitation policy, training of trainers and training content development, technical and social assessments, training programme delivery, research and documentation.