DESIGN MODULE
FOR
CO-TREATMENT
OF FAECAL SLUDGE IN
SEWAGE TREATMENT PLANT
DRAFT

PART C: WORKBOOK
CONTENT
This module is developed by the following partners under the SCBP;
National Institute of Urban Affairs, Delhi
Ecosan Services Foundation, Pune

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The full module should be referenced as follows: NIUA (2020) Design Module for Co-Treatment of Faecal Sludge in Sewage Treatment Plant – Draft (Part C: Workbook)”. Text from this module can be quoted provided the source is acknowledged.

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CO-TREATMENT OF FAecal SLUDGE AND SEPTAGE AT STP DESIGN MODULE

DRAFT

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.
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>Title</th>
<th>Design Module for Design Module for Co-Treatment of Faecal Sludge in Sewage Treatment Plant – Draft (Part C: Workbook)</th>
</tr>
</thead>
</table>
| Purpose | The underutilized STPs and the new STPs which are under planning stage have a good potential to co-treat the Faecal Sludge and Septage (FSS) with the incoming domestic wastewater. However, for this to be done, one needs to understand the designing and functioning of wastewater treatment processes and also the impact of co-treatment of FSS with the domestic wastewater.  

The two-days technical module on “Design Module for Design Module for Co-Treatment of Faecal Sludge in Sewage Treatment Plant” will provide insights to the ULB, Parastatal Department officials or Consultants. It will cover the different approaches of FSS treatment, characterisation of sludge and feasibility assessment of co-treatment. It will also cover the Co-treatment approach/application of FSS at different stages of domestic wastewater treatment systems like at septage receiving station or in a liquid or solid stream. |
| Target Audience | ULB or parastatal agency officials such as engineers and planners, consultants who are involved in managing of faecal sludge and preparing city sanitation plans, early professionals who wish to develop career into faecal sludge and septage management. |
| Learning Objectives | The module aims to convey the following learnings:  

1. There is a scope and significant potential for co-treatment of Faecal Sludge and Septage (FSS) in the existing and proposed sewage treatment plants.  

2. The requirement of framework and policy and its enforcement for successful state-wide implementation of co-treatment of Faecal Sludge and Septage (FSS) with domestic wastewater.  

3. Technical requirements for practicing co-treatment of Faecal Sludge and Septage (FSS) and domestic wastewater and estimating its feasibility. |
| 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 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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### List of Units

#### 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>
<th>millimeter (mm)</th>
<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 (m³) or kilolitre (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 kilolitre (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>
1. Foundation

In order to understand the design of treatment units, it is important to be well versed with the terminologies, their definition 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 plant 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 at the 18 MLD STP with 20h of operation is 900 m³/h” means, the STP is designed to treat 900 m³ of sewage in one hour.

However, the flow rate of the STP is not constant and changes with the time during the day. This is known as diurnal variation of flow. Typically, STP faces two peaks of flow rates in a day, once during the morning between 8.00 – 12.00 hours and the next in evening between 19.00 – 23.00 hours. This is defined as 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 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 per litre 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, 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 defined similar to the flow rate. It is the mass (or volume) of the constituent applied per unit time to a treatment unit. Thus, loading rate can be classified as organic (or solids) loading rate and hydraulic loading rate. For example, “The gravity thickener at 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 which 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 faecal sludge - septage

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Sewage</th>
<th>Faecal sludge and 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 if setting up a Sewage Treatment Plant is recommended or not?

**SOLUTION**

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

Hint: TSS of 1.5% = 15 g/L
2. Sewage Treatment Plant
A semi-urban city is experiencing urbanization due to the development of IT hub in its peri-urban area. As a result of this the ULB is unable to keep pace with 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 at the consumer end 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>
<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>
<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 and one for handling the sewage sludge. The figure below shows the treatment chains at the STP. The top chain is the liquid treatment chain and the bottom chain is the sewage sludge treatment chain.
2.4 Details of the treatment units

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

<table>
<thead>
<tr>
<th>Table 4: Dimensions of the treatment units at sewage treatment plant</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>

<table>
<thead>
<tr>
<th><strong>ASP reactor</strong></th>
<th><strong>Dimension</strong></th>
<th><strong>Unit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>3.00</td>
<td>no.</td>
</tr>
<tr>
<td>Length</td>
<td>15.00</td>
<td>m</td>
</tr>
<tr>
<td>Breadth</td>
<td>15.00</td>
<td>m</td>
</tr>
<tr>
<td>Depth</td>
<td>5.20</td>
<td>m</td>
</tr>
<tr>
<td>Secondary clarifier</td>
<td>Dimension</td>
<td>Unit</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------</td>
<td>------</td>
</tr>
<tr>
<td>Number</td>
<td>3.00</td>
<td>no.</td>
</tr>
<tr>
<td>Diameter</td>
<td>19.50</td>
<td>m</td>
</tr>
<tr>
<td>Depth</td>
<td>3.50</td>
<td>m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gravity thickener</th>
<th>Dimension</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>2.00</td>
<td>no.</td>
</tr>
<tr>
<td>Diameter</td>
<td>11.40</td>
<td>m</td>
</tr>
<tr>
<td>Depth</td>
<td>3.00</td>
<td>m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anaerobic digester</th>
<th>Dimension</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>2.00</td>
<td>no.</td>
</tr>
<tr>
<td>Diameter</td>
<td>18.00</td>
<td>m</td>
</tr>
<tr>
<td>Depth</td>
<td>5.20</td>
<td>m</td>
</tr>
</tbody>
</table>

### 2.5 Efficiency of treatment units

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 5: Efficiency of the treatment units at sewage treatment plant</strong></td>
<td></td>
<td></td>
</tr>
<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</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>(with respect to TSS in to the clarifier)</td>
<td></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 sewage treatment plant

<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 sewage treatment plant

<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>
3. Pre-feasibility Assessment

3.1 Problem statement
In order to curb the indiscriminate disposal of septage into the surface water bodies, the ULB wishes to utilize the current STP for co-treatment. 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 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 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 of the lab analysis.

<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>
<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 the section 2.1, calculate the volumetric utilization.

\[
Volumetric \text{ utilization [MLD]} = \frac{Connected \ Population [no.] \times Water \ consumption [LPED]}{Wastewater \ generation [%]} \times Design \ capacity [MLD] \times 100
\]
### 3.2.2 Load utilization

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

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

<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>

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

<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>

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

<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

Using information given in the section 3.1, calculate the septage handling capacity.

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

Table 14: Septage handling capacity of the sewage treatment plant

<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>

Constraint Parameter:

**INFERENCER**
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 septage at 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 of STP is an additional benefit 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 septage with sewage.

4.2.1 Flow rate
Calculate the design and actual flow rate.

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

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

Table 15: Design and actual flow rate at the sewage treatment plant

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

\[
Loading \ rate \ [\frac{kg}{h}] = Flow \ rate \ [\frac{cum}{h}] \times Concentration \ [\frac{mg}{L}]
\]
### Table 16: Organic and solids loading rate at the sewage treatment plant

<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 Septage load
Calculate load of septage assuming one truck load of septage 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 septage
There are two options for co-treating septage at STP: (1) Addition of septage in the sewage stream, and (2) Addition of septage in the sewage sludge stream.

In case of option one, there is a further option of direct addition in the sump and addition after solid-liquid separation. This mainly depends on the utilization of design capacity and the availability of area at the plant. In this section we will explore all the look deeper into the option addition after solid liquid separation and addition of septage in the sewage sludge 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 septage is to be done in the sump, then the feasible load to be added per hour is 2 truckloads with COD as the constraint.

#### 4.2.5 Solid-liquid separation
Let us assume a settling thickening tank is provided with 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.
Calculate suspended solids load in supernatant and thickened sludge stream.

\[ SS \text{ load in sludge stream} = \text{Solids loading} \times \text{Efficiency} \]

SS load in supernatant stream = kg/h

\[ SS \text{ load in supernatant stream} = \text{Solids loading} \times (1 - \text{Efficiency}) \]

SS load in supernatant stream = kg/h

Calculate volume of thickened sludge.

\[ \text{Volume of sludge} = \frac{\text{SS load in sludge}}{\text{Dry solid content} \times \text{Sludge density}} \]

Volume of thickened sludge = m³/h

\[ \text{Volume of supernatant} = \text{Volume of septage} - \text{Volume of thickened sludge} \]

Volume of supernatant = m³/h

Calculate solid content in the supernatant.

\[ \text{Solid content} = \frac{\text{SS load in supernatant}}{\text{Volume of supernatant} \times \text{Density of water}} \]

Solid content = %

Solid content = mg/L

In case of septage, the organic pollutants are correlated to the total suspended solids. Hence, removal of TSS in the septage also correspondingly reduces the COD and BOD of 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 septage.
Table 17: Characteristics of supernatant from settling thickening tank

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

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

Table 19: Feasible truck load for co-treatment at sewage treatment plant

<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 constraint 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 septage in the sump.
4.3 Addition after solid-liquid separation

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

4.3.1 Primary clarifier

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

Solids loading rate \( \frac{kg}{h} \)

\[ = \text{Solids loading rate of sewage } \frac{kg}{h} \]

\[ + \left( \text{Feasible truck loads } \frac{no.}{h} \times \text{Supernatant load } \frac{kg}{h} \right) \]

Solids loading rate = kg/h

Hydraulic loading rate \( \frac{cum}{h} \)

\[ = \text{Hydraulic loading rate of sewage } \frac{cum}{h} \]

\[ + \left( \text{Feasible truck loads } \frac{no.}{h} \times \text{Supernatant volume } [cum] \right) \]

Hydraulic loading rate = m³/h

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

FEASIBILITY CHECK!

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

Calculate TSS concentration.

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

TSS concentration =

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 cum/h.

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

Primary sludge generation = kg/h

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

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

Primary sludge generation = cum/h

Using the information from section 4.2.6 and 4.2.7 calculate the BOD loading rate similar to the solids loading rate on primary clarifier.

BOD loading rate = kg/h

\[ \text{BOD}_{in} = \text{mg/L} \]

Using the information from section 2.5, calculate the BOD\(_{out}\) from the primary clarifier.

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

\[ \text{BOD}_{out} = \text{mg/L} \]

### 4.3.2. ASP Reactor

Using information from 2.4, calculate the design BOD (S\(_0\)) for ASP reactor.

**Volume of the reactor (V) = \( m^3 \)**

**Design hydraulic load (Q) = \( \text{MLD} \)**

Standard design criteria for 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 (S\(_0\)) = mg/L

**FEASIBILITY CHECK!**

The BOD\(_{out}\) of the 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 the plant, the operator will have to adjust the...
return flow of the activated sludge from the secondary clarifier to maintain the MLSS and F/M ratio of the reactor.

Calculate the hydraulic retention time.

\[
Design \ HRT \ [h] = \frac{V \ [cum]}{Q \ [MLD]} 
\]

Design HRT = \( h \)

\[
Actual \ HRT \ [h] = \frac{V \ [cum]}{Hydraulic \ loading \ rate \ [ \frac{cum}{h}]} 
\]

Actual HRT \( [h] = h \)

**FEASIBILITY CHECK!**

The actual HRT should be more than the design HRT for the 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 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 = mg TSS/L

Area of the clarifier = m\(^2\)

\[
Solids \ loading \ rate \ [\frac{kg \ TSS}{d \times sqm}] = \frac{TSS_{in} \ [mg/L] \times Hydraulic \ loading \ rate \ [\frac{cum}{h}] \times Operation \ hours \ [h]}{Area \ of \ clarifier \ [sqm]} 
\]

Solids loading rate per unit area of clarifier = kg TSS/d/m\(^2\)

**FEASIBILITY CHECK!**

The solids loading rate per day per unit area of the clarifier should be below 120 kg TSS/d/m\(^2\). 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 4.1, 4.3.1 and 4.3.3, calculate the surface loading rate (hydraulic loading per day per unit area of the clarifier).

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

Surface loading rate per unit area of the clarifier = m\(^3\)/d/m\(^2\)
The surface loading rate per day per unit area of the clarifier should be below 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$_{out}$ of the secondary clarifier.

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

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

TSS$_{out}$ = kg/h

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

TSS$_{out}$ = mg/L

The TSS$_{out}$ from the 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 combination of the ASP reactor and the secondary clarifier. The sludge waste is equal to 0.50 kg / kg BOD removed in the secondary stage.

BOD$_{in}$ to the ASP reactor = BOD$_{out}$ of primary clarifier = mg/L

BOD$_{out}$ of the Secondary clarifier = 20 mg/L.

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

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

Sludge wastage = kg/h

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

Sludge wastage = cum/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] to the gravity thickener is equal to 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 [cum/h].

Hydraulic loading rate = m³/d

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

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

Solids loading rate per unit area of gravity thickener = kg TSS/m²

**FEASIBILITY CHECK!**

The solids loading rate per day per unit area of the gravity thickener should be between 25 kg TSS/d/m² and 80 kg TSS/d/m². If the solids loading rate per day per unit area of the clarifier is below 25 kg TSS/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, the adjustment is done later.

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

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

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

**FEASIBILITY CHECK!**

The surface loading rate per day per unit area of the gravity thickener should be between 20 m³/d/m² and 30 m³/d/m². If the solids loading rate per day per unit area of the clarifier is below 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, the adjustment is done later.

Calculate the HRT of gravity thickener.

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

\[ HRT = d \]

FEASIBILITY CHECK!

The HRT of the 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 of foul odor does not arise at the STP.

ADJUSTMENT

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

Solids loading \([\frac{kg}{d}]\)

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

Hydraulic loading \([\frac{cum}{d}]\)

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

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.
Mass of thickened sludge \([\frac{kg}{d}]\)

\[= \text{Solids loading to gravity thickener} \times \text{TSS removal efficiency [\%]} \]

Mass of thickened sludge = kg/d

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

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

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

Calculate solids volumetric load.

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

FEASIBILITY CHECK!

The solids volumetric loading for anaerobic digester should be between 1 kg TSS/d/m³ and 2 kg TSS/d/m³. This ensures that the efficiency of the digester is not hampered.
The anaerobic digester produces two 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 digester sludge stream is sent further for dewatering stage.

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

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

Mass of digested sludge = \( \text{kg TSS/d} \)

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

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

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

### 4.3.6 Sludge Dewatering

At this stage, the dewatering of the digested sludge is done using mechanical equipment such as a 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 dewatering equipment gives highest efficiency.

Calculate the dosage of polymer.

Dose 10 g polymer / kg TSS of sludge

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

Dosage = \( \text{kg/d} \)
**INFERENCE:**
Write your inference here from the findings and observations from the above section of the exercise.

**4.4 Addition in sewage sludge**
Addition of sludge is happening directly in the sewage sludge 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 design solids and hydraulic loading.

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

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

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 TSS load of the one 3 KL truck load septage with TSS content of 15,000 mg/L is 45 kg/truck load.

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

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

Calculate the feasible truck load.

\[
\text{Feasible truck load } \frac{[\text{no.}]}{d} = \frac{\text{Unutilized loading } \frac{[kg]}{d}}{\text{Septage load } \frac{[kg]}{\text{truck load}}}
\]

Feasible truck load = no./d

Calculate actual solids and hydraulic loading after addition of septage sewage sludge stream.

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

Actual hydraulic loading = m³/d

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

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

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

Solids loading rate per unit area of gravity thickener = kg TSS/d/m²

FEASIBILITY CHECK!

The solids loading rate per day per unit area of the gravity thickener should be between 25 kg TSS/d/m² and 80 kg TSS/d/m². If the solids loading rate per day per unit area of the clarifier is below 25 kg TSS/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).

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

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 the gravity thickener should be between 20 m³/d/m² and 30 m³/d/m². If the solids loading rate per day per unit area of the clarifier is below 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, the adjustment is done later.

Calculate the HRT of gravity thickener.

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

HRT = d

FEASIBILITY CHECK!

The HRT of the 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 does 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).

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

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 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

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

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 detention time of the anaerobic digester.

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

Detention time = d

FEASIBILITY CHECK!

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

Calculate solids volumetric load.

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

FEASIBILITY CHECK!

The solids volumetric loading for anaerobic digester should be between 1 kg TSS/d/m³ and 2 kg TSS/d/m³. This ensures that the efficiency of the digester is not hampered.
The anaerobic digester produces two 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 digester sludge stream is sent further for dewatering stage.

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

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

Mass of digested sludge = kg TSS/d

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

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

Volume of digested sludge = m³/d

### 4.4.3 Sludge Dewatering

At this stage, the dewatering of the digested sludge is done using mechanical equipment such as a 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 dewatering equipment gives highest efficiency.

Calculate the dosage of polymer.

Dose 10 g polymer / kg TSS of sludge

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

Dosage = kg/d
**4.5 Summary**

The exercise covered in this workbook gives us an insight into the following aspects of co-treatment of septage with sewage in a STP:

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

The settling thickening tank also provides homogenization of septage and supernatant and hence reduces the risk of co-treatment.

Addition of sewage/supernatant to the sewage stream affects the liquid treatment as well as 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 septage to the sewage sludge treatment chain affects have insignificant to no impact on the liquid treatment chain of the STP.

In case of addition to sewage sludge stream, care needs to be taken regarding ammonia concentration and pH of the faecal sludge and septage. This can severely impact anaerobic digester and monitoring becomes critical in this case.

Co-treatment of faecal sludge and septage provides a good opportunity to handle good quantity of faecal sludge and septage with minimal investment in terms of CAPEX and OPEX.
Notes:
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.

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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.

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