National Institute of Urban Affairs

# DESIGN RECOMMENDATIONS FOR CO-TREATMENT OF FAECAL SLUDGE WITH SEWAGE AT TRANSPORT NAGAR STP, RAMNAGAR

SUBMITTED TO PEY JAL NIGAM, RAMNAGAR, UTTARAKHAND

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SCBP

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# ABBREVIATIONS

| | |
|---|---|
| BIS | Bureau of Indian Standard |
| BOD | Biological Oxygen Demand |
| BoQ | Bill of Quantities |
| DBOT | Design build operate transfer |
| CAPEX | Capital Expenditure |
| COD | Chemical Oxygen Demand |
| CPCB | Central Pollution Control Board |
| CPCHEEO | Central Public Health & Environmental Engineering Organization |
| DPR | Detailed Project Report |
| DWPE | Dewatering Polyelectrolyte |
| FGD | Focus Group Discussion |
| FSS | Faecal Sludge and Septage |
| FSM | Faecal Sludge Management |
| FSSM | Faecal Sludge and Septage Management |
| GoI | Government of India |
| GoUK | Government of Uttarakhand |
| KII | Key Informant Interview |
| KLD | Kilo Litres per day |
| LPCD | Litres per Capita per Day |
| MIS | Management Information System |
| MLD | Million Liters per Day |
| MoHUA | Ministry of Housing and Urban Affairs (Formerly known as MoUD) |
| MSL | Mean Sea Level |
| NFSSMP | National Faecal Sludge and Septage Management Policy |
| NIC | National Informatics Centre |
| NIUA | National Institute of Urban Affairs |
| NMCG | National Mission for Clean Ganga |
| NUSP | National Urban Sanitation Policy |
| OD | Open Defecation |
| OPEX | Operational Expenditure |
| OSS | Onsite Sanitation System |
| OU | Open Urination |
| PPE | Personal Protective Equipment |
| SBM | Swachh Bharat Mission |
| STP | Sewage Treatment Plant |
| SLRM | Solid Liquid Resource Management |
| TSS | Total Suspended Solids |
| UDD | Urban Development Department |
| ULB | Urban Local Body |
| UKJN | Uttarakhand Jal Nigam |
| UJS | Uttarakhand Jal Sansthan |
| UKEPPCB | Uttarakhand Environment Protection and Pollution Control Board |
| BHEL | Bharat Heavy Electricals Limited |
| DEWATs | Decentralized Waste Water Treatment |

# SALIENT FEATURES

| **Name of the project** | **Technical report on the Design of Co-treatment of Faecal Sludge and Septage with sewage at Ramnagar STP** |
|---|---|
| City | Ramnagar |
| Project Implementation time (tentative) | 9-12 months |
| Areas to be benefited | Ramnagar City and Suburbs |
| Population Projection | Geometrical Increase Method Formula |
| Design Period | 2023-2030 |
| Tanker's effective Capacity | 4 KL |
| Types of pump required | Auto-coupling eddy submersible pump |
| No. of pumps (Working +Standby) | |
| Current Sewage Inflow (7 MLD STP) | 2 MLD average (Max: 3.5 MLD, Min: 1.5 MLD) |

# EXECUTIVE SUMMARY

Co-treatment is a process where Sewage Treatment Plant (STP), in addition to treating the domestic sewage, also treats faecal sludge and septage (FSS) emptied from various Onsite Sanitation Systems (OSS) in the city. The need for this facility has arisen to ensure an efficient and appropriate co-treatment of faecal sludge septage (FSS) with sewage, so that the functionality of existing STP is not compromised. Setting up of a dedicated faecal sludge treatment plant (FSTP) is a time-consuming affair due to issues such as land identification, clearances and tendering process. Further, in case of co- treatment, the existing facilities, site infrastructure and human resource of the STP will be used for co-treatment and thus can eliminate the problem of engaging a new O&M operator and additional cost related to site infrastructure. The facility is proposed in accordance to the Swachh Bharat Mission (Urban) Guidelines by GoI and the Advisory note on Co-treatment of Faecal Sludge and Septage with Sewage in STP by Pey Jal Nigam, Dehradun.

Co-treatment will provide access to improved sanitation to households, low-income settlements, commercial and institutional establishments of the targeted areas where sewer connections are not feasible or it may take some time to provide the designed service. Thus, the co-treatment method will restrict the indiscriminate discharge of highly contaminated faecal sludge into holy rivers and surrounding environment of the city.

Excreta Flow Diagram (aka Shit Flow Diagram) of the Ramnagar attributes to 98% of the population is dependent on onsite sanitation systems. However, 11 KLD of FSS is being currently collected in the city but it is estimated that around 36 KLD of FSS would be generated by the Production Method[1]. Although, sewerage systems are not planned for the city, with the growing population in consideration, management of FSS of the city will remain in pursuit of the ULB and parastatal bodies.

- The proposed facility is designed based on the estimated collection Method 1 i.e., 30 KLD of treatment upto 2026 and further based on the feasibility study.
- The state of Uttarakhand is prioritizing FSSM through co-treatment method, and this is evident in its Septage Management Protocol 2017 where Co-treatment method is included for FSS treatment and State Advisory note on co-treatment of septage with sewage in STPs, 2022.
- Land available (currently not in any use) in the STP premise will be used for erecting Co- treatment facility.

In order to implement FSSM 2017 protocol by UDD, Dehradun; a request from Executive Engineer, Uttarakhand Jal Nigam (UKJN), Ramnagar for technical assistance from NIUA about the feasibility, design recommendation and estimated cost for co-treatment, in this regard a letter (Annexure 1) was conveyed to National Institute of Urban Affairs (NIUA) on 08/10/2021.

[1] Production method: FSS generation is 120 litres per capita per year.

# Section 1. Introduction

## 1.1 Background

Transport Nagar Sewage Treatment Plant (STP), Ramnagar which was commissioned in July, 2021 with 7 MLD of designed capacity is one of the two STPs present in the city. Another 1.5 MLD STP in Foji Colony, Puchari, Ramnagar which is currently functional at its designed capacity. In the meeting held on 07/10/2021 of the Septage Management Cell (SMC) Ramnagar, under direction by the Sub Divisional Magistrate (SDM) it was asked to cater the septage generated by Ramnagar and Kaladungi ULBs via installing a co-treatment plant at the 7 MLD Transport Nagar STP, Ramnagar.

## 1.2 City Profile

Ramnagar is small town and municipal board in the Nainital district of Uttarakhand, India. It's located approximately 65 kilometres (40 miles) from Nainital, the district headquarters. Ramnagar is the gateway to the Jim Corbett National Park, the oldest national park and a famous tourist destination of India. Garjiya Devi temple and Seeta Bani temple are located nearby which also adds to the floating population. The town was re-established and settled by Commissioner H. Ramsay in 1856- 1884. Ramnagar is most visited for Jim Corbett National park which is named after the hunter turned conservationist Jim Corbett who played a key role in its establishment. Its oldest national park in India which was established in 1936.

*Table 1 Secondary Data from Ramnagar ULB*

| PARAMETER | No. |
|---|---|
| Municipal Area (Sq. Km) | 2.43 |
| No. of Municipal Wards | 20 |
| Population 2020-21 | 77,702 |
| Households (2011 Census) | 8,256 |
| Literacy rate (%) | 81.76 |
| Sex Ratio | 930 |

## 1.3 Location and connectivity


*Figure 1 Ramnagar, Uttarakhand (SCBP/NIUA/2022)*

Ramnagar is located at 29.40°N 79.12°E.. Ramnagar is the gateway to western Kumaon and Chamoli. It is also the commencement point of Kumaon hills with the nearby town of Haldwani. Ramnagar is also famous for international “Litchi farming”. To facilitate the flow of river Kosi a barrage is placed on the river banks upstream. The nearest proposed airport is 81.6 km away at Pantnagar with rail connectivity kathgodam, Moradabad, Bareilly, Lucknow, Kanpur, Mumbai, Chandigarh, Jaisalmer and Delhi. The National highway 121 which starts from kashipur and ends at Bubakhal, Uttarakhand passes through Ramnagar.

### 1.4 Geography and climate

Ramnagar is located at the foothills of the Himalayas on the bank of river Kosi. It has an average elevation of 345 metres (1,132 ft). The town is well known for being the gateway to Jim Corbett National Park and draws a lot of attention because of its geographical location. Its proximity to Nainital which is a famous hill station of Northern India makes it even more popular. The average annual temperature in the city varies between 15°C to 35°C.In Ramnagar, the average annual temperature is 25.7 °C | 78.3 °F. The rainfall here is around 982 mm. The driest month is April, with 6 mm of rainfall. The greatest amount of precipitation occurs in July, with an average of 305 mm. The warmest month of the year is May, with an average temperature of 33.4 °C | 92.2 °F. The lowest average temperatures in the year occur in January, when it is around 16.0 °C | 60.8 °F.

Ramnagar lies in the Ganga basin, Ramganga sub-basin, which mostly have Bhabar (boulders gravel, sand and clay). The shallowest water level[2] (0-5 m) is observed as a continuous band stretching from the western to the eastern part of the Udham Singh Nagar district and covering the southern part of the Champawat district along with isolated patches in and around Ramnagar- Maldhan Colony- Garjiya in the Nainital district.

[2] Central ground water board Uttarakhand Report 2019-20

# Section 2. Overview of Sanitation Situation

The state government notified FSSM protocol for septage management G.O. No. 597/IV (2) UD2017-50 (Sa)/16 dated 22nd May 2017. The objective of the protocol was to streamline FSSM operations in the state. The protocol was developed by Urban Development Directorate (UDD), Uttarakhand. As per the protocol, all cities shall constitute Septage Management Committee (SMC) for implementation of septage management activities. Currently, in the SMC is formed for Ramnagar. There are 2 STPs present in the city, which intercepts the wastewater through nullahs and drains of the city. The treated water is dumped into Kosi River and there are possibilities that the treated water from the 7 MLD plant can be diverted into the irrigation channel running adjacent to the STP premises.

## 2.1 Excreta flow mapping

To understand and map the excreta management of the city along the sanitation service chain, an intermediate level Shit Flow Diagram[3] is prepared.

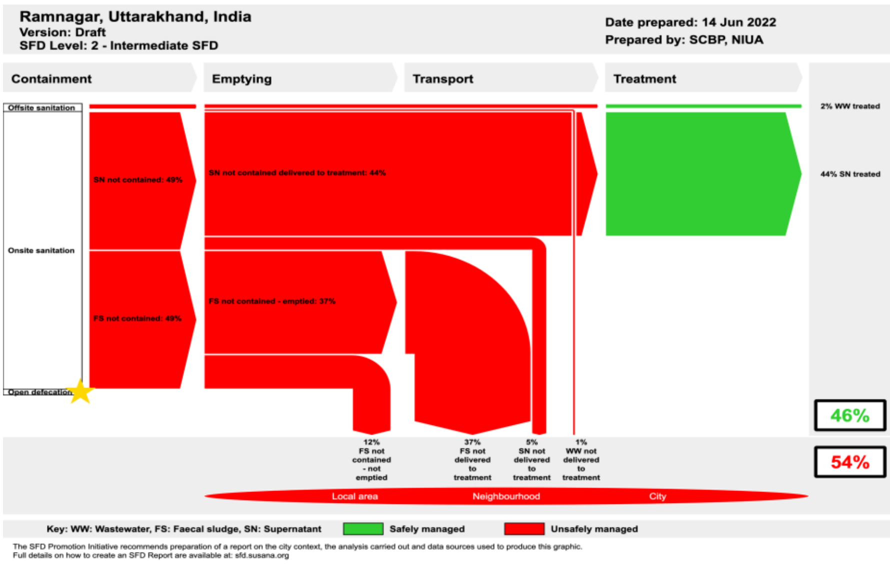


*Figure 2 Shit flow diagram of Ramnagar (Source: Graphic Generator Sfd.Susana.org)*

The service outcomes of the sanitation service chain are analysed below: -

### 2.1.1 Containments

A survey was conducted by the Ramnagar Nagar Palika in which 8,600 properties were identified with a total of 5,972 Residential, 966 commercials, 979 Mix property, 18 religious and 13 school/institutes, 652 are vacant plot. There are 2 Public Toilets present in the city which are near to the Ramnagar Nagar Palika Office Premises and 1 Urinal near the Ramnagar Bus Stand. There is no existing sewer network. The wastewater from bathrooms and effluent from onsite systems is conveyed through big drains/nullahs.

[3] Explanatory note for generating SFD for Ramnagar: https://drive.google.com/drive/folders/1iqkv0VyxEkPypNLfZnVlQ4XNPS5zgxcW?usp=sharing.

Through Key Informant Interviews (KII) and Focus Group Discussions (FGDs) with municipal

*Figure 3 Lined tank with impermeable wall and open bottom (Source: Sachin Sahani/NIUA/2021)*

*Figure 4 Septic tank connected to Open Drain (Source: Sachin Sahani/NIUA/2022)*

officials, desludging operator and households, different kinds of sanitation systems were found which included septic tanks connected to open drains and fully lined tank connected to open drain, whereas in the report shared post ULBs survey, it was reviled that there are toilet which directly ends up into open drains therefore considering the data provided by ULB, the final percentage of Sanitation System present in Ramnagar are described  below.

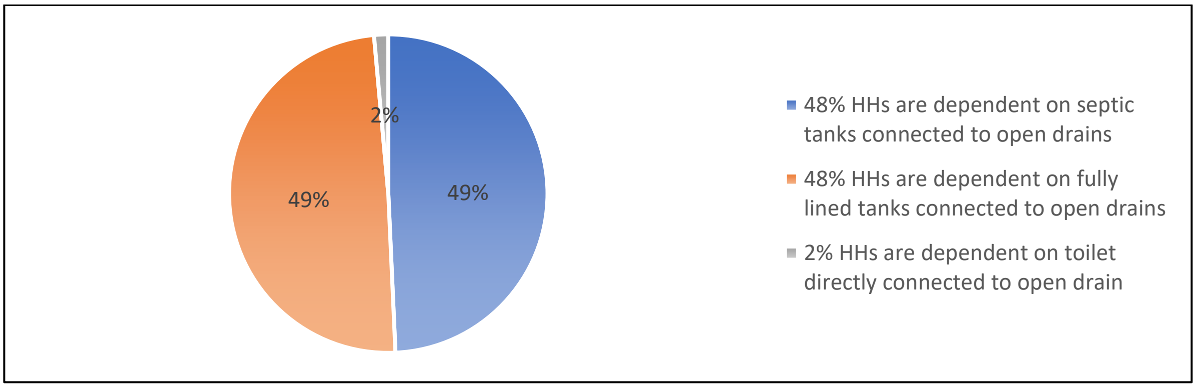


*Figure 5 Corresponding percentage of population dependent on different types of sanitation systems (Source: SFD for Ramnagar)*

### 2.1.2 Emptying and Transportation

The desludging (figure 6. emptying of Septic tank) of Septage/faecal sludge is carried by cess pool vehicles operated by private operators. There are 3-5 such private player operational within the ULB and some cess pool vehicle arrives from the nearby ULB (Kaladungi) as well. For these vehicles, the average vehicle capacity considered is 4000 litres, which makes on an average 20 trips/month. Based on the above data, using “collection method”, it is estimated that 11KLD of septage/faecal sludge is being collected at the present. The average desludging frequency of Septic tanks and fully lined connected to open drains is below 5 years, whereas in case on lined tanks with open bottom it goes well above 10 years.

The desludging charges is approximately 3000-5000 INR per trip with extra charges for any civil work required during the execution of the process.

*Figure 6 Emptying of Septic tank connected to open drain ( Source: Jheelam Sarkar/NIUA/2022)*

*Figure 7 Spillage of Septage during Desludging (Source: Jheelam Sarkar/NIUA/2022)*

With transportation losses in the drains, only 2% (1.8%) of wastewater from offsite system and 44% of the supernatant (figure 7. Spillage of Septage) from onsite system reaches to the treatment plant.

### 2.1.3 Treatment/Disposal

There are 2 STPs operational within the ULB limits, having a capacity of 1.5 MLD and 7 MLD each. The treatment technology of both the STPs are based on Sequential Batch Reactor. The 1.5 MLD plant is operational and its running at its design capacity; the 7 MLD plant is operational and running at 40-50% of its designed capacity. It can be conveyed from the SFD graphic (see figure2. Shit flow diagram of Ramnagar), that only 2% of the wastewater from the Offsite system along with 44% of the effluent/supernatant from Onsite system gets treated, whereas with no provision of co-treatment of faecal sludge, 42% of the emptied FS/Septage never gets delivered to treatment and is currently dumped into private pits (see figure 9. Private disposal sites) made by the Cesspool owners and in some cases dumped into the farm lands.

*Figure8. 7 MLD Transport Nagar STP, Ramnagar (Source: Sachin Sahani/NIUA/2022)*

*Figure 9 Private disposal site for Septage/faecal Sludge. (Source: Sachin Sahani/NIUA/2022)*

The wastewater from both the STP is dumped into the Kosi River, which flows in the vicinity. Continuous monitoring of treated wastewater makes sure that it fulfils the CPCB norms for treated wastewater and illegal dumping of faecal sludge into the STPs units is strictly prohibited by the governing authority. The sludge produced from wastewater post dewatering is disposed off in open field[4] area designated by Peyjal Nigam, Ramnagar.

[4] Authorisation letter for disposal of Sludge produced by the STPs.
Link: https://drive.google.com/file/d/1PsgHL-uinPwI9SusgOpFw2IapPTZej3L/view?usp=sharing

# Section 3. Design Consideration:

As per the 2011 census, the population of Ramnagar Nagar Palika was 54,787. Horizontal growth of the city. The growth pattern was studied using different projection method until the mid-design period (i.e., for 7 years from 2023) of the 7 MLD STP which is considered as a for co-treatment of septage/faecal sludge facility due to its under-capacity utilization.

*Table 2 Population projection Ramnagar ULB*

| **Year** | **Projection Method** | | | |
|---|---|---|---|---|
| | **Curve fitting Method ($y = ae^{bx}$)** | **Arithmetic Increase Method** | **Incremental Increase Method** | **Geometric Increase Method** |
| 2011(census) | 54787 | 54787 | 54787 | 54787 |
| 2021(base year) | 82408 | 77702 | 77702 | 77702 |
| 2022 | 84929 | 78503 | 78566 | 80041 |
| 2023 | 87527 | 79303 | 79441 | 82451 |
| 2024 | 90205 | 80104 | 80327 | 84934 |
| 2025 | 92965 | 80904 | 81225 | 87491 |
| 2026 | 95810 | 81705 | 82134 | 90125 |
| 2027 | 98741 | 82506 | 83055 | 92839 |
| 2028 | 101762 | 83306 | 83987 | 95634 |
| 2029 | 104876 | 84107 | 84931 | 98514 |
| 2030 | 108084 | 84907 | 85886 | 101480 |
| 2031 | 111391 | 85708 | 86853 | 104535 |
| Average Growth Rate per year | 4.3% | 1.03% | 1.17% | 3.5% |

Based upon the discussion with the ULBs officials and recent development in the city, Curve fitting method goes par with the growth regime, therefore geometric increase method was adopted which gave much more realistic judgement for growth to be considered for the upcoming years with an average rate of growth of 3.5% per annum. The predicted average growth rate for the decade up to 2031 works out to 35% subject to the condition that no additional areas are included under the municipal limits.

### 3.1 Design period:

The plant design period is considered as 7 years since the service life of all major structural components shall be of a lifecycle period of 20 years. Considering the year of implementation as 2022, the population to be served at the beginning i.e. 2023, after 7 years shall have to be estimated. For the next 3.5 years depending upon the actual growth pattern of the population, development of the on-site sanitation system within the municipal boundaries, growth of commercial and other institutions, who can contribute to the net demand shall have to be worked out before the end of the service period. In other words, full capacity utilization of the first plant setup is to be achieved and thereafter capacity augmentation can be made with appropriate modification of the facilities. Hence, in this analysis a demand period of 7 years and a service period of 15 years at full capacity after 7 years has been considered.

The projected population for the year 2023 using the above relation comes to 82,451 and population at the end of the period 2030 will be 1,01,480. The co-treatment facility remains in operational for the said period as well as when sewer network is laid in the city, hence a 30 KLD capacity facility is being proposed.

**3.2 Determination of Plant Capacity:**

Plant capacity is dependent upon the volume of sludge that is likely to be produced during the design period. The initial plant loading shall be based on the population contribution at the beginning i.e. during the year 2023 and shall increase @ [{(101480 – 82457) / 7} / 82451] x 100 = 3.29% annually. The design flow can be determined in two different considerations. One is based on the on-site system that is actually existing and likely to be constructed through enforcement of pollution control law / rule with regard to discharge of sewage / wastewater to open environment by the households. The other one is based on the contribution directly by the population. In any case, the demand or generation of sludge shall remain highly fluctuating throughout the service period of the facility. Similarly, collection of the entire faecal sludge or septage that is generated may not be possible due to difficulty in approach, unwillingness of the housekeeper or badly designed on-site system. Therefore, a reasonably precise quantification of the sludge by production method may not be applicable under the present scenario of urbanization in Ramnagar.

Though the ultimate aim is to deliver all septage or faecal sludge that is produced, it is unrealistic to assume that all so produced septage/faecal sludge shall be collected and transported initially to the STP for treatment. Hence, a reasonable quantity is required to be derived.

**3.3 Septage/ Faecal Sludge Estimation**

Collection based Method 1:

1) Average Containment Size : 4 cu.m

   Since, the desludging vehicles operating in Ramnagar have a maximum vehicle capacity of 4500 Litre and while emptying, some portion is still left within the containment.
   In order to pay less only one trip of desludging is performed as multiple trips will be required to desludge the containment for bigger size. HHs in Ramnagar usually desludge the tank only when smell or overflowing of faecal matter is noticed in drains.

2) Percentage of HHs emptied : 50 % within 5-year time
3) Average HHs size : 5
4) Population to be served at end of 2023 : 82451
5) Total HHs : 16490
6) Average house hold septage generation @ emptying done once in 5 year and Service provided 300 day/year : 22 cu.m/d
7) Considering 15% for CT/PT, Commercial & Institutions : 3 cu.m/d
8) Total Septage Generation/ day : 25 cu.m/d

Assuming a growth rate of 3.5% per annum

*Table 3 Estimated Septage generation Upto design period*

| Year | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|
| KLD | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |

Collection based Method 2:

1) Number of tankers operational in Ramnagar ULB (Private & ULB Registered) : 4
2) Average emptying frequency (i.e. KII 20 trips in 30 days) : 0.8/day
3) Tanker size (effective) : 4000 litre
4) Septage generation at present 2022 : 11KLD

Since, all the private truck operator couldn't be tracked during the surveys conducted, as some operators were providing services from the nearby ULB (Kaladungi), in such case the present septage generation can reach a figure of 15 KLD (1 extra tanker size considered).

Therefore, a 30 KLD facility is being proposed which shall be suitable to cater the load only for Ramnagar, as Kaladungi ULB is 27 kms away from the point of disposal (i.e., 7 MLD STP). Although, the current collection of FSS is 15 KLD and the proposed facility is 30 KLD; In order to improve the septage collection and emptying practices in the city-related septage management By-laws will be constituted and further IEC activities shall be carried out.

### 3.4 Septage/faecal sludge characterization

**Analysis Report on Faecal Sludge Characterization of Samples from Ramnagar City**

To check the feasibility of the proposed DPR shared by Ramnagar Peyjal Nigam for Co-treatment at this operational 7 MLD STP and to understand and assess the overall functioning of the plant, faecal sludge samples were collected from different locations (sludge dumping sites, households and CT/PTs) for a characterization study, twice; see Annexure-2 for details of the sample collection with chain of custody forms prepared.

*Figure 10 Household survey, Gangotri Vihar, Ramnagar (Source: Sachin Sahani/NIUA/2022)*

*Figure 11 Sample collection Post Desludging, Gangotri Vihar, Ramnagar. (Source: Sachin Sahani/NIUA/2022)*

The FS samples were collected following grab sampling method, from Gangotri Vihar (figure 11. Sample collection Post Desludging) , Gaujani, on 2nd February, 2022 and processed for analysis on the same day, by the Sample Testing Laboratory at the Transport Nagar STP (Ramnagar). The results were received on 8th February, 2022; as mentioned in Table 4.


*Figure12 .FSS sample collection from Ramnagar*
*(Source: Sachin Sahani/NIUA/2022)*

*Table 4 Faecal Sludge Characterization for Ramnagar city for samples collected on 02.02.2022*

| Sl. No. | Parameter | SI units | Results | | | | Average Value |
|---|---|---|---|---|---|---|---|
| | | | **Sample-01** | **Sample-02** | **Sample-03** | **Sample-04** | |
| 1 | pH | - | 1 | 1 | 1.1 | 1.4 | **1.1** |
| 2 | SVI | mL/g | 57.37 | 64.55 | 64.66 | 69.9 | **64.12** |
| 3 | TS | mg/L | 22,700 | 21,640 | 21,625 | 20,915 | **21,720** |
| 4 | TSS | mg/L | 13,950 | 12,945 | 12,935 | 12,840 | **13,168** |
| 5 | TDS | mg/L | 8,750 | 8,695 | 8,690 | 8,075 | **8,553** |
| 6 | COD | mg/L | 3,040 | 2,986 | 2,826 | 2,400 | **2,813** |
| 7 | BOD | mg/L | 995 | 942 | 876 | 835 | **912** |
| 8 | BOD/COD | - | 0.33 | 0.32 | 0.3 | 0.35 | **0.3** |

Source: Test results provided by Transport Nagar STP Laboratory

Note: To check the results of Transport Nagar STP Laboratory, refer to Annexure 4

Since, the results obtained from the first study were in contradiction to the suggested FSS values given in CPHEEO Manual and the values given IIT Roorkee study[5], therefore, another study was conducted, where FS samples were collected following grab sampling method, from

[5] NIUA (2019). Co-Treatment of Septage at STPs of Ganga Towns in Uttarakhand

5 different locations (including HHs and CT/PTs) viz. Kaniya, Durgapuri, Ramnagar PWD, Jakhanpur and Bhawaniganj on 7th April, 2022 (figure 12. FSS sample collection from Ramnagar) and processed for analysis, by Pollution Control Research Institute (PCRI), BHEL at Ranipur, Haridwar. The results were received on 6th May, 2022; as mentioned in Table 5.

*Table 5 Faecal Sludge Characterization for Ramnagar city for samples collected on 07.05.2022*

| **Sl. No.** | **Parameter** | **SI units** | **Results** | | | | | **Average Values** (Considered) |
|---|---|---|---|---|---|---|---|---|
| | | | **Kaniya** | **Durgapuri** | **Ramnagar-PWD** | **Jakhanpur** | **Bhawaniganj** | |
| 1 | pH | - | 7.7 | 7.2 | 7.4 | 7.0 | 6.9 | **7.2** |
| 2 | Alkalinity | mg/L | 480 | 392 | 540 | 448 | 480 | **468** |
| 3 | Oil and grease | mg/L | 11.3 | 13.1 | 12.9 | 10.3 | 12.93 | **12.11** |
| 4 | SVI | (v/v) % | 26 | 82 | 60 | 62 | 75 | **61** |
| 5 | TS | mg/L | 11,652 | 60,314 | 20,524 | 38,016 | 48,230 | **35,747** |
| 6 | TSS | mg/L | 11,014 | 59,978 | 20,092 | 37,540 | 48,004 | **35,236** |
| 7 | VSS | mg/L | 8,276 | 47,892 | 15,668 | 31,022 | 39,054 | **28,382** |
| 8 | COD | mg/L | 3,600 | 12,400 | 8,800 | 9,200 | 11,200 | **9,040** |
| 9 | BOD | mg/L | 1,100 | 4,800 | 2,900 | 3,700 | 4,600 | **3,420** |
| 10 | BOD/COD | - | 0.3 | 0.4 | 0.3 | 0.4 | 0.4 | **0.4** |
| 11 | Total Coliforms | MPN/ 100 mL | $18 \times 10^6$ | $86 \times 10^6$ | $44 \times 10^6$ | $77 \times 10^6$ | $81 \times 10^6$ | **$61 \times 10^6$** |
| 12 | Faecal Coliforms | MPN/ 100 mL | $7 \times 10^6$ | $34 \times 10^6$ | $15 \times 10^6$ | $32 \times 10^6$ | $40 \times 10^6$ | **$26 \times 10^6$** |
| 13 | TKN | mg/L | 9.8 | 56 | 29.4 | 46.4 | 67.2 | **41.8** |
| 14 | Total Nitrogen | mg/L | 129 | 133.8 | 32.2 | 63.6 | 67.8 | **85.3** |
| 15 | $NH_3$-N | mg/L | 6.85 | 31.8 | 8.27 | 14.53 | 10.81 | **14.45** |
| 16 | Total Phosphate | mg/g | 0.15 | 0.15 | 0.10 | 0.49 | 0.25 | **0.23** |

Source: Test results provided by PCRI, BHEL, Haridwar

Note: To check the results of PCRI Laboratory, BHEL, Haridwar, refer to Annexure “4”

**Observation**

Grab samples were collected from sludge dumping site at Gangotri Vihar, Gaujani, in four sets, and analysed respectively, for the first study, by the Sample Testing Laboratory at the Transport Nagar STP (Ramnagar); see Annexure-II for details of sample site. The parameters checked for the characterization study of all the sets include pH, Sludge Volume Index (SVI), Total solids (TS), Total suspended solids (TSS), Total dissolved solids (TDS), Chemical oxygen demand (COD) and Biochemical oxygen demand (BOD).

The pH of the sample ranges from 1-1.5, which is very acidic. Sludge Volume Index is 64 mL/g, indicating that the sludge is dense and has rapid settling characteristics. Total solids present in the sample counts to 21,720 mg/L and Total suspended solids counts to 13,168 mg/L. The average COD of the sample is 2,813 mg/L and BOD is 912 mg/L, which gives a BOD/COD ratio of 0.3.

Similarly, for the second study, grab samples were collected from 5 different locations (3 HHs and 2 CT/PTs) viz. Kaniya, Durgapuri, Ramnagar PWD, Jakhanpur and Bhawaniganj, and analysed respectively, by Pollution Control Research Institute (PCRI), BHEL at Ranipur, Haridwar; see Annexure-II for details of sample sites. The parameters checked for the characterization study of all the sites include pH, Alkalinity, Oil and grease, Sludge Volume Index (SVI), Total solids (TS), Total suspended solids (TSS), Volatile suspended solids (VSS), Chemical oxygen demand (COD), Biochemical oxygen demand (BOD), Total coliforms (TC), Faecal coliforms (FC), Total Kjeldahl Nitrogen (TKN), Total nitrogen (TN), Ammoniacal nitrogen ($NH_3$-N) and Total phosphates (TP).

The pH of the samples range from 6.9-7.7, which is considerably neutral. Sludge Volume Index is 61mL/g, indicating that the sludge is dense and has rapid settling characteristics. Total solids present in the sample counts to 35,747 mg/L and Total suspended solids counts to 35,236 mg/L representing the amount of Dissolved solids to be 511 mg/L. The average COD of the samples is 9,040 mg/L and BOD is 3,420 mg/L, which gives a BOD/COD ratio of 0.4. The Alkalinity of the sludge ranges from 392-540 mg/L. Oil and grease content ranges from 10.3-13.1 mg/L, which is quite lesser in amount. The Total coliforms count to 61 x $10^6$ MPN/100 mL and Faecal coliforms count to 26 x $10^6$ MPN/100 mL. The average TKN content of the samples is 41.8 mg/L, Total nitrogen content is 85.3 mg/L, Ammonical nitrogen content is 14.45 mg/L and the average Total phosphate content is 0.23 mg/L, which is lesser in amount as well.

Since, there is limited information available, for checking the parameters of faecal sludge, as the standards vary depending upon the location, typology, climate, food habits, desludging frequency etc.; so, the results from both the studies were compared with standards like US EPA guidelines for FS type A and B (1984) and a report on Co-Treatment of Septage at STPs of Ganga Towns in Uttarakhand, by IIT Roorkee; to understand the quality of the sludge, as depicted in Table 6.

*Table 6 Comparison Study of Results*

| Parameter | SI units | Average value of Sludge samples collected from Ramnagar on 02.02.2022 | Average value of Sludge samples collected from Ramnagar on 07.04.2022 | Values reported by IIT Roorkee, 2019 | US EPA (1984) |
|---|---|---|---|---|---|
| **pH** | - | 1-1.4 | 6.9-7.7 | 8-13 | 1.5-12.6 |
| **Alkalinity** | mg/L | Not tested | 392-540 | 400-750 | 970 |
| **Oil and grease** | mg/L | Not tested | 10.3-13.1 | 2000-5500 | - |
| **SVI** | mL/g | 64.12 | 61 | - | - |
| **TS** | mg/L | 21,720 | 35,747 | - | 34,106 |
| **TSS** | mg/L | 13,168 | 35,236 | 28,308 | 12,862 |
| **TDS** | mg/L | 8,553 | Not tested | - | 21,244 |
| **VSS** | mg/L | Not tested | 28,382 | 20,051 | 9,027 |
| **COD** | mg/L | 2,813 | 9,040 | 30,370 | 31,900 |
| **BOD** | mg/L | 912 | 3,420 | 18,372 | 6,480 |
| **Total Coliforms** | MPN/100 mL | Not tested | $61 \times 10^6$ | - | - |
| **Faecal Coliforms** | MPN/100 mL | Not tested | $26 \times 10^6$ | - | $< 2 \times 10^6$ |
| **TKN** | mg/L | Not tested | 41.8 | 140 | 588 |
| **Total Nitrogen** | mg/L | Not tested | 85.3 | 141 | - |
| **$NH_3$-N** | mg/L | Not tested | 14.45 | 123 | 97 |
| **Total Phosphate** | mg/g | Not tested | 0.23 | 481 | 210 |

**Inference based on Comparison**

The pH is very acidic in the first study; where as it is in a neutral range in the second study. Total solids and Total suspended solids lie in a low range than the mentioned limit in US EPA guidelines, in the first study; while in the second study the TS and TSS ranges a little higher than the mentioned standard values by US EPA. Also, the BOD and COD are much lower than the mentioned ranges in US EPA along with the report published by IIT Roorkee, in the first study and the second study as well, even while the values in the second study are quite higher than that in the first study. Though, the BOD/COD ratio indicates that the sludge is slowly biodegradable in nature in both the cases, but needs to be acclimatized for further treatment.

Moreover, the higher content of volatile suspended solids indicate the presence of more readily degradable organic matter; and the VSS/TSS ratio ( i.e. 0.8) stipulates the potential for further stabilization treatment, to reduce the volatile content. A feasibility study was done to check whether it is possible to direct discharge the raw faecal sludge at receiving well sump of STP or not. See Annexure “5” to find the results.

According to DPR of 7 MLD STP in Ramnagar, the Sewage Treatment Plant design period is considered for 15 years. The proposed modules can easily cater to FSS collected in RNPP with no expansion area for similar period. As quantity of faecal sludge is considered for co-treatment is calculated based on the actual demand for faecal sludge being emptied within municipal boundary and in coming years from extended area in the vicinity. STP design parameters as per the data provided by UKJN officials, the STP is designed for the following inlet and outlet parameters, as depicted in Table 7.

*Table 7 Design Parameters of Outlet Characteristics of STP (Source: DPR 7 MLD STP, Ramnagar)*

| **Raw Sewage Characteristic** | **Inlet Concentration** | **Outlet Concentration** |
|---|---|---|
| pH | 6.5 to 8.5 | 6.5 to 8.5 |
| Biochemical Oxygen Demand ( 5days @ 20°C) (mg/l) | 230 | Less than 10 |
| Chemical Oxygen Demand (mg/l) | 450 | Less than 100 |
| Total suspended solids (mg/l) | 400 | Less than 10 |
| Total Kjeldahl Nitrogen (mg/l) | 45 | Less than 5 |
| Total Phosphorus (mg/l) | 8 | Less than 2 |
| Faecal Coliform Count, MPN/100 ml | 1000000 | Less than 230 |

## Section 4. Proposed Co-treatment Module:

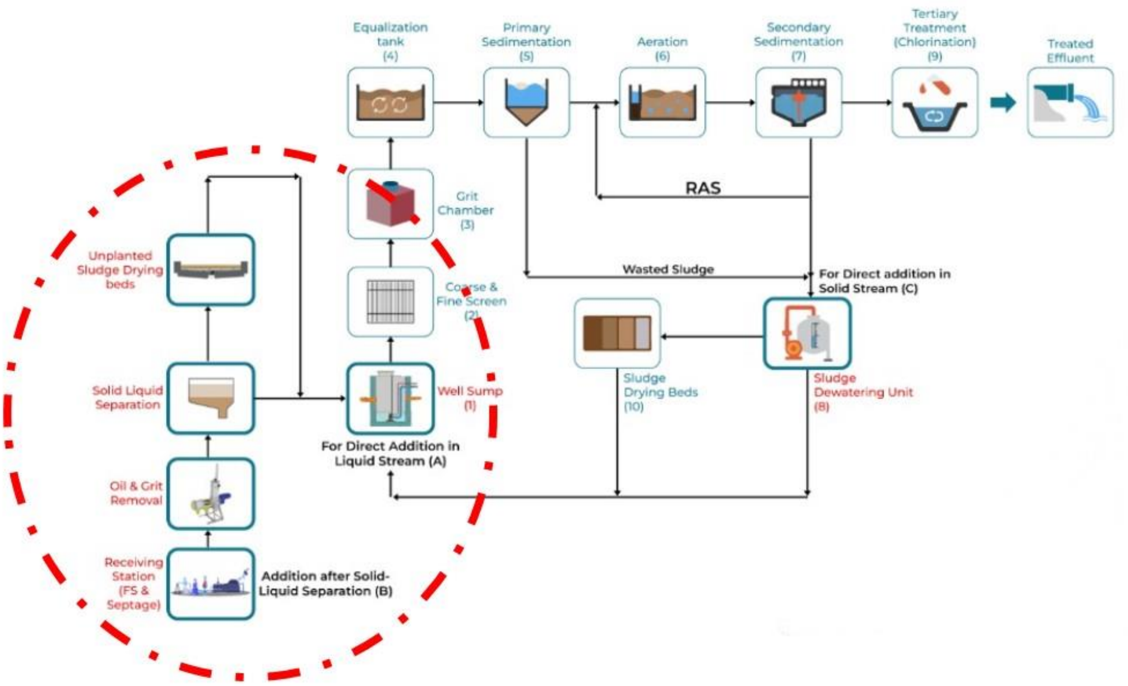


*Figure 13 Process flow diagram depicting Co-treatment at the STP*

The process flow diagram represents the various possibilities of co-treatment of septage at STP, which are direct addition of septage in the liquid Stream, addition after solid- liquid separation and direct addition in the solid stream. Post analysing the DPR of the 7 MLD STP and after performing the Characteristic Study of the faecal sludge/septage, it was decided to go for Addition of faecal sludge/septage post solid liquid separation into the liquid stream of STP. The designed modules may vary as per the space constraint and assumed design parameters.

### 4.1. Design for Inlet Channel (Hydraulic Capacity)

- Flow rate from the Desludging vehicle: 0.0067 $m^3/s$
- Downward slope (I) 0.01
- Width(b) to depth (b) Ratio: 2
- Mean Depth for Rectangular Section (i.e. Cross-Sectional area/ Wetted Perimeter) d/2
- Chezy's Coefficient (C) = 50 (i.e., lined channels)
- Average Mean Velocity(V) by Chezy = C √R * √I = 3.53√d
- Depth of channel = 136 mm, Breadth of channel = 273 mm
- V=3.53√0.1368 = 1.30 m/s

Since these, dimension were relatively small and the equation for $Head_{loss}$ = 0.0728 ($V_s{}^2$- $V_a{}^2$), is not determinate (Kevin Tyler, 2018) because the relationship between $V_s$(flow velocity through the openings in the screen (m/s)) and $V_a$(approach velocity (m/s)) is dependent on the head loss through the screen). The situation is further complicated by the intermittent and variable nature of discharges to the treatment plant. When a tanker starts to discharge, the liquid level upstream of the screen rises until an equilibrium level is reached, at which point the flow through the screen equals the discharge. The level then starts to drop as the flow from the tanker reduces. The equilibrium level may be influenced by downstream conditions. Clogging of the screen will reduce the area available for flow through the screen and so increase the head loss across the screen.

Given the relatively small discharge, flows received at most plants, it will normally be sufficient to use the following criteria to size screening chambers:

• Width: minimum 300 mm, preferably 450 mm to allow easy access
• Depth: minimum 500 mm, preferably 750 mm.

Therefore, based on the size of the screens, the depth and width of the Inlet Channel is derived, as these screens shall be mounted in the channel. The total depth of the channel will be 0.750m and length 2.25 m. A slope of 1% may be provided towards the bar screen inlet of the settling cum thickening tank. The length of channel may vary depending upon the loading point and the settling tank location, since Manning's equation considered more parameters (i.e., channel alignment, surface roughness and cross-section irregularities) for defining the roughness coefficient, it made it more justifiable for consideration.

- Emptying time of one truck of 4000 litre capacity = 10 minutes
- Discharge (Q) = 400 litre per minute = 0.0067 $m^3/s$
- A channel width of 450 mm is considered = 'b'
- Adopt Manning's 'n' = 0.014 (concrete with surface punning)
- Using Manning's equation, the section factor $AR^{2/3}$= n x Q / √S
  = 0.014 x 0.006 / √ (0.01) = 0.009

Considering a rectangular section: hydraulic radius R = (by / b + 2y)

- $AR^{2/3} = BY^{5/3} / (B + 2Y)^{2/3} = 0.009$
- $0.45Y^{5/3} / (0.45 + 2Y)^{2/3} = 0.009.$

y =120 mm or 0.12m $A_w$ (wetted area) = 0.054 $m^2$ . $P_w$ (wetted perimeter) = 0.69m

V: velocity of flow in the discharge channel = (1/0.014) x $(0.054/0.69)^{0.67}$x $0.01^{0.5}$
= 1.29 m/s > 0.8 m/s

The Inlet (mouth) of the Inlet channel should be spill proof with diameter of the mouth 4 inches wide (i.e. 100 mm). The chamber shall have a depth of 750 mm, breadth 450 mm and length of 2250 mm. The inlet should accommodate a fixed hosepipe of 3-4 ft for both the channels. These pipes when not in use should be hanged with a hook (at a height of 4ft from the base). Emptier should connect this hosepipe to discharge mouth of the tanker and then slowly open the valve. The hosepipe must be cleaned with water on regular basis to avoid deposition of sludge in the pipe. A slope of 1% shall be provided towards to the coarse screen to accommodate ease of flow and not let the screenings pass the screen. Two channels should be constructed in parallel, so that one channel remains functional while the other goes for cleaning and maintenance.

### 4.2. Bar Screen:

A coarse bar screen made of stainless steel of 316 grade with 10mm diameter and 25 mm spacing shall be provided at an angle of 135º to the direction of flow or 45º to the vertical. The screen should be placed in the chamber at a distance of 1000 mm from the inlet. The particular screen should be placed through casing in the inner side of wall. Perforated tray must be placed parallel to the screen in order to collect screenings and for ease of maintenance for cleaning purpose.

Dimension of coarse screen

- Height from the bottom of the tank = 600 mm
- Spacing b/w bars = 25 mm
- Diameter of bars = 10 mm

Numbers of bars (n) required:

- Total breadth of the Inlet channel = No. of Circular Bars x Dia. Of bars + (No. of Circular Bars + 1) x Spacing b/w bars
- 450 = 10 x n + (n+1) 25
  No. of bars (n) in the channel = 12   No. of spacing (n) in the channel = 13

### 4.3. Fine screen

Rack mounted Perforated fine screen with 6mm opening should be placed at a distance of 200 mm from the coarse screen with an angle of 120 degree to the direction of flow or 60 degrees to the vertical axis. This screen will be hanged with hinge support by the channel wall and could be removed for cleaning purpose.

### 4.4. Grit chamber

A chamber having a depth of 700 mm from the inlet channel base and width of 300 mm and length 2000 mm shall be made at the outlet of the Inlet Channel in order to accommodate the Grits (detention time approx. 1 minute (2 *0.7*0.3 / 0.0067)). A 2% transverse slope should be provided at the beginning from the inlet to the other end of the outlet and a 3mm perforated tray shall be placed at the outlet in order to collect the grit and ease of maintenance.

### 4.5. Settling-cum-Thickening tank

Settling-thickening tanks are used to achieve separation of the liquid and solid fractions of faecal sludge / septage. They were first developed for primary wastewater treatment, and for clarification following secondary wastewater treatment, and it is the same mechanism for solids-liquid separation as that employed in septic tanks. Settling-thickening tanks for FS / septage treatment are rectangular tanks, where FS is discharged into an inlet at the top of one side and the supernatant exits through an outlet situated at the opposite side, while settled solids are retained at the bottom of the tank, and scum floats on the surface (Figure 14).

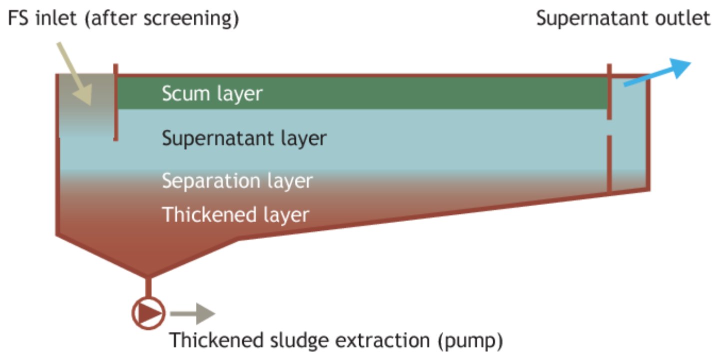


*Figure 14 Schematic of the zones in a settling-thickening tank. (Source: Magalie Bassan et al.)*

During the retention time, the heavier particles settle down and thicken at the bottom of the tank because of gravitational forces. Lighter particles, such as fats, oils and grease, float to the top of the tank. As solids are collected at the bottom of the tank, the liquid supernatant is discharged through the outlet. Quiescent hydraulic flows are required, as the designed rates of settling, thickening and flotation will not occur with turbulent flows. Baffles can be used to help avoid turbulence at the inflow, and to separate the scum and thickened sludge layers from the supernatant. Following settling-thickening, the liquid and solid fractions of FS or septage require further treatment depending on their final fate, as the liquid and solids streams are still high in pathogens, and the sludge has not yet been stabilised or fully dewatered. Settling-thickening tanks can be used in any climate, but are especially beneficial when treating FS or septage with a relatively low solids concentration, and/or in temperate or rainy climates. This is an important consideration in urban locations where space is limited, as it can reduce the required area of subsequent treatment steps. For instance, achieving solids-liquid separation in settling-thickening tanks prior to dewatering with drying beds reduces the required treatment area (footprint) for drying beds.

**4.5.1 Settling mechanism:**

In settling-thickening tanks, the suspended solid (SS) particles that are heavier than water settle out in the bottom of the tank through gravitational sedimentation. The types of settling that occur are:

- Discrete, where particles settle independently of each other.
- Flocculent, where accelerated settling due to aggregation occurs.
- Hindered, where settling is reduced due to the high concentration of particles (Ramallo, 1977)
  .

Discrete and flocculent settling happen rapidly in the tank. Hindered settling occurs above the layer of sludge that accumulates at the bottom of the tank, where the suspended solids concentration is higher. These combined processes result in a reduction of the solids concentration in the supernatant, and an accumulation of solids at the bottom of the tank. Particles with a greater density settle faster than particles with lower densities. Based on the fundamentals of settling the distribution of types and shapes of particles in FS (and their respective settling velocities) could theoretically be used to design settling-thickening tanks. Although this theory is important in understanding the design of settling-thickening tanks, the reality is that when designing a settling tank, empirical values are determined and used for the design based on the characteristics of the FS in specific conditions. The theoretical settling velocity as per Stokes Law of a particle is given by Equation 1. It is defined by the velocity attained by a particle settling in the tank as the gravitational strength.

$$V_c = \frac{4}{3} * \left(\frac{g\ (\rho_s - \rho) d}{C_d\ \rho}\right)^{0.5} \qquad \text{Equation (1)}$$

Here, $V_c$ = final settling velocity of the particle (m/h)
g = gravitational acceleration (m/$s^2$)
$\rho_s$ = particle density (g/l)
$\rho$ = fluid density (g/l)
$C_d$ = drag coefficient

The critical settling velocity $V_c$ is selected based on the amount of solids that are to be removed. Theoretically, if the flow is laminar (i.e., not turbulent) and there is no shortcutting of the hydraulic flow in the tank, all the particles with a velocity greater than $V_c$ will be removed. This allows the tank to be designed based on the percentage of desired particle removal in the settled sludge. As the flow in the tank is lengthwise, the length has to be designed to be long enough to ensure that particles with $V_c$ have adequate time to settle out below the level of the outlet. Particles with $V_c < V_{C0}$ will not have time to settle out, and will remain suspended in the effluent (as shown in Figure 15). Selection of $V_c$ for actual design purposes is discussed in paras to follow.

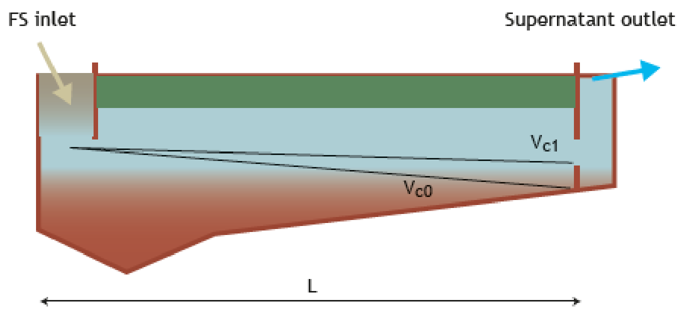


*Figure 15 Schematic of the final settling velocity ($V_c$) needed for a particle to settle in a tank of length L. (Source: Magalie Bassan et al)*

### 4.5.2 Thickening

Particles that accumulate at the bottom of the tank are further compressed through the process of thickening. The settled particles are compressed due to the weight of other particles pressing down on them, and water is squeezed out, effectively increasing the concentration of the total solids. This happens as a result of gravity, when the concentration of SS is high and inter-particle strengths hinder the individual movement of particles. Allowing room in the tank for sludge storage as it settles and accumulates is an important consideration in the design of tanks, because as sludge accumulates, it effectively reduces the depth of the tank available for settling. This is also important in designing the ongoing operations and maintenance, and schedule for sludge removal.

### 4.5.3 Flotation

As stated earlier, similar to the settling and thickening mechanisms, the influence of gravitational strength due to density differences explains flotation. Buoyancy is the upward force from the density of the fluid. For particles that float, the buoyancy is greater than the gravitational force on the particle. Hydrophobic particles such as fats, oils and greases, and particles with a lower density than water are raised to the top surface of the tank by flotation. Some particles are also raised to the surface by gas bubbles resulting from anaerobic digestion. The layer that accumulates at the top of the tank is referred to as the scum layer.

### 4.5.4 Anaerobic digestion

Anaerobic digestion also occurs in settling-thickening tanks, mainly in the thickened layer. The level of digestion depends on the degree of the initial stabilisation of FS / septage, the temperature, and on the retention time inside the tank. This process degrades a part of the organic matter and generates gasses. Operational experience has shown that fresh FS that is not stabilised (e.g., from public toilets that are emptied frequently) does not settle well. This is because anaerobic digestion of fresh FS contributes to an increased up-flow from gas bubbles, and FS that is not stabilised contains more bound water. Thus, stabilised FS, especially the septage i.e. sludge from septic tanks and/or FS that is a mixture of stabilised and fresh sludge are more appropriate for treatment in settling-thickening tanks (Heinss et al., 1998; Vonwiller, 2007).

### 4.5.5 Solids-liquid zones

The interactions of these fundamental mechanisms result in the separation of the FS into four layers, as illustrated in Figure 13 (Heinss, 1998) (Metcalf and Eddy, 2003)

- A layer of thickened sludge at the bottom. The solid concentration is higher at the bottom than at the top of this layer.

- A separation layer between the thickened layer and the supernatant, as the transition between these is not immediate. Hindered settling occurs mainly in the separation layer, where the settled sludge is not completely thickened. Particles in the separation layer can be more easily washed out with the supernatant than particles in the thickened layer.

- A supernatant layer between the separation layer and the scum layer. This consists of the liquid fraction and the particles that do not settle out or float to the surface.

- A layer of scum at the top of the tank. This consists of the floating organic and non-organic matter, the fats, oils, and greases contained in FS, as well as particles that have been raised up by gases up flow.

The tank design is based on the estimated volume of FS, and the resulting supernatant flow, and production of scum and thickened sludge layers. An adequate design needs to include regular and efficient removal of the scum and thickened sludge, which needs to be considered to optimise the solids-liquid separation. These design aspects are discussed below, and examples are provided in the case studies and the design example.

A good understanding of site-specific FS characteristics is required in order to determine the tank surface and the volume of the scum, supernatant, separation, and thickened sludge layers. Determining an accurate value for influent loading of FS can be challenging depending on the local infrastructure and existing management system. The design loading needs to take into account that FS quantities and characteristics can vary seasonally. An empirical estimation of settling ability for the specific FS, for which the tank is being designed for, needs to be determined for adequacy in the design of the tank. Preliminary laboratory analysis should be conducted on the FS that is to be treated, especially in terms of settling ability, thickening ability, potential for scum accumulation and SS concentration (Strauss, 2000). It is important to ensure that the FS used for these tests is that which will actually be treated. For example, if there is an existing collection and transportation of FSS with the help of vacuum trucks, sludge should be sampled from the tankers, as this is what will be discharged into the treatment plant.

*Figure 16 Imhoff cones being used in analyses of sludge volume index (Source: SANDEC).*

The sludge volume index (SVI) is a laboratory method to empirically determine the settling ability of sludge based on the quantum of suspended solids that settle out during a specified amount of time. To determine the SVI, first the suspended solids content of FS is determined, and then a graduated Imhoff cone is filled with the FS sample that is left to settle (see Figure 15). After 30-60 minutes, the volume occupied by the settled FS is recorded in mL/L. The SVI is then calculated by dividing the volume of settled FS by the SS concentration (in g/L), which gives the volume of settled sludge per gram of solids. The Imhoff tests do not provide exact estimates of the depth of the thickened layer, as they are batch tests and not continuous loading as in a settling-thickening tank. Imhoff cones with volumes greater than one litre provide a more representative result as the wall effect is reduced (Heinss, S.A, Larmie,M Strauss, 1999). Based on experiences in the design of settling-thickening tanks for wastewater treatment plants, wastewater sludge with a SVI of less than 100 (mL/g SS) achieves good solids-liquid separation in settling-thickening tanks.

#### 4.5.6 Tank Surface and Length

The length of the tank needs to be sufficient and have adequate hydraulic distribution, to ensure that the entire tank surface area is used, and that particles have enough time to settle. The surface area of the settling-thickening tank can be calculated as shown in Equation 2, based on the up-flow velocity ($V_u$) and the influent flow ($Q_p$) (Metcalf and Eddy, 2003).

$$S = \frac{V_u}{Q_p} \qquad \text{Equation (2)}$$

S = Surface of the tank ($m^2$)
$Q_p$= Influent peak flow ($m^3$/h)
$V_u$ = up flow velocity (m/h)

$Q_p$= Q x $C_p$/h,

Where: Q = mean daily influent flow $C_p$= peak coefficient h = number of operating hours of the treatment plant (influent is only received during operating hours).

The up-flow velocity ($V_u$) is defined as "the settling velocity of a particle that settles through a distance exactly equal to the effective depth of the tank during the theoretical detention period" (Ramallo, 1977). It is used to calculate the acceptable inflow that will allow for particles with the defined settling velocity to settle out. Particles with a settling velocity slower than $V_u$ will be washed out with the supernatant. A value is selected for the desired percentage of suspended solids removal, and then the up-flow velocity is selected to be equal to the final settling velocity of the lightest particles that will settle in the tank. For example, as shown in Figure 14, $V_u$ = Vc0 > Vc1. Thus, for a given FS influent, the up-flow velocity in a tank surface corresponds to the removal of a given percentage of suspended solids. The peak coefficient is calculated by observation of when the greatest volumes of trucks are discharging at the FSTP. $V_u$ can be estimated based on SVI values. Despite the limits of the theoretical calculation for design purposes, methods and calculations to link, SVI and $V_u$ have been developed based on long-term experiences in activated sludge treatment (Pujol et al, 1990). However, this type of empirical knowledge does not yet exist for FS. $V_u$ = 0.5 m/h could be used for rectangular settling tanks treating FS that have a SVI less than 100 (personal experience, Pierre-Henri Dodane). Once the surface area has been calculated, the length: width ratio needs to be selected. For example, (Heinss, 1998) recommend a width to length ratio between 1:10 to 1:5. The lower the selected final settling velocity, the longer the tank needs to be, and the more particles that will settle out.

#### 4.5.7 Tank volume

Once the surface area of the tank has been determined, the volume can be calculated, considering the depth of the four layers described in Figure 13. It is necessary to plan for the reduction in depth that will occur due to the accumulation of scum and thickened sludge, which will result in solids washed out with the supernatant, if underestimated. The following values are recommended for designing tanks for FS / septage with similar characteristics:

- Scum zone: 0.4 m (with 1 week loading, 1 weeks' compaction and cleaning) to 0.8 m (with 4 weeks loading and 4 weeks' compaction and cleaning).
- Supernatant zone: 0.5 m
- Separation zone: 0.5 m

The depth of the thickened sludge zone needs to be calculated given the expected load inflow and the concentration of the thickened sludge ($C_t$). The design of a sufficient storage volume for the thickened sludge is crucial to avoid outflow of settled sludge during one operating cycle. Therefore, the expected operating cycle duration (i.e. loading, compaction and sludge removal) and methods for scum and thickened sludge removal need to be defined in the first place. The volume of the thickened sludge storage zone ($V_t$) can be calculated as shown in Equation 3 (Metcalf and Eddy, 2003).

$$V_t = \left(\frac{Q\ (C_i\ .e\ .N)}{C_t}\right) \qquad \text{Equation (3)}$$

Where:
$V_t$ = volume of thickened sludge storage zone (m3)
Q = mean FS daily inlet flow (m3/day).
$C_i$= suspended solids mean concentration of FS load (g/L)
e = expected settling efficiency (= proportion of suspended solids separated, as %)
N = duration of the FS load for one cycle in days
$C_t$ = suspended solids mean concentration of thickened sludge after the loading period (g/L)

The mean daily flow is used for the sludge accumulation estimate, but the peak flow is used for the tank surface and length design to ensure settling is achieved under all the expected operating conditions. The volume of the thickening zone is based on the expected settling of FS. It is not considered in the design, but longer storage times when the tanks are not loaded prior to sludge removal, result in increased thickening and compaction. In the field, average FS settling efficiencies of only about 60% have been observed, due to poor operation, maintenance, and gas up flow (Heinss, 1998). However, it is recommended to use 80% to estimate the maximum efficiency. Care must be taken to ensure a relatively accurate estimate of $C_t$. An overestimation will lead to an insufficient storage volume and to a reduced settling efficiency, as solids may be washed out without being able to settle. An underestimation will lead to the design of an unnecessarily large storage volume and increase in construction costs.

Inlet and outlet configuration Grit screening must be undertaken before the loading of FS into the settling-thickening tanks in order to facilitate maintenance (e.g., removal of coarse waste to avoid potential damage to pumps). The inlet zone should allow for the uniform and quiescent distribution of the flow in the whole tank and avoid short-circuiting. Therefore, baffles are recommended to help disperse the energy of the inflow, and to reduce the turbulence in the tanks. (Heinss, 1998) recommend locating the inlet zone near the deep end of tanks to improve the solids settling. The pumps for the extraction of the thickened sludge must be adapted to remove concentrated sludge. Easy access points should also be included to allow the sampling of sludge in these zones, and to ensure that easy repair of pumps is possible. The supernatant outlet zone should be located under the scum layer and above the thickened sludge storage layer. Baffles are useful to avoid washout of the scum with the supernatant. To ensure an optimal hydraulic flow, the outlet channel can be extended along the width of the wall (Heinss, 1998) .It must be at the opposite side of the in-let zone. Outlets that are positioned near to the shallower side of the tank reduce the carry-over of the settled solids from the thickening layer.

## Operation and Maintenance of Settling-thickening Tanks

At least two settling-thickening tanks should be operated alternately in parallel, in order to allow for sludge removal, as tanks should not be loaded during this time. The loading of FS, and the compaction and removal of the thickened sludge and scum comprise the main phases of an operating cycle. These periods allow for the expected solids-liquid separation and thickening operations. While the tanks are not loaded, additional compaction occurs prior to the removal of thickened sludge and scum, due to the lack of hydraulic disturbance (Heinss, 1998). During this time further solids-liquid, separation occurs, and the SS concentration increases in the thickened sludge and scum. The timing of the removal of sludge and scum as planned for in the design is essential to ensure that the settling-thickening tanks are functioning properly, and that there is adequate depth for the settling of particles, leading to a reduced solids-liquid separation. If it is observed that a higher volume of thickened sludge has accumulated than what was designed for, this means that the solid load is higher than expected, and operations should be appropriately altered. Sludge removal typically lasts a few hours to a day following the compaction period. Once in operation, detailed monitoring can be done to optimise compaction and sludge removal times based on actual operating conditions. The first step in sludge and scum removal is typically removal of the scum layer. The scum layer generally has a high solids concentration that cannot be easily pumped and can remain after the thickened sludge is removed, in which case it needs to be manually removed. If possible, scum can be removed with shovels from both sides of the tank when the tank is narrow enough for access, or by mechanical means such as vacuum trucks with strong pumps. Scum can also be removed manually or sucked by a vacuum tanker after emptying the tank and can be transferred into the STP well sump.

Secondly, the supernatant layer is frequently removed by gravity (depending on the design), an inspection pipe 150mm diameter is provided in order to completely empty the settling thickening tank. Post desludging, the inspection valve can be opened so that the supernatant layer gets dumped into the STP inlet sump. The thickened sludge can then be pumped or shovelled out of the tank after the supernatant has been removed. When a pump is used for extracting the thickened sludge, the supernatant layer does not need to be removed, as the supernatant layer can facilitate the pumping of thickened sludge as a pressure is maintained or in case of auto coupling eddy submersible pump is provided, a 3-way valve must be provided, to divert the pumped sludge layer into the dewatering beds. As tanks are frequently over 2 m deep, adequate access for sludge removal (and for tank and pump cleaning) is integrated into the design. The operator knows when it is time for sludge removal based on the loadings and times given in the design, and by visual observation. It is possible to design settling-thickening tanks with devices that continuously scrape and pump the thickened sludge out of the tanks, and remove the scum over the supernatant zone. These devices allow easier operation and increase the management flexibility, but increased operating and maintenance costs need to be taken into consideration. In addition, their use in DEWATS may not be viable considering energy requirement and operating cost of the plant.

Start-up period and seasonal variations: As settling-thickening tanks rely mainly on physical processes, there is no special requirement for start-up periods. It is however useful to adjust the load time, assess the depths of the different zones and optimise the compaction time and sludge removal frequency. Seasonal variations of meteorological conditions and FS characteristics may influence the efficiency of the tanks. For example, loss of water through evaporation could increase the solids content of the scum. High temperatures may also increase the anaerobic digestion process, and therefore the height of the scum layer. Performance of Settling-Thickening Tanks: The most important consideration in the performance of settling-thickening tanks is the separation of the liquid and solid fractions. The efficiency of the key mechanisms to achieve this are discussed here. Solids-liquid separation: In the field, the mean settling efficiency of operating tanks and ponds is about 50-60% of SS in the settled volume. This efficiency can reach up to 80% where the tanks have been adequately designed and operated (Heinss, S.A, Larmie,M Strauss, 1999).
The concentration of the thickened sludge (Ct) achieved depends on the operating cycle duration and the initial FS characteristics (thickening ability), as presented in Table 1. Achieving 60 g SS/L in the thickened zone for a seven days' load period seems a reasonable estimate.
The scum layer thickness and SS content depends mainly on the operating cycle duration, the FS characteristics and the evaporation process.

### 4.5.9 Treatment performance

The main objective of settling-thickening tanks is solids-liquid separation, not stabilisation or pathogen reduction. Further treatment steps are required for both the thickened solids and supernatant. Dissolved organic matter, nutrients, and suspended particles will remain in the supernatant. Examples include 50% of influent COD in the settled sludge, and 50% in the supernatant (Badji et al., 2011), and 10% influent BOD and 25% COD in the supernatant (Heinss, et al., 1998). Total pathogen removal or inactivation is also negligible. Many larger pathogens such as Helminth eggs settle out, and the amounts that are partitioned in the solids will be correlated to SS removal efficiency. (Heinss, 1998) Observed that 50% of the total Helminth eggs were partitioned in the thickened sludge.

*Table 8 Results of preliminary studies to determine design parameters (Source: Pierre-Henri Dodane et al ;)*

| Initial raw FS concentration | $\boldsymbol{C_i\,TS} = 7$ g TS/ l<br>$\boldsymbol{C_i\,SS} = 5$g TS/l |
|---|---|
| FS origin | Mainly from Septic Tanks (stabilized FS) |
| Total Volatile Solid % | < **7%** |
| FSTP operating time | 7 h/day<br>5 days/ week<br>52 weeks/year |
| Daily Peak flow coefficient ($\boldsymbol{C_p}$) | 1.6 |
| Concentration of thickened Sludge | 60 g SS/l |

| | |
|---|---|
| Settling ability | Good as SVI = 23 < <100 |

*Table 9 Results of preliminary studies to determine design parameters (Source: PCRI BHEL Lab, Haridwar 2022)*

| | |
|---|---|
| Initial raw FS concentration | $\boldsymbol{C_i\ TS}$ = 35.747 g TS/ l<br>$\boldsymbol{C_i\ TSS}$ = 35.236 g TS/l |
| FS origin | Mainly from Septic Tanks and Fully lined tank (stabilized FS) |
| Total Volatile Solid % | **5%** |
| FSTP operating time | 7 h/day<br>6 days/ week<br>52 weeks/year |
| Daily Peak flow coefficient ($\boldsymbol{C_p}$) | 1.6 |
| Concentration of thickened Sludge | 51 g SS/l as 5% solid content post settling and density of sludge considered 1020 kg/$m^3$ |
| Settling ability | Moderate as SVI = 61 <100 |

Advantages and Constraints of Settling-Thickening tanks

Settling-thickening tanks are efficient as a first treatment step as they rapidly achieve solids-liquid separation, they are relatively robust and resilient, and they reduce the volume of sludge for subsequent treatment steps.

Constraints of settling-thickening tanks include:

- Lack of experience operating with FS, and lack of empirical data and results on which to base designs on.
- Settled sludge still has relatively high water content and requires further dewatering; the liquid fraction remains highly concentrated in SS and organics.
- Pathogen removal is not significant, and the end products of settling tanks therefore cannot be discharged into water bodies or directly used in agriculture

### 4.5.10 <u>Design considerations:</u>

1. Faecal sludge origin: Fully lined tank & Partially from Septic tank (stabilised FS)
2. The terminal settling velocity in the tank is taken as $V_c$ = 0.5 m/hour based on SVI and prior case studies experience.
3. The expected settling efficiency is taken as 60% of SS as SVI is moderate.
4. Two parallel tanks are designed to allow alternate cleaning and loading.
5. The loading of one week is considered to minimise anaerobic digestion and gas up-flow. This entails one tank is to be loaded one week out of every two weeks while the other one is being emptied. Hence, the cycle of operation is two weeks.

6. A short compaction period of 2 days is considered before removal of thickened sludge, which means that the thickened sludge is scheduled to be removed after every 10 days where the sludge is still liquid for extraction through a sludge / slurry pump/submersible pump.
7. The daily peak co-efficient is considered as 1.6
8. The Co-treatment opening time is 7 hours a day and 6 days a week (N).
9. The operator has gained experience in wastewater treatment and therefore, the sludge pumping and tank cleaning is carried out correctly.
10. The initial TSS concentration in the septage is taken as 35.236 g/litre
11. Sludge settling characteristic is good i.e. SVI <100
12. Concentration of thickened sludge, '$C_t$' is taken as 51 g SS / litre

#### 4.5.11 <u>Design Calculation for Dimension:</u>

*Table 10 Dimension of Settling thickening tank*

| | | |
|---|---|---|
| Peak flow $Q_p$ $(m^3/h)$ | Q x $C_p$<br>30*1.6/7<br>6.85 | 6.85 $(m^3/h)$<br>(here 7 is operational hour) |
| Surface area (S) required $(m^2)$ | 6.85/0.5<br>13.71 | 13.71 $(m^2)$<br>Two tanks shall be made parallel to each other |
| Sludge quantity as TSS (M) | 30* 35.236 | 1057 kg/d |
| TSS mass of thickened sludge $(M_t)$ | 0.60* 1057 | 634 kg/d |
| Volume of thickened sludge$(V_t)$ | 634*6/ 51 | 74.61 $m^3$ / 10 days |
| Width to length Ratio | 0.2 | i.e. B = 0.10 L |
| Length | 11.71 m | Provided 21 m i.e.20 m including 1 m length for baffle wall from inlet and 1 m extra for outlet.<br>Note: 20m *2m shall be considered for sludge accumulation area. |
| Width | 1.2 m | Provided 2 m |
| Baffle wall length | 1 m including in 20m and 1 m at outlet. | |
| Zone Depth | | |
| Scum zone | 0.2 m | Considered as per 2 week cycle for 2 Tanks |

| | | |
|---|---|---|
| Supernatant zone | 0.5 m | (Heinss, 1998) |
| Separation zone | 0.5 m | (Heinss, 1998) |
| Thickening zone as per altered area | 74.61 / 42<br>1.77 m | Provided 1.8 m |
| Free board ( including beam depth of 250 mm for supporting slab ) | 0.5 m | |
| Total depth of the tank | 0.2+0.5+0.5+1.8+0.5<br>3.5 m | |
| **Tank Dimension ( 21 * 2 * 3.5 ) ( L x B x H) excluding wall thickness** | | |
| Slope towards Inlet | 2% | |
| Outlet baffle wall opening | 0.7 m below liquid surface | 1 m above bottom outlet |

Post solid-liquid separation the mass balance diagram can help to understand the physical and biological parameters associated with the separated liquid and solid stream of the septage/faecal sludge

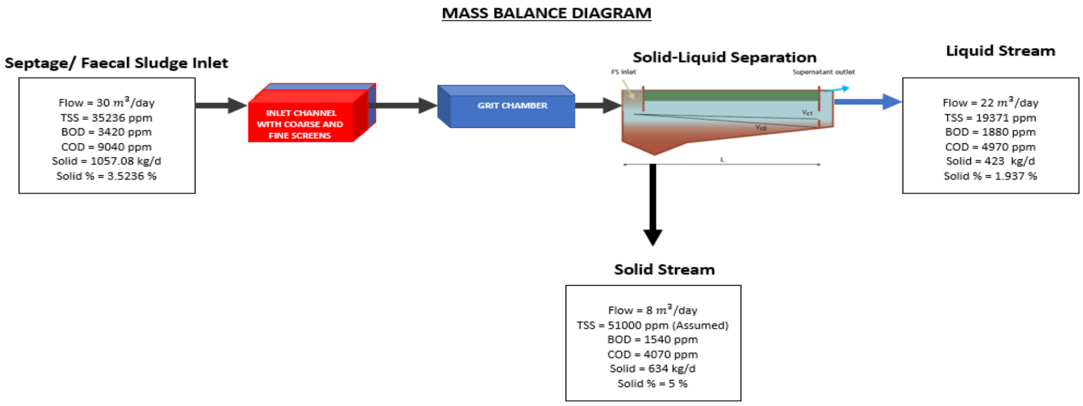


*Figure 17 Mass flow diagram post solid-liquid separation*

*Figure 18 Settling thickening tank, Bhubaneshwar (Source: Dhawal Patil, ESF)*

*Figure 19 Twin settling-thickening tanks of Rufi sque faecal sludge management plant, in Dakar, Senegal ( Source: SANDEC)*

## 4.6 Pump Requirement:

Conventional approach to pump the settled sludge in the settling thickening tank is done by a centrifugal pump placed in the dry well beneath the hopper pit. Since, its maintenance is difficult in the long run, use of submersible sludge pumps can be an economical option. Figure 20. Use of Submersible sludge pump in Basuaghai FSTP, Bhubaneshwar.

*Figure 20 Use of Submersible sludge pump in Basuaghai FSTP, Bhubaneshwar (Source: Sachin Sahani/NIUA)*

*Table 11 Pump requirement Calculation*

| | | |
|---|---|---|
| Volume of Sludge | 74.62 $m^3$ | Area of Settling thickening tank * Sludge thickened zone. |
| Diameter of pipe | 0.15 m | Minimum Dia. as per CPHEEO Manual Chapter 6, Design & Construction of Sludge treatment facilities. |
| Length (L) | 250 m | Approximate length of Delivery |
| Friction Coefficient of GI pipe (f) | 0.014 | |
| Cross sectional area of pipe (A) | 0.018 $m^2$ | |
| Flow rate (Q) (discharge) | 0.0207 $m^3$/s | Pumping done for 1 hour |
| Flow Velocity | 1.6347 m/s | Q = V * A; more than 0.6 m/s to prevent deposition and consequent loss of carrying capacity |
| Head loss $H_l$ due to friction | 1.6347 m | As per Darcy's Weisbach eqn. $H_l = \frac{f\,L\,V^2}{2\,gD}$ |
| Suction lift | 3.7 m | Effective depth of tank + 200mm of slab thickness |
| Work done against appurtenances | 0.5 m | (90-degree Elbows, valves etc.) |
| Total head against work to done | 5.83m<br>Say 6m | |

| | | |
|---|---|---|
| Since, length of delivery can vary with the positioning of dewatering drying beds Therefore, a head value of 11 m is provided. | | |
| Efficiency of Pump | 70% | |
| Unit Weight of Septage | 10.59 kN/ $m^3$ | Density of septage (1020 kg/$m^3$) * acceleration due to gravity (9.81 m /$s^2$) /1000 |
| Break horse power | 4.778 | Unit weight of Septage * Discharge * Total Manometric head / 0.746 * efficiency |
| Horse power | 4.840 | 1 BHP = 1.013HP |
| Power Required | 3610 W or 3.6 kW | 1 HP = 746 W |

Therefore, a 5 HP eddy submersible pump with auto-coupling mount should be placed at a distance of 6667 mm (i.e., L/3 approx.) from the inlet wall with at a ground clearance of 300 mm or 1 ft from the bottom surface and a 1m x 1m x 0.3m sump pit must be placed for effective delivery of sludge. Positioning of the pump can be decided as per the manufacturer, three such pumps shall be required including one pump for standby. Post Pumping of the thickened sludge, the 3-way valve can be used to divert the supernatant volume into the STP well sump. Eddy Submersible pump can withstand sludge that is more viscous, given a 30-70% solid pumping by volume; it must be selected as per the manufacturer’s suggestion.

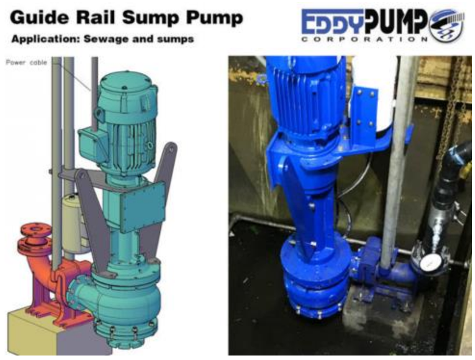


*Figure 21 Auto-Coupling Submersible pump (Source: eddypump.com)*

# Section 5. Dewatering of Settled Sludge:

The 7 MLD STP consists of two centrifuge sludge dewatering units currently operating at 16 hours/day with hourly flow rate of 10 $m^3$/h. Considering the volume of sludge sump which is 27.5 $m^3$, dumping the entire settled sludge from the settling thickening tank might could have over loaded the sludge sump, though achievable in batches. During the KII done with the plant operator, it was mentioned that the operational time for the dewatering units will be in increased in the future as its expected that biological parameter (e.g., BOD) will increase due to tapping of other drains.

In our investigation, in order to check whether these sludge dewatering units can be utilized for septage's settled sludge dewatering, the catalogue for Alfa Laval Decanter (Model: ALDEC) provided by the Plant Operator briefed about the solid content % handling of this model of unit which was in the range of 20-30%. In correspondence to the characteristic study report on faecal sludge/septage provided by BHEL, the TSS range was fluctuating between 11,114 to 59,972 mg/l with an average value of 35,236 mg/l. Utilizing the STPs dewatering unit might would have damaged the dewatering units and would have surely increased the DWPE dosing.

Finally, considering the space availability at the STP it was decided to choose the unplanted drying beds for dewatering the settled sludge from the settling thickening tank. There is ample number of Sun days available

### 5.1 Design and operational principles of unplanted sludge drying bed

A FS treatment plant (FSTP) or septage treatment plant consists of several drying beds in one location. Sludge is deposited on each of these drying beds where it remains until the desired moisture content is achieved. It is subsequently mechanically or manually removed for disposal or further treatment and reuse.

The drying process is based on two principles. The first principle is percolation of the leachate through sand and gravel. This process is significant with sludge that contains large volumes of free water and is relatively fast, ranging from hours to days (Heinss, 1998). The second process, evaporation, removes the bound water fraction and this process typically takes place over a period of days to weeks. (Heinss, 1998) Reported removal of 50 to 80% by volume due to drainage, and 20 to 50% due to evaporation in drying beds with FS. This range is typical for sludge with a significant amount of free water, but there is more evaporation and less percolation with sludge, that has more bound water. For example, no leachate was observed in a study with preliminary thickened sludge (Badji K., 2011). In planted sludge, drying beds evapotranspiration also contributes to water loss.

### 5.2 Unplanted sludge drying bed design parameters

When designing a drying bed, there are several influencing factors that need to be taken into consideration. These aspects vary from location to location, and can be grouped under climate factors and the type of sludge to be treated. Other key parameters that have an impact on the sludge drying process include the sludge-loading rate, the thickness of the sludge layer, and the total bed surface. All these aspects are discussed in the following sections

1) Climate factors

Climate factors affecting the operation of unplanted drying beds include the following:

- Humidity: high humidity reduces the contribution of evaporation to the drying process.
- Temperature: higher temperatures, also in combination with relatively low humidity and high wind, will enhance the total amount of water removed via evaporation.
- Rainfall: in locations where rainfall is frequent and occurs for long periods of time intense, a drying bed may not be feasible. Pronounced rainy seasons can be accommodated for by not using the beds in that period, or by covering them with a roof. Rainfall will may rewet the sludge, the intensity of which depends on the phase of drying.

2) Type of faecal Sludge

The origin of the sludge is important when using drying beds. Septic tank sludge has less bound water and is hence more readily dewatered than fresh FS. In other words, it is considered to contain a lower specific sludge resistance for dewatering. It therefore can be applied in a thicker sludge layer or at a higher total solids loading rate or at a higher sludge-loading rate. Sludge from public toilets is typically not digested: particles have not settled. Because it has a higher specific, sludge resistance for dewatering less water will be removed, a longer sludge drying time may be required, or it may not be appropriate for drying beds. (Pescod, 1971) carried out experiments with fresh pit latrine sludge on drying beds and obtained a wide variation in drying results – some comparable to more stable sludge. Generally, a proper solid liquid separation is difficult to obtain with fresh public toilet sludge. An alternative is to mix this type of sludge with older, more stabilised sludge (e.g. septic tank sludge) to enhance the dewaterability ( (Kone et al, 2007) ; (Cofie et al, 2006)).

3) Sludge loading rate

The sludge loading rate (SLR) is expressed in kg TS/ $m^2$/year. It represents the mass of solids dried on one $m^2$ of bed in one year. (Pescod, 1971) States that any general number linking the total amount of sludge to be dried to a sludge-loading rate, bed surface area and loading depth can only be an estimate, as the local conditions vary greatly. However, it is possible to indicate a range of sludge loading rates, which typically vary between 100 and 200 kg TS/$m^2$/year in tropical climates, with 100 for poorer conditions and 200 for optimal conditions, while approximately 50 kg SS/$m^2$/year is commonly used in temperate climates in Europe (Duchene, 1990) . Poor conditions entail high humidity, low temperature, long periods of rainfall, and/or a large proportion of fresh FS. Optimal conditions comprise a low humidity, high temperature, a low amount of precipitation, and stabilised sludge. It may be possible in some cases to achieve an even higher sludge-loading rate. (Cofie et al, 2006) For example applied sludge at a loading rate of up to 300 kg TS/$m^2$/year. Badji (2011) also found a SLR of 300 kg TS/$m^2$/year to be effective for dewatering thickened FS with 60 g TS/L, while about 150 kg TS/$m^2$/year was estimated to be an effective rate for a FS with 5 g TS/L in the same climatic conditions.

4) Thickness of the sludge layer

A review of the literature shows that sludge is typically applied in a layer of 20 to 30 cm in depth, with a preference for 20 cm. It may seem a better option to apply a thicker sludge layer as more sludge can be applied to one bed; however, this will result in an increased drying time, and a reduction in the number of times the bed can be used per year. For any particular sludge dried under the same weather conditions, (Pescod, 1971) found that an increase in the sludge layer of only 10 cm prolonged the necessary drying time by 50 to 100%.

It is also important that the sidewalls of the drying beds are high enough to accommodate different loadings. For example, if a layer of 20 cm is applied with a water content of 90%, the initial height before the water is drained-off will be much greater than 20 cm. If the beds receive sludge discharged from a truck as opposed to settling tanks, the walls need to be higher than the planned 20 to 30 cm of sludge layer to allow for the increased volume of liquid.

The number of beds required depends on the amount of sludge arriving at the plant per unit of time, the sludge layer thickness and the allowable sludge-loading rate. For instance, for two weeks of drying duration and FS arriving 5 days per week, a minimum of 10 beds is required. The number of beds can then be increased or decreased considering the optimal sludge layer thickness. It is also important to adapt the number of beds based on the actual operating conditions, for example frequency of sludge removal, or frequency of rain. An increased number of beds increases the safety factor for adequate treatment with variable FS, or poor operation, but also increases capital costs. (Cofie et al, 2006) Utilised two beds of 25$m^2$, with a loading rate of 7.5 $m^3$ of sludge per bed at a loading depth of 30 cm.

## 5.3 Summary of design parameters

It must be noted that the calculations and figures provided in this note have been provided based on as recommended by Pierre-Henri Dodane et al which were determined through local research for the local context based on sludge type and climate and therefore cannot be taken as applicable to all cases. However, they do provide examples of acceptable ranges, and an indication of the interdependency of the factors. In order to provide a suitable drying bed design, the design engineer needs to obtain local knowledge either from experience or from preliminary drying tests under local conditions. The first stage in conducting drying tests will be to determine the number of days required in order to obtain a desired total solids content of the sludge, or at least to obtain a sludge that can be readily removed. If for example the results from these drying tests indicate a two-week drying period, including one day for loading and two days for removal, one bed can be filled 26 times per year. Further example calculations are given in illustrations to follow.

### 5.4 Construction of an unplanted sludge drying bed

A drying bed treatment facility consists of the beds with an inlet and an outlet, a leachate collection and drainage system, a designated area outside of the beds for storage and continued drying of the sludge, and potentially settling-thickening tanks. Sludge can be loaded directly from trucks onto the beds. In this case, various configurations exist such as creating one inlet for two beds, with a splitter to divide the sludge between the beds ( (Cofie et al, 2006)), by designing the bed with a ramp for the inlet of the sludge. Alternatively, a holding or settling tank can be installed into which the sludge is first discharged before being pumped into the drying beds. A splash plate must be used to prevent erosion of the sand layer and to allow even distribution of the sludge (Tilley et al, 2014). This is crucial, as without a splash plate, the sand layer would be destroyed during the very first loading operation. Bar screens at the inlet are essential to keep rubble and trash present in the sludge from entering the bed. This is important to allow for proper use or disposal of the sludge after drying. The drying bed is typically a rectangular shape excavated from the soil, with a sealed bottom. As was shown in Figure 20, the bottom of the bed slopes downwards towards where the drainage system is installed such that the leachate can drain to the discharging point or further treatment. As the leachate is high in suspended solids, organic material, and nutrients, it needs to be treated before it can be discharged to the environment, according to the quality required for reclamation or for receiving water bodies.

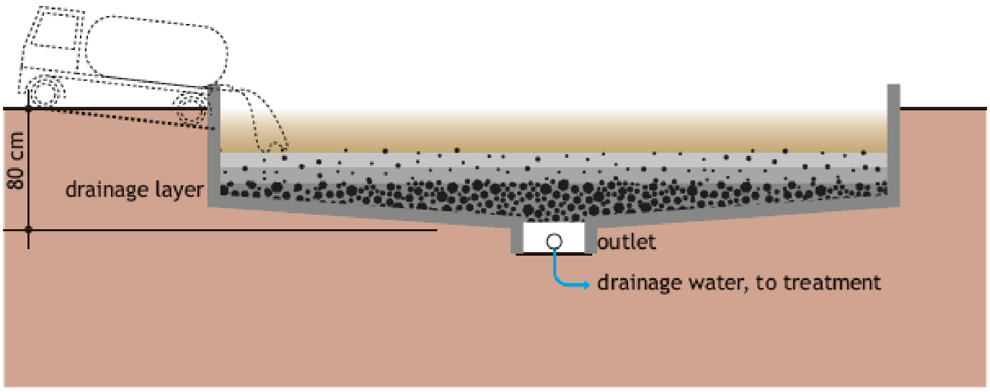


*Figure 22 Schematic overview of an unplanted sludge drying bed (Tilley et al., 2014). A splash plate is not visible*

Gravel and sand Layers of gravel and sand are applied on top of the drainage system. When constructing drying beds, it is essential to use washed sand and gravel in order to prevent clogging of the bed from fine particles. This is important both for the initial construction, and for further supplemental additions of sand. The gravel layer functions as a support and there are typically two or three layers with two different diameters of gravel (Figure 22). The distribution of diameter size in the layers is based on avoiding clogging from small particles washing into the drain. The lower layer usually contains coarser gravel with a diameter of around 20-40 mm and the intermediate layer contains finer gravel with a diameter between the coarse gravel and the upper sand layer, for example, 5-15 mm. locally available materials will also have an influence on the design. For example, (Cofie et al, 2006) made use of gravel with a diameter of 19 mm applied in a 15 cm supporting layer underneath 10 cm of gravel with a 10 mm diameter. To avoid the migration of particles from the sand layer into the gravel layers, a third layer of small gravel can also be used according to what is locally available, for example 2-6 mm. A sand layer is placed on top of the gravel. The sand layer enhances drainage and prevents clogging, as it keeps the sludge from lodging in the pore spaces of the gravel. The diameter of the sand is crucial as sand with a larger diameter (1.0-1.5 mm) can result in the relatively fast accumulation of organic matter, thereby increasing the risk of clogging, the risk is reduced if sand with a smaller diameter (0.1- 0.5 mm) is used (Kuffour et al, 2009). When selecting sand for the bed, it is important to note that the sand will need to be replaced occasionally, as a certain amount of the sand is bound to the sludge and will therefore be removed when the sludge is removed. It has been recommended by Pierre-Henri Dodane et al that the sand that is chosen is easily obtained. Duchene (1990) reported a loss of a few centimetres of sand for each 5-10 drying sequences. In typical cases like at the Camberene FSTP in Dakar, 5 cm is lost after 25 drying sequences (Badji, 2008).

The sand also needs to be replaced when there is a build-up of organic matter and the bed starts to clog. (Kuffour et al, 2009) observed a link between the rate of clogging and the rate of organic matter build-up on the sand. As organic matter builds up faster on sand with larger particles, a bed filled with larger diameter sand is more likely to clog. (Cofie et al, 2006) It had to replace the sand twice in a series of 8 dewatering cycles over 10 months due to clogging in a pilot scale implementation. For a full scale application, (HPCIDBC, 2011)estimated a sand exchange period of three years at a sludge loading rate of 250 kg TS/$m^2$/year, a sludge filling height of 20 cm and a one week drying period (applicable to Nepali conditions).

### 5.5 Sludge removal

In order for the sludge to be removed properly, it needs to be dry enough that it can be shovelled. (Pescod, 1971) carried out experiments with different types of sludge and treatment technologies, including lagoons and drying beds, and found sludge with a TS content of at least 25% fit for removal. The drying time of a specific sludge type depends on a number of factors, one of which is the sludge dewatering resistance. The higher the sludge dewatering resistance, the lower the drainage rate which leads to a prolonged drainage time. Sludge is removed mechanically or manually, with shovels and wheelbarrows being the most common manual method.

In order to remove the sludge, a ramp must be provided to allow wheelbarrows or other equipment to access the bed. If a drier sludge is required, this can be achieved by evaporation after it is removed from the drying bed. The dried sludge is frequently stored in heaps for periods of up to one year, during which time pathogen reduction can occur. It is, however, recommended that a more controlled treatment be employed in order to produce reliable and consistent end products.

Rewetting of the sludge is considered problematic if rainfall occurs before the free water of the sludge is completely drained. In this case, the moisture content of the sludge increases again and the drying period is prolonged. When the sludge is already dry, enough to expose the sand layer through the cracks in the sludge, rainwater can pass straight through the sludge and drains through the drying bed. CPHEEO recommends covering the beds with FRP canopy to avoid rewetting of the sludge. (Sasse, 1998) also recommends for roofing of drying beds in places receiving frequent rains. Therefore, if budget permits, this should be provided with steel framework to cover dried sludge during rainy days.

### 5.6 Quality of dried sludge and leachate

The main purpose of a drying bed is to achieve dewatering; i.e. a physical separation between liquid and solids. Drying beds are therefore not designed with stabilisation or pathogen removal in mind, although some biodegradation may occur. Therefore, any pollutants present in the FS are not removed and either remain in the sludge or are present in the leachate.

*Table 12 Typical characteristics of leachate from sludge drying beds (from Koné et al., 2007)*

| | **First day** | **Last day** | **Difference** |
|---|---|---|---|
| *pH* | 8.2 | 7.9 | -0.3 |
| *EC (µS/cm)* | 21,900 | 11,400 | -10,500 |
| *SS (mg/l)* | 600 | 290 | -310 |
| *COD (mg/l)* | 5600 | 3600 | -2000 |
| *BOD (mg/l)* | 1350 | 870 | -480 |
| $NH_3 - N$ *(mg/l)* | 520 | 260 | -260 |
| *TKN (mg/l)* | 590 | 370 | -220 |
| $NO_3{}^{-} - N$ *(mg/l)* | 50 | 170 | 120 |

(Kone et al, 2007) Carried out experiments with mixtures of septic tank and public toilet sludge, and analysed the leachate on the first and the last day of filtration for a variety of parameters. Although the measured concentrations were lower on the last day, the leachate was still far from environmentally safe for disposal with for example a BOD concentration of 870 mg/L. Hence, according to the final use or standards for receiving water bodies, the leachate should be collected and treated as a concentrated liquid waste stream, for example in ponds (Montangero, A., Strauss, M., 2002), or recovered for an appropriate end use. (Kone et al, 2007) also analysed FS from during beds for Ascaris and Trichuris eggs. Sludge was applied in different ratios to unplanted sludge drying beds at a loading rate between 196 and 321 kg TS /m2/year, and left to dry until the TS content was at least 20%. Dewatering on the drying beds alone was not sufficient to inactivate all helminth eggs, and a total count of up to 38 Ascaris and Trichuris eggs was recovered after dewatering, of which 25–50% were viable (Kone et al, 2007). This illustrates the need for additional storage time or other treatment options for increased pathogen reduction.

### 5.7 Facility design of unplanted sludge drying bed:

*Table 13 Sludge Drying beds design calculation*

| | | |
|---|---|---|
| Sludge loading Rate | 300 | Kg TS/ $m^2/year$ |
| Sludge thickness (SLH) | 0.25 | cm |
| Sludge flow from Thickener | 74.62 | $m^3$/10 days |
| Each bed will be used two times in a month considering two weeks drying period | 14 | Days |
| Sludge concentration from settling-cum-thickening tank | 51 | Kg TS/$m^3$ |
| Sludge produced in a year | 3*12*74.6174*51 | Kg TS/ $m^2/year$ |

| | | |
|---|---|---|
| | 136,998 | |
| Total Area required | 136997/300<br>457 | $m^2$ |
| Sludge loading rate / day | 74.6174/10<br>7.4617 | $m^3$/day i.e. for 10 days |
| Area required for one day loading | 7.4617/0.25<br>29.84 | $m^2$ |
| Length to Breadth Ratio<br>As per IS 10037 Part 1 | 5:1 | |
| Length | 12.2162 m | Provided 15m |
| Breadth | 2.4432 m | Provided 3 m |
| Number of beds required | 457/ 45<br>10 | Provide 10 beds |
| Provide 10 + 1 stand by beds (Total altered area: 495 $m^2$ ) | | |

Considering the sludge scraping time, rains, rewetting and drying time and in order to accommodation of overloading, 11 beds may be provided of 45 $m^2$ size for higher efficiency. The beds may be arranged as twin type with central feeder pipes.

- **Drying bed wall**: this may be constructed using RCC. The free board should be kept a minimum of 0.3 m above the final wet sludge surface. The floors can be built brick on edge and the underdrains can also be made of bricks (fly-ash bricks can be used). The slope towards the drains may be kept 1%. The underdrain width and height shall not be less than 150 mm. laterals can be made of brick on edge with a minimum width of one brick thickness i.e. 75 mm with a spacing of 1 m clear.

- **Sand and gravel**: Depth of sand bed should be 0.15 m or 150 mm with sand size in the range of 0.5 to 1.0 mm with uniformity coefficient not more than 4.

  The gravel layer can be of 300 mm thick with two layers. Bottom layer having size between 20-40 mm and top layer having size 5-15 mm. however, a 50 mm layer of 2 mm to 5 mm size gravel above the top layer should be laid to prevent carrying of finer particles of sludge deep into the gravel bed or washing away with the leachate.

- **Valves**. Piping and splash plate are to be provided for smooth distribution, control and prevention of erosion of sand layer during loading respectively. Refilling of sand after every 25 scrapping of sludge is recommended.

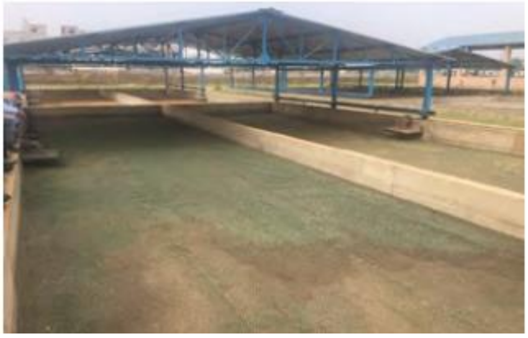

*Figure 23 Unplanted sludge-drying beds, Bhubaneshwar (Source: Dhawal Patil, ESF)*

*Figure 24 Splash Plate (Source: Dhawal Patil, ESF)*

The leachate from the dewatered sludge shall be diverted into the inlet main of the STP by gravity flow, so there will be no need for leachate sump.

- **Rain Cover.** Sludge drying bed in high rainfall areas in the country needs cover with FRP[6] or galvanised iron sheets etc., in accordance with requirement. The height of the rain cover shall be kept between 7-8 ft from the top layer of the sludge drying beds in both transverse and longitudinal direction covering the entire beds with a downward slope of 2% in the transverse direction. The supporting structure should be made using galvanised iron rods/bars.

[6] Design and construction of sludge treatment facilities, Chapter 6, CPHEEO

# Section 6. Recommendation for Re-use of by-products from FSS treatment at Ramnagar STP

Reuse and revenue generation potential of the sludge generated from the co-treatment should be taken into consideration. Dried sludge is not stabilised, but additional composting will allow recycling nutrients and organic matter into agriculture. Some of the methods are advised below and could be chose based upon feasibility check.

- **Co-composting**

  It is the controlled aerobic degradation of organics, using more than one feedstock (faecal sludge and organic solid waste). Faecal sludge has a high moisture and nitrogen content, while biodegradable solid waste is high in organic carbon and has good bulking properties (i.e., it allows air to flow and circulate). By combining the two, the benefits of each can be used to optimize the process and the product.

  There are two types of co-composting designs: open and in-vessel. In open composting, the mixed material (sludge and solid waste) is piled into long heaps called windrows and left to decompose. Windrow piles are periodically turned to provide oxygen and ensure that all parts of the pile are subjected to the same heat treatment. In-vessel composting requires controlled moisture and air supply, as well as mechanical mixing. Therefore, it is not generally appropriate for decentralized facilities. Although the composting process seems like a simple, passive technology, a well-functioning facility requires careful planning and design to avoid failure. The dried sludge should be stored in store yards and should be transferred for co-composting plant in order to prepare manure and further sell it for agricultural purpose.

- **Mechanical Solar drying**

Pathogen requirement for biosolids reuse

| *Organization* | *Guideline requirements* | *Source* |
|---|---|---|
| World Health Organization | Helminth egg count: ≤1 egg per gram of total solids<br>*E. coli*: ≤1 000 count per gram of total solids | WHO (2006) |
| US Environmental Protection Agency (Part 503 biosolids rule) | Class A biosolids: faecal coliform density ≤1,000 per gram of total dry solids, or *Salmonella* subspecies (spp) density ≤3 per 4 grams of total dry solids<br>Class B biosolids: faecal coliform density ≤2,000,000 per gram of total dry solids | US EPA (1994) |

Faecal Sludge and Septage Treatment: A Guide for Low and Middle Income Countries

*Figure 25 Parameter for Bio solids (US-EPA)*

The aim of sludge drying using mechanical equipment is to remove water and reduce pathogen levels in the sludge. For the sludge to be suitable for reuse or disposal, WHO and US EPA proposes certain standards. In general, forced ventilation coupled with tilling equipment is used to drive out the moisture at a higher rate from the sludge. The material of used for preparing the covering (shed) is such that it allows the solar energy to get inside and get trapped. The solar energy heats up the dry air which absorbs the moisture from the sludge. The moisture-laden air is then forced out of the house through the ventilation system.

The performance of solar sludge drying is dependent on solar radiation, air temperature, relative humidity of the air and depth of the sludge. The ventilation flux controls the relative humidity and accelerates the evaporation process of moisture from the sludge. The initial water content and depth of sludge also affects the performance of drying. To regulate the depth of sludge and to expose the maximum area of the sludge, tilling equipment is used, which tosses and turns the sludge while maintaining the height of the sludge and exposes it to the relatively dry air. This method should be adopted only with proper feasibility check with the sludge supplying capacity to the demand for the local market; taken as a business model in terms of resource recovery. See figure 26; the image is just representation purpose only.

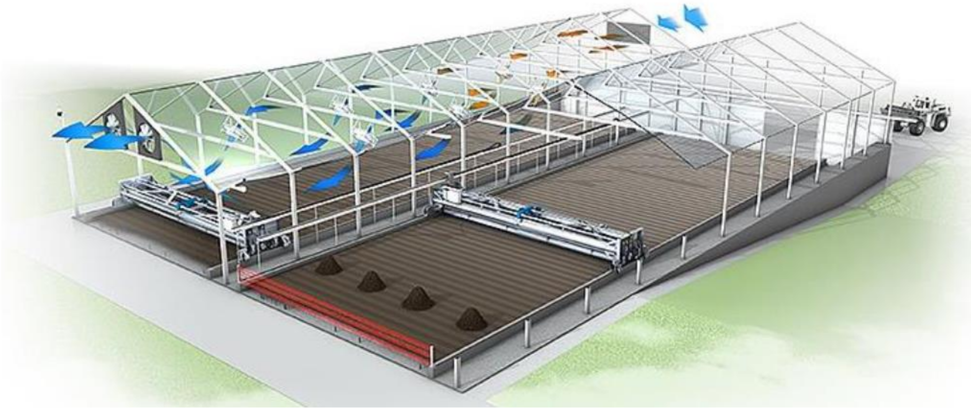

*Figure 26 Solar Drying Beds (Source: Huber Solar Active dryer SRT)*

Since, there is a designated site for disposal of dewatered sludge for the sewage outside the NPP limit as provided by Jal Nigam, Ramnagar. In case to reduce operational expenses and capital expenditure, the dried septage sludge can be disposed off along with the sewage sludge as, no norms are provided for disposal of bio-solids in the CPHEEO manual.

# Section 7

## References


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# Section 8

## ANNEXURE 1

☎ कार्यालय– 05947 251259

फैक्स–05947–255663

E-Mail :- eecdujnramnagar@gmail.com

**कार्यालय अधिशासी अभियन्ता**

**निर्माण शाखा,**

**उत्तराखण्ड पेयजल संसाधन विकास एवं निर्माण निगम**

**रामनगर (नैनीताल) पिन कोड–244715**

पत्रांक 2043 / नमामि गंगे / 21 दिनांक 08/10/2021

ई–मेल द्वारा

To,

Ms. Jyoti Das
Senior Programme Manager
SCBP, National Institute of Urban Affairs
New Delhi

विषयः– रामनगर एवं कालाढूंगी निकाय क्षेत्रान्तर्गत उत्सर्जित होने वाले सैप्टेज के निस्तारण हेतु तकनीकी सहायता के सम्बन्ध में।

महोदया,

उपरोक्त विषय के सन्दर्भ में अवगत कराना है कि रामनगर एवं कालाढूंगी निकाय क्षेत्र जनपद नैनीताल में उत्सर्जित होने वाले सैप्टेज के निस्तारण हेतु रामनगर में ट्रांसपोर्ट नगर स्थित 7.00 एम0एल0डी0 एस0टी0पी0 में को–ट्रीटमेन्ट सुविधा उपलब्ध कराने हेतु दिनांक 07.10.2021 की बैठक में उप–जिलाधिकारी/ अध्यक्ष, सैप्टेज मैनेजमेन्ट सेल, रामनगर द्वारा प्राक्कलन तैयार किये जाने हेतु इस कार्यालय को इंगित किया गया है।

इस सन्दर्भ में आपको अवगत कराना है कि माह जुलाई–2021 से 7.00 एम0एल0डी0 एस0टी0पी0 का संचालन प्रारम्भ कर दिया गया है, जिसमें फीकल स्लज के निस्तारण हेतु को–ट्रीटमेन्ट की सुविधा वर्तमान में उपलब्ध नहीं है। इस एस0टी0पी0 का निर्माण एवं अभिकल्पन शहर में स्थित नालों के श्राव की टैस्टिंग डाटा के अनुसार किया गया है, जिसका डाटा सीट आपके संज्ञानार्थ संलग्न है। उक्त दोनों निकायों द्वारा उत्सर्जित फीकल स्लज की कुल मात्रा 20 KLD अनुमानित की गयी है।

अतः आपसे अनुरोध है कि इस सन्दर्भ में Technical Assistance एवं प्राक्कलन तैयार किये जाने हेतु डिजाइन एण्ड ड्राईंग तथा बजटरी ऑफर उपलब्ध कराने की कृपा करें, जिससे कि शहरी विकास निदेशालय, उत्तराखण्ड द्वारा निर्देशित " प्रोटोकाल फॉर सैप्टेज मैनेजमेन्ट " कियान्वयन हेतु दिये गये निर्देशों के अनुपालन में उक्त प्राक्कलन प्रस्तुत किया जाना सम्भव हो सके।

संलग्नक–उपरोक्तानुसार।

भवदीय
08/10/2021
अधिशासी अभियंता

पृ0सं0 एवं दिनांक–उपरोक्तानुसार।

प्रतिलिपि निम्नलिखित को सादर सूचनार्थ प्रेषित–

1. निदेशक शहरी विकास निदेशालय, उत्तराखण्ड, 31/62 राजपुर रोड, देहरादून।
2. जिलाधिकारी /अध्यक्ष, जिला स्तरीय सैप्टेज मैनेजमेन्ट निगरानी समिति, नैनीताल।
3. अधीक्षण अभियन्ता, निर्माण मण्डल, उत्तराखण्ड पेयजल निगम, काठगोदाम, हल्द्वानी।
4. उप–जिलाधिकारी / अध्यक्ष, सैप्टेज मैनेजमेन्ट सेल, रामनगर।
5. क्षेत्रीय अधिकारी, प्रदूषण नियन्त्रण बोर्ड, हल्द्वानी, जिला–नैनीताल।
6. अधिशासी अधिकारी, नगर पालिका, रामनगर।
7. अधिशासी अधिकारी, नगर पंचायत, कालाढूंगी।

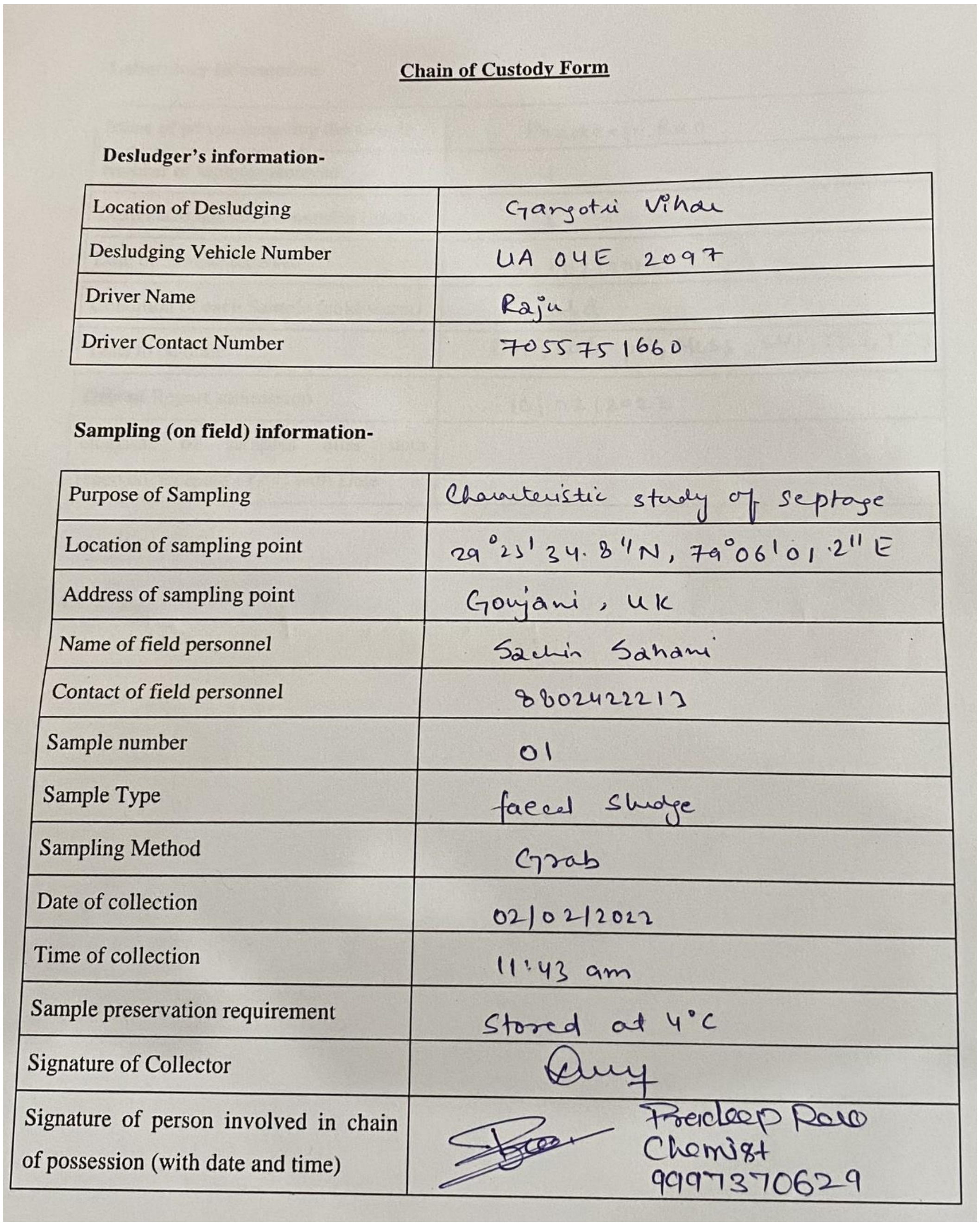
अधिशासी अभियंता

E:\General\Co Treatment Assistance letter 08.10.2021.doc

**ANNEXURE-2**

**Chain of Custody Form for first Characterization Study**

**Sample Collection dated 02.02.2022**



**Chain of Custody Form**

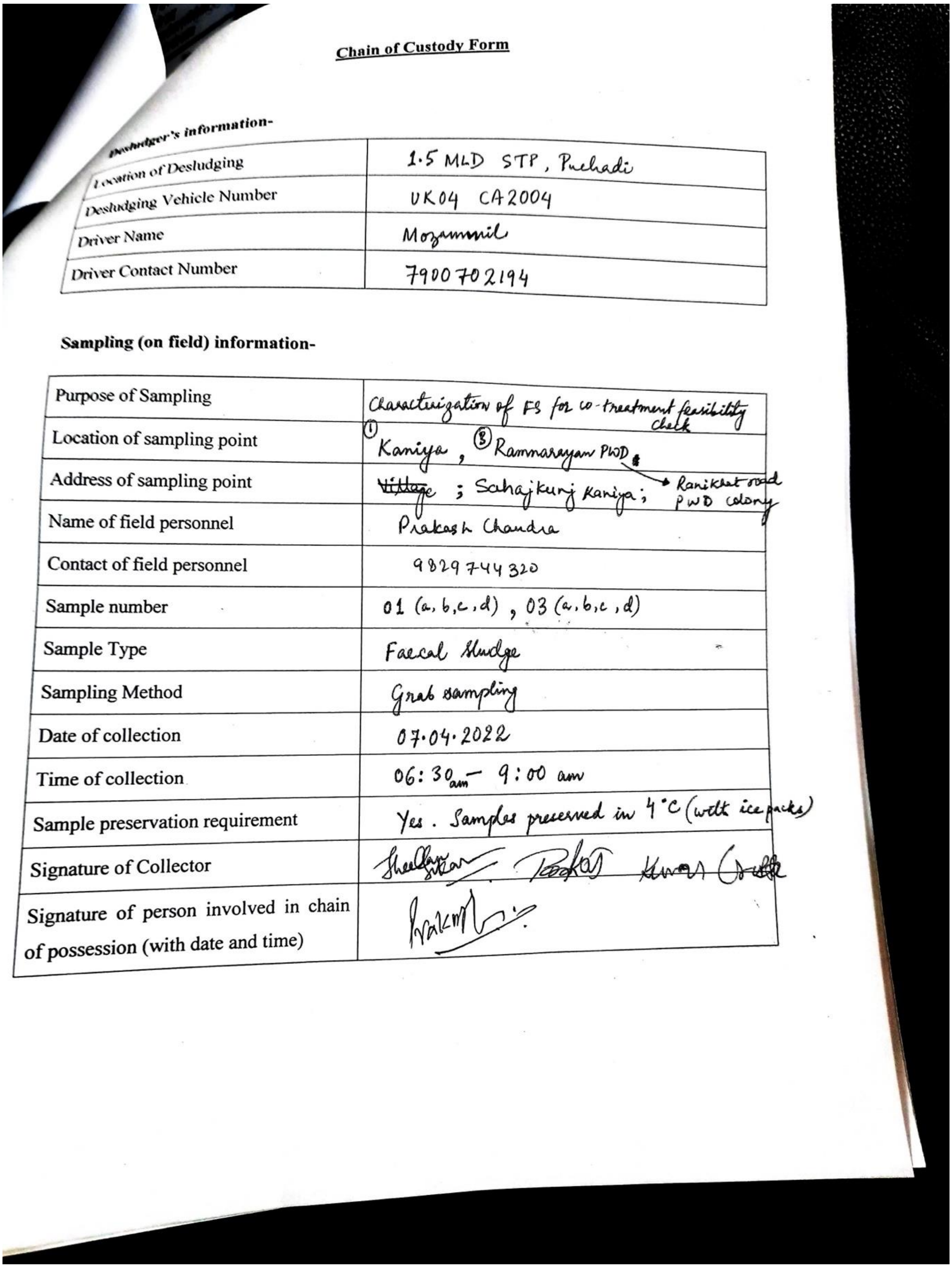
**Desludger's information-**

| | |
|---|---|
| Location of Desludging | Gangotri Vihar |
| Desludging Vehicle Number | UA 04E 2097 |
| Driver Name | Raju |
| Driver Contact Number | 7055751660 |

**Sampling (on field) information-**

| | |
|---|---|
| Purpose of Sampling | Characteristic study of septage |
| Location of sampling point | 29°23'34.8"N, 79°06'01.2"E |
| Address of sampling point | Goujani, UK |
| *Name of field personnel* | Sachin Sahani |
| *Contact of field personnel* | 8802422213 |
| Sample number | 01 |
| Sample Type | faecal sludge |
| Sampling Method | Grab |
| Date of collection | 02/02/2022 |
| Time of collection | 11:43 am |
| Sample preservation requirement | Stored at 4°C |
| Signature of Collector | [signature] |
| Signature of person involved in chain of possession (with date and time) | [signature] Pradeep Rao Chemist 9997370629 |

# Chain of Custody Form for second Characterization Study Sample Collection dated 07.04.2022



Chain of Custody Form

**Desludger's information-**

| | |
|---|---|
| Location of Desludging | 1.5 MLD STP, Puchadi |
| Desludging Vehicle Number | UK04 CA2004 |
| Driver Name | Mozammil |
| Driver Contact Number | 7900702194 |

**Sampling (on field) information-**

| | |
|---|---|
| Purpose of Sampling | Characterization of FS for co-treatment feasibility check |
| Location of sampling point | (1) Kaniya, (3) Ramnarayan PWD → Ranikhet road PWD colony |
| Address of sampling point | ~~Village~~ ; Sahajkunj Kaniya; |
| Name of field personnel | Prakash Chandra |
| Contact of field personnel | 9829744320 |
| Sample number | 01 (a, b, c, d), 03 (a, b, c, d) |
| Sample Type | Faecal Sludge |
| Sampling Method | Grab sampling |
| Date of collection | 07.04.2022 |
| Time of collection | 06:30 am – 9:00 am |
| Sample preservation requirement | Yes. Samples preserved in 4°C (with ice packs) |
| Signature of Collector | [signatures] |
| Signature of person involved in chain of possession (with date and time) | [signature] |

## Chain of Custody Form

**Desludger's information-**

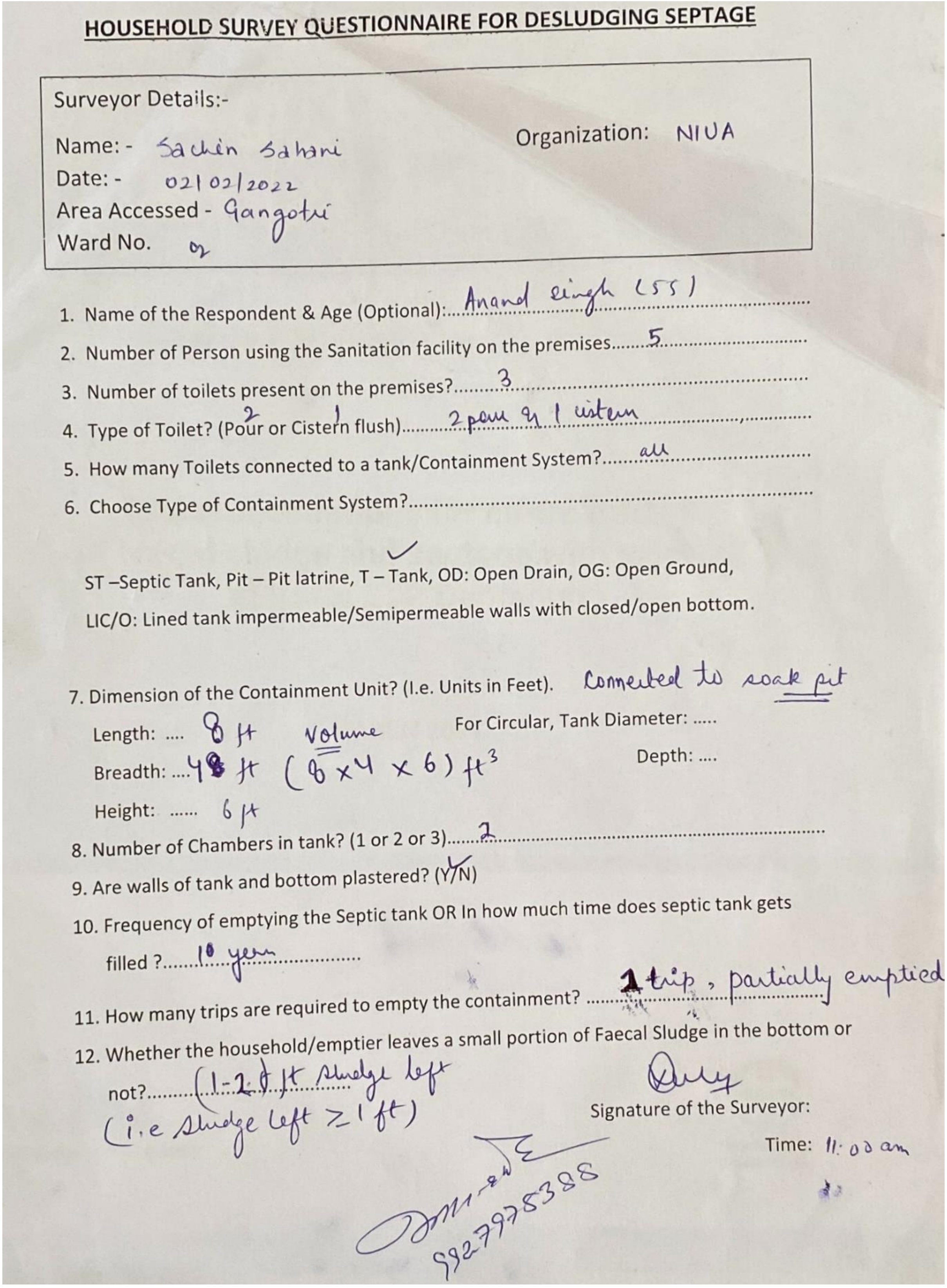
| | |
|---|---|
| Location of Desludging | 1.5 MLD STP, Puchadi |
| Desludging Vehicle Number | UA04E 2097 |
| Driver Name | Shivm |
| Driver Contact Number | 8449029863 |

**Sampling (on field) information-**

| | |
|---|---|
| Purpose of Sampling | Characterization of FS for co-treatment feasibility |
| Location of sampling point | SPS Baldia Phadaun; (4) Lakhanpur; (5) Bhawaniganj |
| Address of sampling point | (2) Durgapuri; H-335; ward 12 |
| Name of field personnel | Prakash Chandra |
| Contact of field personnel | 9829744320 |
| Sample number | 02(a,b,c,d), 04(a,b,c,d), 05(a,b,c,d) |
| Sample Type | Faecal sludge |
| Sampling Method | Grab sampling |
| Date of collection | 07.04.2022 |
| Time of collection | 6:30 am – 9:00 am. |
| Sample preservation requirement | Yes. Preserved at 4°C (with ice packs). |
| Signature of Collector | [signature] Kumar Gupta |
| Signature of person involved in chain of possession (with date and time) | Prakash [signature] |

# ANNEXURE-3

## Household Survey Questionnaire for Desludging Faecal Sludge Sample Collection dated 02.02.2022



HOUSEHOLD SURVEY QUESTIONNAIRE FOR DESLUDGING SEPTAGE

Surveyor Details:-

Name: - Sachin Sahani

Organization: NIUA

Date: - 02/02/2022

Area Accessed - Gangotri

Ward No. 02

1. Name of the Respondent & Age (Optional): Anand singh (55)
2. Number of Person using the Sanitation facility on the premises 5
3. Number of toilets present on the premises? 3
4. Type of Toilet? (Pour or Cistern flush) 2 pour & 1 cistern
5. How many Toilets connected to a tank/Containment System? all
6. Choose Type of Containment System?

ST –Septic Tank, Pit – Pit latrine, T – Tank ✓, OD: Open Drain, OG: Open Ground,

LIC/O: Lined tank impermeable/Semipermeable walls with closed/open bottom.

7. Dimension of the Containment Unit? (I.e. Units in Feet). Connected to soak pit

Length: .... 8 ft Volume

For Circular, Tank Diameter: .....

Breadth: ....4 ft (8×4 × 6) ft³

Depth: ....

Height: ...... 6 ft

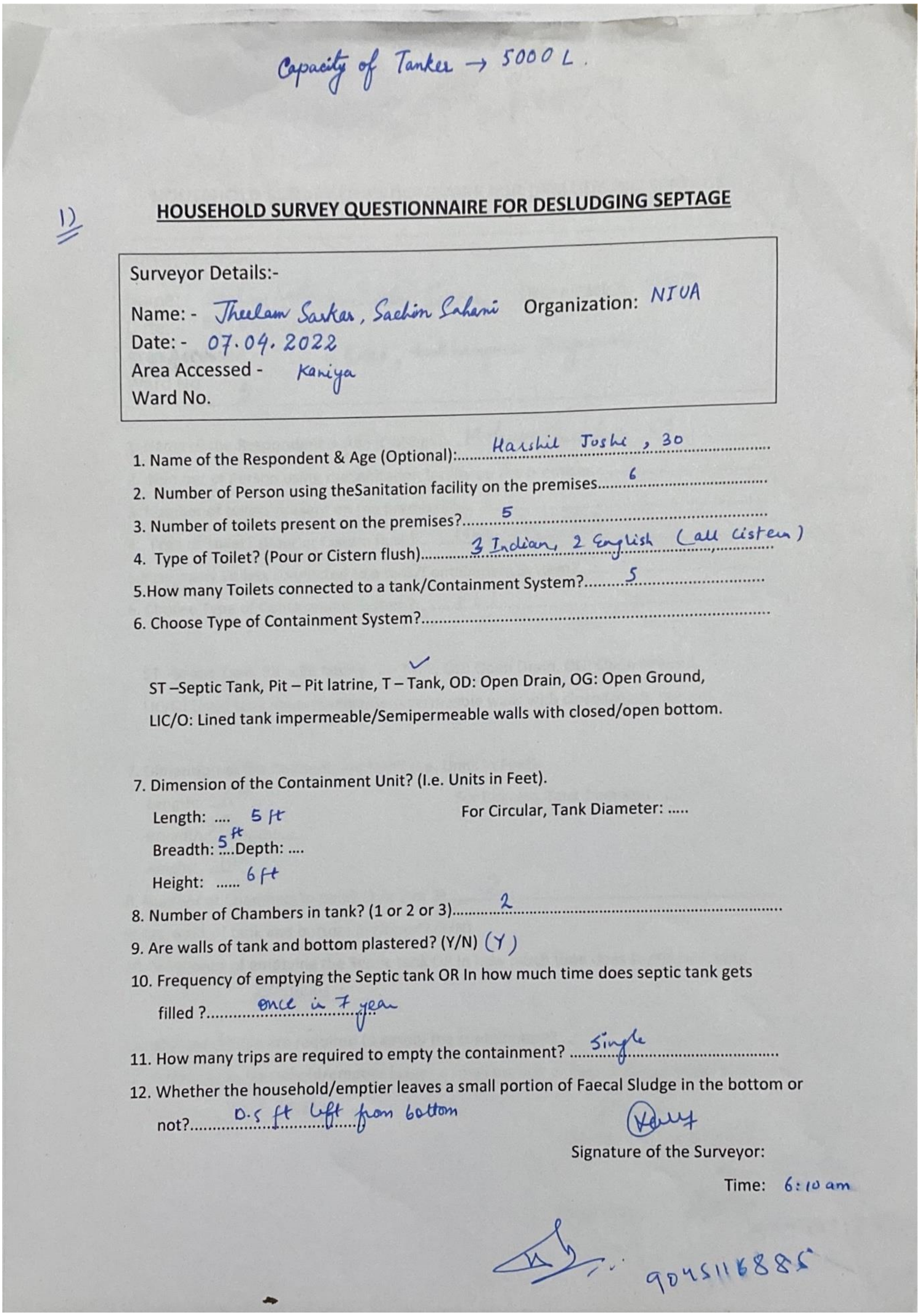
8. Number of Chambers in tank? (1 or 2 or 3) 2
9. Are walls of tank and bottom plastered? (Y/N) Y
10. Frequency of emptying the Septic tank OR In how much time does septic tank gets filled ? 10 years
11. How many trips are required to empty the containment? 1 trip, partially emptied
12. Whether the household/emptier leaves a small portion of Faecal Sludge in the bottom or not? (1-2 ft) ft sludge left (i.e sludge left ≥ 1 ft)

Signature of the Surveyor:

Time: 11:00 am

9927978388

**Household Survey Questionnaire for Desludging Faecal Sludge**
**Sample Collection dated 07.04.2022**



Capacity of Tanker → 5000 L.

1)

HOUSEHOLD SURVEY QUESTIONNAIRE FOR DESLUDGING SEPTAGE

Surveyor Details:-
Name: - Jheelam Sarkar, Sachin Sahani Organization: NIUA
Date: - 07.04.2022
Area Accessed - Kaniya
Ward No.

1. Name of the Respondent & Age (Optional):........Harshil Joshi, 30........
2. Number of Person using theSanitation facility on the premises........6........
3. Number of toilets present on the premises?........5........
4. Type of Toilet? (Pour or Cistern flush)........3 Indian, 2 English (all cistern)........
5. How many Toilets connected to a tank/Containment System?........5........
6. Choose Type of Containment System?........

ST –Septic Tank (✓), Pit – Pit latrine, T – Tank, OD: Open Drain, OG: Open Ground,
LIC/O: Lined tank impermeable/Semipermeable walls with closed/open bottom.

7. Dimension of the Containment Unit? (I.e. Units in Feet).
Length: .... 5 ft For Circular, Tank Diameter: .....
Breadth: 5 ft ....Depth: ....
Height: ...... 6 ft
8. Number of Chambers in tank? (1 or 2 or 3)........2........
9. Are walls of tank and bottom plastered? (Y/N) (Y)
10. Frequency of emptying the Septic tank OR In how much time does septic tank gets filled ?........once in 7 year........
11. How many trips are required to empty the containment? ........Single........
12. Whether the household/emptier leaves a small portion of Faecal Sludge in the bottom or not?........0.5 ft left from bottom........

Signature of the Surveyor:
Time: 6:10 am

9045116885

2)
//-

5000L tank capacity

## HOUSEHOLD SURVEY QUESTIONNAIRE FOR DESLUDGING SEPTAGE

Surveyor Details:-

Name: - Sachin Sahani, Jheelam Sarkar Organization: NIVA

Date: - 07.04.2022

Area Accessed - Tera Road, ~~Lakhanpur~~ Durgapuri

Ward No. 2

1. Name of the Respondent & Age (Optional):.....Mohan Chandra, 59.....
2. Number of Person using theSanitation facility on the premises.......4.......
3. Number of toilets present on the premises?......1......
4. Type of Toilet? (Pour or Cistern flush).......Pour (Indian).......
5.How many Toilets connected to a tank/Containment System?.......1.......
6. Choose Type of Containment System?.......FLT.......

ST –Septic Tank, Pit – Pit latrine, T – Tank, OD: Open Drain, OG: Open Ground,

LIC/O: Lined tank impermeable/Semipermeable walls with closed/open bottom.

7. Dimension of the Containment Unit? (I.e. Units in Feet).

Length: ....6 ft For Circular, Tank Diameter: .....

Breadth: 3 ft ....Depth: ....

Height: ...10 ft

8. Number of Chambers in tank? (1 or 2 or 3).......2.......
9. Are walls of tank and bottom plastered? (Y/N)
10. Frequency of emptying the Septic tank OR In how much time does septic tank gets filled ?.......20 years.......
11. How many trips are required to empty the containment? .......1.......
12. Whether the household/emptier leaves a small portion of Faecal Sludge in the bottom or not?.......Full empty.......

Signature of the Surveyor:

Time: 6:25 am

Sandeep

9837491879

5000 L
Capacity vehicle used

## HOUSEHOLD SURVEY QUESTIONNAIRE FOR DESLUDGING SEPTAGE

Surveyor Details:-

Name: - Sachin Sahani, Jheelam Sarkar Organization: NIUA
Date: - 07.04.2022.
Area Accessed - Ramnarayan PWD.
Ward No. 12, 13

1. Name of the Respondent & Age (Optional):.....Ramnarayan, 60.....
2. Number of Person using theSanitation facility on the premises.......20 {people also come from outside}
3. Number of toilets present on the premises?......1......
4. Type of Toilet? (Pour or Cistern flush).......Pour (Indian).......
5. How many Toilets connected to a tank/Containment System?..........
6. Choose Type of Containment System?..........

ST –Septic Tank, Pit – Pit latrine, T – Tank, OD: Open Drain, OG: Open Ground,
LIC/O: Lined tank impermeable/Semipermeable walls with closed/open bottom.

7. Dimension of the Containment Unit? (I.e. Units in Feet).
   Length: 8 ft.  For Circular, Tank Diameter: .....
   Breadth: 6 ft. Depth: ....
   Height: 7 ft.
8. Number of Chambers in tank? (1 or 2 or 3).......4.......
9. Are walls of tank and bottom plastered? (Y/N)
10. Frequency of emptying the Septic tank OR In how much time does septic tank gets filled ?.......5-6 yrs.......
11. How many trips are required to empty the containment? .......2.......
12. Whether the household/emptier leaves a small portion of Faecal Sludge in the bottom or not?.......~~Full empty~~ (1 ft left from bottom)

Signature of the Surveyor:

Time: 10:15 am.

रामनरायण
9568512685

Vehicle Cap.
5000 L

## HOUSEHOLD SURVEY QUESTIONNAIRE FOR DESLUDGING SEPTAGE

Surveyor Details:-

Name: - Jheelam Sarkar, Sachin Sahani Organization: NIUA
Date: - 07.04.2022
Area Accessed - Lakhanpur
Ward No. 4

1. Name of the Respondent & Age (Optional):........Prashant Kathari, 35........
2. Number of Person using theSanitation facility on the premises........16........
3. Number of toilets present on the premises?........3........
4. Type of Toilet? (Pour or Cistern flush)........Pour (Indian)........
5.How many Toilets connected to a tank/Containment System?........3........
6. Choose Type of Containment System?........FLT........

ST –Septic Tank, Pit – Pit latrine, T – Tank, OD: Open Drain, OG: Open Ground,

LIC/O: Lined tank impermeable/Semipermeable walls with closed/open bottom.

7. Dimension of the Containment Unit? (I.e. Units in Feet).

Length: 7ft For Circular, Tank Diameter: .....

Breadth: 3ft. Depth: ....

Height: 10ft.

8. Number of Chambers in tank? (1 or 2 or 3)........2........
9. Are walls of tank and bottom plastered? (Y/N) ✓
10. Frequency of emptying the Septic tank OR In how much time does septic tank gets filled ?........Once in 5 years........
11. How many trips are required to empty the containment? ........1........
12. Whether the household/emptier leaves a small portion of Faecal Sludge in the bottom or not?........Yes : 3ft · 1.5ft........

Signature of the Surveyor:

Time: 10:10 am.

9315600539

5)

Vehicle 5000L capacity

**HOUSEHOLD SURVEY QUESTIONNAIRE FOR DESLUDGING SEPTAGE**

Surveyor Details:-

Name: - Sachin Sahani, Jheelam Sarkar Organization: NIUA

Date: - 07.04.2022

Area Accessed - Railway Padaw, Bhawaniganj

Ward No. 12

1. Name of the Respondent & Age (Optional): Tilak Raj, 45
2. Number of Person using theSanitation facility on the premises 8
3. Number of toilets present on the premises? 2
4. Type of Toilet? (Pour or Cistern flush) Pour (Indian)
5. How many Toilets connected to a tank/Containment System? All
6. Choose Type of Containment System? Fully lined tank

PLT.

ST –Septic Tank, Pit – Pit latrine, T – Tank, OD: Open Drain, OG: Open Ground,

LIC/O: Lined tank impermeable/Semipermeable walls with closed/open bottom.

7. Dimension of the Containment Unit? (I.e. Units in Feet).

Length: 6 ft For Circular, Tank Diameter: .....

Breadth: 5 ft Depth: ....

Height: 6 ft.

8. Number of Chambers in tank? (1 or 2 or 3) 1
9. Are walls of tank and bottom plastered? (Y/N) Y
10. Frequency of emptying the Septic tank OR In how much time does septic tank gets filled ? 20 years.
11. How many trips are required to empty the containment? Single
12. Whether the household/emptier leaves a small portion of Faecal Sludge in the bottom or not? Yes (0.5 ft.)

Jheelam Sarkar

Signature of the Surveyor:

Time: 8:20 am.

तिलक राज

~~9456321045 8~~

9456324508

# Annexure-4

## Laboratory Test Reports provided by Transport Nagar STP Laboratory

| SAMPLINIG COLLECTION RECEIVE DATE - 02-02-2022 | | | |
|---|---|---|---|
| SAMPLE TESTING LABORATORY | | | |
| 7.0 MLD STP TRANSPORT NAGAR | | | |
| PAYJAL NIGAM RAMNAGAR | | | |
| SAMPLE DESCRIPTION : FAECAL SLUDGE | | | |
| | | SAMPLE TYPE-GRAB | |
| | | PARAMETER | |
| | | REPORTING OF RESULTS SAMPLE-01 | |
| Sr. no. | Parameter,SI units | Test-method | Result |
| 1 | pH value | IS:3025(P-11)-1983 | 1.0 |
| 2 | SV ml/l (30 min.Settling) | IS:3025(P-19)-1984 | 990 |
| | SVI,ml/g | IS:3025(P-19)-1984 | 57.37 |
| 3 | MLSS,mg/l | IS:3025(P-19)-1984 | 17255 |
| 4 | TSS,mg/l | IS:3025(P-19)-1984 | 13950 |
| 5 | TDS,mg/l | IS:3025(P-19)-1984 | 8750 |
| 5 | COD,mg/l | IS:3025(P-58-2006 | 3040 |
| 5 | BOD, mg/l | IS:3025(P-11)-1983 | 995 |
| | | | |
| | | REPORTING OF RESULTS SAMPLE-02 | |
| Sr. no. | Parameter,SI units | Test-method | Result |
| 1 | pH value | IS:3025(P-11)-1983 | 1.0 |
| 2 | SV ml/l (30 min.Settling) | IS:3025(P-19)-1984 | 980 |
| | SVI,ml/g | IS:3025(P-19)-1984 | 64.55 |
| 3 | MLSS,mg/l | IS:3025(P-19)-1984 | 15180 |
| 4 | TSS,mg/l | IS:3025(P-19)-1984 | 12945 |
| 5 | TDS,mg/l | IS:3025(P-19)-1984 | 8695 |
| 5 | COD,mg/l | IS:3025(P-58-2006 | 2986 |
| 5 | BOD, mg/l | IS:3025(P-11)-1983 | 942 |
| | | | |
| | | REPORTING OF RESULTS SAMPLE-03 | |
| Sr. no. | Parameter,SI units | Test-method | Result |
| 1 | pH value | IS:3025(P-11)-1983 | 1.1 |
| 2 | SV ml/l (30 min.Settling) | IS:3025(P-19)-1984 | 980 |
| | SVI,ml/g | IS:3025(P-19)-1984 | 64.66 |
| 3 | MLSS,mg/l | IS:3025(P-19)-1984 | 15155 |
| 4 | TSS,mg/l | IS:3025(P-19)-1984 | 12935 |
| 5 | TDS,mg/l | IS:3025(P-19)-1984 | 8690 |
| 5 | COD,mg/l | IS:3025(P-58-2006 | 2826 |
| 5 | BOD, mg/l | IS:3025(P-11)-1983 | 876 |
| | | | |
| | | REPORTING OF RESULTS SAMPLE-04 | |
| Sr. no. | Parameter,SI units | Test-method | Result |
| 1 | pH value | IS:3025(P-11)-1983 | 1.4 |
| 2 | SV ml/l (30 min.Settling) | IS:3025(P-19)-1984 | 970 |
| | SVI,ml/g | IS:3025(P-19)-1984 | 69.9 |
| 3 | MLSS,mg/l | IS:3025(P-19)-1984 | 13875 |
| 4 | TSS,mg/l | IS:3025(P-19)-1984 | 12840 |
| 5 | TDS,mg/l | IS:3025(P-19)-1984 | 8075 |
| 5 | COD,mg/l | IS:3025(P-58-2006 | 2400 |
| 5 | BOD, mg/l | IS:3025(P-11)-1983 | 835 |

**Laboratory Test Reports provided by PCRI, BHEL, Haridwar**

PCRI/051

# प्रदूषण नियन्त्रण अनुसंधान संस्थान

भारत हेवी इलेक्ट्रिकल्स लिमिटेड, रानीपुर, हरिद्वार (उत्तराखण्ड) -249403

**POLLUTION CONTROL RESEARCH INSTITUTE**

**(A Govt. of India – UNDP / UNIDO Project)**

**BHARAT HEAVY ELECTRICALS LIMITED**

**RANIPUR, HARIDWAR (U.K.) - 249 403**

**(Approved Lab under Environment (Protection) Act, 1986; EIA Consultancy by NABET, QCI)**

## TEST REPORT

**Lab Reference No:** TL220008 **Date :** 06.05.2022

**Indentor** OFFICE OF THE EXECUTIVE ENGINEER, NIRMAN SHAKHA, UTTARAKHAND PAYJAL SANSADHAN EVAM NIRMAN NIGAM, RAM NAGAR (NAINITAL, PIN-244715)

**Customer's Ref. No.:** 573/NAMAMI GANGE/50 DT. 06.04.2022

**Work Order No.:** 22-0003-O-291

**Sample Collected by:** **Indentor** **Collection Date:** 07.04.2022

**Sample/Job:** STP Sample from KANIYA

| PARAMETER | UNIT | OBTAINED VALUE |
|---|---|---|
| Alkalinity | mg/L | 480 |
| Ammonical Nitrogen (as $NH_3$) | mg/L | 6.85 |
| $BOD_3$ at 27°C | mg/L | 1100 |
| COD | mg/L | 3600 |
| Fecal Coliform | MPN/100 mL | $7 \times 10^6$ |
| MLSS | mg/L | 286000 |
| Oil & grease | mg/L | 11.3 |
| pH | - | 7.7 |
| Sludge Volume Index (V/V) | % | 26 |
| Total Coliform | MPN/100 mL | $18 \times 10^6$ |
| Total Kjeldahl Nitrogen (TKN) | mg/L | 9.8 |
| Total Nitrogen | mg/L | 129.0 |
| Total Phosphate | mg/gm | 0.15 |
| Total Suspended Solids | mg/L | 11014 |
| Total Solids | mg/L | 11652 |
| Volatile Suspended Solids | mg/L | 8276 |

Avinash 06/05/22

( Avinash Kumar )

Manager (PCRI)

अविनाश कुमार/Avinash Kumar
प्रबन्धक/Manager
Pollution Control Research Institute
प्रदूषण नियंत्रण अनुसंधान संस्थान
BHEL, Ranipur, Haridwar

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(3) Samples will be disposed off after one month from the date of issue of Test Certificate

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भारत हेवी इलेक्ट्रिकल्स लिमिटेड, रानीपुर, हरिद्वार (उत्तराखण्ड) -249403
POLLUTION CONTROL RESEARCH INSTITUTE
(A Govt. of India – UNDP / UNIDO Project)
BHARAT HEAVY ELECTRICALS LIMITED
RANIPUR, HARIDWAR (U.K.) - 249 403
(Approved Lab under Environment (Protection) Act, 1986; EIA Consultancy by NABET, QCI)

# TEST REPORT

**Lab Reference No:** TL220009 **Date :** 06.05.2022

**Indentor** OFFICE OF THE EXECUTIVE ENGINEER, NIRMAN SHAKHA, UTTARAKHAND PAYJAL SANSADHAN EVAM NIRMAN NIGAM, RAM NAGAR (NAINITAL, PIN-244715)

**Customer's Ref. No.:** 573/NAMAMI GANGE/50 DT. 06.04.2022

**Work Order No.:** 22-0003-O-291

**Sample Collected by:** **Indentor** **Collection Date:** 07.04.2022

**Sample/Job:** STP Sample from DURGAPURI

| PARAMETER | UNIT | OBTAINED VALUE |
|---|---|---|
| Alkalinity | mg/L | 392 |
| Ammonical Nitrogen (as $NH_3$) | mg/L | 31.8 |
| $BOD_3$ at 27°C | mg/L | 4800 |
| COD | mg/L | 12400 |
| Fecal Coliform | MPN/100 mL | $34 \times 10^6$ |
| MLSS | mg/L | 942000 |
| Oil & grease | mg/L | 13.1 |
| pH | - | 7.2 |
| Sludge Volume Index (V/V) | % | 82 |
| Total Coliform | MPN/100 mL | $86 \times 10^6$ |
| Total Kjeldahl Nitrogen (TKN) | mg/L | 56.0 |
| Total Nitrogen | mg/L | 133.8 |
| Total Phosphate | mg/gm | 0.15 |
| Total Suspended Solids | mg/L | 59978 |
| Total Solids | mg/L | 60314 |
| Volatile Suspended Solids | mg/L | 47892 |

Avinash 06/05/22
( Avinash Kumar )
Manager (PCRI)

अविनाश कुमार/Avinash Kumar
प्रबन्धक/Manager
Pollution Control Research Institute
प्रदूषण नियंत्रण अनुसंधान संस्थान
BHEL, Ranipur, Haridwar

प्रदूषण नियन्त्रण अनुसंधान संस्थान

भारत हेवी इलेक्ट्रिकल्स लिमिटेड, रानीपुर, हरिद्वार (उत्तराखण्ड) -249403

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BHARAT HEAVY ELECTRICALS LIMITED
RANIPUR, HARIDWAR (U.K.) - 249 403
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## TEST REPORT

**Lab Reference No:** TL220010 **Date :** 06.05.2022

**Indentor** OFFICE OF THE EXECUTIVE ENGINEER, NIRMAN SHAKHA, UTTARAKHAND PAYJAL SANSADHAN EVAM NIRMAN NIGAM, RAM NAGAR (NAINITAL, PIN-244715)

**Customer's Ref. No.:** 573/NAMAMI GANGE/50 DT. 06.04.2022

**Work Order No.:** 22-0003-O-291

**Sample Collected by: Indentor** **Collection Date:** 07.04.2022

**Sample/Job:** STP Sample from RAM NAGAR PWD

| PARAMETER | UNIT | OBTAINED VALUE |
|---|---|---|
| Alkalinity | mg/L | 540 |
| Ammonical Nitrogen (as $NH_3$) | mg/L | 8.27 |
| $BOD_3$ at 27°C | mg/L | 2900 |
| COD | mg/L | 8800 |
| Fecal Coliform | MPN/100 mL | 15 X $10^6$ |
| MLSS | mg/L | 674000 |
| Oil & grease | mg/L | 12.9 |
| pH | - | 7.4 |
| Sludge Volume Index (V/V) | % | 60 |
| Total Coliform | MPN/100 mL | 44 X $10^6$ |
| Total Kjeldahl Nitrogen (TKN) | mg/L | 29.4 |
| Total Nitrogen | mg/L | 32.2 |
| Total Phosphate | mg/gm | 0.10 |
| Total Suspended Solids | mg/L | 20092 |
| Total Solids | mg/L | 20524 |
| Volatile Suspended Solids | mg/L | 15668 |

Avinash 06/05/22

( Avinash Kumar )

Manager (PCRI)

अविनाश कुमार/Avinash Kumar
प्रबन्धक/Manager
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प्रदूषण नियंत्रण अनुसंधान संस्थान
BHEL, Ranipur, Haridwar

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भारत हेवी इलेक्ट्रिकल्स लिमिटेड, रानीपुर, हरिद्वार (उत्तराखण्ड) -249403

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BHARAT HEAVY ELECTRICALS LIMITED
RANIPUR, HARIDWAR (U.K.) - 249 403
(Approved Lab under Environment (Protection) Act, 1986; EIA Consultancy by NABET, QCI)

## TEST REPORT

**Lab Reference No:** TL220011 **Date :** 06.05.2022

**Indentor** OFFICE OF THE EXECUTIVE ENGINEER, NIRMAN SHAKHA, UTTARAKHAND PAYJAL SANSADHAN EVAM NIRMAN NIGAM, RAM NAGAR (NAINITAL, PIN-244715)

**Customer's Ref. No.:** 573/NAMAMI GANGE/50 DT. 06.04.2022

**Work Order No.:** 22-0003-O-291

**Sample Collected by:** **Indentor** **Collection Date:** 07.04.2022

**Sample/Job:** STP Sample from JAKHANPUR

| PARAMETER | UNIT | OBTAINED VALUE |
|---|---|---|
| Alkalinity | mg/L | 448 |
| Ammonical Nitrogen (as $NH_3$) | mg/L | 14.53 |
| $BOD_3$ at 27°C | mg/L | 3700 |
| COD | mg/L | 9200 |
| Fecal Coliform | MPN/100 mL | $32 \times 10^6$ |
| MLSS | mg/L | 638000 |
| Oil & grease | mg/L | 10.3 |
| pH | - | 7.0 |
| Sludge Volume Index (V/V) | % | 62 |
| Total Coliform | MPN/100 mL | $77 \times 10^6$ |
| Total Kjeldahl Nitrogen (TKN) | mg/L | 46.4 |
| Total Nitrogen | mg/L | 63.6 |
| Total Phosphate | mg/gm | 0.49 |
| Total Suspended Solids | mg/L | 37540 |
| Total Solids | mg/L | 38016 |
| Volatile Suspended Solids | mg/L | 31022 |

Avinash 06/05/22

( Avinash Kumar )

Manager (PCRI)

अविनाश कुमार/Avinash Kumar
प्रबन्धक/Manager
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BHEL, Ranipur, Haridwar

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PCRI/051

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भारत हेवी इलेक्ट्रिकल्स लिमिटेड, रानीपुर, हरिद्वार (उत्तराखण्ड) -249403

## POLLUTION CONTROL RESEARCH INSTITUTE

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BHARAT HEAVY ELECTRICALS LIMITED
RANIPUR, HARIDWAR (U.K.) - 249 403
(Approved Lab under Environment (Protection) Act, 1986; EIA Consultancy by NABET, QCI)

## TEST REPORT

**Lab Reference No:** TL220012 **Date :** 06.05.2022

**Indentor** OFFICE OF THE EXECUTIVE ENGINEER, NIRMAN SHAKHA, UTTARAKHAND PAYJAL SANSADHAN EVAM NIRMAN NIGAM, RAM NAGAR (NAINITAL, PIN-244715)

**Customer's Ref. No.:** 573/NAMAMI GANGE/50 DT. 06.04.2022

**Work Order No.:** 22-0003-O-291

**Sample Collected by:** **Indentor** **Collection Date:** 07.04.2022

**Sample/Job:** STP Sample from BHAWANIGANJ

| PARAMETER | UNIT | OBTAINED VALUE |
|---|---|---|
| Alkalinity | mg/L | 480 |
| Ammonical Nitrogen (as $NH_3$) | mg/L | 10.81 |
| $BOD_3$ at 27°C | mg/L | 4600 |
| COD | mg/L | 11200 |
| Fecal Coliform | MPN/100 mL | $40 \times 10^6$ |
| MLSS | mg/L | 828000 |
| Oil & grease | mg/L | 12.93 |
| pH | - | 6.9 |
| Sludge Volume Index (V/V) | % | 75 |
| Total Coliform | MPN/100 mL | $81 \times 10^6$ |
| Total Kjeldahl Nitrogen (TKN) | mg/L | 67.2 |
| Total Nitrogen | mg/L | 67.8 |
| Total Phosphate | mg/gm | 0.25 |
| Total Suspended Solids | mg/L | 48004 |
| Total Solids | mg/L | 48230 |
| Volatile Suspended Solids | mg/L | 39054 |

Avinash 06/05/22

( Avinash Kumar )

Manager (PCRI)

अविनाश कुमार/Avinash Kumar
प्रबन्धक/Manager
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प्रदूषण नियंत्रण अनुसंधान संस्थान
BHEL, Ranipur, Haridwar

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# Annexure 5

## Pre-feasibility Check for Co-treatment.

In order to propose the Co-treatment module dimensions, the following conditions were evaluated as a pre-feasibility assessment:-

1. Current Utilization of the volumetric capacity of the STP
2. Current Utilization of the loading capacity with respect to BOD, COD and TSS.
3. Volume of septage feasible for co-treatment.

*Table 14 Influent Sewage Characteristics at 7 MLD STP*

| Parameters | Average Influent Concentration (mg/l) | Designed Concentration (mg/l) |
|---|---|---|
| BOD | 87 | 230 |
| COD | 184 | 450 |
| TSS | 123 | 400 |

*Source: 7 MLD STP Lab data*

*Table 15 Faecal sludge and septage characteristic collected in the city*

| Parameters | Average Concentration (mg/l) |
|---|---|
| BOD | 3420 |
| COD | 9040 |
| TSS | 35236 |

*Source: Characteristic Study of faecal sludge Ramnagar/ NIUA/2022*

1. Volumetric Utilization

    Design Capacity = 7 MLD
    Volumetric Utilization of 7 MLD plant = 2 MLD
    Volumetric Utilization (%) = (2/7) *100 = 29%

2. Load Utilization

    Using the data provided in table 14, the design load was calculated

*Table 16 Design load of the STP*

| Parameters | Design Capacity(MLD) | Design Concentration (mg/l) | Design load (kg/d) |
|---|---|---|---|
| BOD | 7 | 230 | 1610 |
| COD | | 450 | 3150 |
| TSS | | 400 | 2800 |

*Table 17 Load Utilization of the STP*

| Parameters | Design Capacity(MLD) | Influent Concentration (mg/l) | Load Utilization (kg/d) |
|---|---|---|---|
| BOD | 2 | 87 | 174.46 |
| COD | | 184 | 368.46 |
| TSS | | 123 | 245.72 |

*Table 18 Load Utilization (%) of STP*

| Parameters | Design Capacity(MLD) | Load Utilization (kg/d) | Load utilization (%) |
|---|---|---|---|
| BOD | 1610 | 174.46 | 11% |
| COD | 3150 | 368.46 | 12% |
| TSS | 2800 | 245.75 | 9% |

*Table 19 Unutilized load of the STP*

| Parameters | Design load (kg/d) | Load Utilization (kg/d) | Unutilized load (kg/d) |
|---|---|---|---|
| BOD | 1610 | 174.46 | 1435.54 |
| COD | 3150 | 368.46 | 2781.54 |
| TSS | 2800 | 245.75 | 2554.28 |

*Table 20 faecal sludge and septage handling capacity of the STP*

| Parameters | Unutilized load (kg/d) | Concentration of Septage (mg/l) | Handling Capacity (KLD) |
|---|---|---|---|
| BOD | 1435.54 | 3420 | 420 |
| COD | 2781.54 | 9040 | 308 |
| TSS | 2554.28 | 35236 | 72 |

We must choose the least of the Handling Capacity, as If we choose BOD as the constraining parameter , it might handle BOD parameter upto 418 KLD but will surely introduce more COD and TSS along with it.

In order to understand the implications of the co-treatment on the operation and maintenance cost of the STP. This would enable to draft a better terms for the maintenance contract with a private operator.

*Table 21 Design and Actual flow rate at the STP*

| Parameter | Quantity $(m^3/h)$ |
|---|---|
| Design flow rate | 291.66 |
| Actual flow rate | 83.33 |

*Table 22 Organic and solids loading rate at STP*

| Parameter | Flow Rate $(m^3/h)$ | | Concentration ( mg/l) | |
|---|---|---|---|---|
| | Design | Actual | Design | Actual |
| BOD | 291.66 | 83.33 | 230 | 87 |
| COD | | | 450 | 184 |
| TSS | | | 400 | 123 |
| | | | | |
| Parameter | Loading Rate (kg/h) | | Unutilized loading (kg/h) | |
| | Design | Actual | | |
| BOD | 53.66666667 | 5.815333333 | 48 | |
| COD | 105 | 12.282 | 92.718 | |
| TSS | 93.33333333 | 8.190666667 | 85.142 | |

*Table 23 Faecal Sludge and Septage Load*

| Parameter | Concentration (mg/l) | Truck Capacity (KL) | Truck Decanted (No. /h) | Truck Load (kg/h) |
|---|---|---|---|---|
| BOD | 3420 | 4 | 1.07142 | 15 |
| COD | 9040 | 4 | 1.07142 | 39 |
| TSS | 35236 | 4 | 1.07142 | 151 |

If direct addition of FSS is to be done in the receiving well sump, then feasible load that can be added is 4 ((85.142/151) *7 ) truckload in 7 hours with TSS as the constraining parameter. It’s not recommended to directly dump the Septage into the well sump as it further create other operational problems such as damaging the diffuser beds of the Aeration tanks, Clogging the screens and altering bacteria culture in the ASP.

In order to add the FSS in the sewage (liquid stream), addition after solid- liquid separation must be practiced. This mainly depends on the utilization of design capacity and availability of land area within the plant premises. For further stage, a safety factor should be considered to accommodate any change in the quality of the influent sewage or septage for which a safety factor of **20%** is assumed. Therefore a solid-liquid separation using a settling thickening tank with a settling proficiency of 60%. For every truck emptied in the settling thickening tank, part of solids are settled in the tank as thickened sludge and the rest of the solids are retained in the liquid phase.

*Table 24 Settling Thickening tank Solid Liquid Separation Calculation*

| Parameter | Quantity | Units & Remarks |
|---|---|---|
| Volume of Septage | 4.285 | $m^3$/h |
| TSS | 35236 | mg/l |
| Solid Content | 3.5 % | Considered, i.e. initial |
| Solid Loading Rate | 151 | Kg/h |
| Efficiency | 60% | Considered |
| Dry Solid Content | 8% | Considered as per practice |
| Thickened Sludge Density | 1020 | Kg/$m^3$, considered |
| Suspended Solid load in Thickened Sludge Stream (kg/h) | 91 | Kg/h |
| Suspended Solid in Supernatant Stream (kg/h) | 60 | Kg/h |
| Volume of thickened sludge | 1.11 | $m^3$/h |
| Volume of Supernatant | 3.2 | $m^3$/h |
| Solid Content(%) in Supernatant | 1.9023 % | |
| Solid Content (ppm) in Supernatant | 19371 mg/l | mg/l as 1 % density of water give 10000 mg/l |

Note: 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 25 Characteristics of Supernatant from Settling thickening tank*

| Parameter | Concentration (ng/l) | |
|---|---|---|
| | FSS | Supernatant |
| BOD | 3420 | 1880 |
| COD | 9040 | 4970 |
| TSS | 35236 | 19371 |

*Table 26 Organic and Solids load of supernatant from settling thickening tank*

| Parameter | Concentration (mg/l) | Supernatant Volume ($m^3$/h) | Supernatant Load (kg/h) |
|---|---|---|---|
| BOD | 1846 | 3.2 | 6 |
| COD | 4880 | 3.2 | 15 |
| TSS | 19023 | 3.2 | 60 |

| Parameter | Unutilized loading (kg/h) | Supernatant Load (kg/h) | Feasible truck Load (No./h) |
|---|---|---|---|
| BOD | 1435.54 | 6 | 245 |
| COD | 2781.54 | 15 | 147 |

| | | | |
|---|---|---|---|
| TSS | 2554.28 | 60 | 42 |

Thus, for Safer treatment the constraining parameter is identified and corresponding trucks loads are taken for further calculation. Thus in this case, the feasible truck loads are 42 no./h. It can also be inferred that because of solid-liquid separation, the STP can handle almost 74 times the load when compared to direct addition of faecal sludge in the receiving well sump.

**Annexure 6**

Operation & Maintenance

It is essential to regularly operate and maintain the co-treatment facility for its smooth function and improved life span. It is necessary that all officials / engineers and staff of STP have a handout of the O&M activities and familiarize themselves with the standard operating procedures. Sign boards with O & M schedules should be displayed at the site. The operator must be familiar with the operating procedures before he starts to operate and maintain the Co-treatment facility. It is a must that the operator undergoes a training program dedicated to O&M of STP and handling Co-treatment facility from the service provider. An operating procedure steps to be followed for co-treatment is presented in a check list format, see annexure.

## 6.1. Truck Arrival & Faecal Sludge Decanting

The truck arrives at the STP and follows the road leading towards the screening chamber – Decanting Station. It should be the responsibility of the respective vacuum tanker operator to connect truck's outlet with the screening chamber through hose pipe and discharge the faecal sludge with half of the opened valve into the screening chamber. Spillage of FS at the decanting station should be avoided. A STP operator should monitor the decanting process and can fine the operator if spillage occurs due to negligence. The working hours to decant FS should be 9 am to 5 pm with one hour lunch time. Record of collection, transport & disposal of FSS should be duly filled and signed by the STP operator before allowing tanker to enter the STP. For safety measures to be followed and personal protective equipment to be taken while handling faecal sludge and septage

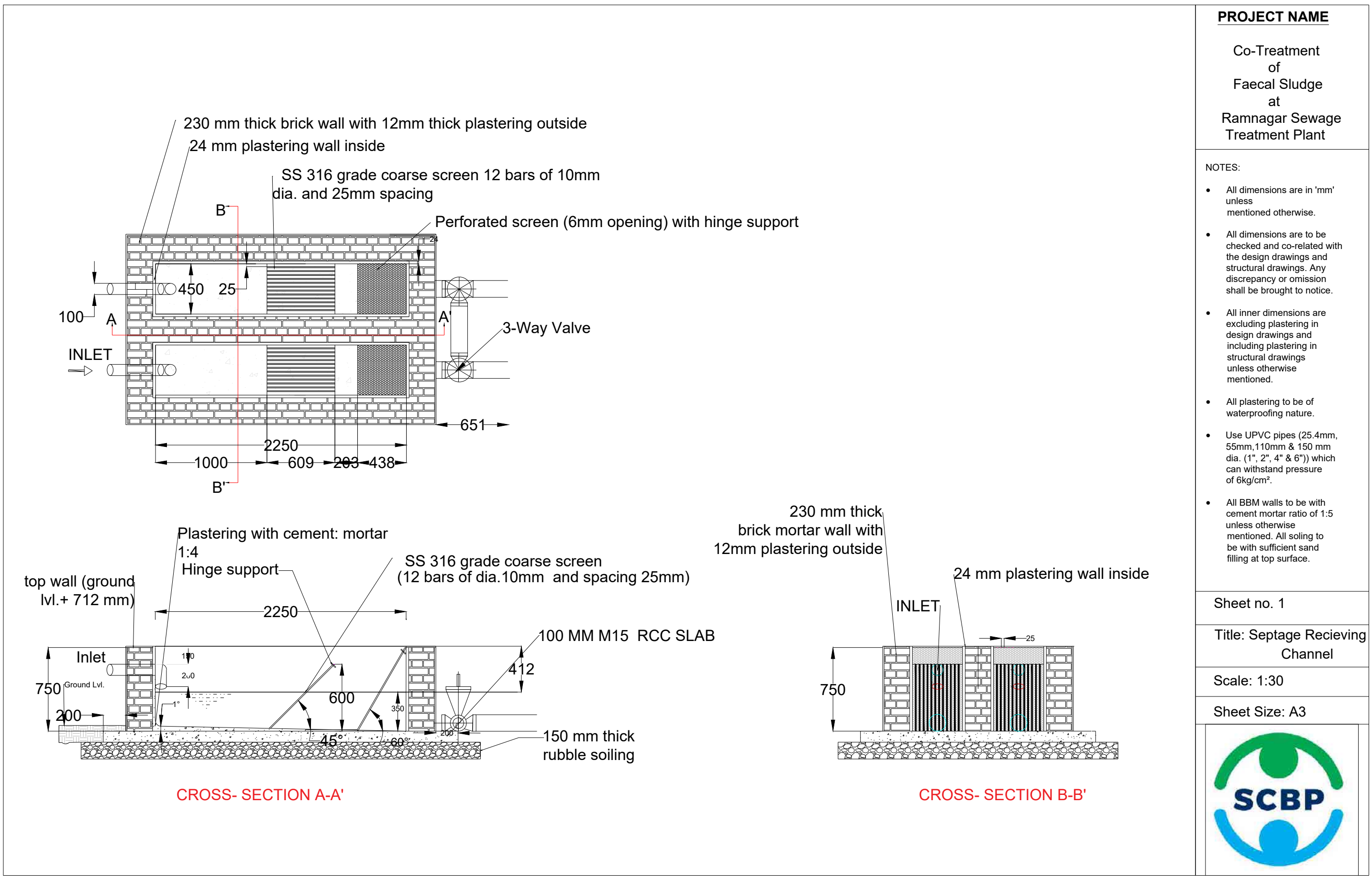
## 6.2. Inlet Channel

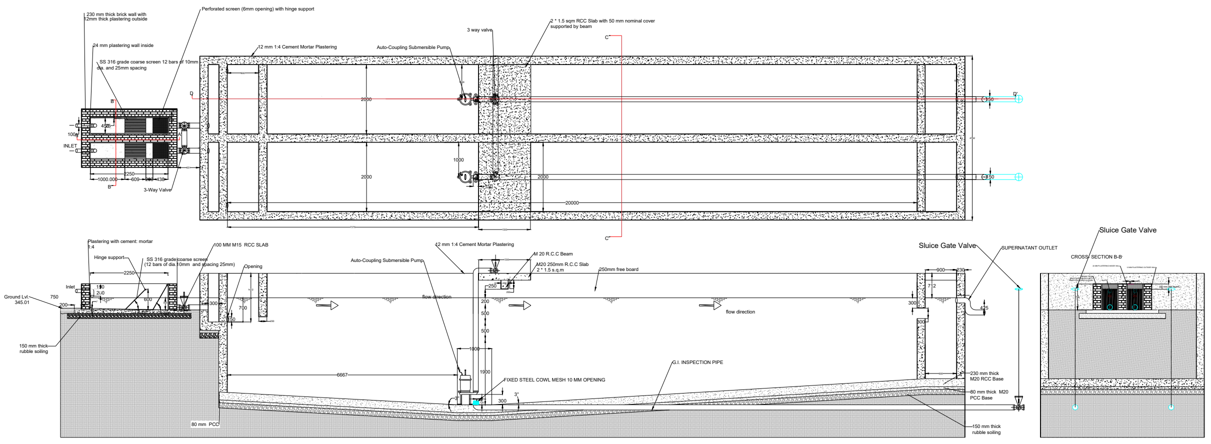
After decanting of faecal sludge by the trucks in a whole day, the screening chamber should be cleaned at the end of the day but before sunset. The solid waste and the grit deposited and screenings at the unit should be removed manually and disposed with trash collected by other screens of the STP. The operator should wear protective equipment such as gloves and make sure to not have skin contact with the faecal sludge.

## 6.3. Tap with Sprayer (Spillage)

A water tap with a sprayer as an additional equipment should be installed near to inlet of screen chamber. This should be used for cleaning in case of spillage by tankers and blockage at screen. For safety reasons, this tap can be used in case of accidental spillage. In case of spillage during decanting operation, based on the intensity of the spillage the staff responsible for supervision should get the affected area washed by using clean water from the sprayer and sprinkle the lime on it.

# Annexure 7 : Drawings of the co-treatment unit






CROSS- SECTION A-A'

CROSS- SECTION D-D'

CROSS- SECTION C-C'

**PROJECT NAME**

Co-Treatment
of
Faecal Sludge
at
Ramnagar Sewage
Treatment Plant

NOTES:

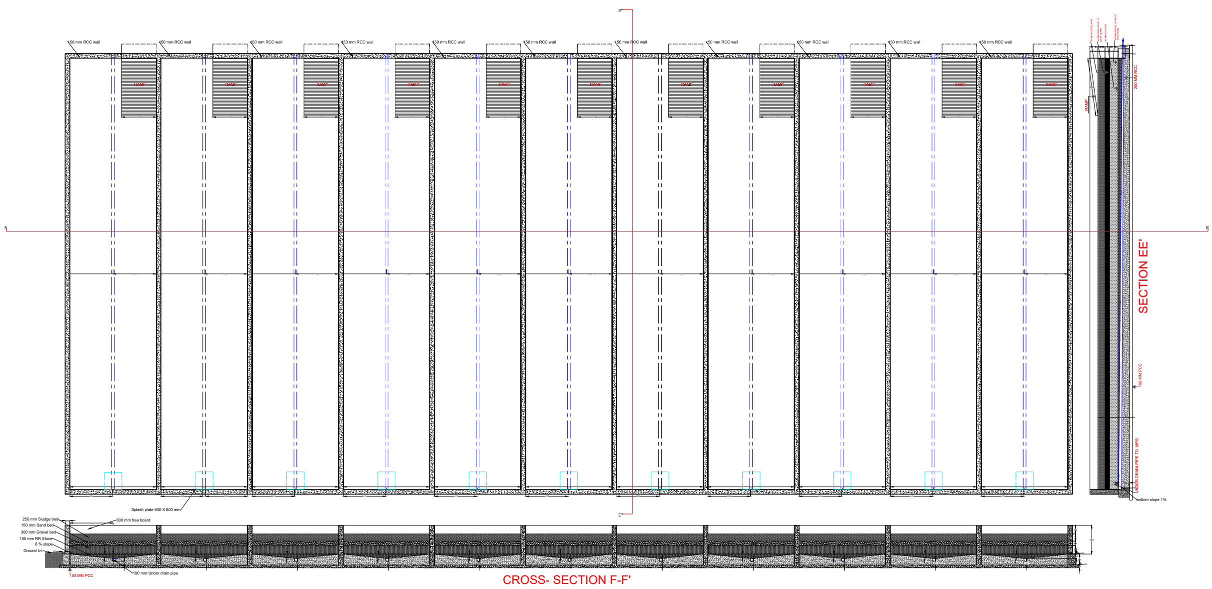
- All dimensions are in 'mm' unless mentioned otherwise.
- All dimensions are to be checked and co-related with the design drawings and structural drawings. Any discrepancy or omission shall be brought to notice.
- All inner dimensions are excluding plastering in design drawings and including plastering in structural drawings unless otherwise mentioned.
- All plastering to be of waterproofing nature.
- Use UPVC pipes (25.4mm, 55mm, 110mm & 150 mm dia (1", 2", 4" & 6")) which can withstand pressure of 6kg/cm².
- All BBM walls to be with cement mortar ratio of 1:5 unless otherwise mentioned. All soling to be with sufficient sand filling at top surface.

Sheet no. 2

Title: Settling thickening tank

Scale: 1: 50

Sheet Size: A1




CROSS- SECTION F-F'

**PROJECT NAME**

Co-Treatment
of
Faecal Sludge
at
Ramnagar Sewage
Treatment Plant

NOTES:

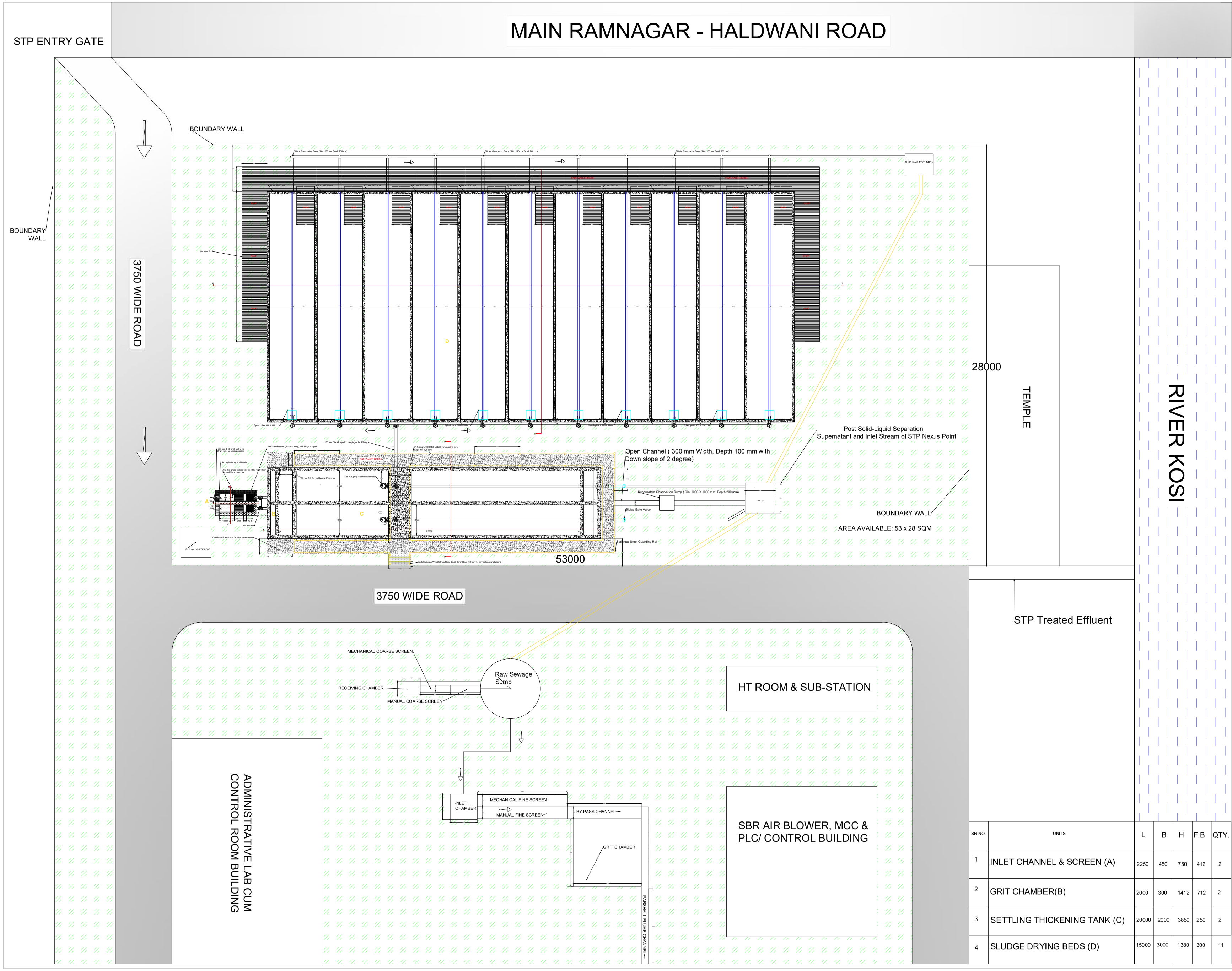
- All dimensions are in 'mm' unless mentioned otherwise.
- All dimensions are to be checked and co-related with the design drawings and structural drawings. Any discrepancy or omission shall be brought to notice.
- All inner dimensions are excluding plastering in design drawings and including plastering in structural drawings unless otherwise mentioned.
- All plastering to be of waterproofing nature.
- Use UPVC pipes (25.4mm, 55mm, 110mm & 150 mm dia (1", 2", 4" & 6")) which can withstand pressure of 6kg/cm².
- All BBM walls to be with cement mortar ratio of 1:5 unless otherwise mentioned. All soling to be with sufficient sand filling at top surface.

Sheet no. 3

Title: Sludge drying beds

Scale: 1: 60

Sheet Size: A1




| SR.NO. | UNITS | L | B | H | F.B | QTY. |
|---|---|---|---|---|---|---|
| 1 | INLET CHANNEL & SCREEN (A) | 2250 | 450 | 750 | 412 | 2 |
| 2 | GRIT CHAMBER(B) | 2000 | 300 | 1412 | 712 | 2 |
| 3 | SETTLING THICKENING TANK (C) | 20000 | 2000 | 3850 | 250 | 2 |
| 4 | SLUDGE DRYING BEDS (D) | 15000 | 3000 | 1380 | 300 | 11 |

**PROJECT NAME**

Co-Treatment of Faecal Sludge at Ramnagar Sewage Treatment Plant

NOTES:

- All dimensions are in 'mm' unless mentioned otherwise.
- All dimensions are to be checked and co-related with the design drawings and structural drawings. Any discrepancy or omission shall be brought to notice.
- All inner dimensions are excluding plastering in design drawings and including plastering in structural drawings unless otherwise mentioned.
- All plastering to be of waterproofing nature.
- Use UPVC pipes (25.4mm, 55mm,110mm & 150 mm dia. (1", 2", 4" & 6")) which can withstand pressure of 6kg/cm².
- All BBM walls to be with cement mortar ratio of 1:5 unless otherwise mentioned. All soling to be with sufficient sand filling at top surface.

Sheet no. 4

Title: Layout Plan for Co-treatment

Scale: 1:225

Sheet Size: A3