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"FSM by Novel Approach of Vermifiltration Adapted to Rural Area: A Case Study of Nachane Village- Ratnagiri District, Maharashtra"

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Abstract -*The primary objective of this case study to analysis population and sanitation coverage data for workout and design calculations for Faecal Sludge Treatment Plant (FSTP) Capacity, appropriate low cost & eco-friendly technology i.e., Tiger Biofilter Technology finalization with appropriate Process Units to treat Faecal Sludge properly and final outlet within limit as per recommended norms by Maharashtra Pollution Control Board (MPCB) for selected cluster villages from Ratnagiri Block, Ratnagiri District. After Construction of FSTP, conclusion includes that before and after installation of FSTP scenario of the villages related to Environment.*

Key Words: *Faecal Sludge Management (FSM), Septage, Treatment, Vermifilter, Earthworm, Tiger Biofilter (TBF), Ratnagiri, FSM Chain*

1. INTRODUCTION

1.1. General

The Government of India recently launched Swachh Bharat Mission (Gramin) (SBM-G) Phase II guidelines to sustain the gains of SBM achieved during the last five years. The aim is to achieve sustainability of Open Defecation Free (ODF) status and creation of Solid and Liquid Waste Management (SLWM) services in rural areas. The guideline focuses on importance of Faecal Sludge Management (FSM) as one of the key components of SBM (G) phase II.

Maharashtra has been a pioneer state in water supply and sanitation sector. In responsive to the initiative of SLWM undertaken through SBM (G) phase II, Government of Maharashtra has selected villages for immediate planning and execution of SLWM interventions.

FSM is an evolving field which is becoming increasingly significant. The overflow from filled-up septic tanks and indiscriminate disposal of faecal sludge in open areas, water bodies, open drains, outside the village, etc. is causing the spread of diseases and environmental pollution. Safe and environmentally responsible management of faecal sludge is crucial for maintaining the ODF status of the country.

Under the SBM (G) Phase II it is proposed that faecal sludge treatment plant to be constructed to cater for treatment of Septic tank, Single pit toilet sludge. In rural as well as urban areas recently the large numbers of septic tanks have been constructed.

As there is no Faecal treatment facility near Nachane. A Faecal sludge treatment plant is proposed to be installed in Nachane village of Ratnagiri Taluka and district of Maharashtra state under SBM (G) II. The proposed plant is of 10 KLD capacity. This FSTP plant proposed for GP cluster of Nachane, Shirgaon, Mirjole, Kuvarbav and Khedshi.

1.2. Objective

- To identify existing status of sanitation and faecal sludge management options
- To investigate Septage characteristics, treatment methods for faecal sludge and suitable low cost and eco-friendly technology finalization
- To verify process description and design specification for treatment of faecal sludge
- To finalize suitable location for treatment plant

1.3. Need of the Project

Faecal sludge management is the collection, transport, and treatment of faecal sludge from pit latrines, septic tanks or other onsite containment systems. Faecal sludge is a mixture of human excreta, water and solid wastes (e. g. toilet paper or anal cleansing materials, menstrual hygiene materials) that are disposed in pits, tanks or vaults of onsite sanitation systems. Faecal sludge that is removed from septic tanks is called septage. FSM is necessary in densely populated areas where a proportion of population is not connected to a sewerage network, and the covering and rebuilding pit latrines is not possible.

1.4. Scope of the work

- Basic sanitation and population data collection, analysis and problem identification
- Various technology data collection, comparison and finalization
- Verification and analysis design calculation, hydraulic design, layout and drawings
- Commissioning of the FSTP after completion of construction work
- Conclusion includes that before and after installation of FSTP scenario of the village

1.5. Methodology

- To determine FSTP capacity as per design calculation as specification
- To visit at site for identification and finalization land for work
- To visit at site for checking construction work as per approved design and drawings

2. APPROACH METHODOLOGY

2.1. About Nachane

Nachane is a village in Ratnagiri Taluka & District of Maharashtra State. It is located 4.0 KM towards West from District headquarters Ratnagiri. Shirgaon, Mirjole, Kuvarbav and Khedshi are the nearby Villages to Nachane. The village is about 4.0 km away from Ratnagiri city and about 130 km away from Kolhapur city. Owing to its access to the taluka place, the village is experiencing high growth rate as well as the migrated population in the village is also high.

2.2. Status of Sanitation in selected villages

Ratnagiri taluka was declared to be ODF in the year 2015. Currently, majority of the households rely on on-site sanitation systems such as septic tanks and pits to contain and partially treat black-water that is generated. Septic tanks or single pit latrines require routine de-sludging of accumulated faecal matter. In absence of such routine activities, there is a chance of overflowing of septic tank or even choking of toilets. This in turn has a possibility that the user switch to open defecation practice. Therefore, de-sludging facilities as well as faecal sludge treatment plant are crucial to maintain ODF status of the Taluka. As per ODF status reported on Swachh Bharat Mission, septic toilets in rural Maharashtra state in 35 to 40 %.

Following table showing the details of Septic tank/ Single Pit latrine in Project Area.

Sr. No.	Name of GP	Households	Septic Tank/ Single Pit
1	Nachane	2,575	2,575
2	Shirgaon	3,464	3,464
3	Mirjole	2,383	2,383
4	Kuvarbav	3,053	3,053
5	Khedshi	884	884
	Total	**12,357**	**12,357**

Table 1 Septic tanks / Single Pit latrines in Project Area

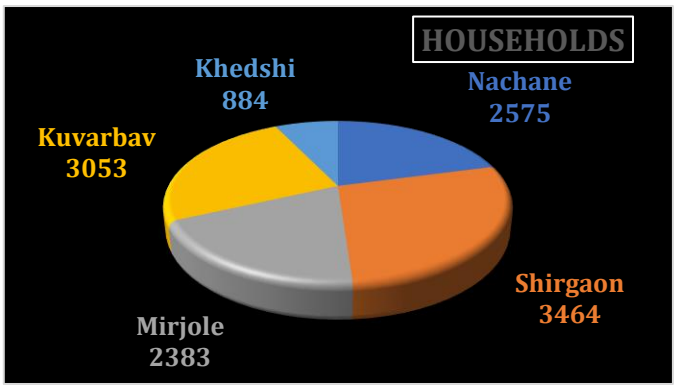

Figure 1 Households in Project Area

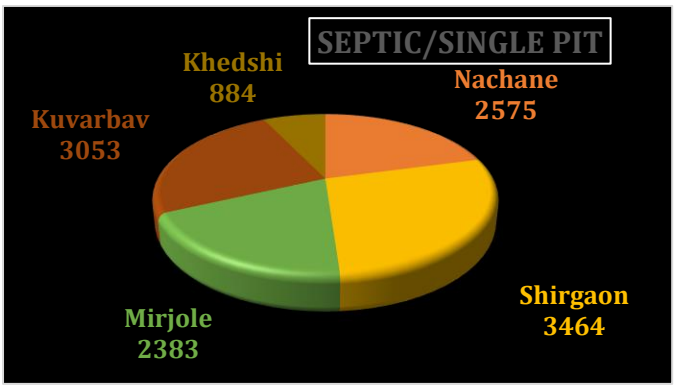

Figure 2 Septic Tank/Single Pit Latrines in Project Area

2.3. Current Collection Status

Currently, some private agencies have invested in procuring desludging vehicles. The de-sludging vehicles are of various capacities, ranging from 1 cubic meter to 3 cubic meters. These private operators provide de-sludging facility on the demand of house owners.

Figure 3 Honeysucker vehicle in Nachane

However, in absence of a faecal sludge treatment plant; the sludge transported by these vehicles is disposed in open drains or open lands in outskirts of the villages which again contaminates land and water bodies.

In Project area Nagarpalika engaged in the process of desludging of septic tank. Capacity of vehicle is 3000 lit. In the interaction with Nagarpalika service provider found that they made 3 to 4 trips daily.

SBM (G) II guidelines mention cluster level approach for construction of FSTP. In simple words, the design and location of the proposed FSTP should be such that it can cater the faecal sludge from villages up to a distance of 10 km from the proposed FSTP. Keeping in view, the grave effects of open disposal of faecal sludge and the provisions under SBM (G) phase II, it is proposed to construct a faecal sludge treatment plant adopting Tiger Bio Filter Technology. The proposed plant will be located in Nachane and have the capacity to cater faecal sludge from villages, Nachane, Ambeshet (Nachane GP), Shirgaon, Aadi (Shirgaon GP), Muslimwadi (Shirgaon GP), Tiwandewadi (Shirgaon GP), Zadgaon (Shirgaon GP), Mirjole, Kuvarbav, Khedshi. These villages are located at a distance of up to 10 km from Nachane.

The photograph below shows the location of these villages with respect to Nachane.

Figure 4 Google image of Nachane and other villages

Following table shows location details of cluster formed for faecal sludge management.

GP Name	Distance	Latitude	Longitude
Nachane	0 KM	16°59'17.90"N	73°20'16.16"E
Shirgaon	10 KM	17°01'24.39"N	73°17'43.67"E
Mirjole	8 KM	17°01'29.41"N	73°20'04.00"E
Kuvarbav	7 KM	16°57'29.84"N	73°21'52.92"E
Khedshi	5 KM	17°01'07.70"N	73°22'39.18"E

Table 2 FSM Cluster details in Project Area

2.4. What is faecal sludge?

Faecal sludge is the waste accumulated in a septic tank which is a raw or partially digested mixture mostly of excreta and water. This sludge has high organic and pathogenic contents and hence requires further treatment prior to its disposal in the environment.

2.5. FSM chain

Faecal sludge management consists of the following activities:

- **De-sludging-** On-site sanitations systems like single pits, septic tanks, etc. need to be emptied/ de-sludge using improved methods like vacuum trucks, tractor mounted vacuum pumps, tanker etc. Manual scavenging of Faecal sludge from containment units is strictly prohibited under Manual Scavengers and Their Rehabilitation Act, 2013.

- **Transport-** The de-sludge material needs to be transported to designated treatment plant. Even during the transport phase, it needs to be ensured that the faecal sludge has no human contact and the process of emptying the tanker into the treatment unit is fully mechanised.

- **End treatment-** The Faecal sludge disposed at the treatment unit needs to be treated in environmentally responsible manner so that the by-products are stable and can be re-used or safely disposed in to the environment.

- **By-products-** Usually, the organic solids from the Faecal sludge can be used as soil conditioner after treatment. The liquid component of the sludge post-treatment can be used for irrigation or other non-potable uses. Establishing market linkages for effective use of the by-products is also encouraged under SBM (G) II.

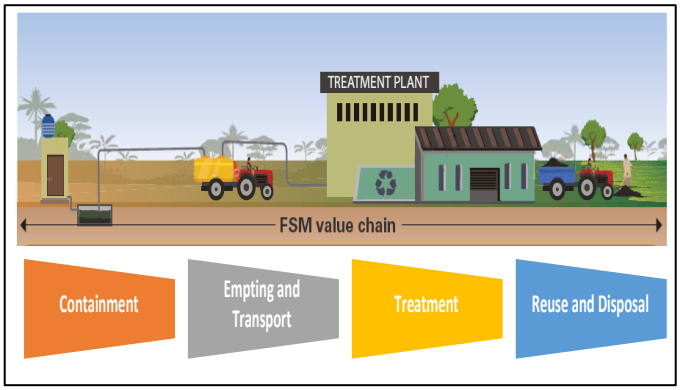

Figure 5 Value chain in faecal sludge management

2.6. Characteristics of septage

The quality and quantity of septage coming out of the tank depends largely on the type of sewage, the frequency of de-sludging, water usage and household chemicals going in the septic tank. Hence, the physical and biological characteristics of septage are highly variable. Faecal sludge or septage contains constituents that may result in unpleasant odour, risk to public health and serious environmental hazards. Disposal of septage into a water body could result in depletion of oxygen, eutrophication and health hazard on account of the pathogens.

Therefore, knowledge of septage characteristics, its variability, dewater ability are important in determining acceptable treatment and disposal methods.

Characteristics of septage are summarized in the table below.

Sr. No.	Parameters (mg/l), except pH)	Average	Range
1	Biochemical Oxygen Demand	6,480	440 -78,600
2	Chemical Oxygen Demand	31,900	1,500 –7,03,000
3	Total Solids	34,106	1132 – 1,30,745
4	Total Volatile Solids	23,100	353 – 71,402
5	Total Suspended Solids	12,862	310 - 93,378
6	Volatile Suspended Solids	9,027	95 - 51,500
7	Total Kjeldahl Nitrogen	588	66 - 1,060
8	Ammonia-Nitrogen	97	3 - 116
9	Total Phosphorus	210	20 - 760
10	Alkalinity	970	522 - 4,190
11	Grease	5,600	208 - 23,368
12	pH	7.00	1.5 - 12.6

Table 3 Characteristics of incoming faecal sludge

The strength or organic content of the sludge largely depends on the age of the sludge being de-sludge and hence the de-sludging frequency. The other factors like weather, rate and regularity of water supply and sanitation habits also play a role in characteristics of the faecal sludge.

2.7. Treatment Methods for Faecal Sludge

The technologies adopted for treatment of faecal sludge, generally include separation of solids and liquids followed by their treatment. The technologies can be broadly divided based on the nature of treatment. Different treatment options are as given below.

Natural Process	Mechanized Treatment Process
Sludge Drying Beds (Planted/ Unplanted)	Moving bed biofilm reactor (MBBR)
Deep row entrenchment	Pyrolysis
Vermiculture Technology Tiger Biofilter (TBF)	Incineration
Bio methanation	Gasification
Decentralized wastewater treatment System (DEWATS)	Mechanical Dewatering Screw Press Technology

Table 4 Faecal Sludge Technology Options

A few FSM technologies are described in the SBM (G) II guidelines. Moreover, innovative technical interventions and low-cost technologies are encouraged for effective FSM. The objective of these interventions is to provide a solution to the emerging problem of faecal sludge disposal in environmentally responsible and financially sustainable manner.

SBM (G) phase II guidelines have a mention of Deep Row Entrenchment and Sludge Drying Beds technology options for effective treatment of Faecal sludge. However, the guidelines also mention that SBM (G) II hall also be made available for any other technologies that have proven to be effective in FSM. One of the effective methods for treatment of faecal sludge is Vermifiltration based technology; the same is adopted in Tiger Bio Filters (TBF). This technology is accepted for liquid waste treatment under Government resolution number Swabhami-2019/PR No. 141/WS-16 dated 19th July 2019. It is proposed to adopt this technology in the upcoming FSTP in Nachane village. Components and working of this technology are given in the section below.

2.8. Vermifiltration Based Technology

Vermifilter has proven to be effective for treatment of wastewater (black and grey) as well as Faecal sludge. In this process a special species of earthworms is used for digestion of faecal matter converting it into vermicompost.

Earthworms are well known to promote digestion of organic waste, which results in the production of vermicompost. In Tiger Bio Filter, this behaviour is combined with filtration to digest organics present in faecal sludge / septage. This technology comprises four stages- anaerobic digestion, vermifiltration-I, vermifiltration-II and tertiary treatment. The worms need air, water and organic matter to form a sustainable population in the Vermifilter bed.

The Tiger Bio Filter FSTP combines anaerobic processes with vermifiltration to improve the degree of treatment at a reduced cost, optimum space utilization and negligible operation maintenance cost. The application of vermifiltration based Tiger Bio Filter Technology has been found to be appropriate for faecal sludge treatment as the system is capable of handling very high organic loads.

3. DESIGN AND CALCULATIONS- FAECAL SLUDGE MANAGEMENT IN NACHANE

3.1. Population Forecasting

Population of each village as per census 2011 is given in the table below. The district decadal population increase rate is found to be about 16%. Based on this, the current population of the villages is also given in the table. The FSTP is to be constructed with a view to cater increasing population at least for next 15 years. The rural growth rate is assumed to be 18% for next 15 years as per JJM guidelines. The same is considered while calculating the capacity of proposed FSTP.

Sr No	Village Name	Pop. (2011)	Pop. (2021) Projected (@16%)	Projected Pop. for 15 Years (@18%)
1	Nachane	13,080	15,173	17,904
2	Shirgaon	15,111	17,529	20,684
3	Mirjole	8,453	9,805	11,570
4	Kuvarbav	6,497	7,537	8,894
5	Khedshi	4,651	5,395	6,366
	Total	**47,792**	**55,439**	**65,418**

Table 5 Population consideration of each village

As per information given by Grampanchayat, there are 12,357 nos. containment tank are based on septic tank and single pit type. The septic tank capacity varies from 2-5 cubic meters and the de-sludging interval is 5-10 years. Based on these inputs, calculation for plant capacity is given in the table below.

3.2. Faecal Sludge Quantity Calculation

Sr No	Description	Value	Unit	Range
1	**Population Details as per Census 2011**			
a	Nachane	13,080	Soul	
b	Shirgaon	15,111	Soul	

Sr No	Description	Value	Unit	Range
c	Mirjole	8,413	Soul	
d	Kuvarbav	6,497	Soul	
e	Khedshi	4,651	Soul	
Total Population as per Census 2011		**47,792**	**Soul**	
2	**Projected Population 2021 (Considered 16% Growth rate for Ratnagiri District of Census 2011)**			
	Total Projected Pop. 2021	**55,439**	**Soul**	
3	**Rural Growth Rate for next 15 years as per JJM Guideline (Considered 18% Growth rate)**			
	Total Population for next 15 years	**65,418**	**Soul**	
4	**Village wise Containment Tanks Details (As per data provided by GP)**			
a	Nachane	2575	Nos.	
b	Shirgaon	3464	Nos.	
c	Mirjole	2381	Nos.	
d	Kuvarbav	3053	Nos.	
e	Khedshi	884	Nos.	
	Total	**12,357**	**Nos.**	
5	Average Volume of Containment Tanks	2.00	Cum	0.5 to 2 Cum
6	Average Emptying Volume of Septage from Tank	65.00	%	50-80
		1.30	Cum	
7	Desludging period @once in	5	years	5-10
8	Effective operating Days per Annum	300	Days	250-300
9	FSTP Capacity	10.71	Cum/Day	
10	**FSTP Capacity Adopted**	**10.00**	Cum/Day	
11	**No. of Houses emptied daily**	**7.00**	Nos./Day	

Note: - containment tank = Septic or Single pit Latrine tanks

Table 6 Faecal Sludge Quantity Calculation

Therefore, the proposed capacity of the plant is 10 cum/day or 10 KLD. The recommended system for Tiger Bio Filter based FSTP would comprise of Screen Chamber, Sludge Storage Tanks, Anaerobic Stabilization Reactor, Tiger Bio Filter I & II, Liquid Storage Tank I & II followed by Filter Feed tank with tertiary treatment in form of pressure sand filter, activated carbon filter and disinfection. The system configuration can be altered depending upon end use of treated water.

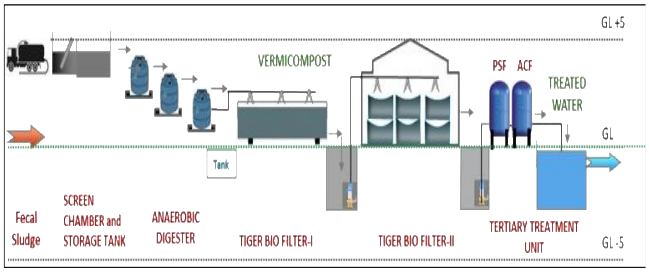

Figure 6 FSTP Process Configuration with TBF technology

Tiger Bio Filter uses Tiger worms or Eisenia Fetida worm species. Tiger worms are capable of compositing human waste rapidly. The system is designed accordingly with sufficient surface area and worm quantity. The worm population is self-regulating depending upon availability of food (organics) resulting in increased efficiency and operational flexibility.

4. PROCESS DESCRIPTION

4.1. General

In treatment process the screened faecal sludge is stored into sludge storage tank and then taken to anaerobic stabilization reactor to carry out destruction of volatile organic carbon. This process also reduces pathogens. The sludge is then allowed to pass through Tiger Bio Filter-I (TBF-I). This is designed to separate digested sludge and water. As the sludge passes through TBF-I solids are trapped in filter media. These trapped organics are consumed by Tiger worms. This provides energy for reproduction and living for worms. The organics are converted into vermicompost that needs to be harvested periodically from the filter bed. The effluent from TBF-I is then passed through Tiger Bio Filter II, which is designed to handle higher liquid load. This function is similar to TBF-I. As the organics in the influent are digested in the subsequent filter beds, the quality of effluent is enhanced. The effluent collected from TBF-II is more or less clear water. This is further applied to tertiary treatment units such as Pressure Sand Filter (PSF) and Activated Carbon Filter (ACF) in order to polish it. After polishing the water is disinfected using chlorination to make it suitable for human handling, reuse and disposal.

The filter unit provides a habitat & respiration zone for earthworm growth and propagation. The filtration through TBF-I provide a unique single step and synchronous process for treating liquid and solid components of digested sludge. The by-products generated as the result of treatment are vermicompost and treated effluent, which are safe of human handling. Treated effluent can be used for any non-potable purpose and the vermicompost is an excellent soil conditioner.

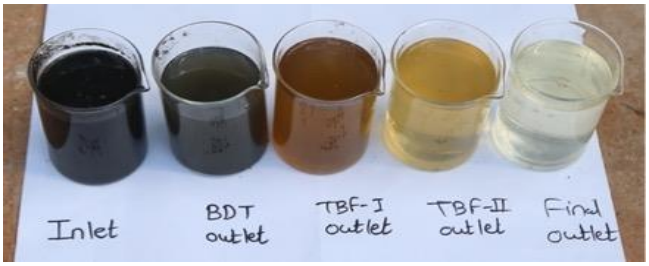

Figure 7 Inlet to Outlet Sample by using TBF Technology

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4.2. Screen Chamber and Sludge Storage tank

Screen Chamber is used to remove large size floating matters, plastic etc from faecal sludge coming from households or customers.

After screening, sludge will be stored in the Sludge Storage Tank. The sludge will be pumped to Anaerobic Stabilization Reactor for further process.

4.3. Anaerobic Stabilization Reactor (ASR)

Anaerobic digestion is a collection of processes by which micro-organisms breakdown the biodegradable material in the absence of oxygen.

These tanks are used to reduce organic load from Faecal Sludge. This tank contains specially formulated bacterial culture which consumes organics from faecal sludge. Total five chambers are provided and this is a three-stage process which includes mixing, digestion and collection.

4.4. Tiger Bio Filter – I

The digested sludge is then spread on beds comprising earth worms, bacterial culture that provides a favourable habitat and respiration zone for earthworm growth and reproduction.

This tank is used to separate residual solids and liquid stream coming from anaerobic digesters. The offensive odours are completely removed in this stage. The trapped solids are consumed by earthworms and converted to vermicompost further reducing the organic load. The liquid stream leaves the tank from bottom and stored into the Intermediate Storage Tank I.

4.5. Tiger Bio Filter - II

This is setup consisting staggered media and earth worms in a module. The effluent from stage I enter the module from top and leaves from bottom leaving behind the impurities in media. The trapped solids are consumed by earthworms and converted to Vermicompost.

4.6. Horizontal Planted Gravel Filter

This is polishing unit, provided for removal of nutrients from effluent. Canna plants are used to consume nutrients and grow rapidly. Simultaneous reduction in TKN and nitrate pointed to good nitrification rates, and efficient plant, assimilation as the dominant nutrient removal mechanism, that impact on the reduction in TKN and nitrate. The effluent is stored into Intermediate Storage Tank II.

4.7. Tertiary Treatment

Pressure Sand Filter, Activated Carbon Filter and Chlorination Unit a polishing unit, provided to remove any colour or odour remaining from secondary treatment. The disinfection by Chlorination is provided to make treated effluent safe for human handling and disposal.

4.8. Design Specification

Sr. No.	Unit Description	Qty	Size	MoC
1	Screen Chamber	01	2.0 X 0.50 X 0.70 m	RCC
2	Sludge Storage Tank	01	5.00 X 3.00 X 1.90 m	RCC
	Anaerobic Stabilization Reactor			
3	Mixing Chamber	02	1.50 X 3.00 X 1.50 m	RCC
4	Digestion Chamber	06	1.50 X 3.00 X 3.00 m	RCC
5	Liquid Storage Tank-I	01	1.50 X 1.50 X 3.00 m	RCC
6	Tiger Bio Filter-I	08	3.00 X 3.00 X 1.00 m	Brick
7	Liquid Storage Tank-II	01	1.50 X 3.00 X 1.50 m	RCC
8	Tiger Bio Filter-II	01	5.00 X 3.40 X 1.20 m	Brick
9	Filter Feed Tank	01	1.50 X 3.00 X 1.50 m	RCC
10	Treated Water Tank	01	1.50 X 3.00 X 1.50 m	RCC
11	Pressure Sand Filter	01	Dia-0.30 H-1.20	FRP
12	Activated Sand Filter	01	Dia-0.30 H-1.20	FRP
13	Chlorination Unit	01	0.30 X 0.30 X 3.00 m	PVC
14	Control Panel Room	01	3.00 X 3.00 X 3.00 m	Prefab

Table 7 Faecal Sludge Treatment Plant Unit Sizing

4.9. Land Availability

For set up of FSTP the survey has been carried out in Nachane Grampanchayat and nearby villages. As per SBM (G) phase II, Grampanchayat owned land is to be proposed for the project implementation. As per survey sufficient land is available at Nachane village which is located near the Smashan Bhumi.

During survey, total open land has been measured which is available for development of FSTP project. As per the design of the FSTP, area requirement for the plant is 432 Sq.M while the total available area is 500 Sq. m. The proposed FSTP location Google image is attached below.

Figure 8 Location of the proposed plant

As per consultation with GP level, Nachane Grampanchayat will provide the NOC for develop the FSTP plant for cluster of Shirgaon, Mirjole, Kuvarbav, Khedshi along with Nachane. All Gram panchayats are interested to develop faecal sludge treatment plant in Nachane Grampanchayat.

4.10. Fund Availability

Component	10 KLD Faecal Sludge Treatment Plant
Fund Available- SBM (G) II	230 Rs / Per Capita.
Population (2021)	55,439 Souls
Total Fund Available as per Population	**1,27,50,970/-**
Total Project Cost with GST	**1,27,41,839/-**

Table 8 Details of Fund Availability

4.11. Site Photographs- During Execution


FSTP Site Before Cleaning


Site Surveying and Measurement Work


Site Cleaning and Excavation and Levelling Work


Site Demarketion and PCC Work


RCC Work


Brick Work and Fabrication Work at Site

4.12. Site Photographs- After Execution


Office Cabin and Screen Chamber


Anaerobic Stabiization Reactor and Piping Work


Tiger Bio Filter Bed- I and II


PSF, ACF and Pumps

Overall Plant View

5. CONCLUSIONS

Based on the case study, vermifiltration based Tiger Biofilter Technology is provided for treating faecal sludge generated Nachane and nearby villages. The capacity of the FSTP is 10,000 Litres per day and which is generated from upto 7 households. Before the construction of the FSTP, all faecal sludge is dumped into the river, nalla, sea as well as open land nearby areas and that is directly affected on environment i.e., Land and Water Pollution. Due to sludge dumped on the open land which directly affected on soil contamination and dumped into the river or sea which is affected water contamination and aquatic life.

Vermifiltration based Tiger Biofilter which is novel Technology and it is treating sludge by scientifically for getting better result as well as to reduce environmental pollution and avoid water and soil contamination occurs due to faecal matter. In this technology, Eisenia Foetida worm species are major factor which performs very well as compared to other species to treat faecal sludge and converted into vermicompost as a byproduct which can be reuse for gardening or farming purpose. Tiger Biofilter Technology is Unique, Low Cost, Natural, Sustainable and Eco-Friendly, which is appropriate and suitable technology to treat faecal sludge properly and converted into Vermicompost.

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