Chapter 6

Experimental Details for Solving Problem of Pollution in Nallas and Foam in STPs

6.1 Wetland Treatment for Nalla

The sewage system in Nashik city is incomplete in few of the sewerage zones, particularly Gangapur, Pimpalgaonkham and partly for Agar Takali. There are various issues like land acquisition, selection of technology and laying of sewerage network. Efforts are being made to complete coverage of Nashik city for sewage collection and system, but significant delay in completion of the job is observed due to factors mentioned above.

The natural drains in Godavari river basin which are now converted into nallas will continue to carry domestic wastewater till the work on interception, diversion and joining of sewer lines in all the 108 wards within Nashik Municipal Corporation area. The pollution problems of nallas can be easily addressed through the use of a constructed wetland technology to minimize pollution load. The following chapter presents technical details about Phytorid technology which has been specially designed for such decentralized sewage flows. The development carried out at NEERI has been tested and validated in many locations with a view to establish its working in the natural drain which can work on gravity. Technical details of technology developed are presented in **Annexure 18.**

Phytorid deals with a combination of various filter medias such as stones, gravels and other which is locally available and economical in terms of finance along with aquatic, semi aquatic, ornamental and/or terrestrial plants either singly or in combinations for the treatment of wastewater generated in the form of municipal/domestic wastewaters, commercial establishments, agricultural runoffs, storm water runoffs and neutralized effluent from common effluent treatment plants.

The consortium of lower and higher biota takes part in the degradation and removal of pollutants from the wastewater. The importance of plant species in the treatment system is not only the direct uptake and enzymatic degradation of the pollutants but also as a support for the microbes that remain active around the rhizosphere area that are defined as those portions of the root profile that give rise to new growth from the plant. The plant systems act as oxygen diffusers via uptake through the leaves and its transfer through the stem to the roots. Thus, it creates staggered septic and aseptic zones for enhanced microbial growth and activity.

Feasibility study for application of Phytorid Technology for sewage treatment in open nallas in Nashik is assessed. For these, all open channels /nallas are being assessed in terms of flows, sewage characteristics, open space available, etc which flows in Godavari river.

6.1.1 Preliminary Survey

A joint site visit with NEERI and Nashik Municipal Corporation was carried out on 19/03/2014 to observe the site conditions and the land available nearby the nallas for treatment purpose. During the site visits, 14 nallas were found and details are mentioned in the **Table 6.1**.

Bhoi and Waghadi are sewage channels which overflows finally meets to the Godavari River. Ghandarwadi, Kusumgraj and Kapilla nallas are the channels from which natural ground water/ storm flows. Chapter 5 show the conditions of the nallas during the flow assessment.

Table 6.1 : List of Nallas Flowing in Godavari River

Name of Nallas	**Details**
Right Bank of Godavari	
Someshwar	Located near the Godavari river with small flow of sewage
Chikhli	High flow of sewage with some industrial wastewater
Anandwali	Pure sewage flows directly to river
Forest Nursery	High flow of sewage into river
Chopda	Sewage flows through goda park
Bhoi	Overflow of sewage chamber goes to river
Kashimali Karyalay	Overflow of sewage chamber flow to river
Jadhav Farm	Small flows of sewage from houses goes to river
Left Bank of Godavari	
Ghandarwadi	Small flows of natural ground storm water observed
Kusumgraj	Small flows of natural ground water observed
Ramwadi	Sewage flows directly to river
Waghadi	Overflow going to river
Kevdiban	Dry during site visit
Kapilla	Natural storm water flows to river

6.1.2 Flow Assessment

During site visit, nallas details were taken such as breadth, depth of water level, length, etc. to prepare the V notch of the respective nallas. Flow assessment was carried out from 12/04/2013 to 14/04/2014 at nallas mentioned in **Table 6.2** using v notch and float method wherever applicable. Flow reading was measured at 8.30 am, 11.30 am, 1.30 pm, 3.00 pm, 6.00 pm and 8.00 pm respectively.

Table 6.2 : Method of Flow Assessment at Nallas

Name of Nallas	Flow Assessment Method
Someshwar	V notch
Chikhli	V notch
Anandwali	V notch
Forest Nursery	Float method
Chopda	Float method
Jadhav Farm	Bucket method
Ramwadi	V notch

6.1.3 Results of the Flow at Nallas

Flow reading was taken for 3 consecutive days which include Saturday as well as Sunday. **Table 6.3** shows the average flow results of the three days measured at nallas.

Table 6.3 : Average Flow of Sewage at Nallas

Day Time*	Nallas (M^3/d)						
	Someshwar	**Chikli**	**Anandwali**	**Forest**	**Chopda**	**Jadhav**	**Ramwadi**
08.30	25 ± 1.7	285 ± 16	397 ± 43	5522 ± 28	2356 ± 105	17 ± 4	338 ± 41
11.30	35 ± 2.6	338 ± 24	272 ± 25	6212 ± 70	2577 ± 322	22 ± 2	447 ± 32
13.30	8 ± 1.5	338 ± 15	135 ± 11	4235 ± 127	1578 ± 130	9 ± 0.5	338 ± 49
15.00	8 ± 0.5	327 ± 6.5	217 ± 24	518 ± 24	1473 ± 44	5 ± 0.5	349 ± 23
18.00	17 ± 1.1	124 ± 3	113 ± 14	3681 ± 45	1767 ± 36	16 ± 5	338 ± 36
20.00	8 ± 0.5	137 ± 12	128 ± 11	1739 ± 59	1963 ± 74	5 ± 0.5	338 ± 24
Highest	35	338	397	6212	2577	22	447
Lowest	8	124	113	518	1767	5	338
Average	17	258	237	3651	1952	12	358

It has been observed that Someshwar nalla has peak flow of 35 m^3/d at 11.30 am and average flow of 17 m^3/d. Chikli and Anandwali nallas has highest sewage flow of 338 and 397 m^3/d respectively whereas average flow is 258 and 237 m^3/d. Forest nursery and Chopda nallas were assessed using float method and peak flow is 6212 and 2577 m^3/d. Average flows of the forest nursery and chopda nalla are 3651 and 1952 m^3/d respectively. Jadhav farm nalla is smallest nalla which flows from the farm house and average flow is 12 m^3/d. Ramwadi nalla has peak and average flow of 447 and 358 m^3/d respectively. **Figure 6.1** shows the V notch flow reading at nalla sites.

Figure 6.1 : V notch at Anandvali Nalla

6.1.4 Phytorid Treatment for Nallas

The main objective of the proposed Phytorid project is to provide a simple, feasible, practically sound, eco-friendly, maintenance free and cost-effective technology, which can handle the sewage waste water treatment leading to reuse of treated water for purposes like gardening. PHYTORID is a scientifically developed systematic treatment methodology for wastewater.

- PHYTORID combines Physical, Biological and Chemical processes.
- Works on gravity
- No electric power requirement
- Scalable technology
- Easy to maintain
- Adds to aesthetics
- Cost effective

Advantages of Phytorid Technology

- Treatment efficiencies for the removal of fecal coliforms, BOD, COD, nutrients are up to 80%, which is greater than the traditional chemical methods.
- It is a very cost effective technology when compared with the traditional wastewater treatment methods.
- Since it utilizes natural vegetation and rhizosphere microorganisms, it is eco-friendly method of treating sewage.
- An important factor to be considered is the aesthetic improvement that is provided by this methodology.
- No mosquitoes and odour nuisance.
- The treated water can be used for enhancement of environmental architecture such as roadside fountains.
- The quality of treated water is comparable to irrigation standards

a) Phytorid Treatment for Someshwar Nalla

Peak flow at Someshwar nalla is 35 m^3/d. Design flow of the STP is 40 m^3/d. STP using Phytorid Technology consists of screen chamber, primary settler and Phytorid Bed. **Table 6.4** shows the details estimates.

Table 6.4 : Detail Estimates for Someshwar Nalla

Items	Quantity	Unit Cost (IND)	Total Cost (IND)
Excavation (cum)	133	250	33250
Total PCC Quantity	40	4095	163800
Total RCC Quantity	65	7800	507000
Steel Quantity (MT)	5.79	50000	289500
Gravel Media (cum)	89.7	2000	179400
Biomedia (cum)	25	8200	205000
Landscaping (sqm)	39	455	17745
Sewage Pump	0	0	0
DPR, Drawing & Design Cost	0	0	0
Site Preparation	L/S	0	15000
Total Cost		About	**14 Lakhs**
Area sqm	62		

b) Phytorid Treatment for Chikli and Anandvali Nalla

Peak flow of the Chikli and Anandvali nalla is 338 and 397m^3/d. STP will design for the flow of 400 m^3/d. Details of the estimates and cost for phyorid system of capacity 400 m^3/d is given in **Table 6.5**.

Table 6.5 : Detail Estimate for Phytorid System for 400 m^3/d (Chikli and Anandvali Nalla)

Items	Quantity	Unit Cost (IND)	Total Cost (IND)
Excavation (cum)	2114	250	528556
Total PCC Quantity	137	4095	562199
Total RCC Quantity	313	7800	2438051
Steel Quantity (MT)	31	50000	1562853
Gravel Media (cum)	1000	2000	2000000
Biomedia (cum)	200	8200	1640000
Landscaping (sqm)	400	455	182000
Sewage Pump	1	25000	25000
DPR, Drawing & Design Cost	400000	0.5	200000
Site Preparation	L/S		100000
Total Cost		About	**92 Lakhs**
Area sqm	676		

c) Phytorid Treatment for Forest Nursery, Chopda Nalla and Ramwadi Nalla

During the study, Forest nursery and Chopda nallas have highest flow of sewage among all the nallas. Peak flow of Forest nursery and Chopda nalla is almost 6212 and 2577 cu m per day.

Ramwadi nalla peak flow is 447 m^3/d. STP can be designed at Forest nursery for 6500 m^3/d, at Ramvadi for 500 m^3/d and at Chopda Nalla for 3000 m^3/d considering with future flow. STP can be made in modules of 500 m^3/d at both the sites. Estimated cost for the 500 m^3/d is given **Table 6.6**.

Table 6.6 : Estimate for 500 Cu m module (Forest Nursery, Chopda Nalla and Ramwadi Nalla)

Items	Quantity	Unit Cost (IND)	Total Cost (IND)
Excavation (cum)	2615	250	653836
Total PCC Quantity	171	4095	699354
Total RCC Quantity	367	7800	2866310
Steel Quantity (MT)	37	50000	1837378
Gravel Media (cum)	1250	2000	2500000
Biomedia (cum)	250	8200	2050000
Landscaping (sqm)	500	455	227500
Sewage Pump	1	25000	25000
DPR, Drawing & Design Cost	500000	0.5	250000
Site Preparation	L/S		100000
Total Cost		About	**112 Lakhs**
Area sqm	842		

d) Phytorid Treatment for Jadhav Nalla

During assessment, peak flow of Jadhav nalla is 22 m^3/d. STP shall be design for 25 cu m/d flow **(Table 6.7)**.

Table 6.7 : Estimate for Phytorid for 25 Cu .m. (Jadhav Nalla)

Items	Quantity	Unit Cost (IND)	Total Cost (IND)
Excavation (cum)	109	250	27250
Total PCC Quantity	32	4095	131040
Total RCC Quantity	46	7800	358800
Steel Quantity (MT)	4.12	50000	206000
Gravel Media (cum)	78	2000	156000
Biomedia (cum)	12.5	8200	102500
Landscaping (sqm)	34	455	15470
Sewage Pump	0	0	0
DPR, Drawing & Design Cost	0	0	0
Site Preparation	L/S	0	15000
Total Cost		About	**10 Lakhs**
Area sqm	50		

6.2 PSRT Based Improved Sanitation Treatment Unit (IIT, Bombay)

In Nashik City it is mandatory to construct a septic tank as a toilet facility for every house. NMC is attempting to connect the overflow of septic tanks and soak pit to the sewer lines thereby preventing entry of pollutants into nallas, however the O&M with respect to sludge removal from this tank is not satisfactory. PSRT technology has an advantage of reduce sludge quantity and better performance so that the strength of overflow is significantly reduced. In the light of this all new construction activities should adopt PSRT technology to improve sanitation. Reduction of BOD at source can also give better performance of phytorid technology in nallas.

Objective of this technology is to reduce the total suspended solid load and organics of raw sewage. Basic construction of the system consists of a baffled settler chamber as well as three anaerobic baffled chambers.

The working principle of the PSRT system involves the wastewater entering the tank where large particles will be settled in the first part (as per their terminal velocity and hydrostatic pressure) of the system and further degradation of organics will be completed in the second part of the system.

Removal efficiency of the system is 30-35% higher in comparison to the conventional septic tank in term of organics. Optimum Hydraulic Retention Time of the PSRT system is in the range of 24 hour for achieving removal efficiency of 75-85% TSS removal and 70-75 % BOD removal.

Principle of Technology

PSRT system consists of following units:

- Settler unit
- Anaerobic baffle tank

Anaerobic baffle unit consist of three compartments (A, B and C), outlet of A becomes inlet for B and outlet of B becomes inlet for C. outlet of C is final outlet of PSRT system.

PSRT based system is working on the principle of discrete settling, flocculation hindered settling, that will lead to partial treatment or removal of suspended solid in settler unit. Complete anaerobic treatment of wastewater has been taken place in the anaerobic treatment unit for further removal of organics and suspended solid.

- Settling
    - Discrete, flocculation, Hindered settling & compression settling
- Anaerobic treatment
- Partial treatment in settling zone
- Complete anaerobic treatment

Performance Evaluation

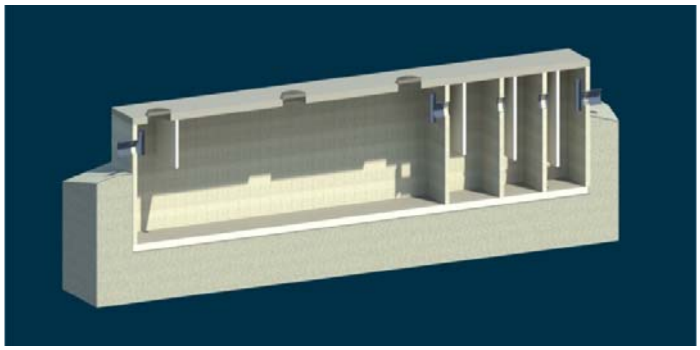
Efficiency of the system is between 75-80% for total suspended solid, 65-75% for chemical oxygen demand, around 30% for nitrogen removal and about 20% for phosphorus removal. The above efficiency was observed when the influent characteristics were as follows:

Phosphorus: 2.25 mg/L; Ammonical Nitrogen: 36 mg/L;
COD: 280 mg/L and TSS: 192mg/L

Efficiency of this system is higher than septic tank or conventional primary removal system.

PSRT System Efficiency				
HRT	**% Removal of Pollutants**			
	Phosphorus	**Ammonical Nitrogen**	**COD**	**TSS**
24 hrs	17.77	2.25	57.14	89.5
36hrs	23.11	17.4	64.2	91.6
48hrs	31.1	32.5	78.5	92.7

Cross section view of PSRT based treatment unit



Advantages of this technology are:

- Low cost treatment
- No energy involved in the treatment
- Can bear shock Load
- Use of bio culture (though it is not mandatory) and use in combination with other technologies possible
- Nearly **90 – 95%** TSS removal
- Continuous System
- Decentralized treatment
  - Numerous advantages
    - No need to carry stored water frequently
    - Reduces load at STP/ River/ Nalla
    - Reduces silting in drainage system
    - Improves life of sewer line and efficiency of STP
- Recycle of water through combined application with natural treatment
- Low maintenance
- Treated water can be used
  - In construction site (Labour Camps)
  - In slum Areas
  - In rural areas
  - For irrigation

6.3 Detail Investigation on Problem of Foam Formation at Tapovan with USAB Reactor

Problem of Foaming at Tapovan STP

Tapovan STP was established in the year 2003. It has Upflow Anaerobic Sludge Bioreactor technology (UASB). Generally UASB reactor is recommended for with high organic loading with BOD in the range of minimum 250 to 300 mg/L. There are 2 UASB plants at Tapovan having capacity of 78 MLD and 52 MLD. The plant currently faces extensive foaming in UASB reactor, aeration tank, polishing tank and at final outlet in the river. The technology was installed as a part of JnNURM.

6.3.1 Probable Causes of Foaming in UASB

a) Surface Active Agents

Foaming appears in the water and wastewater as the surface tension of the medium is altered. The term ‘surface active agents’ refers to substances that are either surfactants or bio-surfactants. The surfactants include oil, grease, volatile fatty acids, detergents, proteins. The term biosurfactants refers to substances produced during the metabolic activity of microorganisms found in sludge, such as hydroxylated and cross-linked fatty acids, glycolipids, proteins, lipoproteins, phospholipids and polysaccharide-lipid complexes. It has been observed that the foaming potential of the surface active agents is higher when the concentration is higher than critical micelle formation. Beyond CMC the surface activity increases which enhances the foam formation.

Proteins are one of the causes of foaming. In activated sludge the proteins are broken down to amino acids by exoenzymes produced by microbes. In anaerobic digestion the degradation of the proteins is lesser as compared to other surface active agents like lipids and fiber. The accumulation of the proteins at the air/liquid interface facilitated during the Anaerobic digestion could lead to enhance foaming potential.

Detergents are the one of the group of surface active agents. Linear Alkylbenzene-sulphonates the most commonly used surfactants worldwide in detergents. The low removal of detergents during AD, especially for the anionic detergents, along with their properties as surface active agents results in increased surface activity in sludge that could potentially contribute to foaming events in AD.

b) Filamentous Organisms

Anaerobic digester foaming has often plagued operators of wastewater treatment plants (WWTPs). Due to the complexity of the problem and the variables involved, it is often difficult to correctly identify the cause of the foaming. Foaming in conventional anaerobic digesters has been attributed to a number of causes from inadequate mixing to *Nocardia*bacteria carried over from the secondary treatment process. An extensive study investigating the behaviors of foaming in anaerobic reactors reported that the aggregations bacteria *Gordonia* and *Microthrix* have been considered the main cause of foam initiation and stabilization. Other studies have also reported that foaming in UASB reactors have occurred in the three phases (gas–liquid–solid). It is depended upon temperature of treatment, UASB design, substrate concentration and components, organic loading, and concentration of filamentous microorganisms in sludge bed. All of these factors affected the foam generation [Kalyuzhnyi et al.,1998]. However, foaming could be reduced with controlling the above factors, whereas no experimental evidence has implemented as yet.

c) Temperature

Thermophilic digestion is more resistant to foam generation than mesophilic digestion. Lowering the temperature can result in microbial metabolic upset, resulting in accumulation of surface active agents. The Nashik city faces considerable drop in temperature during winter which can enhance the foam formation. Foam formation was observed to be more in winter during the visit of NEERI team.

d) Organic Loading

A number of authors have broadly been reported that overloading and under loading of reactor can cause foam formation as in both cases, the microbial metabolism will be hampered. A further increase of organic loading rate will cause operational problems which result in foam formation at the gas-liquid-solid separator (GLS) and also caused sludge bed flotation. According to the CPHEEO manual for sewage and sewerage system 2013, the ideal organic loading should be in the range of 1-3 Kg COD/m^{3}day. But the Tapovan STP is under loaded with organic loading rate of 0.6 Kg COD/m^{3}day. This can be one of the factor responsible for foam formation.

e) Alkalinity of Sewage

The pH and alkalinity range for anaerobic digestion is also vital for the methanogens. The desired pH range for a healthy population of methanogens in anaerobic digesters is 6.5-7.6. The typical pH ranges for anaerobic digestion are 6.8-7.2, within the range for the methanogens (Metcalf and Eddy 2003). Since methanogens are sensitive to acid conditions and can be inhibited by a drop in the pH (Rittmann and McCary, 2001), fluctuations of pH in anaerobic digesters are not recommended. The pH and alkalinity of the raw sewage received at Tapovan STP is not sufficient to support the proper functioning of microbes. The ill function of microbes may lead to the formation of foam.

f) Slope gradient

There is a slope gradient at the outlet of the Tapovan STP which is enhancing the foam formation. But this cannot justify the foam formation in UASB reactor as well as in the aeration and polishing tank.

As can be seen apparently the dilute sewage (low strength sewage) treatment by UASB is not appropriate. Many factors contribute to foam formation, of which low BOD and UASB reactor design for better mixing are prominent reason.

6.3.2 Experiments Conducted at NEERI

In order to solve the problem of foam formation in STP a detailed study was carried out which addressed:

- Effect of increase in BOD of raw sewage on foam formation
- Identification of foam forming filamentous bacteria
- Estimation of detergent content in the sewage
- Application of Phytorid Technology

The UASB reactor (dimensions) was set up on 23 January 2014 with sludge and effluent from UASB reactor of Tapovan STP, Nashik. In order to assess the performance of the reactor, raw sewage of BOD 100-150 mg/L and COD 200-300mg/L from Lovegrove Pumping station, Worli was pumped into the reactor in upward direction using peristaltic pump at 113 rpm.

HRT= Reactor volume (m^3)/ Flow rate (m^3/h)

Upflow velocity (m/h) = Reactor height /HRT (h)

Upto 60% reduction in BOD and 50% reduction in COD of sewage were achieved after treatment.

Performance of Lab Scale UASB Reactor

The lab scale UASB was assessed for its performance. The average BOD value for influent was around 140 mg/L and that of effluent was 70mg/L. The UASB showed BOD reduction in the range of 40- 50% whereas COD reduction was observed to be in the range of 40-60%. The UASB was also assessed for VFA reduction. The VFA concentration in the influent was found to be around 60 mg/L and that of effluent was around 9mg/L. Hence VFA reduction upto 88% was achieved.

1. Effect of Increase in BOD of Raw Sewage on Foam Formation

To assess the effect of BOD on form formation, the BOD of the raw sewage was increased to 200mg/L and 400mg/L by adding glucose and glutamic acid @ 150mg/L each (Std. Methods). The raw sewage was introduced into the UASB reactor using a peristaltic pump and treated sewage was collected after 8 hrs. Though upto 50% reduction in BOD was achieved, there was no significant decrease in quantity of foam generation.

2. Identification of Foam Forming Filamentous Bacteria

The sludge sample from Tapovan STP was investigated for presence of following filamentous bacteria

a) *Microthrix pervicella*
b) *Gordonia sp.* Gram staining

Neisser staining of the sludge sample was performed to check the presence of the above mentioned bacteria. The microbes responsible for foam formation could not be detected in the sludge collected from Tapovan.

3. Estimation of Detergent Content in the Sewage

No significant content of detergents was observed in the influent sewage sample of Tapovan STP.

4. Application of Phytorid Technology for Foam reduction

Phytorid Technology based on “re-engineer” wetlands systems to solve the wastewater quality problems. These are constructed as shallow basins or channels with a subsurface barrier to avoid seepage. The Phytorid Technology is a subsurface flow type wetland system wherein water is applied to the cells/ beds filled with porous media such as gravel and stones. The hydraulics is maintained in such a manner that water does not rise to the surface retaining a free board at the top of the filled media. These systems may include a wide variety of foliage in the form of aquatic, marsh, ornamental, herbs, grasses and also terrestrial plants known to grow in water logged conditions. The phytorid technology can provide slow aeration which can avoid formation of foam due to rigorous aeration. The efficiency of phytorid has been tested at pilot scale which has shown significant reduction in the BOD levels.

Pilot Scale Experiment Using Phytorid Technology

A pilot scale experiment was carried out at Tapovan STP in Nashik. The Experiment was carried out for 4 days **(Table 6.2)**. The details of Phytorid unit used during the pilot scale experiment are given below:

- Two horizontal rectangular units were used in the experiment. A rectangular unit of Phytorid was filled with gravels of similar size along with the *Acorus calamus* planted in it. The plants were present in all the compartments of units. The total volume of the units was 50L whereas due to presence of gravels and roots, the active volume was calculated to be 22 L.
- A control was run with a unit without gravels and plants. The effluent of 78 MLD UASB was used an influent for Phytorid. The retention time was decided to be 4 hrs. in each unit hence total retention time of 8 hrs. was provided. The flow was calculated to be 5.5 L/hr.

Figure 6.2 : Experimental set up of Phytorid at Tapovan

The UASB effluent did not show any foam formation after passing through the Phytorid unit.

The effluent of the Phytorid was analyzed for selective parameters including DO, BOD, COD, Ammoniacal nitrogen and Phosphates. The effluent was allowed to fall from height 1.5 m to check the foam formation potential. The Biochemical Oxygen Demand (BOD) of the wastewater of inlet was in the range of 42-93 mg/L while the Chemical Oxygen Demand (COD) ranged from 80-141 mg/L. After treatment from the Phytorid unit, the BOD levels were considerably reduced to less than 20 mg/L with effective reduction in the ammonia nitrogen levels as well.