Report of AP PHED Team
On study visit to Mumbai from 15-16th May 2016
on Soil-Bio-Technology (SBT) based
Sewage Treatment Plants

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1. INTRODUCTION

1.1 In Urban Local Bodies, major quantity of waste water is being discharged directly in to rivers, tanks and creeks. It leads to environmental pollution and indirectly affects the health of citizens and of aquatic life. In major cities also, treatment and disposal of waste water is a big problem and in most of the cases, the waste waters is directly allowed in to the streams without any treatment. It causes eutrophication of water bodies, in turn affecting the aquatic life and leading to environmental pollution.

1.2 To overcome this problem, the Municipal Administration and Urban Development (MA&UD) Department, Government of Andhra Pradesh (GoAP) desires to study the technologies / processes involving low cost and least operation and maintenance in treating the domestic waste water, so as to safeguard the environment and public health. Accordingly the GoAP vide G.O. Rt. No.20 MA&UD Dated: 13.01.2016 has constituted a Technical Expert Committee with Chief Engineer, APUFIDC as one of the members and desired to study the adoption of Soil Bio-Technology (SBT) process for Sewage Treatment in all ULBs of AP. Accordingly, the following Team of Engineers from PHED have visited the STPs in Mumbai with SBT/CAMUS-SBT process of sewage treatment developed by IIT Bombay and interacted with IITB Experts.

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The following is the report of the PHED Team for consideration of the Government.

2. SBT PROCESS AND PRINCIPLES

2.1 Soil Bio-Technology (SBT) Process:

Soil Bio-technology or (SBT) process of waste water treatment and its recycling and reuse has been developed by Indian Institute of Technology Bombay (IITB) indigenously after two decades of research. It is a green engineering approach and is considered as notable technology contribution from IITB to waste management. This technology has been awarded US and Indian patents. SBT is based on a bio-conversion process, maintenance free, claims non production of bio-sludge & foul odour, consumes least energy, claims to give effluent compliant to River water disposal standards and has green aesthetics. Its operation is simple, economical & energy efficient. It claims to have served industries, housing societies, resorts, schools / universities / ashrams, hotels, municipal corporations & airports etc.

2.2 Technology

A presentation has been given by Emeritus Prof. H.S. Shankar on the principle of SBT and the bio-chemistry behind the SBT process. He explained the SBT / CAMUS-SBT process in detail as follows:

2.2.1 The Working principles of SBT/CAMUS-SBT Process

- Soil Bio-technology is a terrestrial eco-system for wastewater treatment based on the principle of trickling filter. In this system, combination of physical processes like sedimentation, infiltration and bio-chemical processes are carried out to remove the suspended solids, organic and inorganic contents of the wastewater.
- The technology is based on a bio-conversion process where fundamental reactions of nature, namely respiration of micro and macro organisms, photosynthesis by plants, and mineral weathering take place in a media housing micro & macro organisms which bring about the desired purification.
- SBT is an oxygen supplying biological engine and so the process can treat all types of water - domestic, municipal & industrial. SBT is suitable for treating water with salinity <10,000 mg/L. In conventional STP technologies, the solubility of oxygen in water is low and hence oxygen for biological digestion is to be supplied through mechanical aeration.

- The process requires mesophyllic temperatures (20-45^{o}); however the process can work at high ambient temperatures.
- An advanced version of SBT called **"CAMUS-SBT"** (Continuous Aerobic Multi-Stage-SBT) has been developed which is capable of even higher levels of purification.
- CAMUS-SBT resolves this problem using a bio-chemical method of oxygenation, which not only uses the atmospheric oxygen, but also uses the nitrogen from the atmosphere in a specially engineered ecology to achieve the desired level of purity.
- In addition, conventional technologies generate large amount of sludge for which additional disposal facilities have to be created. CAMUS-SBT does not face any such problems due to the ecology.

2.2.2 Salient features of SBT / CAMUS-SBT Process

The SBT bio-reactor comprises suitable natural mineral constituents as additives, an engineered ecology of soil-plant system configured as a packed bed reactor with multi-grade media consisting of soil-like media enriched with culture, and select plants as bio-indicators. The SBT bio-reactor comprises the following:

- **Under drain**: Stone rubble of various sizes ranging upto Gravel (200.0-2.0 mm), Very coarse sand (1.0-2.0 mm), Coarse sand (0.5-1.0 mm), Medium sand (0.25-0.5 mm), Fine sand (0.1-0.25 mm).
- **Media**: Formulated from soil as required and primary minerals (stone, gravel etc.) of suitable particle sizes and composition.
- **Culture**: Containing native micro-flora (bacterial culture and Geophagus (Soil living) earthworm Pheretima elongate). The bacterial culture will be from natural sources containing bacteria capable of processing cellulose, lignin, starch, protein, also nitrifying and denitrifying organisms. Anaerobic organisms for methanogenesis. For industrial wastes, development of appropriate culture required.
- **Additives**: As a process regulator to achieve desired treated sewage quality. Formulated from natural materials of suitable particle size and composition to provide sites for respiration, CO2 capture
- **Bio-indicators**: Green plants particularly with tap root system. The wastewater processing area is thus developed into a green belt, which easily integrates into any existing landscape.
- It is also known as **Constructed Soil Filter (CSF)**. SBT systems are constructed from either RCC, stone-masonry or soil bunds. It consists of raw water tank,

bioreactor containment, treated water tank, piping and pumps. The SBT consists of an impervious containment typically 1.0–1.5 m below ground. The reactor bed is dried prior to next cycle of use.

- Purification takes place by adsorption, filtration and biological reaction. The process operates in **aerobic** mode, eliminating possibility of foul odour. It comes under attached growth process and is similar to trickling filter.
- Chemistry, Biology and Ecology in SBT facilitates both aerobic & anaerobic respiration, and reactions like nitrification, de-nitrification, acidogenesis etc. depending on the types of waste water load.
- Organics get removed by adsorption & filtration and are biologically converted to CO_2 with the help of indigenous soil micro-flora.
- Suspended Solids are removed in Primary Settling Tank (PST). Dissolved Solids are removed by adsorption followed by bio-degradation and uptake by green plants in the Bio-reactor (BR).
- Media and additives provide sites for biological transformation. Earthworm culture regulates microbial ecology.
- The process can be run on batch or continuous mode.
- No sludge production in view of the presence of ecology.
- Mechanical aeration is not required.
- The overall time of operation is 6-7 hours per day.
- For treatment of septage, suitable additional treatment units like anaerobic digesters with necessary standby units may have to be added prior to Primary Settling Tank.
- Land requirement for these plants is reasonable and on par with the modern sophisticated technologies.
- This kind of technology is not implemented in any ULB of AP for treatment of wastewater so far.

2.3 Comparison of CAMUS-SBT with Conventional STPs

Parameter	Conventional process	Soil Biotechnology process
Fundamental Process	Separation of streams and break-down of resource (waste) molecules leading to other output streams (waste gasses, water, sludge)	Synthesis of resource (waste) molecules into usable output products (flowers, plants, water, fertilizer)
Odour	Odour due to ammonia and	No aerosol generation. Smell control

	aerosols generated from aqueous phase aeration device	is achieved via addition of natural additive and high rate ammonia oxidation (used in Golf Clubs, where people are particular of smell)
Sludge Production	Chemical and biological sludge is produced as waste by-product which needs further handling like dewatering and drying for disposal	No sludge is produced. Bio-mineral fertilizer is produced as useful by-product.
Process Loss	15 – 20 percent of water is lost in the process since the water is held within the sludge generated during the process apart from surface loss.	Water loss is only due to evapo-transpiration loss from the filter surface. More than 90% recovery is seen.
Process Down Time	Characterized by high mechanization; therefore the downtime is high.	Mechanization limited to effluent transfer / distribution pumps only. Practically no process down time.
Energy	All conventional aerobic treatment processes are based on aqueous phase reaction and therefore mechanical aeration is highly energy intensive.	Process driven by Natural Aeration in engineered soil ecosystem and therefore no external energy required for aeration; hence energy conservative
Useful by-products	No useful by-product is produced.	Harvestable fodder biomass, flowers, biofertiliser apart from fish compatible treated water is produced.
Sound Pollution	Due to high mechanization, the process is characterized by sound pollution	Operates quietly and therefore can be located very close to human habitation.(used in hotels)

3.WASTE WATER TREATMENT PLANTS WITH SBT PROCESS IN BOMBAY CITY

3.1 The team has visited Bombay and inspected the working STPs based on SBT/CAMUS-SBT process from 15.05.2016 to 16.05.2016 and also interacted with Emeritus Prof. H. S. Shankar, Department of Chemical Engineering, IIT Bombay and Dr. Chandrasekhar of Vision Earthcare Pvt. Ltd. During the visit, following plants have been inspected.

	Locat	Cap	Owner
I.	VIRAR	0.65 MLD	Housing Development and Infrastructure Limited (HDIL), a Private Developer
II.	VIRAR	0.60 MLD	Housing Development and Infrastructure Limited (HDIL) E-buildings, a Private Developer
III.	WORLI, Mumbai	3.00 MLD	Brihan Mumbai Municipal Corporation

3.2 The Team also interacted with the Superintending Engineer, Sewerage of BMMC and discussed regarding the working of the 3 MLD plant at Worli.

3.3 Following are the PROCESS Features

- Very low energy use intensity due to high Natural oxygen transfer in process (0.06 kWh/kL of sewage).
- Very low space intensity of 0.8-1.0 sqm / kLD sewage.
- An engineered evergreen natural process with no moving parts except for pumps.
- No sludge due to ecology at work.
- Very high bacteria, BOD, COD, suspended solids, colour, odour, ammonia removal.
- Practically maintenance free.

The Bioreactor consists of a media housing an engineered ecology of soil, bio-indicator plants, soil containing culture with selected micro organisms like bacteria and macro-organisms such as Geophagus earthworms. The media is formulated from sand, silt, clay etc. and is bio-processed before filling in the bioreactor. By addition of the earthworm culture, the rates of biological processes are enhanced to bring about the waste processing. Bioconversion takes

place via bacterial processing of waste materials where geophagus worms serve as predator to select and regulate the bacterial action. Details of culture, media and additives used are covered by patents.

Table: Specifications of the Bioreactor media (Pattanaik et al., 2003b)

Item	Details
Under drain	Gravel- dp - 25 mm,
	White Sand dp - 2 mm,
Media*	Specific gravity- 2.62
	BET specifica surface area-23 m2/g
	Cation Exchange capacity- 1.5 g/kg
Soil*	Sand: 67% Silt- 23%, Clay- 10%
	Specific gravity- 2.66
	BET area- 33.6 rn2/g
	Cation Exchange capacity- 1.5 g/kg
Earthworm	Phertima elongate

dp=Particle diameter. BET" Brunauer, Emmett ~Teller (isotherm). * Particle size distribution is similar initially, but due to prolonged earthworm movement, it changes with time.

The key features, process and test results of the plants are given below:

I. 650 KLD plant in HDIL, Virar

This plant is located in housing colony at Virar about 50 KM away from Bombay. It is on NH-3 and it is in Kalyan Municipal corporation area.This plant is located below the ground in the entrance of the housing colony with plantation on top.

INFLUENT	DOMESTIC WASTEWATER
PROJECT	STP with CAMUS-SBT process
CAPACITY	650 CUM/DAY
YEAR	2012
AREA	700 SQM
COST	Rs.1.25 CR

Features

- Project proposed in the 6m wide median on the road between two residential apartments.
- Preliminary, Primary, Secondary treatment and tertiary treatment, administrative and control room all facilities are RCC structures
- CAMUS-SBT itself incorporates secondary and tertiary treatment processes.
- Treated water is recycled and being reused.
- Power requirement is 0.1-0.15 kWh/KL

Process Flow

1. Domestic waste water is being collected from the dwelling units through the planned plumbing arrangement, and it is allowed to pass through the screen-cum-grit chamber to separate heavier particles and lighter materials.
2. Then Sewage is collected and pumped into the Primary Settling Tank (**PST**) by using pumps.
3. The PST is designed with baffles to separate the scum and suspended solids by gravity/mechanical. Clear effluent from the final chamber of PST will be pumped on top of Bio Reactor 1 (**BR1**) by using Pumps duly mixing some additives.
4. Sewage is distributed on top of BR1 using pipes, and the distributed sewage will be percolated through the soil bed and collected from the collection tank 1 (**CT1**).
5. Similarly the treated water from CT1 is passed through 2nd stage of Bio Reactor (**BR2**) and collected into the collection tank-2 (**CT2**).
6. Finally the treated sewage (effluent) is pumped into the final effluent tank. The effluent is being used for flushing of toilets, development of green belts and sometimes for construction activity. A drawing showing the plan of the plant is enclosed in Annex.I.

Results

The maintenance of the SBT plant is being taken care of by M/s Vision Earth Care Company and the staff incharge of the plant reported that in a recent study of the discharged effluent of the SBT plant, the test results show that the BOD and COD are less than 5 with the removal efficiency of BOD and COD greater than 99%, and the treated sewage (effluent) quality is nearly equal to drinking water. The effluent is used for construction, flushing, plantation, car washing and floor cleaning. Details of influent and effluent parameters are furnished in Annex.II.

II. 60 KLD SBT plant at HDIL, E-Building, VIRAR

This plant is close to the above plant and it is also located at the entrance of the housing colony. This plant is located above the ground and its shape is L. It is about 2 meters above the ground level and top of the surface is plantation.

INFLUENT	DOMESTIC WASTEWATER
PROJECT	STP with CAMUS-SBT process
CAPACITY	600 CUM/DAY
YEAR	2015
AREA	100 SQM
COST	Rs.1.23 CR

Features

- **P**roject proposed in the 2m wide median on boundary wall. That space is not useful for any other activity.
- Preliminary, Primary, secondary treatment and tertiary treatment, administrative and control room all facilities are RCC structures.
- CAMUS SBT itself incorporates secondary and tertiary treatment.
- Treated water (effluent) is being recycled and reused.
- Power requirement is 0.1-0.15 kWh/KL

Process Flow

The process for this plant is similar to that of the 650 KLD plant in HDIL, Virar. A drawing showing the plan of the plant is enclosed in Annex.-III.

In this plant BR1 is above the BR2 and the collection tanks are also one above the other. They are planned and constructed in vertical direction.

Results

The maintenance of the plant is being taken care of by M/s Vision Earth Care Company, and the staff in charge of the plant reported that in a recent study of the plant effluent, the tests show that the BOD and COD are less than 5 with removal efficiency of

BOD and COD greater than 99% and the effluent quality nearly equal to drinking water. The effluent is used for construction, flushing, plantation, car washing and floor cleaning. Details of influent and effluent parameters are furnished in Annex.-II.

III. 3000 KLD plant in BMC Worli, Mumbai

This plant is located in Worli opposite to the Arabian Sea. In this area, about 700 MLD of sewage from various localities is being collected through different trunk mains and gravitated in to the sea by providing larger diameter pipelines along the bed of the sea. This wastewater contains domestic sewage, industrial effluents, grey water from commercial establishments etc. Out of the 700 MLD, only 3 MLD is being collected separately and pumped in to the SBT plant for treatment. After treatment the effluent is being pumped to the race course for greenery applications.

INFLUENT	SEWAGE
PROJECT	MUMBAI MUNICIPAL CORPORATION
CAPACITY	3000 CUM/DAY
YEAR	2005
AREA	2500 SQM
COST	Rs.3.00 CR

Features

- 3 MLD waste water is being pumped out for treatment out of the total 700 MLD coming at the site.
- Direct pumping of sewage over the top of Bio-reactor without any primary treatment as the Corporation didn't allow pre-settling tank.
- Facility is constructed in half masonry and half media bund.
- Power requirement 0.05 kWH / kL.

Process Flow

1. The Sewage collected from various areas is being collected though small chamber constructed in big collection sluice area.
2. But only 3 MLD is being separated from the 700 MLD of incomig sewage and is diverted to the SBT plant. Total influent sewage is allowed to pass through a screen-cum-grit chamber to separate heavier particles and lighter materials.
3. Then the sewage is collected and pumped into the Primary Settling Tank (PST) by using pumps.
4. The PST is designed with baffles to separate the scum and suspended solids by gravity/mechanical. Clear effluent from final chamber of PST will be pumped on top of Bio Reactor1 (BR1) by using Pumps duly mixing some additives.
5. Sewage which is pumped on top of Bio Reactor 1 is distributed using pipes, and the distributed sewage will be percolated through the soil bed and collected from collection tank 1 (CT1).
6. The treated sewage (effluent) from CT1 is collected into the collection tank having earthen bund lined with polyethylene. Finally the treated effluent pumped into golf course for green belt development. Drawing showing the plan of the plant is enclosed in Annex.I.
7. The Corporation is maintaining the Plant at present with meagre staff, and since it doesn't need higher quality of effluent since the present effluent is being supplied to race course and is being accepted by it, the Bio-reactor2 (BR2) is not being utilized.

Results

At present, the maintenance of the plant is being taken care of by Mumbai Municipal Corporation, and the staff in charge of the plant reported that in a recent study of the plant, the tests show that the BOD and COD are less than 30 with the removal efficiency of BOD and COD greater than 90%, and treated water is used for golf course. Since the effluent after treatment in BR1 is accepted by the golf course, further treatment through BR2 is not being carried out. Detailed results are furnished in Annexure-II.

4. OBSERVATIONS, CONCLUSIONS & RECOMMENTATIONS

4.1 On 0.65 MLD and lesser capacity SBT plants at HDIL & HDIL E-Building

- The SBT sewage treatment plants of 0.65 MLD and lesser capacity plants at HDIL and HDIL E-Building are eco-friendly, pollution free, with no odour, no mosquito & fly nuisance, no sound pollution.
- As per visual inspection, the appearance of treated effluent is clear and similar to that of potable water, and the effluent discharge standards are satisfactory as per test report.
- These two treatment units are compact units and the plantation which is a bio-indicator, is flourishing well above the ground, inferring satisfactory treatment.
- The plantation is being maintained by the supplier itself and the residents of the apartments are the stakeholders at this location.

4.2 On 3 MLD plant of Brihan Mumbai Municipal Corporation

- However, the 3 MLD plant of Brihan Mumbai Municipal Corporation, is different from the other two plants, as it doesn't have a pre-settling tank as per the Corporation's requirement. The plant is being maintained by the Corporation at present.
- The quality of treated effluent and the ambience is neither satisfactory nor eco-friendly as per visual inspection with odour, leakage, pollution and fly nuisance. Sludge is being dried in one reactor and the other reactor is treating the sewage. Only partial treatment is being carried out and two stage treatment is not taking place due to poor maintenance.
- Maintenance of the plant would be satisfactory and effluent standards may be met if the plants are maintained by the plant vendor having the technology, or the technology provider.
- It requires semi-skilled and trained team to run the plant, since bio- culture, additives, media etc. are to be maintained properly conforming to the SBT design parameters.
- Maintenance cost is considered to be low, since mechanical equipment is less and power consumption is minimum.
- Septage management activities cannot be integrated directly in these plants. It needs additional units of anerobic digester with 100% standby for subsequent treatment.
- Industrial effluents, complex chemicals, toxicants, bio-medical waste etc. should not be off loaded into these plants.

- It is soil bund construction, all based on local skills and materials and 1 MLD size may cost Rs 150 Lakhs.
- O&M costs works out to Rs.3.5 to Rs.4 per kL, of which power cost is 10%, and the rest goes to local skills and materials.
- **Capital cost of works for plant is Rs.1000 per capita and O&M cost Rs 0.2 per capita daily.**
- The effluent from this plant is of recyclable quality and proposed for reuse for different non-potable applications such as gardening, construction activity, washing of cars, roads, toilet flushing, golf course wetting, agriculture needs, industrial needs, boiler cooling water for power pants etc.

4.3 Advantages of CAMUS-SBT Technology:

- Colorful, Green Ambiance as a by-product
- Low O&M cost; Low energy consumption; Low mechanization, hence zero down time
- No disposables or process residues (bio-sludge)
- Potential for Zero
- Discharge
- No air or sound pollution. Free from foul odour
- No use of synthetic chemicals. Uses natural ingredients
- Scalable to any size of operation
- Best option for decentralized wastewater treatment
- Ideal for getting high Green Rating, Carbon Credits
- Ideal option for implementation under CSR Schemes
- Water recovery - 90% (Minimum)
- Unskilled people can Operate
- Long life; one time installation of Media
- Customized solution feasible
- The land requirement for STPs constructed using SBT process is comparable to that required for other modern processes like MBBR / SBR, but more than that required for MBR process.

4.4 Disadvantages of CAMUS-SBT process:

- The Technology is patented and the Operation & Maintenance of this type of treatment plant is very difficult unless the technology providers take up the operation and maintenance.
- Additives are required for effective treatment of sewage. The additives are patented and have purchased from the technology providers only. Hence it is very difficult to assess the actual O&M for the stake holder.
- The plant capacities so far constructed / in operation are very small i.e max of 3.00 MLD only.

4.5 Conclusions

1. These plants up to 3 MLD have been constructed in gated communities, housing layouts, satellite towns, scattered housing, hamlets, hostels, hospitals, offices, commercial establishments and in BMMC. The plants are working satisfactorily wherever they are being maintained by the technology provider.
2. This process has been awarded US and Indian patents. It is cost competitive, requires little more land than those of modern technologies, minimum pumping and other maintenance costs besides less capital cost.
3. Evaluation of technologies may be done based on total life cycle costs including energy charges, for the CPCB effluent discharge standards.
4. Experience so far indicates that the SBT/CAMUS-SBT process may be initially adopted for up to 5 MLD capacity STPs in smaller towns, for decentralized treatment plants in bigger towns and in peripheral settlements / areas in different regions of AP. Scaling up of capacity of individual plants may be considered based on experience.
5. The sludge generation is very minimum and no land is required for disposal of sludge.
6. Septage management is also feasible with the septage from the septic tanks being treated through additional processes like anaerobic digestion with suitable standby units. The effluent of the septic tanks and the sullage mixed with sewage from unconnected households (to septic tanks) will be intercepted and diverted and is also treated through primary settling and SBT bioreactor/s.
7. Expansion through modular construction is feasible. Suitable PPP model may be feasible due to recyclable quality of effluent. The plants also lead to reduction in quantity of piped water to be supplied.

4.6 RECOMMENDATIONS

- This technology can be used for STPs up to 5 MLD in smaller towns, for decentralized treatment plants in bigger towns and in peripheral settlements in different regions of AP.
- For higher capacity plants, the technology provider has to develop the model to accommodate in smaller foot prints so that it can be taken up in major cities also where land is a constraint.
- For ensuring effective O&M of SBT/CAMUS-SBT plant, its Operation & Maintenance should be carried out by the original technology provider only during the plant's life cycle, or he should be involved in a joint venture with the construction agency, or the complete patented information must be transferred to the Construction / Implementing Agency.
- These plants may be proposed with long maintenance periods preferably minimum 10 years after Defects Liability Period through provision of O&M by technology developer through suitable PPP model as the process requires patented culture and additives. Accordingly relevant conditions may be incorporated in bid documents to ensure efficient treatment and for meeting the CPCB / CPHEEO effluent discharge standards.
- The ULBs are generating lot of waste water which is being let out into the natural water bodies without any treatment causing environmental pollution. At the same time the Government is spending huge amounts for supplying water for irrigation purpose. If the waste water is treated with the above technology, it can be utilized for irrigation purpose so that the environmental pollution is reduced and exploitation of ground water / surface water can be minimized, achieving water use efficiency.
- This technology being cost effective and with less O&M cost is best suited for waste water treatment and needs to be taken up as part of Irrigation Projects so that the waste water is treated effectively before being used for irrigation or downstream industrial uses.
- The quantity of drinking water being supplied to all 110 ULB's of Andhra Pradesh is around 1600 MLD, which in turn generates 1250 MLD of waste water (16 TMC per annum). This water if treated can be reused either for irrigation / industrial use. The treatment plants with SBT Technology are suitable for treatment of waste water as it is very cost effective, with low O&M cost and the treated effluent can be reused.

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