UASB TECHNOLOGY FOR SEWAGE TREATMENT IN INDIA

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ABSTRACT

It's nearly two decades since UASB (Upflow Anaerobic Sludge Blanket) concept for sewage (municipal wastewater) treatment was started in India and today it has taken an edge over the other developing countries having similar climatic conditions in the use of this technology. At present, about 23 full-scale UASB plants are in operation at various places in India with total installed capacity of about 9,85,000 m^3/day (985mld) and about 20number are in pipeline which are likely to be commissioned within next 3-4 years. With financial assistance from international funding agency, the National River Conservation Directorate (NRCD) under the Ministry of Environment & Forests (MoEF), Government of India (GoI), formulated and launched a comprehensive action plan project for conservation of the river Yamuna under which 16 UASB sewage treatment plants (STPs) were commissioned in the period of 1999-2002. Experience shows that the present UASB reactor design and construction is quite different from the very first module of 5 mld treatment capacity that was constructed as a demonstration plant at Kanpur, India under the Ganga Action Plan (GAP) in late 80's. The discrepancies in the initial UASB plants were recorded and now a new breed of UASB reactor is available with respect to the design, operation and maintenance, and materials of construction. Initially, most of the UASB plants were provided with final polishing ponds as post-treatment unit, but now other options for the same are being explored to meet the stringent regulations. This paper reviews the overall implications of UASB technology in India. Institutional and technical aspects with special reference to the Yamuna Action Plan (YAP) are presented. It also presents the potential of UASB technology in other developing countries with its future within India as well based on the evaluation of life cycle cost (LCC). Other sewage treatment technologies were also included while evaluating LCC. The LCCE can be used as a tool for selecting appropriate technology under similar climatic and economic conditions in other developing countries. LCC supports that UASB as one of the most favourable methods of wastewater treatment from all aspects.

Keywords:UASB, Anaerobic Process, Sewage Treatment, India

1. INTRODUCTION

Sewage treatment is not a cheap proposition. Public bodies have to think twice before making substantial investments particularly in developing countries where environmental issues could not be given due priority due to financial constraints. Over the years, treatment related issues are becoming expensive as governments are not only giving emphasis to treat wastewater in order to protect their resources but the concept of reuse & recycling is also becoming an important aspect. Not only this, residues emanating there from, and other treatment by-products are also being included in the overall wastewater management system. On the other hand, emphasis is also being given to clean technologies to minimize waste production. However, in countries like India, the treatment issue is dominant and receiving due attention these days.

During the past two decades, several new sewage treatment technologies have been developed and are being adopted in many developing countries particularly in the South-East Asian region including India. Some of the technologies are Fluidized Aerobic Bed (FAB), Anaerobic Filter (AF), Expanded Granular Sludge Blanket (EGSB), Sequencing Batch Reactor (SBR), Membrane Bioreactor (MBR), Fluidized Aerated Bed Reactor (FAB), Submerged Aeration Fixed Film Reactor (SAFF), BIOFOR (Biological Filter Oxygenated Reactor), Upflow Anaerobic Sludge Blanket (UASB) process etc. Every technology has its pros & cons and therefore has to be applied in accordance to the local conditions.

In India, where the government has felt a need to prevent pollution of its rivers and preserving natural resources, a major action plan has been formulated under which a good number of towns and cities have been identified by the National River Conservation Directorate under the Ministry of Environment & Forests (MoEF), Government of India. The objective of river action plan is to conserve the river water bodies. Within this framework, the Ganga Action Plan (GAP) was incepted and implemented in mid 80's. After the implementation of GAP in few states, Yamuna Action Plan (YAP) was formulated in early 1990 for the states of Uttar Pradesh,
Haryana and Delhi where major part of Yamuna River flows.

With respect to the application of UASB technology, the experience gained in India is unique and diverse. India is one of the leading countries in terms of the amount of sewage volume treated by the UASB process (Sato *et al*, 2007). It has been recognized as one of the most cost effective and suitable sewage treatment process considering the environmental requirements in India. At present about 23 number of sewage treatment plants with total installed capacity of 985 mld (MoEF, 2005, 2006) based on the UASB are in operation and about 20number are in pipeline which are likely to be commissioned within next 3-4 years. These plants have come up under different national plans during the last 20 years under various river catchments, i.e., GAP from Himalayan region to the Bay Bengal, Sabarmati in the state of Gujarat, Godavari in the states of Maharasthra and Andhra Pradesh, Sutlaj in the state of Punjab, Khan in the state of Madhya Pradesh and YAP. However, the present study focuses on the Yamuna action plan. In this study, efforts have been made to present the experience to treat 985 mld sewage wastewater using UASB with respect to its design, operation and maintenance, material of construction, effluent quality, post-treatment options etc. and its potential in other developing countries having similar climatic conditions.

UPFLOW Anaerobic Sludge Blanket (UASB) reactor also called as anaerobic reactor was used to treat various industrial wastewaters like petroleum, distillery, Canning industry, Heavy metals, Paper and Pulp, Tannery , Pharmaceutical, domestic waste water etc. The sludge blanket in the UASB comprised of microbial granules, i.e. small agglomerations (0.5 to 2mm in diameter) of microorganisms and because of their weight able to resist being washed out in the upflow. Bacteria living in the sludge, break down organic matter by anaerobic digestion and transforming it into biogas. The rising bubbles mix the sludge without the assistance of any mechanical parts. Sloped walls push down the material that reaches the top of the tank. The gas that rises to the top is collected in a gas collection dome and can be used as energy (biogas).

Hydraulic Retention Time (HRT)

HRT is considered as an important for operating parameter which controls the performance of UASB reactor. Very long HRT will affect adversely on the process of sludge granulation in UASB reactor and very short HRT is disadvantageous due to the fact that the biomass may move out with effluent.

Organic Loading Rate (OLR)

This is another important parameter to control the performance of UASB reactor. Increase of OLR will cause an operation problem. OLR is an important factor for the removal of COD. Aerobic biological treatment involves microbial degradation and oxidation of waste in the presence of oxygen. Conventional treatment of dairy wastewater by aerobic processes includes processes such as activated sludge, trickling filters, aerated lagoons, or a combination of these. All compounds of dairy wastewater are biodegradable except protein and fats which are not easily degrades.

Organic matter + microorganisms + O 2 5CO 2 + 2 H 2 O + NH 3 + energy (1)

Anaerobic microorganisms are those that do not have oxygen as a terminal electron acceptor. The oxidation of organic matter in anaerobic respiration is coupled with the reduction of other electron acceptors such as sulphate (sulphate reduction), ferric iron (iron reduction), nitrate (denitrification), CO2 (methanogenesis) or some organic compounds. An anaerobic process involves the degradation of complex high-molecular- weight organic compounds to mainly methane (CH4) and car- bon dioxide (CO2). The chemical reactions (fermentation) involved in the reactor to produce hydrogen are

$$CH_3CH_2CH_2COOH + 2H_2O \longrightarrow 2CH_3COOH + 2H_2 \quad (2)$$

Butyric acid water Acetic acid Hydrogen

$$CH_3CH_2COOH + 3H_2O \longrightarrow CH_3COOH + 3HCO_3 + 3H_2 \quad (3)$$

Propionic acid water Acetic acid Hydrogen

$$CH_3COOH + 2H_2O \longrightarrow 4H_2 + 2CO_2 \quad (4)$$

Acetic acid water Hydrogen Carbon-di-oxide

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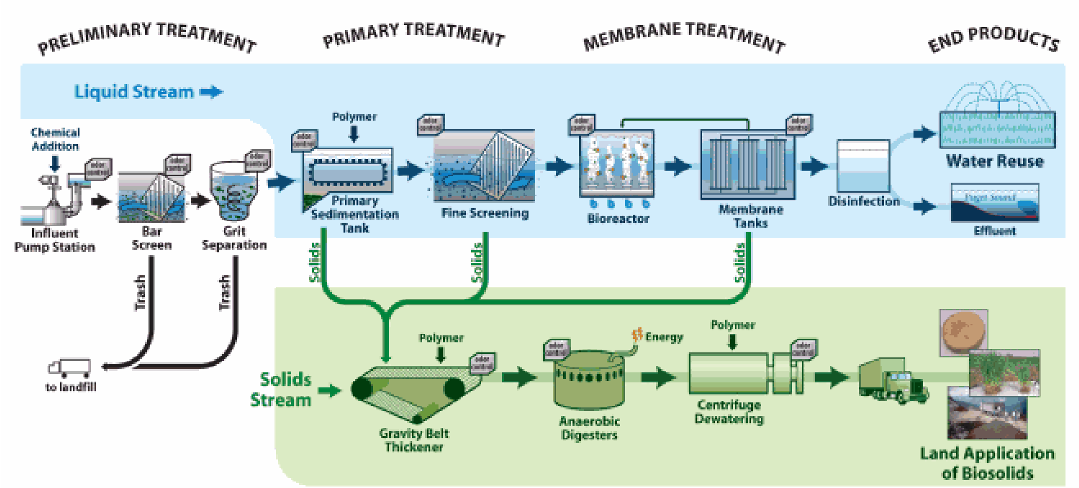

Sewage treatment process

2. INSTITUTIONAL FRAMEWORK FOR YAMUNA ACTION PLAN

The Yamuna River Basin is one of the major tributaries of the river Ganga, contributing about 40% basin area of Ganga River and 10% of the total landmass of India. The catchment of the Yamuna River System covers parts of the states of Uttar Pradesh, Himachal Pradesh, Haryana, Rajasthan and Madhya Pradesh and the entire State of Delhi.

YAP project was started in 1993 with a restriction to only 15 cities in the Yamuna catchment. A central nodal agency, National River Conservation Directorate (NRCD) under the Ministry of Environment & Forests (MoEF) was made responsible for the overall implementation, coordination and monitoring of river action plans in India including YAP since 1993. One of its key roles is to channelise Central Government funds to the concerned State governments for the implementation of the river conservation schemes. At the state levels (i.e. in Uttar Pradesh, Haryana and Delhi), designated state agencies known as the Project implementing Agencies (PIAs) were given the responsibility for implementing the YAP project.

- In Haryana, Public Health Engineering Department (PHED) under the state Government of Haryana.
- In UP, Uttar Pradesh Jal Nigam (UPJN), an autonomous organization under the Department of Urban Development of Government of UP.
- In Delhi, Delhi Jal Board (DJB) and Municipal Corporation of Delhi (MCD). The institutional linkages for the implementation and operation of the YAP.

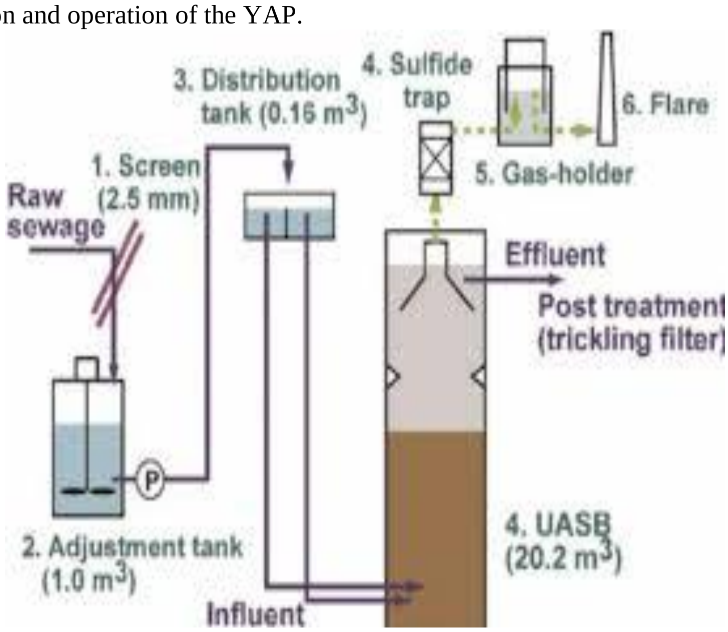

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Figure 1: Yamuna Basin and towns under YAP

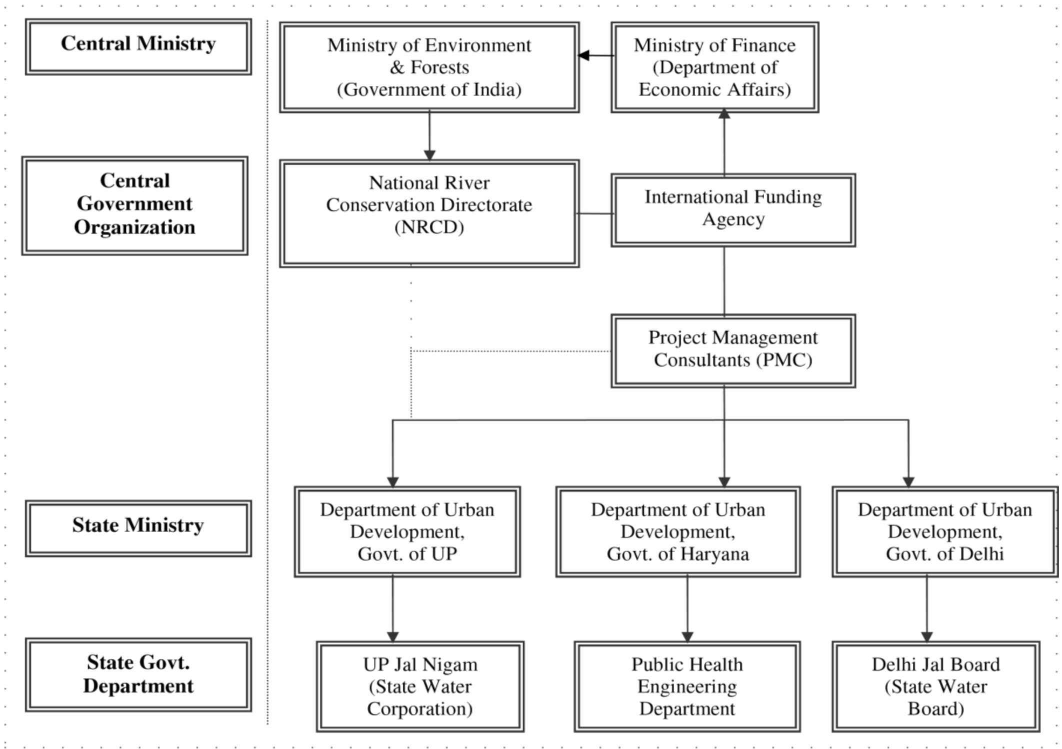

Figure 2: Institutional Framework for YAP

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3. UASB TECHNOLOGY EXPERIENCE IN INDIA

3.1 Historical Developments of UASB Technology

Worldwide presently over 200 full-scale UASB plants are in operation for the treatment of both domestic and industrial wastewaters. However, in India the UASB Process is being widely adopted for domestic wastewater and it can be claimed that 80% of total UASB reactors worldwide for domestic wastewater treatment is in India. The basic approach towards selection of technology for sewage was low capital costs, low energy requirements, low O&M costs and sustainability aspect. This was derived from the experience of Ganga Action Plan (Kanpur-Mirzapur). Based on the successful results of 5 mld demonstration plant was constructed at Kanpur, Uttar Pradesh. The experience GAP was mixed in terms of efficiency of treatment versus energy consumption and cost of operation and maintenance. Drawing lessons from GAP, the YAP opted for energy neutral and energy recovery technologies like anaerobic processes for the sewage treatment. Conventionally, anaerobic processes are to be used for the treatment of high strength organic wastewaters. However, typical hydro-dynamics of UASB coupled with its unique characteristic of holding high granular biomass (Sunny *et al*, 2005), made it possible to apply the anaerobic processes for the treatment of low strength wastewaters.

After studying the performance of the demonstration plant for a few years, a full scale UASB plant of 14 MLD was constructed at Mirzapur for treating the domestic wastewater (Draaijer*et al*, 1992.) In view of the fact that the USAB effluent does not meet discharge standards, the plants were used in conjunction with a settling pond called 'final polishing unit' to achieve desired BOD and suspended solids reduction. These being pilots and experimental plants, their performance were varied. However they were found to be promising in terms of energy consumption, biogas yield and reduced requirements for sludge disposal.

The key factors that influenced selection process against the conventional aerobic systems were their high energy requirements, unreliable power supply situation in the states, and higher O&M costs; while those in favour of UASB were their robustness, low or no dependence on electricity, low cost of O&M. Moreover, the possibility of resource recovery from biogas and aquaculture respectively also influenced the selection process. Among the large capacity plants under YAP, in all 28 STPs comprising 16 UASBs, 10 Waste Stabilization Ponds (WSPs) and 2 BIOFOR technology STPs with aggregate capacity of 722 MLD were constructed. UASBs accounted for an overwhelmingly high 83% of the total created capacity.

The state of Haryana almost entirely opted for UASB technology where 10 out of the 11 large plants were based on this.

3.2 Design Considerations

The most important feature is the modular approach adopted for the design of UASB reactors. This facilitates in having more flexibility in the operation of the STP. The major treatment units, which includes UASB reactors and Final Polishing unit (FPU) has been provided in modules of same capacity. Each reactor operation is independent of each other and during trouble shooting in one reactor the flow can be suspended and diverted to the other reactors for its maintenance without disturbing the operation of the STP. Final Polishing units (FPU) also have been provided in modules.

The design of UASB reactors for domestic wastewater is mainly based on hydraulic principles and the incoming wastewater composition. A top view and sectional views of UASB reactor are shown in Figure 3.

Table 2: Basic Assumptions and Design Criteria adopted for UASB Reactors

Parameter	Value/Range	Unit
Ambient Temperature	18-42	*°C*
Temperature of Sewage	20-25	*°C*
Bacterial Yield Coefficient	0.06-0.08	*kg VSS/kg COD*
Sludge Retention Time (SRT)	32-38	*Days*
VSS Destruction in Reactor	50	*%*
Maximum Sludge Bed Height	80-85	*% of height to gas collector*
Sludge Bed Concentration	65-70	*kg TSS/m* ^{3}
Upflow Velocity at Average Flow	0.52-0.58	*m/h*
Maximum biogas loading	1.0	*m3.m-2.h -1*
HRT (Hydraulic Retention Time)	8-12	*Hours*
Maximum Aperture Velocity	5	*m/h*
Volumetric Loading Rate	1.15-1.25	*kg COD/m*^{3}*/day*

Biogas production	0.08-0.11	*m^3. kg^{-1} COD rem.d^{-1}*
Methane Content in Biogas	60-65	*%*
Gas Hood Width	0.44-0.50	*m*
Settling Zone Surface	75	*%*
Angle of Gas Collector	50	*Degrees*
Angle of Deflector	45	*Degrees*
Feed Inlet Density	0.25	*m2*
Overlap of gas collector over deflector beam	0.15-0.20	*m*
Centre to centre distance between gas domes	4.0	*m*
Clear distance between gas domes	3.0	*m*
Feed pipe velocity	1.0	*m/s*
COD removal efficiency	75-80	*%*
BOD removal efficiency	65-70	*%*
TSS removal efficieny	75-80	*%*

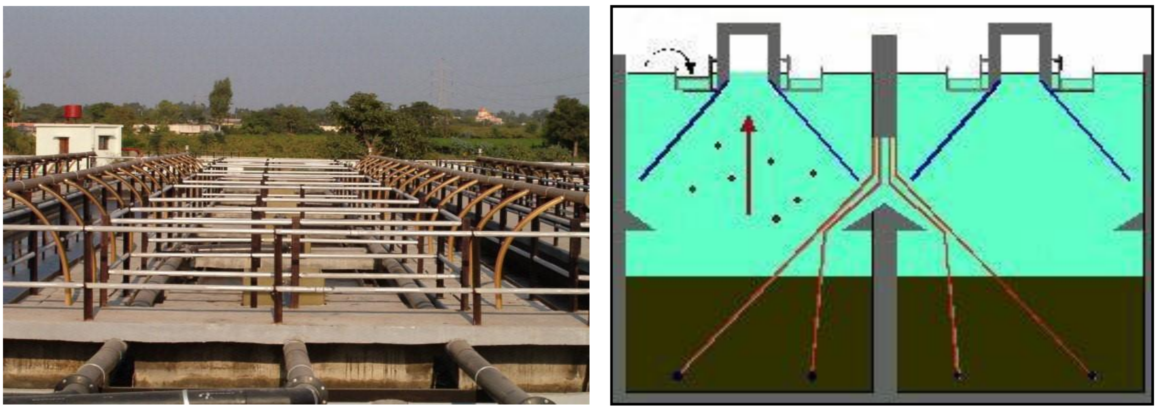

Figure 3: Top and Sectional Views of UASB Reactor

Material of Construction of UASB Reactors

From the time of introduction of UASB concept in India in late 1980s and till date, there have been significant modifications in the material of construction of UASB reactors, which has significantly resulted in lowering capital costs. The modifications incorporated in the 14 MLD UASB plant at Mirzapur constructed in 1989 over that of 5 MLD UASB plant at Kanpur under GAP were in the selection & introduction of Fibre Reinforced Plastic (FRP) (bisphenol resin) to rectify corrosion problems and resulting in longer durability. Simpler wastewater feed inlet system in the UASB reactors is adopted to take care of choking, operation and maintenance problems surfaced at 5 MLD plant. But, in the ten UASB STPs designed for YAP in Haryana and recently in other UASBs, further necessary improvements were incorporated, such as, improvement in fixing of FRP Feed inlet boxes, Gas Liquid Solids Separator (GLSS), change in design of deflector beam, selection of most appropriate material with respect to durability and costs etc.

In the present scenario, the main structure of UASB reactor being constructed at various places in India is with RCC (Reinforced Cement Concrete) since concrete is easily available and has been used in most of the developing countries for construction works. The inside surface was coated with epoxy paint as a protective layer to avoid corrosion due to formation of H_2S and CO_2. FRP of Isothelic resin class gas hoods and domes have been provided in the GLSS (gas-liquid-solid separation). The purpose of use of FRP was because of easy construction, light weight, anti-corrosion and simple maintenance. The feeding boxes, effluent gutters, baffle plates and gas collection pipes are also constructed with FRP material. For feeding pipes, HDPE (High Density Polyethylene) pipes are being used to distribute the wastewater uniformly over the surface of the reactor. For sludge discharge, CI (Cast Iron) pipe is being generally used. However, further R&D shows that the reactors can be constructed fully in FRP using Isothelic resin instead of RCC for small flows provided modular approach is adopted.

4.CONCLUSION:

Sewage treatment is not a cheap proposition. Public bodies have to think twice before making substantial investments particularly in developing countries where environmental issues could not be given priority due to financial constraints. During the past three decades, several new sewage treatment technologies have been developed and are being adopted in many developing countries particularly in the South-East Asian region including India. Recent developments in the field of anaerobic treatment have proved that the anaerobic treatment processes specially UASB reactor are not restricted to the high strength wastewaters, but also they can successfully be applied to low strength domestic wastewaters. The physico-chemical properties and methanogenic activity of sludge from seven treatment plants were determined. The highest activity was found in the sludge from the treatment plan in El Viejo city, which means that this sludge could be used as inoculum in new treatment plants. Very useful experience was acquired working with sludge from the municipal treatment plants. In the case of the brewery wastewater treatment plant, the deficient concentrations of sulphide and iron were probably the reason for the unsatisfactory granular sludge formation. The addition of these elements to the anaerobic reactor was suggested to the authorities of the treatment plant. The ability of small, UASB systems may be suitable for increased use in the urban environment.

Two main reasons behind the importance of Using UASB are:

(1) generation of large volume of low-strength wastewaters, which are often disposed untreated due to high costs, and

(2) the potential of stabilizing the organic wastes by producing valuable energy by product. Finally, it may be concluded that, UASB reactor has been recognized as one of the most cost effective and suitable sewage treatment process considering the environmental requirements in India.

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