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ABSTRACT

In last two decades, large number of sewage treatment technologies got implemented in our country. Some of them are very good from point of view of treatment efficiency, while some others are low cost but unable to meet effluent standards. India is a developing country with lot of resource constraints, so performance levels can not be the sole criteria for selection of sewage treatment technology for any specific site. We have to give due weightage to life cycle cost and local limitations affecting operation & maintenance. There can also be constraints on account of availability of adequate land particularly in big cities. According to the report of CPCB the estimated sewage generation from class1 cities and class 2 towns is 38254.82MLD, out of which only 17787.38MLD which is 35% is being treated and the remaining is disposed of into water bodies without any treatment.

The manual on sewerage and sewage treatment published by the ministry in 1993 lays emphasis on conventional sewage treatment technologies such as ASP, WSP etc. but over the last two decades many new technologies have emerged . These technologies which are being used in other parts of the world have not been deployed in India on a large scale. Therefore their techno-economic viability under Indian conditions needs to be proven. Each of these technologies has its own merits and demerits. The following treatment technologies though these have been randomly tried out so far, need to be investigated under Indian conditions to arrive at their techno economic viability. As per the compendium of sewage treatment technologies issued by the national river conservation directorate (NRCD), ministry of environment and forest, published in 2009, the cost aspects based on capital cost, O&M cost, reinvestment cost, energy and land cost based on data of STPs in the Ganga river basin and elsewhere in India indicates that unlined WSPs has the lowest treatment cost but the highest land requirements. The conventional ASPs ha moderate treatment cost and moderate land requirement.

This study aims to develop a methodology for selecting most appropriate technology suitable for a particular location taking into account all the constraints specific to the site. No universal solution to be adopted for different sites. Current decision support tools for selection of sewage treatment alternative focus primarily on effluent quality, treatment efficiency& indirectly the environmental consequences of receiving water bodies

For the purpose of the study, performance data of 21 STPs (spread over the length and breadth of the country) was analysed. The initial capital cost / operation &maintenance cost per unit MLD incurred in the past for the different STPs mentioned in this report were converted to a common base year 2011. For computation of above, Cost Inflation Indices were used. It is necessary to compute the above costing data of all STPs for same year because construction year of all STPs are different.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In developing countries the sewage disposal is not given proper priority so treatment and disposal of sewage is still area of major concern. Untreated sewage from cities and towns is the biggest source of pollution of water bodies in third world countries (CPCB Highlights, 2001). In India there are 211 Sewage Treatment Plants (STPs) in 112 of the 414 Class I cities and 31 STPs in 22 of the Class II towns (CPCB Highlights, 2005). Besides, 27 STPs are in 26 other smaller towns. In all there are 267 STPs, Including 231 operational and 38 are under construction. There remain 302 Class I cities and Class II towns together generate an estimated 29129 ML/day sewage. Against this, installed sewage treatment capacity is only 6190 ml/day. There remains a gap of 22939 ML/d between sewage generation and installed capacity. In percentage this gap is 78.7%. Another 1742.6 ml/day capacity is under planning or construction stage. If this is also added to existing capacity, even then there is gap of 21196 ml/day (equal to 72.2%) in total sewage treatment capacity. The untreated sewage causes many problems where it has been discharged. In India it is estimated that 75 to 80% of water pollution by volume is caused by domestic sewage. It pollutes the river streams, fertile land and ground water mainly besides causing odour nuisance Ministry of Environment and Forests, 2006. Untreated sewage is also a source of health hazards which manly affect children and poor people. Infectious diarrhoea makes the largest single contribution to the burden of disease associated with unsafe water, sanitation and hygiene . The concept of Decentralized Sewage Treatment System (DTS) is quite effective to come over these major problems with unique solution. In present proposal the technology used for designing a DTS is very known and indigenous but the process design is new and widely applicable where sewage is a problem. Under this circumstances, the decentralized sewage treatment system (DTS) for population varying from 1000 to 10,000 that is, 120 to 1200 Kl/day or more can play a major role in water pollution abetment with multifaceted benefits. The amount spent on this sewage treatment can be fully recovered within 8 to 10 years. Total expenditure on initial capital cost, operation &maintenance cost, life cycle cost of STPs are calculated under the techno-economic evaluation. Study was carried out on 21 STPs based upon different aerobic or anaerobic treatment technologies to evaluate the performance of the STPs on the basis of performance levels (BOD, COD, and SS), land availability, unit MLD expenditure. The techno-economic evaluation of sewage treatment technologies has been prepared, based on data available from the operations of sewage treatment plants (STPs) in the country over the last two decades. The data gathered was analyzed for determination of treatment efficiency, treatment costs and land requirement of various technological options available for sewage treatment.

Various technologies adopted for sewage treatment in India include,

- Waste stabilization ponds (WSPs)
- Activated sludge process and its modifications
- BIOFOR Processes
- Fluidized aerated bed (FAB) Process
- Up Flow Anaerobic Sludge Blanket (UASB)process
- 2-stage ASP based BIOFOR F process
- Submerged aerated fixed film process (SAFF)

In India, functioning of STPs are mainly categorised into 3 parts are as follows:

1. **Primary treatment**

The purpose of preliminary treatment is to protect the operation of the wastewater treatment plant. This is achieved by removing from the wastewater any constituents which can clog or damage pumps, or interfere with subsequent treatment processes. Preliminary treatment devices are, therefore, designed to remove or to reduce in size the large, entrained, suspended or floating solids. These solids consist of pieces of wood, cloth, paper, plastics, garbage, etc. together with some faecal matter and to Remove heavy inorganic solids such as sand and gravel as well as metal or glass and excessive amounts of oils or greases. These objects are called grit. It involves removal of readily settable solids prior to biological treatment. Sedimentation chambers are the main units involved but various auxiliary processes such as floatation, flocculation and fine screening may also be used.

2. Secondary Wastewater Treatment

Secondary wastewater treatment is the second stage of wastewater treatment that takes place after the primary treatment process. The process consists of removing or reducing contaminants or growths that are left in the wastewater from the primary treatment process. Usually biological treatment is used to treat wastewater in this step because it is the most effective type of treatment on bacteria, or contaminant, growth.

Secondary treatment processes can remove up to 90 percent of the organic matter in wastewater by using biological treatment processes. The two most common conventional methods used to achieve secondary treatment are attached growth processes and suspended growth processes.

3. Tertiary Wastewater Treatment

Tertiary treatment is the next wastewater treatment process after secondary treatment. This step removes stubborn contaminants that secondary treatment was not able to clean up. Wastewater effluent becomes even cleaner in this treatment process through the use of stronger and more advanced treatment systems. Tertiary treatment technologies can be extensions of conventional secondary biological treatment to

further stabilize oxygen-demanding substances in the wastewater, or to remove nitrogen and phosphorus. Tertiary treatment also includes physical-chemical separation techniques such as carbon adsorption, flocculation or precipitation, membranes for filtration, ion exchange, dechlorination and reverse osmosis.

Water quality monitoring studies carried out by various national and international agencies (including CPCB) reports that the fresh water bodies in India contains high level of organic and microbial pollutants. Pollution abatement works undertaken by national river action plans tried to sort out the water quality problems through diversion of urban waste water to sewage treatment plants before disposal. The organic pollutant (measured as BOD) removal performance of conventional technologies employed in a majority of STPs whereas microbial pollutants (measured as MPN of total and faecal coliforms). Removal performance is not good. Few STPs in India maintains the records of microbiological quality of waste water.

In order to set criteria for designing STPs, .it is important to have standards for coliform to be achieved in different situations

1.2 Centralised vs. Decentralised waste water systems

Urban waste management systems are being increasingly transformed from a disposal based linear system to a recovery based closed- loop system that promotes the conservation of water and nutrient resources thereby contributing to sustainable development. The origins of municipal wastewater treatment dictated a centralized treatment approach. Considering the shortage of water resources in most parts of the country it is becoming essential to reuse wastewater (with treatment and without treatment) to meet the requirements of water. To maximize the use of reclaimed water in a centralized system, water transfer and distribution pipe lines have to be constructed for reclaimed water supply, if the benefit of reclaimed water is to reach the customers which are generally dispersed in the city area. As was the case with waste water collection system, the construction as well as the operation cost for the transfer and distribution pipelines for reclaimed water often becomes more expensive than the construction cost for the treatment facility itself.

In fact, in order to promote waste water reuse, a number of cities have set the selling price of the reclaimed water at a very low level no matter how much is spent for its production, and the government is providing subsidies for business. Owing to the above stated limitations, “decentralized” systems for wastewater treatment and reuse are drawing attention widely. Such a system stresses onsite wastewater treatment and local reuse. Therefore, construction of a long distance transfer pipeline and a large scale distribution network for the reclaimed water may no longer be necessary. This approach would allow for independent, self sustained and self maintained facilities that are capable of recovering wastewater resources.

1.3 Daily expenditure on STPs

The daily expenditure on STPs includes power requirement, fuel for operating generators, manpower cost, repairs cost with operation & maintenance. The government or agencies are going to own the project. They may also need the O&M cost over the whole life cycle for budgetary purpose. Very often it has been experienced that the capital cost of project is made available but they have to struggle for daily expenditure cost.

1.4 Objective of the Study

In last two decades large number of STP technologies have been implemented in India. Considering the scale of unfinished task, 70% of sewage generated in towns is yet to be treated. In the future thousands of STPs is need to be constructed to maintain the health of our water bodies and ground water resources. The sewage treatment plants are going to involve the expenditure of thousands of crores. It is essential that due diligence be carried out in making the appropriate choice of sewage treatment technology to deliver treated effluent meeting the discharge standards in the most cost effective manner. On the basis of STP statistics (CPCB) that the choice of technology have been adhoc, resulting in higher cost or poor effluent quality. Despite heavy expenditures there isn't a discernable improvement in environmental quality.

The study aims to develop a methodology for making appropriate choice of sewage treatment technology based on location and other local constraints.

The objectives of this study are as follows:

- To collect technical details of various technologies based STPs in India.
- To collect the cost details of STPs in their construction years
- To convert all the cost details of STPs for base year 2011
- To create a comparison table of different factors which affects methodology in selection of appropriate technology.

CHAPTER 2

LITERATURE REVIEW

2.1 WSP - Waste Stabilization Pond (Combination of Anaerobic and Aerobic Pond)

In this technology sewage is treated in a series of earthen ponds. After primary treatment (screening and de-gritting) sewage is filled into an anaerobic pond for initial pre-treatment. Depth of anaerobic pond lies between 3 to 3.5 m due to which the bottom section of pond does not get oxygen and an anaerobic condition is developed, therefore, BOD value of sewage reduces by 35-40% .Production of Gases like ammonia and hydrogen sulphide are creating odour problems. After this sewage enters into the facultative/aerobic pond, which is normally 1 - 1.5 m in depth. Lesser depth allows continuous aeration from atmosphere; in addition algae present in the pond also produce oxygen. Though BOD of effluent remains within the range, sometimes the effluent has green colour due to presence of algae. The algae growth can deteriorate the effluent quality (higher total suspended solids). Moreover, coli forms removal is also in 1-2 log order. The operating cost of a waste stabilization pond is mainly spent in cleaning the ponds. Cleaning of ponds is done in every two to three years. So, O&M cost of WSP is minimum. A waste stabilization pond requires a very large land area therefore it is used where large amount of land is available. It is used for small capacity plants.

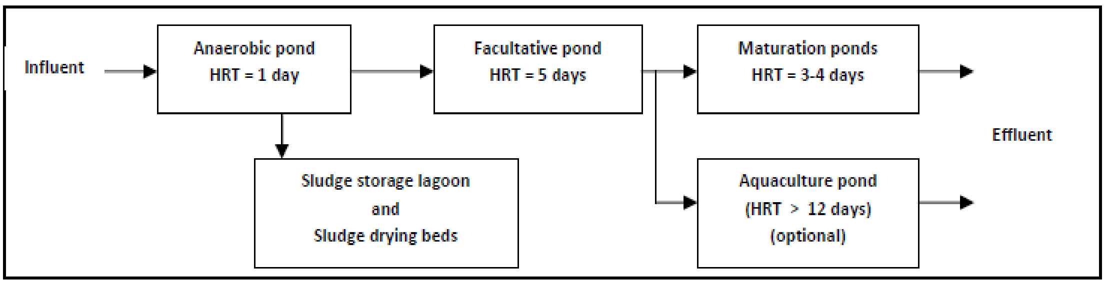

Fig1: Schematic Diagram of a Waste Stabilization Pond

Advantage

- Its operation and maintenance cost is less.
- It is very much efficient from economic & environmental point of view.
- Possible recovery of the complete resources
- Variation in hydraulic and organic loading can bear by it effectively

Disadvantages

- Need large amount of land area.
- Large amount of water is lost because of evaporation.
- Inadequate lining result in ground water contamination.
- Quality of effluent varies from season to season.
- Doesn't produce any resource recovery
- Effluent quality is inferior in comparison to other treatment technologies.
- Its nutrient removal efficiency is not good.
- Requires large amount of chlorine for disinfection.
- Doesn't have proper collection system due to this valuable GHGs

2.2 ASP - Conventional Activated Sludge Process

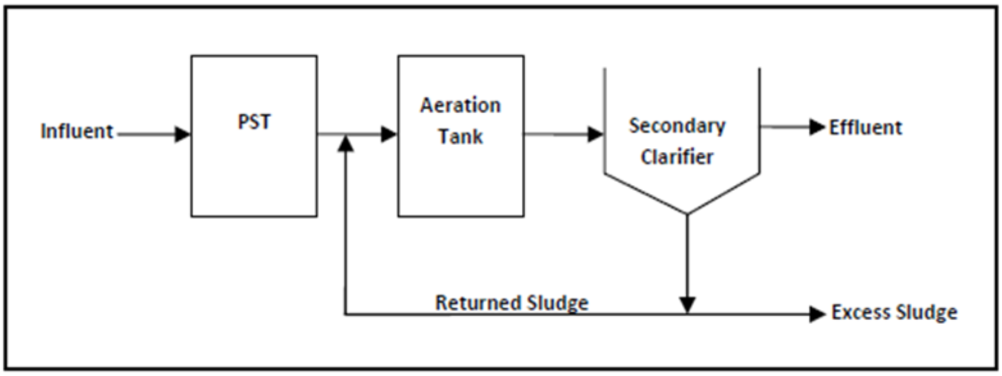

Fig 2: Schematic Diagram of an Activated Sludge Process

Activated Sludge Process (ASP) is a suspended growth aerobic process. It is provided with primary clarifier to reduce the organic load in biological reactor (aeration basin). About 40% of organic load is intercepted in primary clarifier in the form of sludge, decreasing the loading in the aeration tank. Detention period in aeration tank is maintained between 4-6 h. After aeration tank, the mixed liquor is sent to secondary clarification where sludge and liquid are separated. A major portion of the sludge is re-circulated and excess sludge is sent to a digester. Sludge generated in primary clarifier and excess sludge from secondary clarifier are not matured, digestion of such sludge is essential before disposal. In anaerobic sludge digestion, such sludge produces biogas which can be used for power generation by gas engines. Generated power can be used for operation of plant.

Advantages

- Flexible in working
- Reliable operation
- It is a universal technique working for all size of STPs
- Area requirement is lea.
- Amount of odour gas generation is less.
- Energy production is not good.
- Capable in working with nominal changes in water characteristics

Disadvantages

- High energy consumption
- Skilled operators needed
- Uninterrupted power supply is required
- Requires sludge digestion and drying
- Less nutrient removal

2.3 BIOFOR Technology

Key features of the technology

- This technology uses coagulants and flocculants with primary treatment.
- Requires very less area by using High rate primary tube settlers and integrated thickening.

- Two stage high rate filtration through a biologically active media and with enhanced external aeration
- Co-current up flow movement of wastewater and air enable higher retention and contact
- Treatment scheme excluding secondary sedimentation but recycling of primary sludge
- Deep reactors enabling low land requirements
- A compact and robust system

Specific requirements

- Requires alum as coagulant.
- Requires Polyelectrolyte in tube settlers for improving sedimentation efficiency.
- Requires special kind of filter media made of clay known as 'biolite'
- Requires backwashing of filter bed.

Energy requirement

- It requires 220-335 kWh/ML of electric supply for treatment. This value is almost the double of ASP value.

Land requirement

- It requires 0.04 hectares per MLD capacity of treatment plant. This value is much lesser in comparison to ASP.

Sludge production

- Sludge production value is about 1000kg/MLD of wastewater treatment.

Advantages

- Its design is very compact.
- The aeration efficiency of diffused aeration system used in this technology is very high.

- As there is no use of sedimentation tank in this technique it requires less space.
- Able to withstand fluctuations in flow rate and organic loads
- Its effluent meets all discharge standards very well.
- Its effluent can be used for industrial purposes.
- It is odour free so cannot affect its surrounding areas.

Disadvantages

- Requires large amount of Continuous chemical dosing in primary treatment.

2.4 FAB -Fluidized Aerated Bed

Key features of the technology

A compact and robust system which involves extended aeration process along with submerged aeration

- Biomass growth on fluidized bed of plastic media increases retention of biomass leading to low 'food to micro-organism ratio' and higher organic removal
- Two stage biological oxidation
- Any value of organic loading can be handled by adjusting quantity of fluidized media
- Doesn't involve primary sedimentation and sludge digesters.
- Land requirements is minimised owing to the use of more depth reactors (5m)
- Tube settlers also offer space economy

Specific requirements

- For creating high specific surface area special grade plastic media is used
- Diffused aeration system
- Submerged stainless steel screens at the outlet of FAB reactors to prevent media overflow
- High rate tube settlers for space control.

Land requirement

- It requires 0.06 hectares per MLD capacity of treatment plant. This value is much lesser in comparison to ASP.

Energy requirement

- It requires 99-170 kWh/ML of electric supply for treatment. This value is lower of ASP value.

Other aspects

- Effective multi stage screens needed to prevent choking of submerged screen at FAB outlet and tripping of system due to plastic bags and pouches.
- Possibility of choking at FAB outlet due to fluidized media. Requires effective air flushing valve to prevent tripping of the system
- Blockage of media can occur either due to excess biomass growth or low hydraulic loads
- Power requirements needed to prevent septic conditions.

Advantages

- Excludes primary sedimentation.
- Reactors used in this technology are large in depth enabling small space requirements
- Capable of treating dilute domestic wastewaters effectively.
- Capable to bear high rate loadings.
- Head loss is less.
- Sludge production is less and stable so, there is no need for digesters.
- Easy to operate.
- It is odour free so cannot affect its surrounding areas.

Disadvantages

- Reliance on patented filter media
- Reliance on flocculants, polyelectrolyte and chemical disinfectant

- Requires skilled manpower

Applicability

- Small to medium flows in congested locations
- Sensitive locations
- Decentralised approach
- Reliving existing overloaded STPs

2.5 UASB-Up-flow anaerobic sludge blanket process

Key features of the technology

- Process is invulnerable to power cuts because of no mechanical components or external energy requirements
- No primary treatment; suspended solids in the wastewater serve as carrier material for microbial attachment
- Calorific value of gas recovered is high.
- Sludge production is low
- Low maintenance and easy to operate.
- Biological activity can be restarted without any external seeding or special care after interrupted operations

Performance

An UASB reactor can bring down the BOD of the domestic wastewater to 70-100mg/l and suspended solids (TSS) to 50-100 mg/l. However, sludge washout from the reactor is possible and effluent BOD and TSS is very high during such episodes. The effluent is strongly anoxic with high immediate oxygen demand (IOD). It should not be directly discharged into water used for aquaculture.

Specific requirements

- Use of anticorrosive materials on exposed surfaces.
- Regular cleaning is required for distribution boxes and influent pipes

- Skilled supervisors are required to control the flow of biomass levels within the reactor during start-up.
- Post treatment of the UASB effluent is necessary.

Land requirement

- It requires 0.02-0.03 hectares per MLD capacity of treatment plant. This value is comparable to ASP value.

Energy requirements

- 10-15 kWh/ML treated,. very less than ASP, but more than WSPs

Advantages

- Sludge handling is minimized
- Plant performance unaffected by power supply interruptions.
- Can bear organic shock loading

Disadvantages

- In general cannot meet the desired effluent discharge standard unless proper post treatment is adopted, which in turn may make the treatment scheme energy intensive or may require large land area.
- Effluent is anoxic and invariably exerts substantial initial oxygen demand which may have adverse impact on receiving inland water bodies or when used for irrigation.
- Stability in performance is questionable unless sludge washout is prevented
- Removal efficiency of faecal and total coliform removal is poor
- Aesthetic appearance is poor.
- Exploitation of biogas generated is unsustainable during domestic sewage treatment

Applicability

The suitability of this technology may be doubtful as a stand-alone secondary treatment option.

2.6 2 Stage ASP based BIOFOR F process

Key features

- In general, the plant has high level of mechanisation and sophistication
- Doesn’t involve primary sedimentation tank
- Superior aerated grit chamber and classifier
- Circular aeration tank with tapered air diffusion system
- Biologically active filter media helps to achieve second stage aeration and rapid sand filtration
- Dissolved air floatation for sludge thickening
- Temperature controlled anaerobic sludge digestion takes place in digester.
- Mixing of digester contents through biogas
- Simultaneous generation of electrical and thermal energy through gas engines

Specific requirements

- Multiple grade of filter media for combined rapid filtration and biological oxidation
- Use of Poly electrolytes in filter press for sludge thickening
- Gas cleaning chemicals and bioreactor for desulphurisation

Land requirement

- Land requirement value is 0.08 ha/MLD.

Power requirement

- Unit power requirements value is 180 kWh/MLD
- 85% requirement being met through captive generation from biogas cogeneration system

Biogas generation

Biogas generation from sludge digestion: 77 m^3/d

Advantages

- Compact layout as a result of high rate processes
- Diffused and tapered aeration system increases its aeration efficiency
- Excludes primary sedimentation
- Maintains discharge standards effectively
- Effluent used for high end industrial applications
- Sludge produced is stable
- Almost self sufficient in energy requirement due to gas engine based cogeneration system
- Odour free working area

Disadvantages

None, except high life cycle cost

Applicability

The high rate activated sludge cum BIOFOR-F treatment system is suitable under complex situations requiring:

- Higher effluent quality for industrial purposes
- Compact large capacity plants under limited land availability situation
- Large installations with option for bio-energy generation
- Impact on local environment is minimized (e.g., odour control) in sensitive locations

2.7 SAFF-Submerged aerated fixed film

Key features of the technology

- Essentially a trickling filter with enhanced oxygen supply through submerged aeration
- Unconventional plastic media offering high void ratio and specific area compared to stone and aggregates
- Large biomass and long solid retention time in the reactor leading to low ‘food to microorganism ratio’ and higher organic removal

- Two stage biological oxidation
- Primary sedimentation and sludge digestion is absent
- Large depth reactors facilitate low land requirements
- High rate tube settlers are present

Specific requirements

- Special grade plastic proprietary media offering high specific surface area
- Diffused aeration system
- Tube settlers for compact clarifier

Power requirement

Electrical energy requirement is 390 kWh/MLD

O&M aspects

- Requires effective multi stage screens to prevent blockage of submerged media
- Blockage of media in case of excess biomass growth
- Uncertainty regarding durability of media under varying climatic conditions

Advantages

- Deep reactors enabling small space requirements
- Ability to effectively treat dilute domestic wastewaters
- Low and stabilised sludge production eliminating the need for sludge digestion
- Absence of odour and improved aesthetics
- Absence of emission of corrosive gases

Disadvantages

- Clogging of reactor due to absence of primary sedimentation
- Reliance on proprietary filter media
- High reliance on external energy input
- Requires skilled manpower

Applicability

The SAFF technology based system is particularly applicable for:

- small to medium flows in congested locations
- sensitive locations
- decentralised approach
- reliving existing overloaded trickling filters

CHAPTER 3

METHODOLOGY

The government agencies/concessionaire are going to own the project. They also need tobudget the project for the O&M cost over the whole life cycle, if the plant has to run satisfactorily. Very often it has been experienced that whereas the capital cost of project is made available but they have to struggle every year for getting O&M expenditure particularly when the O&M costs are underestimated. This section deals with methods for evaluation of life cycle costing of sewage treatment plants. To compute capital cost of STPs in year 2011, we follow cost inflation chart and to calculate capitalised O&M cost for next 20 years we have used net present value method. The methods used for computation and analyses are described as under:

3.1 Cost inflation index

An inflation index is a tool used to measure the rate of inflation in an economy. There are several different ways to measure inflation, leading to more than one inflation index with different economists. An index is just a collection of data that serves as a baseline for future reference.

Indexed cost method is used to determine the present capital cost of STP from its past value. Formula for computing inflation indexed cost is

$$\text{CII} = \frac{\text{Index value of present year}}{\text{Index value in year of construction}} \times \text{Cost value in year of construction}$$

Table-1: Cost inflation index (CII) as notified by central government along with analysis

Year	Cost inflation index	Year	Cost inflation index
1981-1982	100	1996-1997	305
1982-1983	109	1997-1998	331
1983-1984	116	1998-1999	351
1984-1985	125	1999-2000	389
1985-1986	133	2000-2001	406
1986-1987	140	2001-2002	426
1987-1988	150	2002-2003	447
1988-1989	161	2003-2004	463
1989-1990	172	2004-2005	480
1990-1991	182	2005-2006	497

1991-1992	199	2006-2007	519
1992-1993	223	2007-2008	551
1993-1994	244	2008-2009	582
1994-1995	259	2009-2010	632
1995-1996	281	2010-2011	711
		2011-2012	785

3.2 Life cycle costing

A life-cycle cost analysis (LCC) gives the total cost of system - including all expenses incurred over the life of the system. LCC analysis is used to determine the most cost effective system designs.

Life cycle cost calculation:

$$\mathbf{LCC = C + M_{pv} + E_{pv} + R_{pv} - S_{pv}}$$

Where,

pv subscript indicates the present value of each factor

- The capital cost (C) of a project includes the initial capital expense for equipment, the system design, engineering, and installation. This cost is always considered as a single payment occurring in the initial year of the project, regardless of how the project is financed.
- Maintenance (M) is the sum of all yearly scheduled operation and maintenance (O&M) costs. O&M costs include such items as an operator's salary, inspections, insurance, property tax, and all scheduled maintenance.
- The energy cost (E) of a system is the sum of the yearly fuel cost. Energy cost is calculated separately from operation and maintenance costs, so that differential fuel inflation rates may be used.
- Replacement cost (R) is the sum of all repair and equipment replacement cost anticipated over the life of the system. The replacement of a battery is a good example of such a cost that may occur once or twice during the life of a PV system. Normally, these costs occur in specific years and the entire cost is included in those years.
- The salvage value (S) of a system is its net worth in the final year of the life-cycle period. Future costs must be discounted because of the time value of

money. One dollar received today is worth more than the promise of $1 next year, because the $1 today can be invested and earn interest.

3.2.1 Estimation of total costs considering inflation

Estimation of annual cost in 2nd year is=annual cost in 1st year× (1+i)

Estimation of annual cost in 3rd year is= annual cost in 1st year× $(1+i)^2$

Similarly, Estimation of annual cost in Nth year is= annual cost in 1st year× $(1+i)^{N-1}$

Total cost for N years is:

Let, annual cost of 1st year is A

Then, total cost = $A+A(1+i)+A(1+i)^2+A(1+i)^3.........+A(1+i)^{N-1}$

Using geometric progression,

$$\text{Total cost} = A\left[\frac{(1+i)^N - 1}{i}\right]$$

Where, i is inflation rate

3.2.2 Estimation of net present value or life cycle cost

Net Present Value is the present worth of total cost. It is calculated by using the formula

$$\text{NPV} = \sum_{1}^{N} \frac{\text{Annual cost in year t with inflation}}{(1+r)^{t-1}}$$

$$\text{NPV} = A\left[\frac{(1+i)^N - (1+r)^N}{(1+r)^{N-1}(i-r)}\right]$$

Where, i is the inflation rate

r is the discount/ interest rate

N is total number of years

3.3 Calculation of life cycle cost of STPs

3.3.1 Computation of life cycle cost of ASP based 60MLD STP at Allahabad

Year of construction is 1998

Capital cost of plant (civil +E&M) is 165 million in 1998

Cost inflation index (CII) value in 1998 =351 (as shown in above table)

Capital cost of plant (civil+E&M) in 2011=

$$\frac{\text{CII value in 2011} \times \text{capital cost in 1998}}{\text{CII value in 1998}}$$

CII value in 2011 = 785

So, **Capital cost in 2011 = 369 million**

Similarly, **O&M cost in 2011 is also calculated=37.54 million**

Life cycle cost in 2011for 20 years = capital cost in 2011+ capitalised O&M cost for next 20 years

Capitalised O&M cost:

Assume, inflation rate (i) =8% & discount/interest rate(r) = 10%, N=35 years

A is the annual O&M cost in 2011= 37.54 million

$$\text{capitalised O}\&M\ cost = A\left[\frac{(1+\mathrm{i})^{\mathrm{N}} - (1+\mathrm{r})^{\mathrm{N}}}{(1+\mathrm{r})^{\mathrm{N}-1}(\mathrm{i}-\mathrm{r})}\right]$$

By putting the above values in above formula, we get

Capitalised O&M cost = 647.57million

Total life cycle cost= 369 million+647.57 million= 1016.57million

$$\text{unit life cycle cost} = \frac{1016.57}{60}$$

=16.9 million/MLD

3.3.2 Computation of life cycle cost of WSP based 12.5MLD STP at Mathura

Year of construction is 2000

Capital cost of plant (civil +E&M) is 40 million in 2000

Cost inflation index (CII) value in 2000 =406 (as shown in above table)

Capital cost of plant (civil+E&M) in 2011=

$$\frac{\text{CII value in 2011} \times \text{capital cost in 2000}}{\text{CII value in 2000}}$$

CII value in 2011 = 785

So, **Capital cost in 2011 = 77.34 million**

Similarly, **O&M cost in 2011 is also calculated=1.196 million**

life cycle cost in 2011for 20 years = capital cost in 2011+ capitalised O&M cost for next 20 years

Capitalised O&M cost:

Assume, inflation rate (i) =8% & discount rate®= 10%, N=20 years

A is the annual O&M cost in 2011= 1.196 million

$$\text{capitalised O\&}M\ cost = A\left[\frac{(1+\mathrm{i})^{\mathrm{N}} - (1+\mathrm{r})^{\mathrm{N}}}{(1+\mathrm{r})^{\mathrm{N}-1}(\mathrm{i}-\mathrm{r})}\right]$$

By putting the above values in above formula, we get

Capitalised O&M cost = 20.63 million

Total life cycle cost= 77.34 million+20.63 million= 97.97million

$$\text{unit life cycle cost} = \frac{97.97}{12.5}$$

=7.8 million/MLD

3.3.3 Computation of life cycle cost of UASB based 78 MLD STP at Agra

Year of construction is 1998

Capital cost of plant (civil +E&M) is 153.6 million in 1998

Cost inflation index (CII) value in 1998 =351 (as shown in above table)

Capital cost of plant (civil+E&M) in 2011=

$$\frac{\text{CII value in 2011} \times \text{capital cost in 1998}}{\text{CII value in 1998}}$$

CII value in 2011 = 785

So, **Capital cost in 2011 = 343.52 million**

Similarly, **O&M cost in 2011 is also calculated=9.19 million**

Life cycle cost in 2011for 20 years = capital cost in 2011+ capitalised O&M cost for next 20 years

Capitalised O&M cost:

Assume, inflation rate (i) =8% & discount rate(r)= 10%, N=20 years

A is the annual O&M cost in 2011= 9.19 million

$$\text{capitalised O\&}M\ cost = A\left[\frac{(1+\mathrm{i})^{\mathrm{N}} - (1+\mathrm{r})^{\mathrm{N}}}{(1+\mathrm{r})^{\mathrm{N}-1}(\mathrm{i}-\mathrm{r})}\right]$$

Capitalised O&M cost = 158.5 million

Total life cycle cost= 343.52 million+158.5 million=502.02million

$$\text{unit life cycle cost} = \frac{502.02}{78} = 6.44\text{million/MLD}$$

3.3.4 Computation of life cycle cost of BIOFOR based 10 MLD STP at DSNH, Delhi

Year of construction is 1998

Capital cost of plant (civil +E&M) is 53.9 million in 1998

Cost inflation index (CII) value in 1998 =351 (as shown in above table)

Capital cost of plant (civil+E&M) in 2011=

$$\frac{\text{CII value in 2011} \times \text{capital cost in 1998}}{\text{CII value in 1998}}$$

CII value in 2011 = 785

So, **Capital cost in 2011 = 120.54 million**

Similarly, **O&M cost in 2011 is also calculated=10.85 million**

Life cycle cost in 2011for 20 years = capital cost in 2011+ capitalised O&M cost for next 20 years

Capitalised O&M cost:

Assume, inflation rate (i) =8% & discount rate(r) = 10%, N=20 years

A is the annual O&M cost in 2011= 10.85million

$$\text{capitalised O\&}M\ cost = A\left[\frac{(1+\mathrm{i})^{\mathrm{N}} - (1+\mathrm{r})^{\mathrm{N}}}{(1+\mathrm{r})^{\mathrm{N}-1}(\mathrm{i}-\mathrm{r})}\right]$$

By putting the above values in above formula, we get

Capitalised O&M cost = 187.16 million

Total life cycle cost= 120.54 million+187.16 million=307.7 million

3.3.5 Computation of life cycle cost of two stage ASP- BIOFORF based 182 MLD STP at Rithala, Delhi

Year of construction is 2001

Capital cost of plant (civil +E&M) is 914.7 million in 2001

Cost inflation index (CII) value in 2001 =426 (as shown in above table)

Capital cost of plant (civil+E&M) in 2011=

$$\frac{\text{CII value in 2011} \times \text{capital cost in 2001}}{\text{CII value in 1998}}$$

CII value in 2011 = 785

So, **Capital cost in 2011 = 1685.53 million**

Similarly, **O&M cost in 2011 is also calculated=114.68 million**

Resource recovery in 2003= 56.575million

Then, resource recovery in 2011=

$$\frac{\text{CII value in 2011} \times \text{Resource recovery in 2003}}{\text{CII value in 2011}}$$

Resource recovery in 2011=96 million

Life cycle cost in 2011for 20 years = capital cost in 2011+ capitalised O&M cost for next 20 years

Capitalised O&M cost:

Assume, inflation rate (i) =4% & discount rate®= 5%, N=35 years

A is the annual O&M cost in 2011= 114.68million

$$\text{capitalised O}\&M\ cost = A\left[\frac{(1+\text{i})^{\text{N}} - (1+\text{r})^{\text{N}}}{(1+\text{r})^{\text{N}-1}(\text{i}-\text{r})}\right]$$

By putting the above values in above formula, we get

Capitalised O&M cost = 322.23 million

Total life cycle cost= 1685.53 million+322.23 million= 2007.53million

Unit life cycle cost=11million/MLD

3.3.6 Computation of life cycle cost of FAB based 3 MLD STP at Delhi

Year of construction is 2003

Capital cost of plant (civil +E&M) is 13.8 million in 2003

Cost inflation index(CII) value in 2003=463 (as shown in above table)

Capital cost of plant (civil+E&M) in 2011=

$$\frac{\text{CII value in 2011} \times \text{capital cost in 1998}}{\text{CII value in 1998}}$$

CII value in 2011 = 785

So, **Capital cost in 2011 = 23.4 million**

Similarly, **O&M cost in 2011 is also calculated=2.55 million**

Life cycle cost in 2011for 20 years = capital cost in 2011+ capitalised O&M cost for next 20 years

Capitalised O&M cost:

Assume, inflation rate (i) =8% & discount rate(r) = 10%, N=20 years

A is the annual O&M cost in 2011= 2.55 million

$$\text{capitalised O}\&M\ cost = A\left[\frac{(1+\mathrm{i})^{\mathrm{N}} - (1+\mathrm{r})^{\mathrm{N}}}{(1+\mathrm{r})^{\mathrm{N}-1}(\mathrm{i}-\mathrm{r})}\right]$$

By putting the above values in above formula, we get

Capitalised O&M cost = 44 million

Total life cycle cost= 23.4 million+44 million=67.4 million

3.3.7 Computation of life cycle cost of SAFF based 2 MLD STP at Holambi, Delhi

Year of construction is 2003

Capital cost of plant (civil +E&M) is 14 million in 2003

Cost inflation index (CII) value in 2003=463 (as shown in above table)

Capital cost of plant (civil+E&M) in 2011=

$$\frac{\text{CII value in 2011} \times \text{capital cost in 2003}}{\text{CII value in 2003}}$$

CII value in 2011 = 785

So, **Capital cost in 2011 = 23.7 million**

Similarly, **O&M cost in 2011 is also calculated=3.46 million**

Life cycle cost in 2011for 20 years = capital cost in 2011+ capitalised O&M cost for next 20 years

Capitalised O&M cost:

Assume, inflation rate (i) =8% & discount rate(r) = 10%, N=20 years

A is the annual O&M cost in 2011= 3.46 million

$$\text{capitalised O\&}M\ cost = A\left[\frac{(1+\mathrm{i})^{\mathrm{N}}-(1+\mathrm{r})^{\mathrm{N}}}{(1+\mathrm{r})^{\mathrm{N}-1}(\mathrm{i}-\mathrm{r})}\right]$$

By putting the above values in above formula, we get

Capitalised O&M cost = 59.7 million

Total life cycle cost= 23.7 million+59.7 million= 83.4 million

$$\text{unit life cycle cost} = \frac{83.4}{2} = 41.7\text{million/ml}$$

CHAPTER 4

CASE STUDY OF SEWAGE TREATMENT PLANTS

This section deals with the performance parameters such as BOD, COD, SS, etc. as well as different parameters such as capital cost, operation & maintenance cost, repairs cost & life cycle cost of sewage treatment plants.

4.1 Activated sludge process (ASP)

ASP, also known as activated sludge process, involves the use of activated mass of micro organisms to stabilise the sludge under aerobic conditions.

Following plants have been covered under the current study:

- 60 MLD STP at Allahabad
- 72 MLD STP at Okhla, New Delhi

4.1.1 STP at Allahabad

STP at Allahabad is based on the conventional activated sludge process and it consists of typical flow scheme of screens, grit removal, primary sedimentation, aeration and secondary sedimentation. Besides it also has a facility for sludge digestion, gas cleaning and bio-energy generation with the help of duel fuel engines. The plant has been constructed in three modules of 20 MLD each. An uncommon feature that is present in the flow scheme at this STP is that, the secondary settled sludge returns not only to the aeration tank but also to the primary sedimentation tank (PST). So, the excess sludge is withdrawn only from PST. However, this arrangement has several disadvantages:

- There is a considerable increase in the amount of solid loads in the PST which affects the fundamental characteristics of the sedimentation process as well as its efficiency.
- It generates anaerobic digestion in the PST which is due to the presence of gas bubbles.
- The gas bubbles reduce the solids removal efficiency from the PST.

Mesophilic conditions are required to operate the sludge digester without temperature control, insulation or sludge heating arrangement which affects its performance from season to season giving suboptimal biogas yield, and there are large variations in the total quantity available for subsequent uses. Average biogas availability is around 3200 cum/d which is nearly 58 cum/MLD of sewage treated.

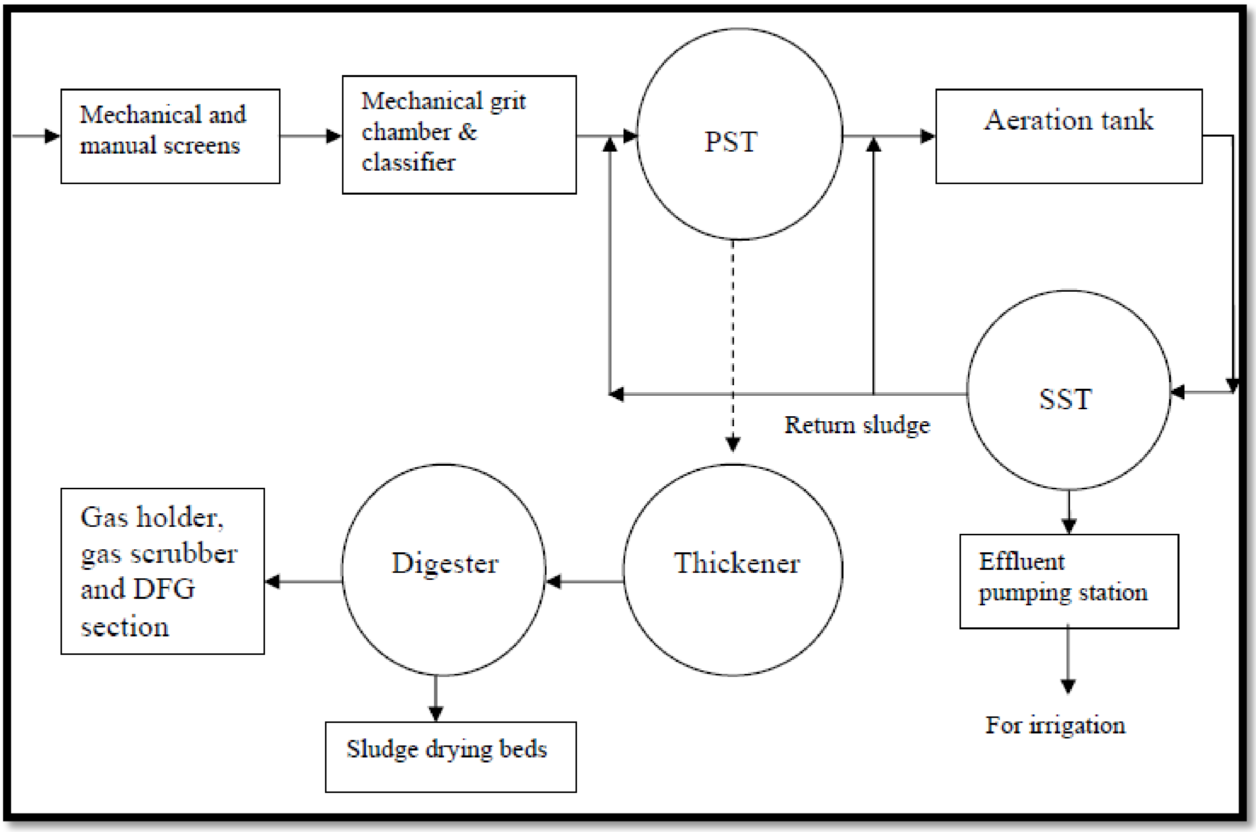

Fig 3: Schematic diagram of 60 MLD ASP based STP plant at Allahabad

Performance of the plant

The annual average effluent values of BOD and suspended solids are found to be 30.9 and 88.8 mg/l thereby representing removal efficiencies of 78% and 89% respectively. While there is no doubt that an activated sludge plant can deliver equal or still better performance, the above values are rather close to the specified discharge limits. Average efficiency of Faecal coliform removal is found to be 91% with effluent concentrations in the range of 106 to 107/ 100 ml. Largely, the treated effluent has an acceptable aesthetic appeal and it is utilised extensively for irrigation of vegetable crops.

Resource recovery

An elaborate bio-energy generation system involving duel fuel generators has been installed at Allahabad but it is not in working state due to a variety of factors:

- Lack of funds for procurement of diesel
- Electricity charges linked to contracted minimum load irrespective of actual consumption
- Insufficient quantity of biogas for meeting entire energy requirement of the plant

Clearly, there is no incentive in utilising the bio-energy and therefore currently entire quantity of biogas is flared. In view of this, there is general lack of interest in optimising the performance of the digesters as well.

Operation and maintenance

The routine operation and maintenance of the plant has been given on labour contract to a local agency, however, an interesting aspect found only at this plant is that the operation of the laboratory has been retained with the supervising agency i.e., the UP Jal Nigam. This arrangement enables higher involvement of the UPJN staff and better control over the performance of the contractor.

Table -2: A comparison of ASP based STPs

Assessment parameter	**ASP, Allahabad**	**Dinapur, Varanasi**	**Okhla ASP, Delhi**
Capacity (MLD)	60	80	72
Hydraulic loading (%)	92	100	100
Plant area (ha)	11.00	20.00	10.50
Area per MLD (ha/MLD)	0.18	0.25	0.15

Performance

Effluent BOD (mg/l)	**29-33**	**13-77**	**<30**
Effluent COD (mg/l)	**280**	**98-168**	**40-60**
Effluent DO (mg/l)	3	3	2
Effluent SS (mg/l)	**40-44**	**25-121**	**30**
Effluent faecal coliform (MPN/100 ml)	10^6-10^7	10^5-10^8	Total Coliform 10^4-10^5
Sludge digestion	Included	Included	Included
Resource recovery-biogas (Rs. Pa)	Nil	1,360,000	Na
Resource recovery-sludge (Rs. Pa)	Nil	1,240,000	204,400
Resource recovery-effluent (Rs. Pa)	Significant	102,000	Nil
Total resource recovery (Rs. Pa)	**significant**	**2,702,000**	**Approx. 1,000,000**

Computation of life cycle cost

Contract value of plant civil+ E&M (Rs in million)	165	80	183.2
%of work civil works	60%	60%	56%
In million	99	48	102.6
% of work E&M works	405	40%	44%
In million	66	32	80.6
Year of construction	1998	1991	2001
Cost Inflation Index			
CII: year of construction	351	199	426

CII: in 2011 estimated	785	785	785

Unit cost of STP

Capital Cost of plant in 2011			
Civil works (Rs. In millions)	221.4	189.34	202.548
E&M component (Rs. In millions)	147.6	126.23	135.032
Total cost of plant (Rs. In millions)	**369**	**315.57**	**337.58**
Unit cost of STP (Rs. Million/MLD)	**6.15**	**3.94**	**4.67**

Operation & maintenance costs

Technology power requirement (kWh/d)	Na	Na	14800
Non technology power requirement (kWh/d)	Na	Na	400
Total daily power requirement (kWh/d)	13500	14400	15200
Unit power requirement (kWh/MLD)	**225**	**180**	**211**
Daily power costs @ Rs.5.5 /kWh	74250	79200	83600
Annual power costs (in million) in 2011	**27.10**	**28.90**	**30.5**

Manpower operation & maintenance costs

Manager (30000)	½	2	1
Chemist/operating engineer (14000)	2	5	4
Operators (9000)	30	26	10
Skilled technicians (10000)	6	6	8
Unskilled personnel (5000)	6	36	20
Cost of manpower (in millions)	**4.84**	**7.25**	**4.27**

Repairs cost

Civil works per annum as % of civil works cost	0.5%	0.5%	0.5%
E&M works as % of E&M works cost	3%	3%	2%
Civil works maintenance (million)	1.1	0.95	1
E&M works maintenance (in millions)	4.5	3.78	4
Annual repairs cost (in millions)	**5.6**	**4.75**	**5**

Total annual O&M costs (in million) in 2011	**37.54**	**40.9**	**39.77**
Unit O&M costs (in million) in 2011	**0.62**	**0.51**	**0.55**

Life cycle cost of plant @10% rate of interest &@8% inflation rate for next 20 years

Net present value factor	17.25	17.25	17.25
capitalised O&M cost for 20 years (in millions)	647.5	705.5	686
Capital cost of plant (2011)	369	315.57	337.58
land cost @ Rs.8million/ha	88	160	84
Life cycle cost excluding land (in 2011)	**1016.5**	**1021.07**	**1023.58**
Unit life cycle cost (2011)	**16.94**	**12.7**	**14.21**

4.1.2 STP at Varanasi

The STP at Varanasi is essentially a combination of roughing filter and conventional activated sludge processes. Roughing filter consists of a high rate trickling filter which is generally provided in situations where industrial wastewater is expected to join sewage. It follows the same flow scheme observed in case of Allahabad STP, in that there is an arrangement for bringing the sludge back into the primary sedimentation tank. and excess sludge is withdrawn from the latter. On account of it, rising gas bubbles are observed which indicate beginning of anaerobic digestion in primary sedimentation tank itself. Presence of floating scum and sludge blanket in the PST can be attributed to this feature of the return sludge scheme. Although effluent quality data at intermediate stages of the STP are not available, it is understood that solids overflow and thereby solids loading on the subsequent stages would be high. It is unusual that there are no sludge thickeners at this plant and the excess sludge from the PST is introduced directly into the digesters. The digesters have been provided with improved features of mechanical mixing arrangement as well as with heating of sludge from the waste heat released from the duel fuel engines. Incidentally the digesters have developed structural defects and the gas leaks out through the cracks in the roof. Another unusual feature of this STP is the steep fall in hydraulic gradient along the flow scheme. Apparently the water level in secondary settling tanks is about 2.5-3 m below ground and in the treated effluent sump it is about 3.5 m below ground. As a result, high degree of pumping is involved at multiple stages of the plant. From the point of view of safety against flooding this type of arrangement may not be desirable. The capacity of this plant is 80 MLD. It consists of 2 streams each of 26.7 MLD. Its components are coarse screen and grit chamber at Konia pumping station. Coarse screen, primary sedimentation tank, Roughing filter, aeration tank, secondary sedimentation tank, Digesters, biogas holders, duel fuel generators (no sludge thickeners). Treated effluent pump, return sludge pump, raw sludge pump, filtrate pump, etc.The roughing filter is designed for a hydraulic loading of 68 m/d, has a relatively much larger size of the media between 7 – 10 cm and shorter depth of media bed of 1 m.

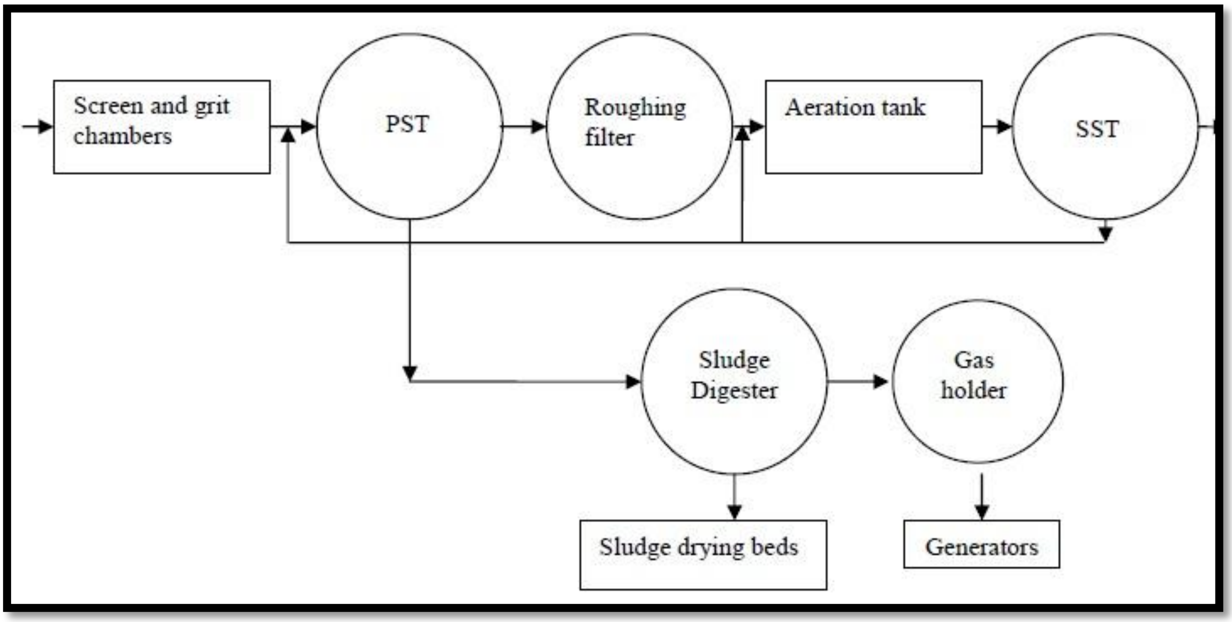

Fig 4: Schematic diagram of ASP based STP at Varanasi

Performance

Long term effluent quality data shows that BOD and suspended solids are in the range of 13-77 mg/l and 25-121 mg/l respectively. The corresponding removal efficiencies are in the order of 49-86% and 57-97% respectively. The faecal coliform values in the effluent are in the range of 10^5 – 10^8/100 ml and their removal efficiency varies between wide limits from 6% to 99% (CPCB). Among other factors, the higher BOD and SS values are attributed to hydraulic over loading as well as to the inappropriate return sludge scheme. However, the treated effluent has good aesthetic value.

Power requirement

Power requirement during average flow condition is 600kW whereas energy consumption is 12000-14000 kWh/d. Daily power cut is about 3-5 hrs.

Resource recovery – Biogas to energy

It is possible to generate about 3200 kWh of electrical energy from biogas. For this four duel fuel engines each of 400 kW were installed. However, due to lack of funds procurement of diesel has become difficult and therefore the engines have not been running from last few years. Currently entire biogas is flared. There is no gain for maximising biogas generation or utilisation due to following reasons:

- Minimum electricity charges have to be paid any way
- Budget for diesel purchase is very limited
- Cost of own generation is only 20% lower than the grid supplied energy
- Excess electricity if any, cannot be transmitted to Konia sewage pumping station
- Estimated revenue from sale of energy is about Rs. 1.36 million/annum in 2002.

Resource recovery – sludge

Over the years several local micro-enterprises have evolved which are involved in collecting, processing sludge and blending with other mineral additives. This value added product is then sold as a soil conditioner to tea plantations in north-east state of

Assam. Estimated revenue from sale of sludge is about Rs. 1.24 million/annum in 2002.

Resource recovery – treated effluent

Although the treated wastewater is extensively utilised by the farmer community over 1600 ha.along the effluent channel, no significant revenue has accrued from this activity. Notional resource recoveries in the form of use of nutrients for increased agriculture produce and economic benefits to farmer community are significant.

Total resource recovery

Total resource recovery in 2002 is as follows:

Electricity + Sludge + Effluent + Floriculture = Rs. 1.36 million + 1.24 million + 95,000 + 7000)

= Rs. 2.7 million

Total resource recovery in 2011 is=4.74 million

Total resource recovery as a percentage of current capital cost (Rs. 315 million) is an insignificant 1.5%. With respect to original capital investment of Rs. 80 million the recovery is about 6%.With respect to the current actual annual O&M cost (Rs. 40.9 million) the resource recovery amounts to 11.6%.

O&M aspects

Introducing secondary sludge into primary settler is ineffective in solids removal.

High energy costs due to excessive drop in hydraulic profile and multiple pumping stages

- Wear and tear of turntable in roughing filter. Currently one of the filters was out of operation due to this fault
- Cleaning of filter media once in 7-8 years
- Unlike most other STPs in UP, the Dinapur STP is operated and maintained by UPJN staff.

Cost aspects

The total capital cost of plant in 2011 including civil, electrical and mechanical works is 315.57 million. Unit capital cost is 3.94 million/MLD. Total O&M costs including power cost, manpower cost, and repairs cost in 2011 is Rs 40.9million. Unit O&M cost is 0.57 million/MLD. Total life cycle cost for next 20 years duration is Rs. 1021 million & unit life cycle cost is 12.7 million/MLD.

4.2 Waste stabilisation pond (WSP)

A WSP treatment system consists a series of anaerobic pond, a facultative pond and a maturation pond. The process of treatment is completely dependent on natural forces for biological degradation and bacterial die-off and does not involve external energy or chemical inputs.

4.2.1 WSP at Kaliadeh, Vrindavan

The capacity of this plant is 0.5MLD .its components are manually cleaned bar screen and grit chambers, 1 anaerobic pond and 1facultative pond. The schematic is shown below:

At this plant only anaerobic and facultative ponds of one and four days detention are provided while the maturation pond has been excluded. The reasons for adopting such scheme could have been lack of space, less stringent effluent quality requirement as there is no scope for utilisation of effluent for irrigation, etc. In WSP plants the problem of ground water contamination was reported soon after their commissioning. In view of this, at these locations the ponds had to be provided with impervious lining comprising polymer sheet and a layer of cement concrete.

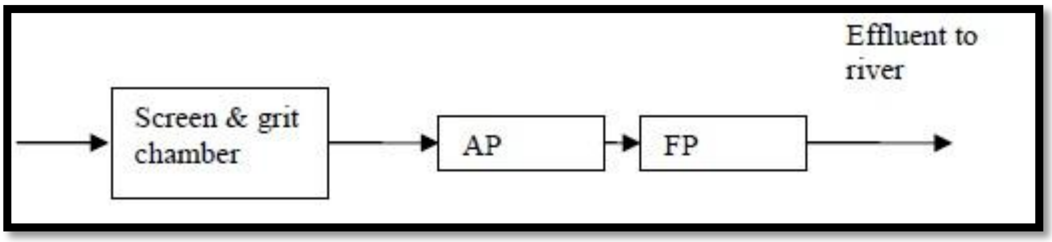

Fig 5: Schematic diagram of WSP based STP at Vrindavan

Performance of the plant:

Average effluent values of BOD and SS are 40-79 mg/l and 54-139 mg/l. Effluent Faecal coliform value is in the range of 10^6 to 10^8/100 ml and the average removal efficiency is 85%.

Power requirement:

There is no need of power in this treatment plant.

Resource recovery: Aquaculture

Not feasible as there is no maturation pond or aquaculture pond besides, the demand for fish in general in Vrindavan is expected to be low.

Resource recovery: Sludge

No resource recovery from above source.

Resource recovery: Treated wastewater

No resource recovery from above source.

Total resource recovery:

No resource recovery from above source.

O&M aspects:

UPJN has given the O&M work of the WSP along with the connected sewage pumping stations to a contractor on an annual contract.

Cost aspects

The total capital cost of plant in 2011 including civil, electrical and mechanical works is 5.8 million. Unit capital cost is 11.6 million/MLD. Total O&M costs including power cost, manpower cost, repairs cost in 2011 is Rs 0.447 million. Unit O&M cost is 0.894 million/MLD. Total life cycle cost for next 20 years duration is Rs. 13.5 million & unit life cycle cost is 27 million/MLD.

Table 3: A Comparison of WSP based STPs

Assessment parameter	**Vrindavan**	**Vrindavan**	**Mathura**	**Karnal**	**Palwal**	**Howrah**
Capacity(MLD)	0.5	4	12.5	8	9	30
Hydraulic loading (%)	180	90-100	130	100	100	100
Plant area(ha)	0.5	6	14	18.50	18.75	23.50
Area per MLD(ha/MLD)	1	1.50	1.12	2.31	2.08	0.78
Performance						
Effluent BOD(mg/l)	**40-79**	**30-60**	**70-100**	**20-30**	**-**	**13**
Effluent COD(mg/l)	**n/a**	**n/a**	**n/a**	**nla**	**-**	**n/a**
Effluent DO(mg/l)	n/a	n/a	n/a	2-3	-	5
Effluent SS(mg/l)	**54-139**	**-**	**44-70**	**-**	**-**	**39**
Effluent faecal coliform(MPN /100ml)	1E+06-1E+08		1E+05-1E+08	1E+04	-	Na
Sludge digestion	n/a	n/a	n/a	n/a	n/a	n/a
Resource recovery-Biogas (Rs.pa)	n/a	n/a	n/a	n/a	n/a	n/a
Resource recovery-Sludge (Rs.pa)	No buyers for the sludge	No buyers for the sludge	No buyers for the sludge	Sludge is not removed since commis	n/a	n/a

				sioning		
Resource recovery-effluent/aquaculture (Rs.pa)	In form of irrigation fish kill observed	Increased auction value of municipal farm	Fish kill observed	Fish kill observed	n/a	2lakh-5 lakh from aquaculture
Total resource recovery(Rs.pa)	In form of irrigation	In form of irrigation	nil	Notional	n/a	2lakh-5lakh

Computation of life cycle cost

Contract value of plant civil+E&M(Rs.million)	3	15	40	10	19	51.3
% of work civil works	98%	98%	98%	98%	98%	98%
Rs.million	2.9	14.7	39.2	9.8	18.6	50.3
% of work E&M works	2%	2%	2%	2%	2%	2%
Rs. Million	0.1	0.3	0.8	0.2	0.4	1
Year of construction	2000	1998	2000	2000	2003	1995
Cost inflation index						
CII: Year of construction	406	351	406	406	463	281
CII :in 2011	785	785	785	785	785	785

Unit cost of STP

Cost of plant						
Civil	5.684	32.87	75.8	18.95	31.55	140.44

works(Rs.million)						
E&M component(Rs.million)	0.116	0.67	1.55	0.39	0.65	2.87
Total cost of plant(Rs.million)	**5.8**	**33.54**	**77.34**	**19.34**	**32.2**	**143.31**
Unit cost of STP(Rs.million/MLD)	**11.6**	**8.39**	**6.2**	**2.42**	**3.58**	**4.78**

Operation& maintenance costs

Technology power requirement (kWh/d)	Nil	Nil	Nil	Nil	Nil	Nil
Non technology power requirement(kWh/d)	Nil	Nil	Nil	Nil	Nil	Nil
Total daily power requirement (kWh/d)	Nil	Nil	Nil	Nil	Nil	Nil
Unit power requirement (kWh/MLD)	Nil	Nil	Nil	Nil	Nil	Nil
Daily power cost @ Rs5.5 /kWh	Nil	Nil	Nil	Nil	Nil	Nil
Annual power costs (Rs. In million)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Manpower costs

	Cost/MM						
Manager	30000	1/5	¼	½	1/8	1/8	¼
Chemist/operating engineer	14000	0	0	0	1	1	1
Operators	9000	1	1	2	1	1	2
Skilled technicians	10000	0	0	1	4	4	18
Unskilled personnel	5000	6	7	8	8	8	12
Annual Cost of manpower (Rs. In million)		**0.432**	**0.558**	**0.996**	**1.28**	**1.28**	**3.36**

Repairs cost

Civil works per annum as % of civil works cost	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
E&M works per annum as % of E&M works cost	3%	3%	3%	2%	3%	3%
Civil works maintenance	11368	65740	151600	37900	63100	280880
E&M works maintenance	3480	20100	45300	7800	19500	86100
Annual repairs cost (in million)	**0.015**	**0.085**	**0.2**	**0.046**	**0.082**	**0.37**
Total annual O&M costs (Rs.in million)	**0.447**	**0.643**	**1.196**	**1.326**	**1.362**	**3.73**
Unit O&M costs (million/MLD)	**0.894**	**0.160**	**0.096**	**0.166**	**0.151**	**0.124**

Net Present value factor over life cycle of plant of 20 years @ 10% discount &@ 8% inflation rate

Net present value factor	17.25	17.25	17.25	17.25	17.25	17.25
Capitalised O&M costs over 20 years (Rs. In	7.71	11.09	20.6	22.9	23.5	64.34

millions)						
Capital cost of plant in 2011 (Rs. In millions)	5.8	33.54	77.34	19.34	32.2	143.31
Land cost @8 million/ha	4	32	100	64	72	240
Life cycle cost (excluding land) in 2011 (Rs. In millions)	**13.5**	**44.63**	**97.94**	**42.24**	**55.7**	**207.65**
Unit life cycle cost in 2011 (million/MLD)	**27**	**11.15**	**7.83**	**5.28**	**6.18**	**7**

4.2.2 WSP at Masanighat nala in Mathura

The capacity of this plant is 12.5 MLD. It consists of 2 streams. Main Components of this STP are: Manually cleaned coarse screen and grit chambers, 2 anaerobic ponds, 2 Facultative ponds, 2 maturation ponds. The flow scheme is as shown below:

Hydraulic retention time : 1 day in anaerobic ponds, 4 days in facultative ponds and 3 days in maturation ponds. Aquaculture was initiated in facultative and maturation ponds, however due to reported incidents of fish kills, this has been discontinued

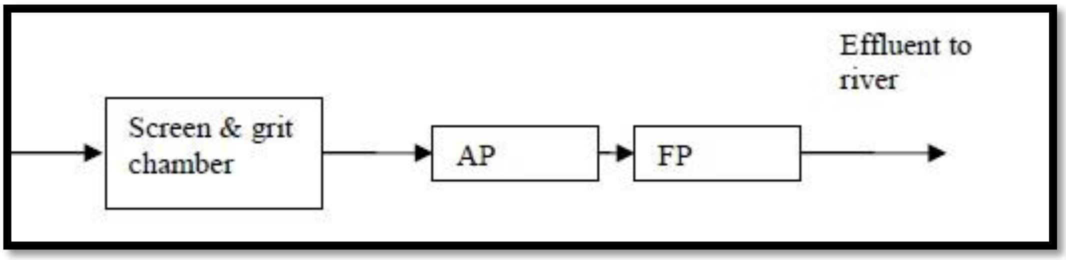

Fig 6: Schematic diagram of WSP based STP at Mathura

Performance

The collected data indicate that the plant is performing well and the effluent is within desired quality standards. However, the influent BOD is in the range of 250-450 mg/l and the plant was receiving 30-40% extra flow. Organic overloading was attributed to discharges from industrial units. Treated effluent BOD is reported to be around 70-100 mg/l whereas effluent SS is 44-70 mg/l.

Power requirement

Negligible

Resource recovery – Aquaculture

Discontinued due to reported cases of fish killing.

Resource recovery – sludge

The operating agency has not been able to sell the sludge to farmers in the region. Therefore no recovery is attributed on this account.

Resource recovery – treated wastewater

In absence of separate irrigation infrastructure for conveying treated wastewater to agriculture fields, it is drained into a nalla. As a result there is no recovery from this account as well.

Total resource recovery

Nil

O&M aspects

- The plant is operating in 30% over loaded conditions
- Bar screens at the pumping station are manual and are found to be not effective in removal of plastic bags. Often functioning of even the non-clogging vertical pumps is affected.

- Bar screens at the STP are also unable to remove plastic bags and pouches which float in the ponds. These are then removed manually through improvised screen on long bamboos. This practice causes disturbance in the settling regime of the anaerobic pond
- Grit removal is done manually once in 10 days.
- Grit storage volume is low, which causes overflow into anaerobic ponds
- STP workers are exposed to infectious wastewater at the bar screen and grit chamber stage which could be a concern from occupation health point of view.

- Sludge removal from anaerobic pond is supposed to be once in 6 months, however longer intervals are common.
- Manual sludge removal entails emptying of the pond and thereby shutting off 50% part of the plant.
- In absence of a separate storage facility e.g., a sludge storage lagoon, the sludge is stacked along the boundary of the plant which leads to un aesthetic surroundings.
- UPJN has given the O&M work of the WSP along with the connected sewage pumping stations to a contractor on an annual contract.

Cost aspects

The total capital cost of plant in 2011 including civil, electrical and mechanical works is 77.34 million. Unit capital cost is 6.2 million/MLD. Total O&M costs including power cost, manpower cost, and repairs cost in 2011 is Rs 1.196 million. Unit O&M cost is 0.096 million/MLD. Total life cycle cost for next 20 years duration is Rs. 97.94 million & unit life cycle cost is 7.83 million/MLD.

4.2.3 WSP at North Howrah

The capacity of plant is 30 MLD. It consists of 3 streams each of 10 MLD merging into two of 15 MLD at maturation stage. Its components are Coarse screens, 3 anaerobic ponds, 3 facultative ponds, 2 maturation ponds in series. Hydraulic retention time : 1 day in anaerobic ponds, 4 days in facultative ponds and 3 days in maturation ponds. Aquaculture is being practiced in facultative and maturation ponds.

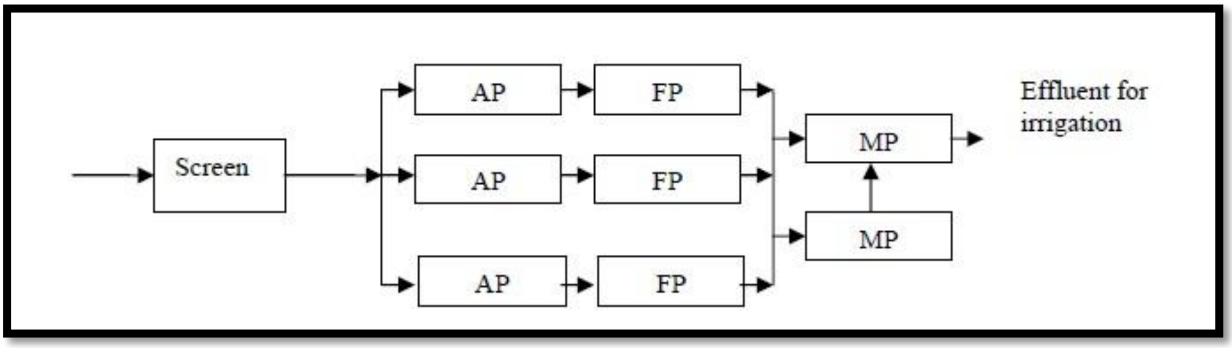

Fig 7: Schematic diagram of WSP based plant at North Howrah

Performance of the plant

Influent values of BOD_5 and SS are 64mg/l and 315 mg/l.

Effluent values of BOD_5 and SS are 13mg/l and 39 mg/l

DO at the outlet of facultative pond is 11.4 mg/l and after maturation pond it is 5.2 mg/l. Data on removal of Faecal Coliform is not available

Power requirement

Nil

Resource recovery – Aquaculture

Lease agreement signed with a fishermen's cooperative in 1997 for 7 years with royalty of Rs.0.2 million pa for first two years, Rs. 0.3 million pa for next two years and Rs. 0.45 million pa for the remaining period. Resource recovery in 2011 is: 0.76million pa.

Resource recovery – sludge

There was no recovery from this possible line of revenue.

Resource recovery – treated effluent

Although the treated wastewater is utilised by the farmer community, no tangible revenue has accrued from this line as well. Notional resource recovery in the form of use of nutrients for increased agriculture produce and economic benefits to farmer community are significant, however these have not been quantified.

Total resource recovery

No estimate of the total income to the fishermen's cooperative is available; however it pays a royalty of around Rs. 0.76 million pa to the Calcutta Metropolitan Water and Sanitation Authority.

O&M aspects

No major O&M problems are stated; however special security guards have been included in the O&M team to prevent theft of the aquaculture stock.

Cost aspects

The total capital cost of plant in 2011 including civil, electrical and mechanical works is 143.31 million. Unit capital cost is 4.78 million/MLD. Total O&M costs including power cost, manpower cost, and repairs cost in 2011 is Rs 3.73 million. Unit O&M cost is 0.124 million/MLD. Total life cycle cost for next 20 years duration is Rs.207.65 million& unit life cycle cost is 7 million/MLD.

4.3 Up flow Anaerobic Sludge Blanket Process

4.3.1 UASB plant at Agra

The capacity of plant is 78 MLD. It consists of 6 streams each of 13MLD. Its components are manually operated bar screens, grit chamber, UASB reactor, final polishing units, biogas holders and duel fuel generators. No thickeners are used for sludge thickening and sludge is sent directly to drying beds. Hydraulic retention time in UASB reactor is 8 hrs whereas Hydraulic retention in FPU is 1 day.

Land requirement

Plant area of this STP is 20 ha. Therefore, unit land requirement is 0.26 ha/MLD

Performance

With the help of tertiary treatment its BOD removal efficiency rises upto 75% whereas its S.S removal efficiency rises upto 78%.

Table 4: Performance data of UASB at Agra

	Raw Sewage	UASB outlet	FPU outlet	% Removal
1st set of monitoring				
BOD (mg/l)	262	83	55	79
SS (mg/l)	461	145	89	81
2nd set of monitoring				
BOD (mg/l)	264	77	50	70
SS (mg/l)	444	133	111	75

Source: IIT Roorkee,

The influent quality parameters are higher than the designed values which are attributed to discharges from industries. e.g., tanneries and petha manufacturing. Higher outlet BOD can also be attributed to solids overflow from the combined UASB-FPU system. However, the plant personnel informed that current effluent values for BOD and SS are 28-31 mg/l and 48-51 mg/l respectively.

Power requirement

Total load required including screens, sludge pumps, filtrate pumps, office, lab, borewells, staff quarters etc.is 56KW. Consumption during average flow conditions is 825 kWh/d (approximately). Average power cut is 4-5 h/d

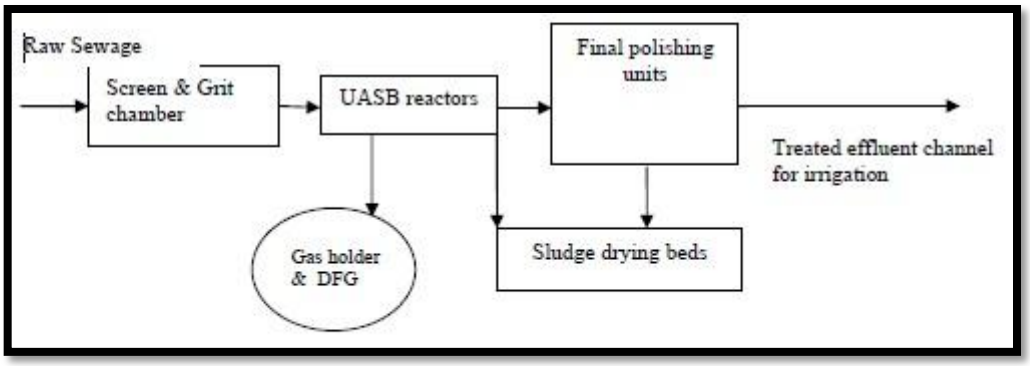

Fig 8: Schematic diagram of UASB based STP at Agra

Resource recovery – Biogas to energy

Possible electrical energy from biogas: 1000 m3/d x 5 kWh/m3 x 25% = 1250 kWh/d. There are two duel fuel generators each of 64 kW.Specific energy generation values are not available. System runs only during prolonged power cuts. Otherwise almost entire biogas is flared.

Resource recovery – sludge

Sludge generation: 70 cum/day/reactor = 420 cum/day

Almost 2500 cum of dried sludge is accumulating on the sides of the drying beds in three years as there is no demand for sludge in an area of over 80 km radius. The agencies have been unable to provide necessary marketing inputs. In the meanwhile about 800 cum of sludge was lifted by the UP Forest Department at a rate of Rs. 38/cum, giving a recovery of Rs. 30,400 only over a period of 3 years which is insignificant in comparison to the capital investment and annual O&M costs.

Resource recovery – treated effluent

Although the treated wastewater is extensively utilised by the farmer community along the effluent channel, no significant revenue accrues from this activity.

Total resource recovery

Rs. 30,400 over last 2 years

O&M aspects

O & M of the plant is still by default with the construction agency without a formal contract as it has not been taken over by UPJN apparently due to disagreement on quality of construction. O&M of electrical and mechanical components has been sub-contracted to another agency. Screen and grit chambers are operated / cleaned manually, thereby exposing the workers to bacterial and viral infection. Bar screens installed at the pumping station and the STP are unable to remove floating matter e.g., plastic bags, pouches etc. As a result, problem of choking of distribution system of the UASB reactor is being experienced at this plant. Separate manpower is deployed for removing floating matter from the UASB reactor, which adds to the cost of operation as well as causes disturbance in the settling zone of the reactor. The O&M contractor is also given the charge of laboratory and carries out waste water sample analysis. Apparently there is conflict of interest as it is the contractor himself who is also responsible for adhering to discharge quality specifications.

Table 5: Comparison of UASB based STPs

Assessment parameter	**Agra UASB**	**Faridabad UASB**	**Ghaziabad UASB**	**Gurgaon UASB**	**Karnal UASB**	**Panipat UASB**	**Yamunanagar UASB**
Capacity (MLD)	78	20	56	30	40	10	25
Hydraulic loading (%)	64	80-90	80	n/a	n/a	n/a	n/a
Plant area (ha)	20	5.8	12.70	9.71	8.10	3.04	10.52
Area per MLD (ha/MLD)	0.26	0.29	0.23	0.32	0.2	0.3	0.28
Performance							
Effluent BOD (mg/l)	**50-55**	**27-30**	**28-33**				
Effluent COD (mg/l)		**99-170**	**280**	**112**	**112-128**	**336**	**240-320**
DO (mg/l)	0	0	0	0	0	0	0
Effluent SS (mg/l)	**89-111**	**25-45**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Effluent faecal coliform (MPN/100ml)	1.0 E+6	1.0 E+5	1.0 E+6	1.0 E+6	1.0 E+6	1.0 E+6	1.0 E+6
Resource recovery-biogas (Rs.pa)	Nil	145000	n/a	n/a	n/a	n/a	n/a
Resource recovery-sludge (Rs. Pa)	10000	100000	n/a	n/a	n/a	n/a	n/a

Resource recovery-effluent(Rs. Pa)	Nil	Nil	n/a	n/a	n/a	n/a	n/a
Total resource recovery(Rs.pa)	**10000**	**245000**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Computation of life cycle cost							
Contract value of plant civil+E&M (Rs. Millions)	153.6	64	128.8	78	107	28.5	69
%of work civil works	65%	65%	68%	65%	64%	66%	65%
Rs. Million	99.84	41.6	87.58	50.7	68.48	18.81	44.85
% of work E&M works	35%	35%	32%	35%	36%	34%	35%
Rs. Million	53.76	22.4	41.22	27.3	38.52	9.69	24.15
Year of construction	1998	1999	2001	1998	1998	1998	1998
Cost inflation index							
CII: year of construction	351	389	426	351	351	351	351
CII: in 2011	785	785	785	785	785	785	785
Unit cost of STP							
Cost of plant							
Civil works (Rs. Millions)	223.3	83.95	161.39	113.39	153.15	42.05	100.3
E&M component (Rs. Millions)	120.2	45.20	75.6	61.05	86.15	21.67	54.01
Total cost of plant (Rs.	**343.52**	**129.15**	**237.34**	**174.44**	**239.3**	**63.74**	**154.3**

Millions)							
Unit cost of STP (Rs. Million/MLD)	**4.404**	**6.46**	**4.24**	**5.81**	**5.98**	**6.37**	**6.172**
Operation & Maintenance costs							
Technology power requirement (kWh/d)	165	73	280	150	200	50	125
Non technology power requirement (kWh/d)	660	262	500	260	350	100	240
Total daily power requirement (kWh/d)	825	335	780	410	550	150	365
Unit power requirement (kWh/MLD)	**10.58**	**16.75**	**14**	**13.66**	**13.75**	**15**	**14.6**
Daily power cost@ 5.5 Rs./kWh	4537.5	1842.5	4290	2255	3025	825	2007.5
Annual power costs (in million)	1.65	0.67	1.56	0.82	1.1	0.3	0.73
Man power costs							
Manager (30000/head)	2/5	¼	¼	¼	1/4	1/8	¼
Chemist /operating engineer	2	2	2	2	2	2	2

(14000/head)							
Operators (9000/head)	4	4	4	4	4	4	4
Skilled technicians (10000/head)	4	4	4	4	4	4	4
Unskillied personnel (5000/head)	24	10	16	12	12	8	12
Cost of manpower	2.83	1.46	2.3	2.06	2.06	1.78	2.06
Repairs cost							
Civil works per annum as % of civil works cost	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
E&M works as % of E&M works cost	3%	3%	3%	3%	3%	3%	3%
Civil works maintenance	1.11	0.42	0.8	0.57	0.77	0.21	0.50
E&M works maintenance	3.6	1.36	2.2	1.8	2.6	0.65	1.62
Annual repairs cost	**4.71**	**1.78**	**3.0**	**2.37**	**3.37**	**0.86**	**2.12**
Total annual O&M costs	**9.19**	**3.91**	**6.86**	**5.25**	**6.53**	**2.94**	**4.91**
Unit O&M costs	**0.12**	**0.19**	**0.12**	**0.17**	**0.16**	**0.29**	**0.19**
Net present value factor	17.25	17.25	17.25	17.25	17.25	17.25	17.25
Capitalised O&M costs	158.53	67.3	117.3	90.6	112.6	50.7	84.7

over 20 years (Rs. Millions)							
Capital cost of plant (Rs. Millions)	343.52	129.15	237.34	174.44	239.3	63.74	154.3
Land cost @ Rs. 8 million/ ha (Rs. Millions)	624	160	448	240	320	80	200
Life cycle cost (excluding land) Rs. Million	**502.05**	**196.45**	**354.64**	**265.04**	**351.9**	**114.44**	**239**
Unit life cycle cost (Rs. Million/MLD)	**6.43**	**9.8**	**6.33**	**8.83**	**8.8**	**11.4**	**9.56**

Notes: 1 Electrical and mechanical cost of plant includes duel fuel generators cost

4.3.2 UASB plant at Faridabad

The capacity of plant is 20MLD. It consists of two streams each of 10 MLD. Its components are Mechanical and manual bar screens, manually cleaned grit chambers; UASB reactors, final polishing units, biogas holders, duel fuel generators.

No thickeners, instead sludge goes directly to drying beds Hydraulic retention time in UASB: 8 h

Hydraulic retention in FPU: 1 day

Land requirement

Plant area is 5.8 ha. Therefore, unit land requirement is 0.29 ha/MLD

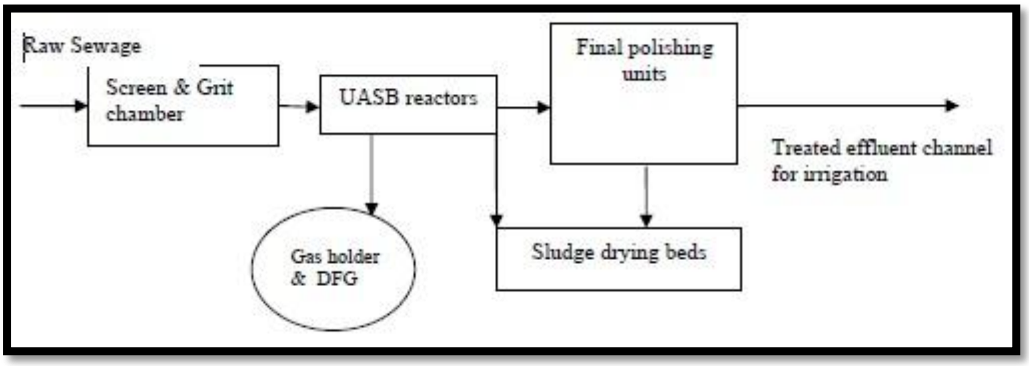

Fig 9: Schematic diagram of UASB based STP at Faridabad

Performance

month	Raw sewage		UASB outlet		FPU outlet		%removal	
	BOD	SS	BOD	SS	BOD	SS	BOD	SS
Jan	184	268	74	85	30	44	84	84
Feb	183	220	74	83	30	38	84	83
March	183	207	76	77	29	45	84	78
April	190	202	72	73	28	32	85	84
May	184	216	57	59	27	29	85	87
June	194	215	62	64	29	26	85	88
July	180	212	59	64	28	25	84	88
August	185	242	73	67	29	31	84	87
Sept	197	289	74	75	30	34	85	88
Oct.	196	304	70	89	29	32	85	89
Average	187.6	237.5	69.1	73.6	28.9	33.6	85	86
Std.dev.	6.1	36.7	7.0	10.1	1.0	6.9	0.6	3.4

Source: PHED Haryana

Power requirement

Plant load during average flow conditions is15 kW this includes screens, office, laboratory, staff quarters etc. STP power consumption is 360 kWh/d and average power cut is 4-5 hrs/d.

Resource recovery – Biogas to energy

Electrical energy generated from biogas is 280 m^3/d x 5 kWh/m^3 x 25% = 350 kWh/d

Two duel fuel generators are used one is of 40KW and another is of 160 KW.

Fuel consumption: 3.5 l/h diesel, 22 m3/h biogas; 17 l/h diesel, 55 m3/h biogas

- Running of the DFG : 40 kW set only during power cuts to meet STP load
- Quantity of biogas utilised: 88 m3/d while the rest of 200 m3 biogas is flared.
- Quantity of electricity generated from duel fuel generators : 160 kWh

Resource recovery – sludge

The O&M contractor has been given the responsibility of selling or disposing off the dry sludge. The mode of disposal is not defined and under the assumption that the sludge is being sold to agriculture farmers, PHED is deducting Rs. 1 Lakh pa from the fee of the contractor.

Resource recovery – treated effluent

Although the treated wastewater is utilised by the farmer community along the nalla, no revenue accrues from this activity. Notional resource recovery in the form of use of nutrients for increased agriculture produce and economic benefits to farmer community are significant, however these have not been quantified.

Total resource recovery

Rs. 1 Lakh pa

O&M aspects

- Manual operations of screen and grit chambers are a cause of concern from the point of view of occupational health of the workers who are directly exposed to raw sewage.

- Bar screens installed at the pumping station and the STP are unable to remove floating matter e.g., plastic bags, pouches etc. problem of choking of distribution system of the UASB reactor is being experienced at this plant.
- Inadequate stilling volume in the mechanical screen chamber causes high hydraulic pressure on the bar screens and leads to their deformation/damage.
- Separate manpower required for removing floating matter from the UASB reactor, which adds to the cost of operation as well as causes disturbance in the settling zone of the reactor.
- The O&M contractor is also given the charge of laboratory and carries out waste water sample analysis. Apparently there is conflict of interest as it is the same contractor who is also responsible for adhering to discharge quality specifications. This aspect is reflected by narrow range of effluent BOD and SS values which fall close to the respective discharge limits.

4.4 BIOFOR (Biological filtration and oxygenated reactor)

The objective of setting up these STPs was to assess suitability of BIOFOR system, for very high end performance where land availability is a constraint and where the site is located in a prime and sensitive area. Under these constraints, the systems were required to be compact as well as free from any odour nuisance. At the planning stage, treated effluent was envisaged for industrial application and therefore it was all the more important that the plant could consistently produce effluent of high quality. An agreement was reached between the sewage treatment authority and a power utility (thermal power plant) located adjacent to the STP for sale of effluent. According to this agreement, the treated effluent is being used as cooling water in the power plant and in exchange the STPs are getting free electricity. In view of the crucial role of these STPs for the power utility, of late the latter has agreed to take over their O&M responsibility as well. The main components of the treatment process of BIOFOR plant comprises of coagulation and flocculation in a specially designed clarisettler, followed by two stage filtration through a special medial bed where organic degradation is facilitated by external oxygenation. Interesting to note is that there are no primary or secondary clarifiers and conventional aeration reactor and as a result the entire system is very compact. Special design of the clarisettler enables simultaneous thickening of the sludge and thereby eliminates the need for a separate thickener and thus saves space.

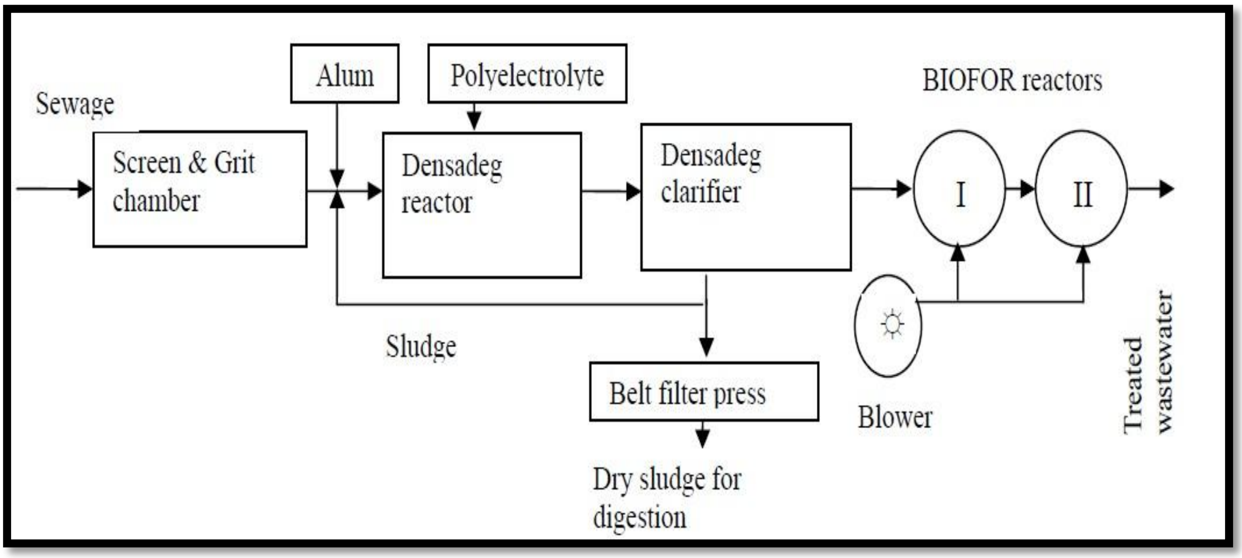

Fig 10: Schematic diagram of BIOFOR based STP

Alum is added as coagulant at concentrations of 60 mg/l and then the sedimentation of flocculants is enhanced by addition of polyelectrolytes. In fact a bulk of the treatment takes place at this primary clarification stage where almost 90% of suspended solids and 70% of BOD are removed. The second stage is up-flow rapid sand filtration and is considered more as a polishing treatment. In view of this, the technology can be characterised as a physico-chemical process and less of a biological process.

Performance

Very high quality effluent with BOD < 10 mg/l and SS < 15 mg/l. Corresponding removal efficiencies across the plant are 94-99.9% and 98% respectively. However, from pathogen removal point of view there is wide variation and maximum values are of the order of 106/100 ml while average removal is of the order of 2 on the log scale. As seen from these results, the effluent is of very high quality and it is not surprising that the power utility has agreed to barter it with electricity.

	STP at Sen Nursing Nalla-10MLD					
	BOD			**Suspended solids**		
Month	Inlet	Outlet	%Rem	Inlet	Outlet	%Rem
January	547	1	99.8	1585	37	97.7
February	269	2	99.3	453	11	97.6
March	269	2	99.3	453	11	97.6
April	242	14	94.2	633	12	98.1
May	246	6	97.6	469	11	97.7
June	291	2	99.3	791	14	98.2
October	357	5	98.6	746	11	98.5
Average			98.2			97.8

Land requirement

Plant area: 0.4 ha. (excluding sludge treatment component)

Power requirement

- Total load: approximately 92 kW including office, lab, ancillary equipment etc.

- Consumption during average flow conditions: 2200 kWh/d

Chemical requirements

- Alum as coagulant @ 60 ppm
- Polyelectrolyte for high rate sedimentation @ 0.2-0.3 ppm
- Polyelectrolyte for sludge dewatering (~ @ 3 kg/t of dry solids)

Resource recovery – Biogas to energy

Not applicable

Resource recovery – sludge

Separate estimates are not available as the sludge is first sent to Okhla STP for drying and then it is sold along with digested sludge of that STP, the sludge contains higher proportion of alum and polyelectrolyte and may not fetch high value manure.

Resource recovery – treated effluent

A very high level of recovery in terms of monetary value as the effluent is bartered with free electricity from the power utility. Considering price of electricity at Rs. 4.8/ kWh this is estimated to be around Rs. 3.85 million per annum. This is a unique case and may not be applicable at other locations.

Total resource recovery

An amount of Rs. 3.85 million per annum

O&M aspects

- Use of multi stage screens that are effective in removal of floating objects including plastic bags and pouches etc.
- Though grit chambers are mechanised, screens are still cleaned manually, thereby exposing workers to bacterial and viral infection.
- Aerated grit chambers with classifier are mechanically cleaned and minimise occupational health hazards typically seen in other STPs.
- High though optimised dosage of alum and polyelectrolytes
- Cleaning of tube settlers, sludge withdrawal and recirculation
- Sludge drying is not provided due to space constraints and therefore it is transported everyday to another STP
- O& M of the plant is given on a contract to the construction agency / technology provider
- O&M is supervised by the power utility
- A manual on O&M of the plant has been provided by the contractor

Cost aspects

The total capital cost of plant in 2011 including civil, electrical and mechanical works is 120 million. Unit capital cost is 12 million/MLD. Total O&M costs including power cost, manpower cost, and repairs cost in 2011 is Rs 10.85 million. Unit O&M cost is 1.085 million/MLD. Total life cycle cost for next 20 years duration is Rs.307.7 million& unit life cycle cost is 30.7 million/MLD.

Table 6: Comparison of advanced technologies based STPs

Assessment parameter	**BIOFOR DSNH,delhi**	**Two stage Asp BIOFOR-F, Rithala Delhi**	**FAB molarband, Delhi**	**FAB , Lucknow**	**SAFF Holambi , Delhi**
Process Type	Physico-chemical; and biological treatment in two stage aerated submerged filter	Two stage biological oxidation(ASP +BIOFOR-F)	Extended aeration in two stage fluidized bed of plastic media	Extended aeration in two stage fluidized bed of plastic media	Two stage filtration through submerged plastic media with aeration
Capacity (MLD)	10	182	3	42	2
Hydraulic loading (%)	100	88	10	100	50-60
Plant area (ha)	0.40	13.8	0.18	1.2	0.098
Area per MLD (ha/MLD)	0.04	0.08	0.06	0.03	0.05
Performance					
Effluent BOD (mg/l)	**<10**	**<15**	**<10**	**<20**	**1.4**
Effluent COD (mg/l)	**60**	**80**	**88**	**<100**	**16**
Effluent DO (mg/l)	2-3	>1.5	1-2	1-2	Na
Effluent SS (mg/l)	**<15**	**12-22**	**20**	**27**	**15**
Effluent taecal coliform (MPN/100ml)	1.0E+6	Nav	1.0E+5	1.0E+5	750

Sludge digestion	Not included	included	Not required	Not required	Not required
Resource recovery-biogas (Rs.pa)	Na	56,575,000	Na	Na	Na
Resource recovery – sludge (Rs.pa)	Nil	Nil	Nil	Nil	Nil
Resource recovery-effluent (Rs.pa)	4,015,000	Nil	Nil	Nil	Nil
Total resource recovery(Rs.pa)	**4,015,000**	**56,575,000**	**Nil**	**Nil**	**Nil**

COMPUTATION OF LIFE CYCLE COST

Contract value of plant civil+E&M (Rs. In millions)	53.9	914.7	13.8	126.6	14.0
% of work civil works	58%	25%	33%	40%	40%
Rs. In million	31.3	228.7	4.6	50.6	5.6
% of work E&M works	42%	75%	67%	60%	60%
Rs. In million	22.6	686	9.2	76.0	8.4
Year of construction	1998	2001	2003	2002	2003
Cost inflation index					
CII: year of construction	351	426	463	447	463
CII:2011 (estimated)	785	785	785	785	785
Cost of plant (as in 2011)					
Civil works	70.0	421.43	7.8	88.9	9.5
E&M component	50.54	1264.1	15.6	133.5	14.2
Total cost of plant	120.54	1685.53	23.4	222.4	23.7
Unit cost of STP	12.0	9.26	7.8	5.3	11.9
Operation &					

Maintenance costs					
Technology power requirement (kWh/d)		32000			
Non-technology power requirement (kWh/d)		700			
Total daily power requirement(kWh/d)	2200	32700	400	4150	780
Unit power requirement(kWh/MLD)	**220**	**180**	**133**	**99**	**390**
O&M charges for cogeneration system (Rs. millions)		2.4			
Daily power cost @Rs.5.50/kWh (Rs.)	12100	1,79,850	2200	22825	4290
Annual power costs(Rs. millions)	4.4	65.64	0.80	8.3	1.57
Chemical costs					
Alum (kg/d)	150	0	90	0	0
Polyelectrolyte (kg/d)	10	0	3	0	0.25
Chlorine (kg/d)	-	0	15	126	8
Caustic soda (kg/d)	-	200	-	-	-
Alum@ Rs.5/kg (Rs .million)	0.27	0	0.16	0	0
Polyelectrolyte @ Rs.350/kg (Rs .million)	1.28	0	0.38	0	.032
Chlorine @ Rs.12/kg	-	0	0.065	0.55	0.035
Caustic soda @ Rs.17/kg	0	1.24	-	-	-
Total chemical costs (Rs.in Million)	**1.55**	**1.24**	**0.60**	**0.55**	**.35**
Manpower operation & maintenance cost (cost/man)					
Manager (30000)	1	1	2/5	1	2/5

Chemist/operating engineer (14000)	3	10	¼	1	¼
Operators (9000)	8	15	1	6	1
Skilled technicians (10000)	8	25	2	8	2
Unskilled personnel (5000)	6	20	4	25	4
Cost of manpower (Rs. In millions)	**3.04**	**7.8**	**0.65**	**3.6**	**0.77**
Repairs cost					
Civil works per annum as % of civil works cost	0.5%	0.5%	0.5%	0.5%	0.5%
E&M works as % of E&M works cost	3%	3%	3%	35	2%
Civil works maintenance (Rs.million)	0.35	2.10	0.039	0.44	0.48
E&M works maintenance (Rs.million)	1.515	37.9	.468	4	.284
Annual repairs cost (Rs. Millions)	1.865	40	0.50	4.44	0.764
Total annual O&M costs (Rs.million)	10.85	114.68	2.55	16.85	3.46
Unit O&M costs (million/MLD pa)	**1.085**	**0.63**	**0.85**	**0.40**	**1.73**

Consider inflation rate = 8% & discount/interest rate = 10% for 20 years

Capitalised O&M cost over 20 years (Rs.million)	187.16	322.23	44	290.6	59.7
Capital cost of plant(Rs.million)	120.54	1685.53	23.4	222.4	23.7
Land cost @ 8 million/ha (Rs.million)	80	1456	24	336	16

Life cycle cost(excluding land)2011 (Rs.million)	**307.7**	**2007.76**	**67.4**	**513**	**83.4**
Unit life cycle cost (2011) (Rs.million/MLD)	**30.7**	**11.03**	**22.5**	**12.2**	**41.7**

4.5 High Rate ASP BIOFOR-F Technology

A treatment plant based on this technology with an overall capacity of 182 MLD is located at Rithala, Delhi. Case study of this plant has been included here which enable consistently high degree of treatment. This plant has also been designed for very high end performance involving multistage treatment. However, unlike the DSNH STP described in the previous section, effluent at this plant after such high degree of treatment is currently not being utilised for any profitable application. Some of the unique features of the main treatment process are absence of primary sedimentation, high rate activated sludge process, second stage aeration and granular filtration through a biologically active filter media. The activated sludge process I operated under high rate conditions by maintaining higher organic loading on the reactor and keeping MLSS concentration of around 4000 mg/l. Subsequent granular filtration is carried out through a bed of multiple media with the top layer comprising specially produced clay granules called ‘biolite’. Residual organic matter gets biologically oxidised when the pre-aerated effluent passes through the ‘biolite’ layer. Moreover, the grit chamber is also based on dissolved air floatation system where the concentrated stream is separated in another tank and the grit is removed mechanically through a screw pump/impeller. This type of grit chamber offers high removal efficiency as well as involves least occupational health hazard typically seen at other STPs. In addition to the main process line, the plant has special sludge treatment arrangement comprising thickening through dissolved air floatation system and anaerobic digestion under controlled temperature conditions.

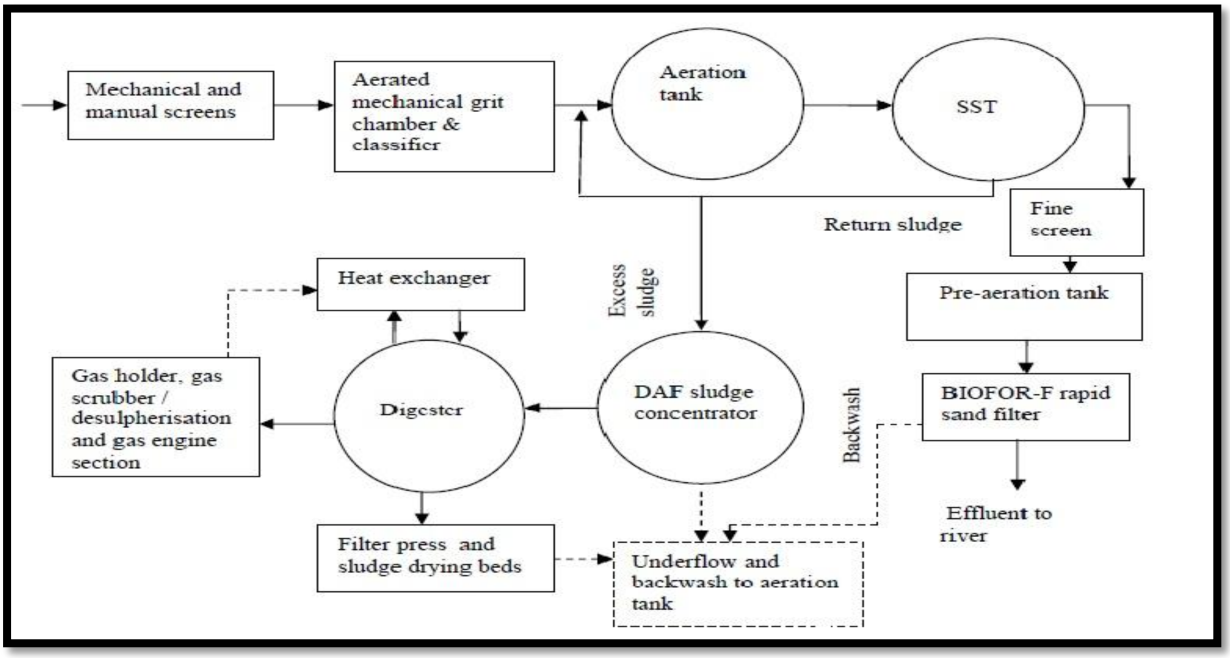

Fig 11: Schematic diagram of BIOFOR F based STP at Rithala, Delhi

Performance of the plant

	Design values		**Current actual values**	
	BOD(mg/l)	**SS(mg/l)**	**BOD(mg/l)**	**SS(mg/l)**
Influent	200	410	130	230
Effluent	15	20	9-16	12-22

Resource recovery

Besides the high quality effluent, the plant scores high on biogas generation and its utilisation for electricity generation. As a result of controlled temperature operation and continuous mixing through gas circulation, the digesters produce about 14,000 cum of biogas/day. This biogas is utilised for power generation in biogas engines and the available waste heat is utilised for heating the sludge to about 24 to 26º C. Though this temperature is not close to the optimum of 37º C for mesophilic digestion (as the available waste heat is not enough) it is still effective as it prevents wide fluctuations and disruption of bacterial activity typically observed at other STPs during winter season The performance of the digesters can be gauged from the fact that they are guaranteed to meet almost 85% of the total power requirements of the entire STP. Against a requirement of 36,000 kWh/d, the plant is authorised to draw only about 5000 kWh/d from the grid and the rest it is supposed to meet from captive generation through the biogas driven gas engines. Under the current hydraulic and organic loading the plant is able to generate about 32,000 kWh/d of electricity (and an estimated 40,000 kWh/d of thermal energy). However, during monsoon season, due to dilute wastewater the quanta of sludge generation and as a consequence the biogas and power generation are reported to go down. The annual savings on energy costs are estimated to be of the order of Rs. 56 million which constitutes a significant resource recovery.

Land and power requirement

The treatment system is effective in removal of dissolved organics and suspended solids in a comparatively small plot of land. While the approach of excluding primary sedimentation leads to higher organic load on aeration tank, but it also avoids the need for a separate primary thickener. The combined effect of these features and high rate operations enables economy on land requirement. The unit land requirement of the plant is about 0.08ha/MLD as compared to that of 0.25 to 0.4 ha/MLD for ASP and 1 to 2.8 ha/MLD for WSP.

Power requirement

On the other hand, the unit power requirement of the plant is about 180 kWh/d which is comparable to ASP plants described earlier. However, here the distinguishing feature is meeting 85% of requirements through captive generation of bio-energy which helps in reducing the operation costs.

Cost aspects

The total capital cost of plant in 2011 including civil, electrical and mechanical works is 1685.53 million. Unit capital cost is 9.26 million/MLD. Total O&M costs including power cost, manpower cost, chemicals cost, repairs cost in 2011 is Rs114.68 million. Unit O&M cost is 0.63 million/MLD. Resource recovery value is 56 million. Total life cycle cost for next 20 years duration is Rs.2007.76 million & unit life cycle cost is 11.03 million/MLD.

4.6 Fluidized Aerated Bed Technology

The capacity of two fluidized aerated bed (FAB) technology based STPs are 3MLD and 42 MLD. They are located at molarband, (Delhi) and Lucknow. Case study of these plants has been included here. These plants have also been designed for very high end performance involving multistage treatment.

Process scheme

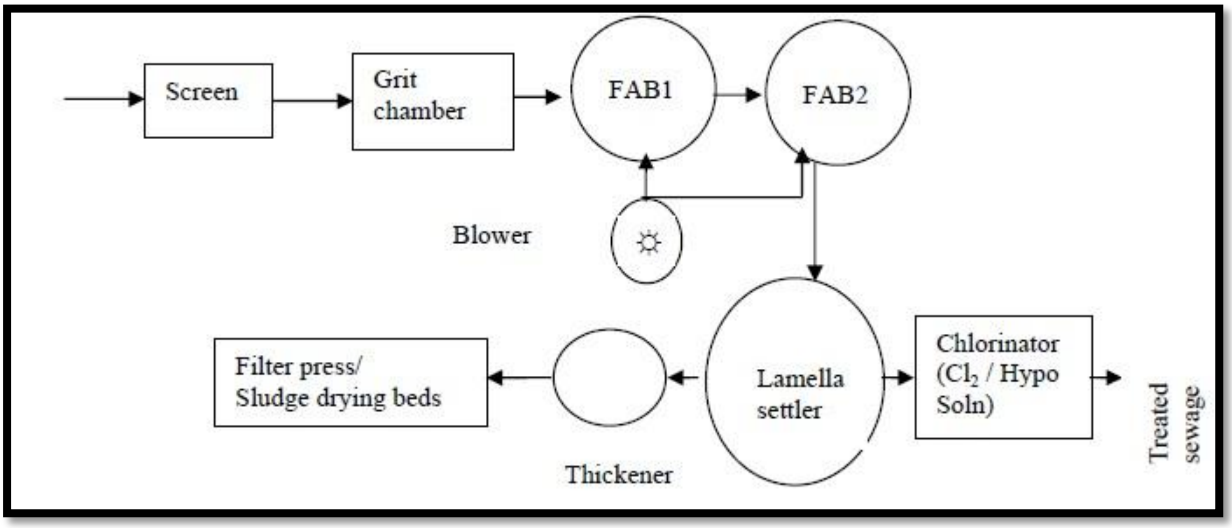

Fig 12: Schematic diagram of FAB based STP at Molarband, Delhi

The flow scheme consists of screens and grit chamber. Primary sedimentation is absent from its flow scheme. After passing through grit chamber sewage passes into two fluidized aerated bed reactors. Both the reactors are operating in series. This is followed by secondary sedimentation in lamella settlers. Both of FAB reactors are 5 m in depth. Detention time offered by them is very low (45 minutes). The reactors are aerated through a submerged aeration system. Its special feature is the use of special plastic media which is used as the base material for the growth of the biomass. The media is about 2 cm in diameter and 1 cm in height. For growth of biomass media offers high specific surface area. Quantity of media is decided specified according to the expected organic load and desired effluent quality. The bed remains in fluidized form because of the combined effect of the low density of media, hydraulic arrangement and submerged aeration. As a result the FAB reactors function as hybrid of attached and suspended growth processes offering advantages of both. The reactor is offering a completely mixed type of flow scheme flow regime which again helps in higher contact between the biomass and the dissolved organics. In order to prevent overflow of the media, special submerged stainless steel screens are installed at the outlet of FAB reactors. However, if bar screens at the beginning of the plant are not effective in removing plastic sheets, there is risk of clogging of the submerged screens and thus disruption in hydraulic flow through the plant. The STP is flushed with a mixture of air to prevent the risk of clogging of submerged screens. As a large quantity of the biomass is grown and retained on the media, there is no requirement for sludge recirculation and associated process monitoring for maintaining as specified Apparently the process operates at a low food to microorganism ratio and from that point of view it corresponds to an extended aeration system. However, from hydraulic retention point of view it achieves the same level of performance in a much shorter span of time. It takes only 90 minutes compared to 12 hours or above in the latter. As the sludge produced from the FAB reactors is in fully stabilised form, the technology does not require a sludge digester. The systems installed at Molarband and Lucknow confirm to the above general arrangement. The Molarband plant is designed as a decentralised sewage treatment facility in a congested low income locality and it receives concentrated sewage from 18 community toilet complexes which are connected to the sewerage network. As a result it has adopted additional feature of concurrent coagulation and flocculation. Moreover, due to space constraints, it has adopted belt filter press instead of the typical drying beds for sludge treatment. On the other hand, at Lucknow the influent is diluted as it is lifted from the outfall of an open drain and therefore addition of coagulants and flocculants is not included. The sludge after thickening is sent directly to sludge drying beds. In order to comply with the norm for Faecal coliform level in the final effluent, at both the plants the tertiary treatment step comprises chlorination with a dosage of 2-4 ppm and contact time of 20-30 min. While at Molarband a separate contact chamber has been provided, at Lucknow an additional circular wall around the lamella settler tan provides the necessary volume for disinfection to take place.

Land and power requirements

As a result of the compact design, the foot print area of the Molarband and Lucknow plants are very low at 0.06 ha/MLD and 0.03 ha/MLD. Similarly the power requirements are 133kWh/MLD and 99 kWh/MLD respectively. In case of a typical extended aeration system the corresponding values are 0.1 ha/MLD and 228 kWh/MLD respectively. Thus in comparison to the latter type of system, a FAB technology based plant offers significant land and energy economy. The lower energy requirements could be attributed to arrangement for biomass retention and submerged aeration system.

Performance of the plant

While the Molarband plant is receiving only one tenth of the designed flow, it carries higher organic and solids load than what is typically found in sewage. Compared to the nalla flow lifted at Lucknow, it is almost 3-4 times stronger in BOD and SS values and corresponding removal efficiencies are found to be 97%.The plant at Lucknow is receiving almost 100% hydraulic loading. While removal efficiencies are somewhat lower, the final effluent quality is well within the discharge standards. At times the plant has been subjected to hydraulic overloading to the extent of 62MLD (48% overloading). It is expected that the increased surface overflow rate would lead to wash out of solids from the reactor and the tube settler. However, as per the available effluent quality data monitored by the O&M agency, the suspended solids and BOD concentrations are found to be 26 mg/l and 24 mg/l respectively. These values are quite in line with those observed on the days of normal flow. However, it must be noted that the average influent BOD is way below the designed BOD of 250 mg/l and on the day of overloading under consideration it was found to be only 140 mg/l.

It should be noted that the final effluent characteristics correspond to post chlorination stage and undoubtedly this also helps in reducing the chemical and biological oxygen demand to a certain extent. Effluent quality at pre-chlorination stage is not monitored and therefore removal efficiency exclusively from the FAB reactors cannot be commented upon.

	Lucknow			**Molarband ,N.delhi**		
	Influent	**Effluent**	**%Rem.**	**Influent**	**Effluent**	**%Rem.**
BOD(mg/l)	120	19	84	357	9.2	97
COD(mg/l)	260	68	74	920	88	90
SS(mg/l)	140	27	81	650	20	97

Faecal coliform (MPN/100ml)	9×10^6	600	99.99	10^7	640-730	99.99

Investment costs

The total capital cost of FAB based plants at molarband(Delhi) and Lucknow are Rs.23.4 million and Rs.222.4 million respectively. There unit capital costs are Rs.7.8 million/MLD and 5.3 million/MLD. The annual O&M cost of FAB based plants at Molarband(delhi) and Lucknow are Rs.2.55 million and Rs.16.85 million respectively. There unit capital costs are Rs.0.85 million/MLD and 0.40 million/MLD.The Life cycle cost of FAB based plants at Molarband(delhi) and Lucknow are Rs.67.4 million and Rs.513 million respectively. There unit capital costs are Rs.22.5 million/MLD and 12.2 million/MLD.

4.7 Submerged Aeration Fixed Film Technology

The capacity of plant based on this technology is 2MLD. The main objective of this plant is to serve a low income congested locality. Thus, its low land requirement is the main advantage for opting this technology.

Process scheme

The flow scheme consists of application of screened and degritted sewage to two trickling filter reactors without passing through sedimentation tank. Both the reactors are operating in series. This operation is followed by secondary sedimentation in lamella settlers. The media in the trickling filter comprises fixed corrugated plastic sheets which are arranged in the form of blocks stacked in multiple layers. The depth of media is around 3.6 m while the side water depth in the reactor is 6m. At the bottom of trickling filter submerged aeration is provided which enhanced biological oxidation process. The total hydraulic retention time of both the reactors is about 10 hours which is almost 7 times of what is provided in the FAB reactors. The sludge comes out in stabilised form which is thickened and then dewatered. A tertiary treatment has been provided for pathogen removal through chlorination.

Land and power requirement

Due to use of the deep reactors and high rate tube settlers, the design of plant turns into a compact design. The land area requirement is around 0.05 ha/MLD which compares well with other systems in the advanced technology category. However, unit power requirements of this technology turnout to be somewhat high at 390 kWh/MLD, in comparison to FAB technology which requires 99 to 170 kWh/MLD.

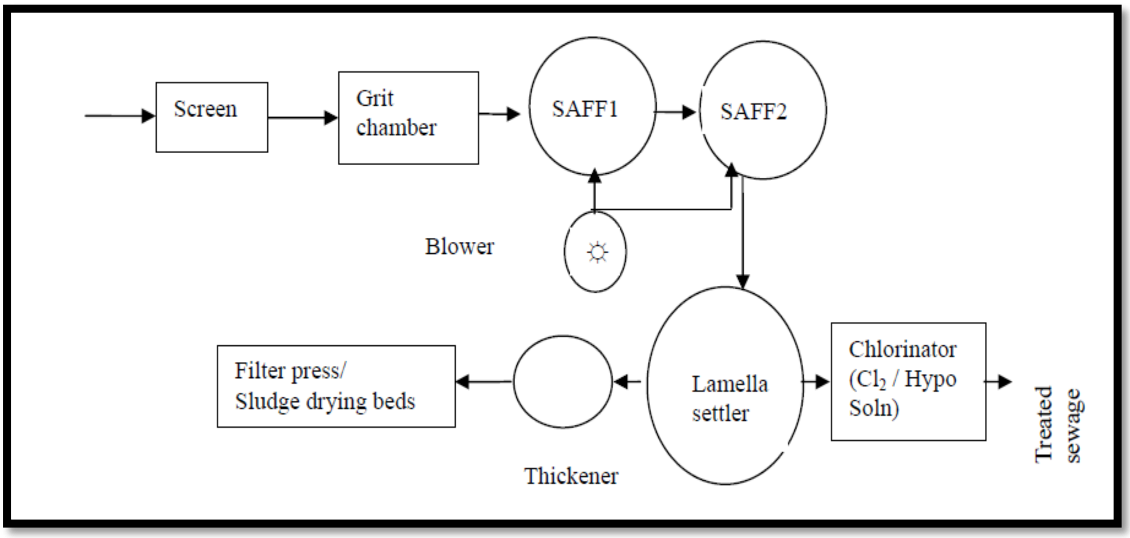

Fig 13: Schematic diagram of SAFF based STP at Holambi

Performance of the plant

Performance of this plant has been affected due to clogging of the fixed plastic media. The effluent quality received from the plant has achieves very good performance level. Its effluent BOD value is 1.4 mg/l and S.S is about 15 mg/l.

Investment costs

The total capital cost of plant in 2011 including civil, electrical and mechanical works is23.7 million. Unit capital cost is11.9 million/MLD. Total O&M costs including power cost, manpower cost, chemicals cost, repairs cost in 2011 is Rs 3.46 million. Unit O&M cost is 1.73 million/MLD. Total life cycle cost for next 20 years duration is Rs.83.4 million & unit life cycle cost is 41.7 million/MLD

CHAPTER 5

RESULTS AND DISCUSSIONS

Wastewater (sewage) generated from domestic sector is the major cause for deteriorating conditions of the rivers. Large portion of the funds under RAPs has been utilized for interception, diversion and treatment of sewage. However, the gap between funds required and available for this purpose has been widening at an alarming rate and the sustenance of present practice is a serious matter that needs to be addressed. The infrastructure/assets created for sewage treatment are not being maintained properly for various reasons including want of requisite funds. By and large the investigation of the causes for deteriorating conditions of rivers due to discharge of sewage and the concept adopted for sewage treatment have been primarily guided by (i) the practices adopted elsewhere, particularly the developed world, and (ii) experience, expertise and interest of the financial aid giving agencies. The ground realities in India are far from those assumed during planning and design, and as a result it has not been possible to build public acceptability and support to such schemes. The local bodies and governments are either reluctant or have not been able to generate/allocate adequate funds for the sustenance and growth of sewage treatment facilities. Also the justification for large expenditure on sewage treatment facilities is much based on speculation than scientific investigations and analysis. This study focused on the critical analysis of the sewage treatment technology options under Indian conditions and attempts to make recommendations for future course of action in management of sewage under RAPs based on the experience gained through monitoring of sewage treatment plants vis-à-vis river water quality monitoring

5.1 Evaluation of Technology Options

As part of evaluation methodology, a number of criteria have been identified to judge the available options which involves land requirement, power requirement, capital cost, annual O&M cost, life cycle cost, BOD, COD and S.S etc. The rationale for assessment of the technology options along these identified evaluation criteria is presented in the sections that follow.

Table 7: Comparison of parameters for different technologies

S.NO.	FACTORS	UNITS	ASP	WSP	UASB	BIOFOR	BIOFOR-F	FAB	SAFF
1	Land Req.	Ha/MLD	0.19	1.46	0.27	0.04	0.08	.045	0.05
2	Power Req.	kWh/MLD	180-225	Negligible	10-15	220	180	120	90
3	Capital cost	Million/MLD	8.1	6.16	5.63	12	9.36	6.55	11.9
4	Annual O&M cost	Million/MLD	0.56	0.27	0.18	1.08	0.63	0.62	1.73
5	Life cycle cost	Million/MLD	14.6	10.74	8.73	30.7	11.03	17.35	41.7
6	BOD	mg/l	30	35	37.33	10	15	15	1.4
7	COD	mg/l	150	170	211	60	80	90	16
8	SS	mg/l	47.33	61.33	67.5	15	20	25	15

Detailed evaluation of all the factors affecting the selection of STP and its treatment unit are carried out. On the basis of the initial capital cost of STP in million/ MLD STP with the different treatment units vary between 5.634 to 12. Where, UASB reactor comes out best treatment unit on the basis of initial capital cost and BIOFOR has the highest initial capital cost.

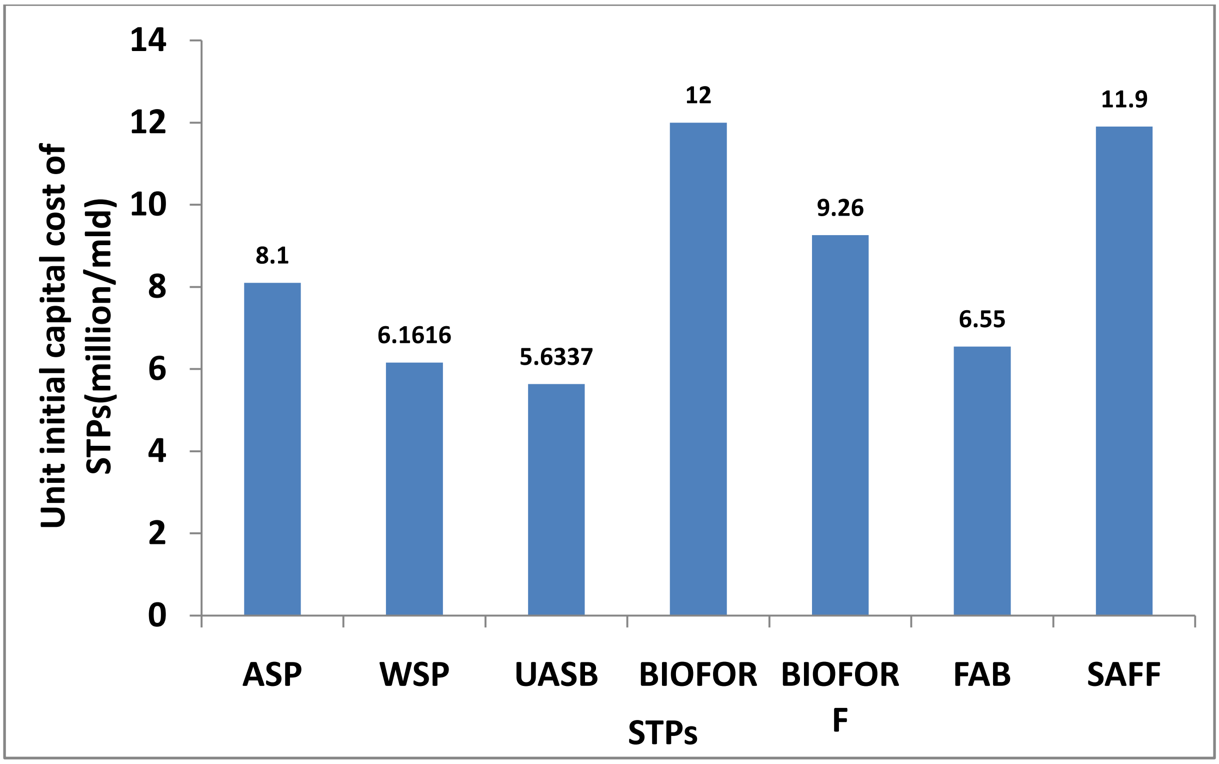

Fig 14: Graph showing the variation of unit initial cost for different STPs

On the basis of the unit O&M of STP in million/ MLD, STP with the different treatment units varies between 0.1771 to 1.73. Where, UASB reactor comes out best treatment unit on the basis of unit O&M and SAFF has the higest unit O&M.

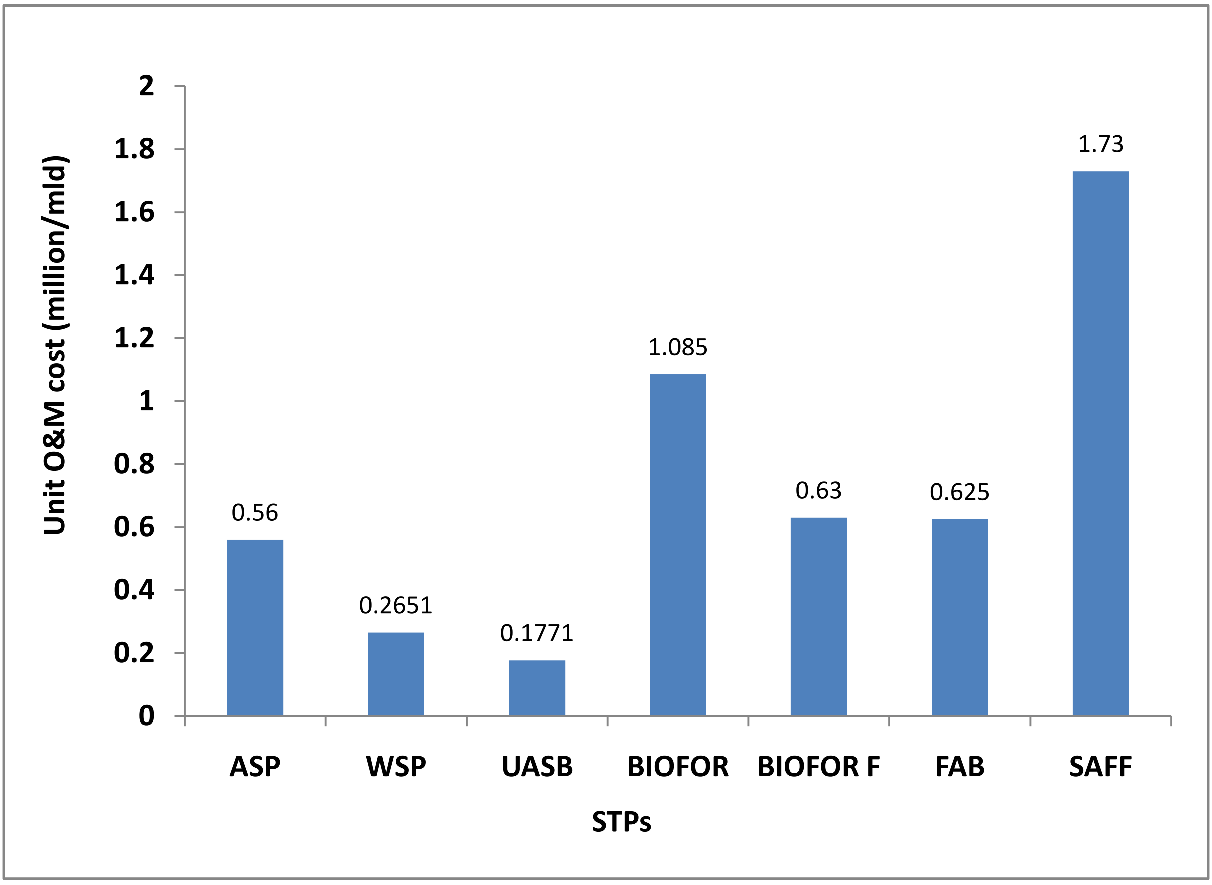

Fig 15: Graph showing the variation of unit O&M costs for different STPs

On the basis of the Area in hectare per MLD of STPs, STP with the different treatment units vary between 0.04 to 1.465. Where, BIOFOR using the lowest area for the treatment on the basis of Area and WSP has the highest area requirement as shown in fig 16

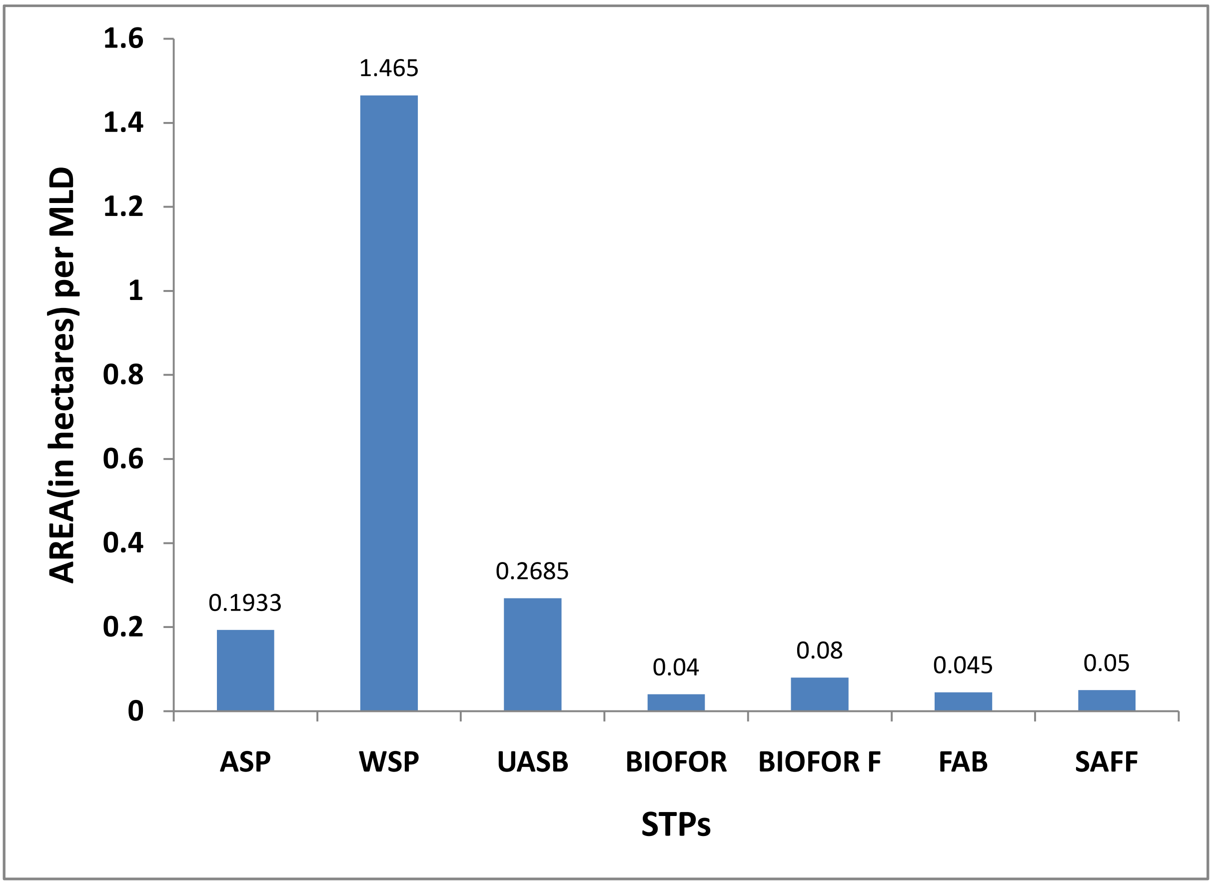

Fig 16: Graph showing the variation of land requirement for different STPs

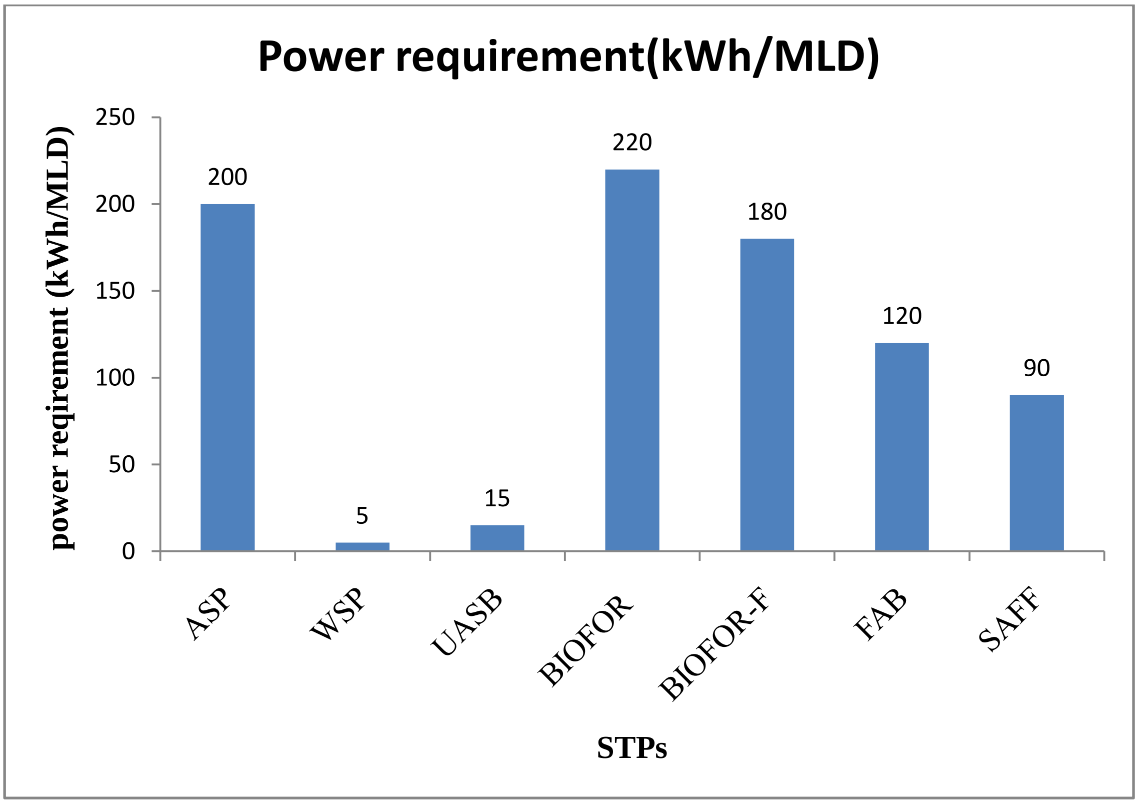

Fig 17: Graph showing the variation of Power values for different STPs

From fig 17 we observed that power value is maximum for BIOFOR based STPs and minimum for WSP based STPs.

From fig 18 we observed that BOD (mg/l) of the sample from the SAFF having the lowest value 1.4 mg/l and highest was 45.6 of WSP plant.

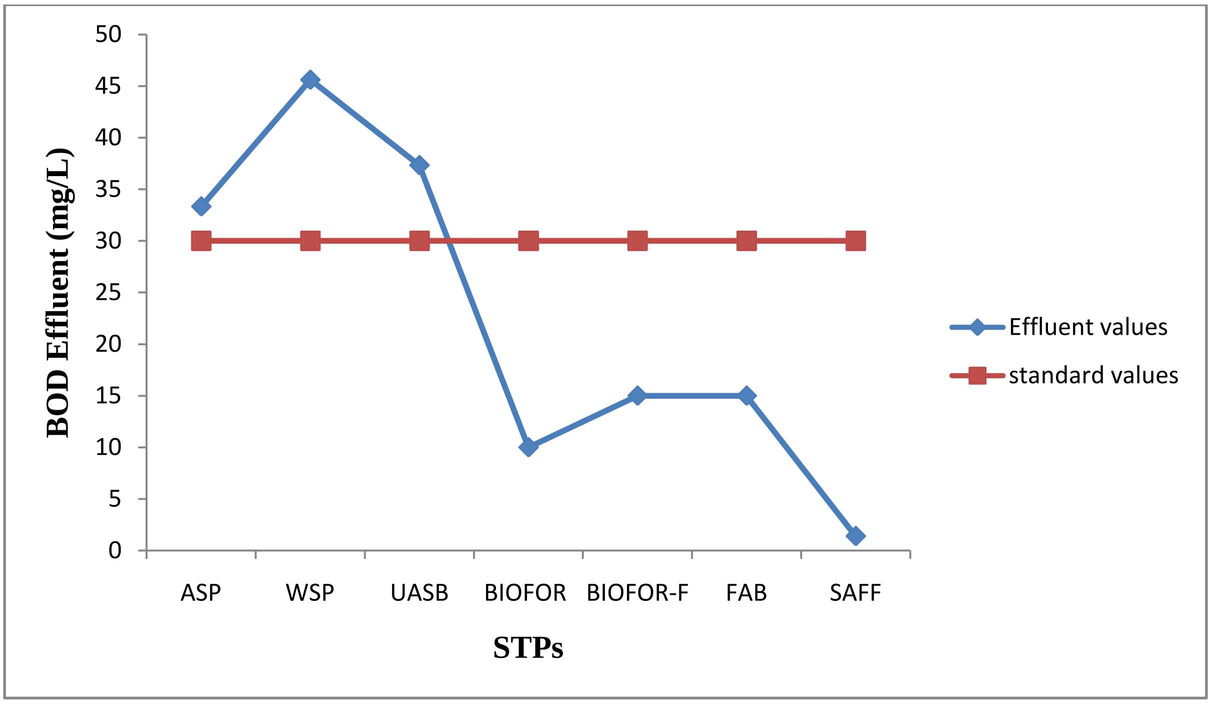

Fig 18: Graph showing the variation of BOD for different STPs

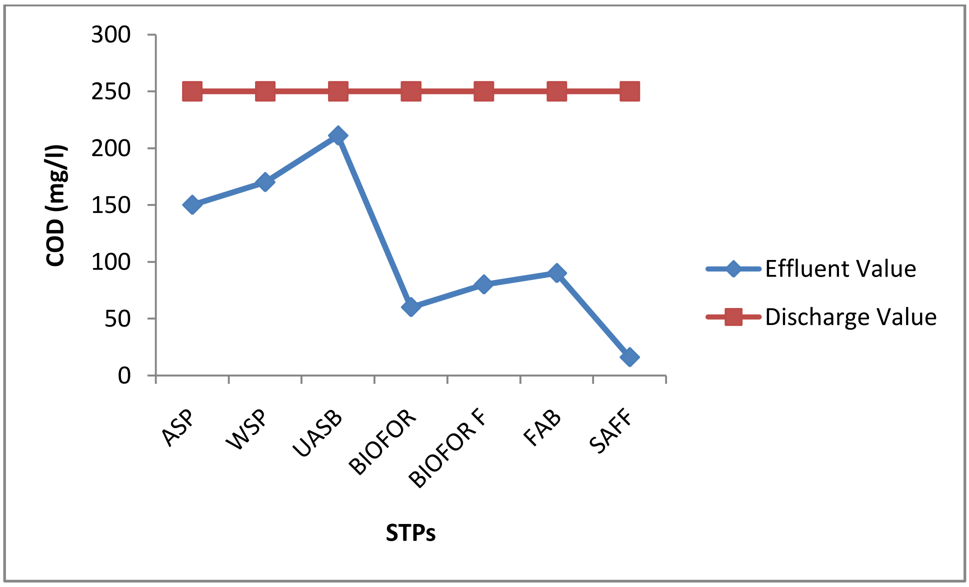

Fig 19: Graph showing the variation of COD for different STPs

From fig 19 and fig 20 we observed that COD of the SAFF having the lowest value 16 mg/l and highest was 211 of UASB plant. SS of the sample from SAFF and BIOFOR having the lowest value 15 mg/l of each and highest was 67.5 of UASB plant. Detailed results of the BOD, COD and SS are shown in figures below.

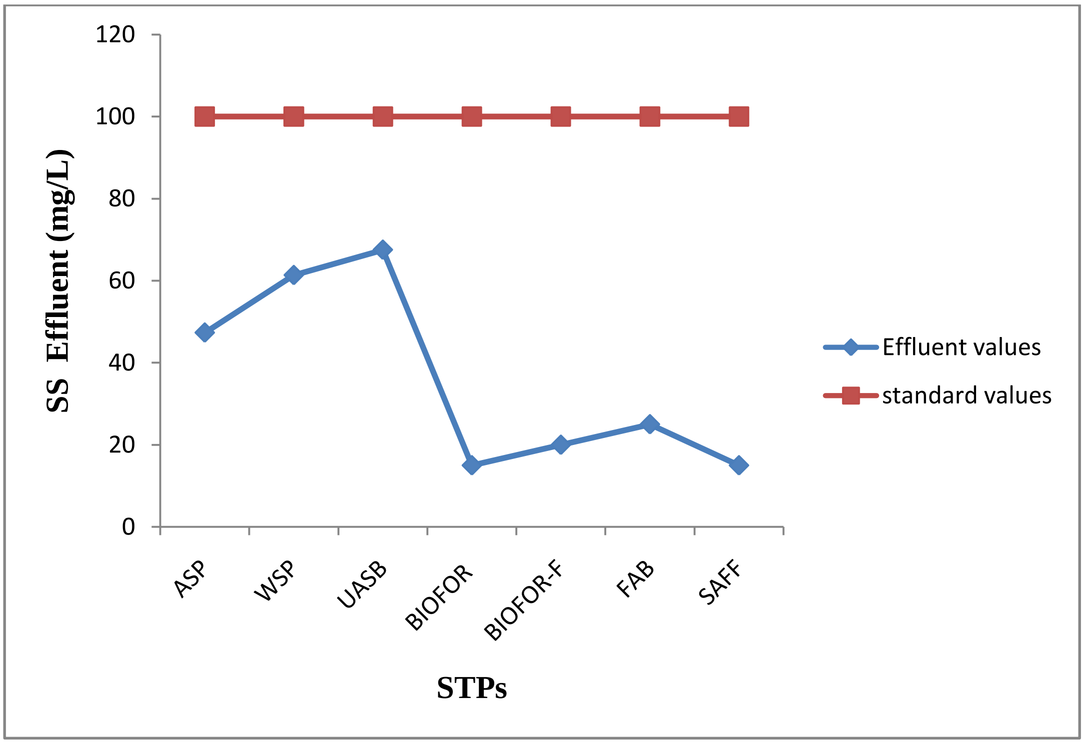

Fig 20: Graph showing the variation of SS for different STPs

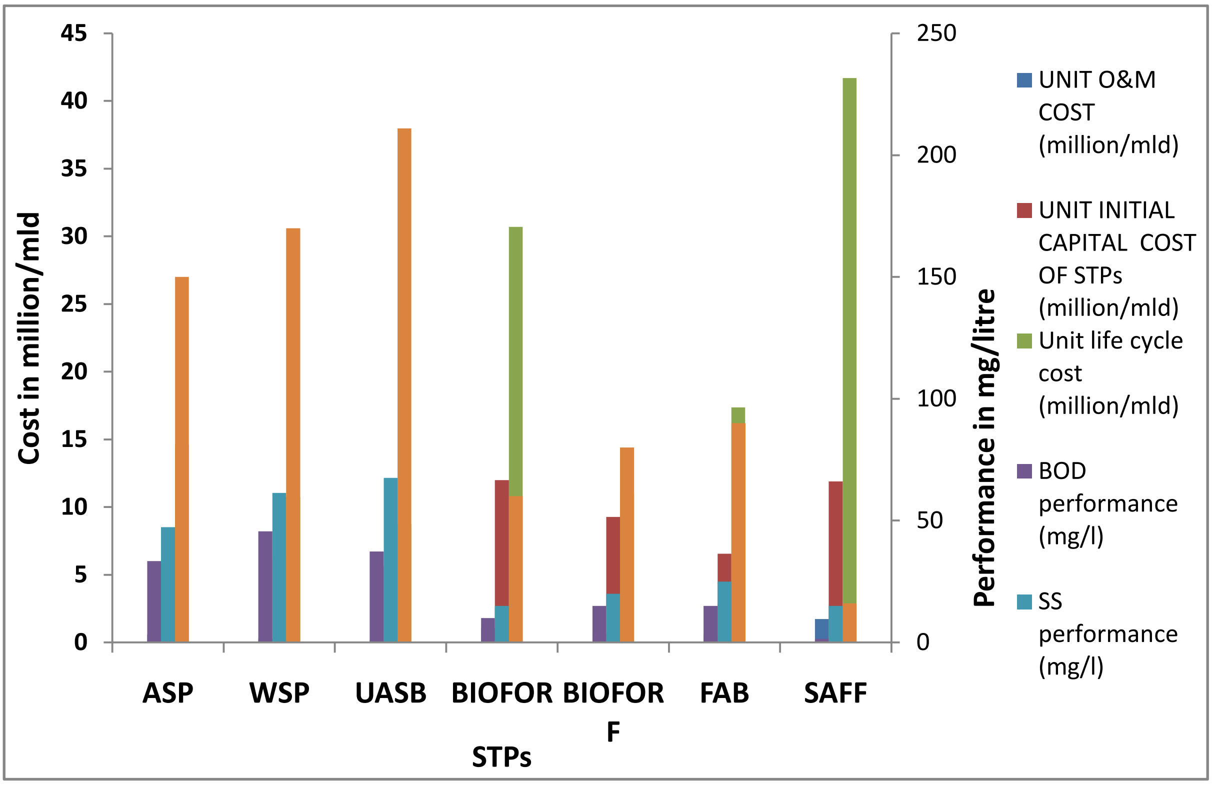

Fig 21: Graphs showing different parameters for different STPs

As per discharge standards of effluent parameters, categorization of technologies. In this approach we are categorising the STPs of different technologies on the basis of availability of funds, requirement of performance level, availability of land.

Category 1:

Technologies with good performance, minimum energy requirement, minimum capital costs, minimum O&M costs, low life cycle cost but high land requirements fall in this category. Waste stabilization pond systems (WSPS). Effluent from this type of systems will meet Indian standards for discharge into water bodies (i.e., BOD_5<30 mg/L, 100< 30 mg/L)

Category 2:

Technologies with good performance, high energy requirement, moderate associated costs, and moderately low land requirements fall in the category. The 1) ASP system and its minor modifications fall in this category. Effluent from this type of systems will meet Indian standards for discharge into water bodies (i.e., BOD_5<30 mg/L, SS< 100 mg/L) .

Category 3:

Technologies with very good performance, very high energy requirement, very high associated costs, and low land requirements fall in this category. Various advanced aerobic processes i.e., BIOFOR, BIOFOR-F, FAB, SAFF are examples of this category of treatment systems. . Effluent from this type of systems will meet Indian standards for discharge into water bodies (i.e., BOD_5<20 mg/L, SS< 20 mg/l).

Category 4:

Technologies with marginal performance, but low energy requirement, minimum associated costs, and moderately low land requirements fall in the category. The UASB based STPs fall in this category. Such a system may not meet the Indian standards(i.e. ,BOD_5<30 mg/L, SS <30 mg/L)for disposal into water bodies even when a Final Polishing Unit (FPU) having 24-48 hr retention time is provided for further treatment of UASB effluent. Beyond this one important approach i.e. decentralization of wastewater treatment plant has also been used now days

5.2 Site based selection of STPs

On the basis of different parameters discussed in the previous sections we have devised a method for the appropriate selection of sewage treatment technology for different locations

Fully developed location

Fully developed locations are described as those where land availability is minimum because population is large but it enjoys all the facilities of power supply, water supply and other resources including adequate funds. So the treatment technology suited for this type of location should have less land requirements and have very good performance. FAB satisfies the above criteria and is the technology of choice for such locations.

Undeveloped location

The characteristics of such locations includes on the one hand, high land availability because population density is very less but on the other hand suffers from the drawbacks of high power cuts, lack of adequate funds. The treatment technology that fits best into this location should not rely on availability of funds and also give moderate performance with the least use of resources. WSP suits the best for this type of location.

Developing location

The most important and complicated of all the locations is the developing locations. Such locations includes, moderate land availability, moderate funds with average resources. The treatment technology suited for this type of locations should have an average of all the qualities. ASP is found to possess such stringent qualities and hence is the method of choice for such locations.

CHAPTER 6

SUMMARY AND CONCLUSIONS

With the help of available data and cost estimations following conclusions can be drawn:

- Efficiency of UASB based STPs is not good
- Efficiency of advance aerobic technology based STPs are very good
- Practically the amounts of energy generation from UASB plants are very less than theoretical calculation. It is economically not feasible to use generators for such small amount of energy generation.
- Resource recovery value is almost negligible in all STPs in comparison to their initial costs
- Only BIOFOR F technology based STP at Rithala is getting 85 percent of its total energy requirement at name of resource recovery
- Due to shortage of land availability for STPs, advanced technologies like FAB, BIOFOR should be promoted. Their performance is also very good
- Most of the advance technology based STPs are based on decentralised approach. Decentralised approach is very useful in case of advance technology use because their BOD, COD and SS effluent values are very less. Effluent water can easily use for gardening purpose.

CHAPTER 7

FUTURE RECOMMENDATIONS

The discount rate and inflation rate in our exercise has been assumed, though realistically but they cannot be considered sacrosanct for all future requirement/estimation/ design. The cost inflation index can be refined further if sufficient data on similar type of construction is available. Here, cost index for building construction will not be appropriate as the construction activity in STPs is of very specialised nature, not covered well in CPWD analysis/schedule of rates.

Additionally we need to quantify the potential to convert the pollutants to recoverable resources. This may include bio-energy recovery, nutrient recovery and utilisation of sludge. Apart from this the green house gas potential of different waste treatment alternation also needs concentration as STPs are regarded as significant source of green house gas emission.

CHAPTER 8

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