TECHNO ECONOMIC EVALUATION OF VARIOUS WASTEWATER TREATMENT PLANTS

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

CONSERVATION OF RIVERS AND LAKES

By

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JUNE, 2008

CANDIDATE'S DECLARATION

I hereby declare that the work which has been presented in the dissertation entitled **"TECHNO ECONOMIC EVALUATION OF VARIOUS WASTEWATER TREATMENT PLANTS"** in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Conservation of Rivers and Lakes,** submitted in Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee, is an authentic record of my own work carried out during the period from July 2007 to June 2008 under the supervision of Dr. Renu Bhargava, Professor, Department of Civil Engineering, Indian Institute of Technology, Roorkee and Shri.M.K.Singhal, Senior Scientific Officer, AHEC, Indian Institute of Technology, Roorkee. The matter embodied in the dissertation has not been submitted by me for the award of any other degree or diploma.

Place: Roorkee

Date: 30th JUNE, 2008

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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ABSTRACT

One of the greatest challenge that India is facing today is the gradual depletion of natural reserve of water and land against the growing demand of water, food and shelter by an ever increasing population, which has crossed the one billion mark. As per the census 2001, the total land area of India is 9600000 sq km and its population 1.027 billion. To feed and supply water to such a gigantic population is a huge task and it surely calls for recycling of water and judicious use of land.

The study highlights the application of the Techno Economic Analysis tools for the selection of appropriate technology of sewage treatment and aims to provide guidance/methodology in incorporating state-of-the-art STP technology selection suitable for urban, semi-urban, mega and metro town, which can significantly cut treatment and disposal costs. As there are many Sewage Treatment technologies available for the treatment and reuse of sewage in India, and in this study five existing sewage treatment technologies that are mostly used are selected for techno evaluation analysis in terms of three basic parameters: BOD, TSS and Fecal Coliform, as per NRCD direction. The economic evaluation of technology is made by calculating the Life cycle cost analysis considering three major variables/parameters that affect the selection, are taken into account for analysis: capital cost, annual maintenance cost, and land cost. Detailed design of various STPs is prepared to arrive the capital cost and land area required per MLD, for life cycle cost analysis.

It is observed that the Waste Stabilization Pond is the most economical and cost effective technology to treat municipal sewage where the cost of land is low i.e. approx. in the range upto Rs. 50 Lacs per ha. Where the cost of land is medium, i.e. beyond Rs. 50 Lacs per ha, the Upflow Anaerobic Sludge Blanket (UASB) with final polishing pond is economical, upto Rs.100Lacs per ha. For high land cost or scarcity of land Fluidized Aerobic Bed (FAB) Reactor, Sequencing Batch Reactor (SBR) & Activated Sludge Process (ASP) are found to be economical. The treated effluent from Sequencing Batch Reactor (SBR) as can be reused for non-potable purpose like, gardening, car washing, toilet flushing, as effective option to conserve the potable water. The revenue generation potential from UASB with FPU is the highest, as the treated effluent preserving N, K, & P, is suitable for irrigation, use of dry sludge as manure, utilization of bio-gas generated for power saving and encouraging aquaculture in FPU.

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AHEC	Alternate Hydro Energy Centre
AM	Annual Maintenance
ASP	Activated Sludge Process
BOD	Biochemical Oxygen Demand
C	Centigrade
CPCB	Central Pollution Control Board
CPHEEO	Central Public and Health Environmental Engineering Organisation
COD	Chemical Oxygen Demand
TVS	Total Volatile Solids
CO_2	Carbon dioxide
DO	Dissolved Oxygen
EB	Electricity Bill
EIA	Environmental Impact Assessment
FAB	Fluidized Aerobic Bed
FC	Feacal Coliform
FPU	Final Polishing Unit
GOI	Government of India
ha	Hectares
HP	Horse Power
HRT	Hydraulic Retention Time
IITR	Indian Institute of Technology, Roorkee
km	kilometer
lpcd	Liters per capita per day
FAB	Fluidized Aerobic Bed
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
mg/l	Milligram per liter
MoEF	Ministry of Environment and Forest
MPN	Most Probable Number

MPS	Main Pumping Station
ml	Milli liter
MLD	Million Liter per Day
MLSS	Mixed Liquor Suspended Solids
NRCD	National River Conservation Directorate
NPV	Net Present Value
OHT	Over Head Tank
O&M	Operation and Maintenance
PLC	Programmable Logic Controller
ROI	Return On Investment
Rs.	Rupees
SBR	Sequencing Batch Reactor
SS	Suspended Solids
STP	Sewage Treatment Plant
SVI	Sludge Volume Index
sqft	Square Feet
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UASB	Upflow Anaerobic Sludge Blanket
UNEP	United Nations Environment Programme
Vs	Versus
WHO	World Health Organization
WSP	Waste Stabilization Pond

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Municipal waste-water is the combination of liquid or water-carried wastes originating in the sanitary conveniences of dwellings, commercial or industrial facilities and institutions, in addition to any groundwater, surface water and storm water that may be present. As per the latest information of CPCB, out of 33,000 million litre of wastewater generated every day from Class-I cities (cities with population >100,000) and class -II towns (population 50,000-100,000), of which only about 30% is collected and treatment capacity exists for less than 20%. Thus a large gap exists between generation and treatment of wastewater.

Wastewaters are waterborne solids and liquids discharged to the sewers and represent the wastewater of community life. In composition wastewater includes dissolved and suspended organic solids, which are "putrescible" or biologically decomposable. Domestic wastewater also contains countless numbers of living organisms - bacteria and other microorganisms whose life activities cause the process of decomposition. When decay proceeds under anaerobic conditions, that is, in the absence of dissolved oxygen in the wastewater, offensive conditions result and odors and unsightly appearances are produced. When decay proceeds under aerobic conditions, that is, in the presence of dissolved oxygen, offensive conditions are avoided and the treatment process is greatly accelerated.

Over the years wastewater treatment management practices have evolved into a technically complex body of knowledge based on past practice and applied engineering and environmental sciences. The intelligent application of these fundamentals goes a long way toward assuring that, the environment will be maintained in a safe and acceptable condition. Wastewater treatment systems are generally capital-intensive and require expensive, specialized/skilled operators. Therefore, before selecting and investing in wastewater treatment technology, it is always preferable to investigate whether pollution can be minimized or prevented. For any pollution control initiative an analysis of cost effectiveness needs to be made and compared with all conceivable alternatives. The technology that is more appropriate in terms of technical acceptability, economic affordability and social attractiveness has to be considered. In developing countries where capital is scare and poorly skilled workers are abundant, solutions to wastewater treatment should preferably be low technology oriented. Technology selection eventually depends upon wastewater characteristics and on the treatment objectives as translated into desired effluent quality. Effluent quality control is typically aimed at public health protection, preservation of the oxygen content in the water, prevention of eutrophication, prevention of sedimentation, preventing toxic compounds from entering the water and food chains and promotion of water reuse. Wastewater needs to be adequately treated prior to disposal or reuse in order to:

1. Protect receiving waters from gross fecal contamination as they are often used as a source of untreated drinking water by downstream communities.
2. Protect receiving waters from deleterious oxygen depletion and ecological damage.
3. Produce microbiologically safe effluents for agricultural and aquacultural reuse.

The latest innovative and technological developments are the changes in process design, which incorporate energy conservation, resource recovery such as nutrient, energy and water for reuse. Even though there are many sewage treatment technologies available, it is difficult to select a technology that is appropriate for the desired treatment. The study highlights the application of the Techno Economic Analysis tools for the selection of appropriate technology of for mega, metro, urban and semi-urban areas.

1.2 OVERVIEW OF TECHNOLOGIES

The selection technologies should be environmentally sustainable, appropriate to the local conditions, acceptable to the user, and affordable to those who have to pay for them. Simple solution that are easily replicable, that allow further upgrading with subsequent development, and that can be operated and maintained by the local community, are often considered the most appropriate and cost-effective. The choice of a treatment system depends on various factors which can be grouped together under three key words: affordability, acceptability and manageability.

Affordability depends on the financial ability of the community to be served and on the requirement of the process in terms of power and land requirement. Acceptability mainly depends upon the performance of the treatment system. The acceptability of the system depends on the pollution control authorities who have to approve the treatment proposed and the riparian public who have to live near the treatment facility and manageability refers to both the routine operation of the plant and its maintenance and repair when needed. If the three key tests of affordability, acceptability and manageability are met by a process or treatment method, it could be considered for adoption as an appropriate technology. Appropriate technology is also most likely to be a sustainable one. In order to arrive at the best feasible sewage treatment option, the following technologies were proposed to be considered for techno-economic evaluation in this study.

1) Activated Sludge Process (ASP).
2) UASB Technology with post treatment final polishing pond (UASB+FPP).
3) Fluidized Aerobic Bed (FAB) reactor.
4) Sequencing Batch Reactor (SBR).
5) Waste Stabilization Pond (WSP).

1.3 OBJECTIVES

The Objectives of the study are:

1. To study the performance efficiency concept to evaluate the optimal use of all the technical parameters of the existing Sewage Treatment Plants (STPs) in India, as per NRCD guidelines.
2. To design and prepare the cost estimate based on PWD schedule of rates, Govt. of West Bengal, of various treatment technologies for Life cycle cost analysis.
3. To examine key issues regarding selection of appropriate Sewage Treatment Technology on the basis of life cycle cost and performance.
4. To arrive at the best feasible sewage treatment option separately for the urban, semi-urban, medium and small size cities/towns, mega and metropolitan areas in India, from economic point of view through Life cycle cost analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

An understanding of the nature of waste-water is fundamental for the design of appropriate wastewater treatment plants and the selection of effective treatment technologies. Waste-water originates predominantly from water usage by residences and commercial and industrial establishments, together with groundwater, surface water and storm water (shown in figure 2.1). Consequently, waste-water flow fluctuates with variations in water usage, which is affected by a multitude of factors including climate, community size, living standards, dependability and quality of water supply, water conservation requirements or practices, and the extent of meter services, in addition to the degree of industrialization, cost of water and supply pressure.

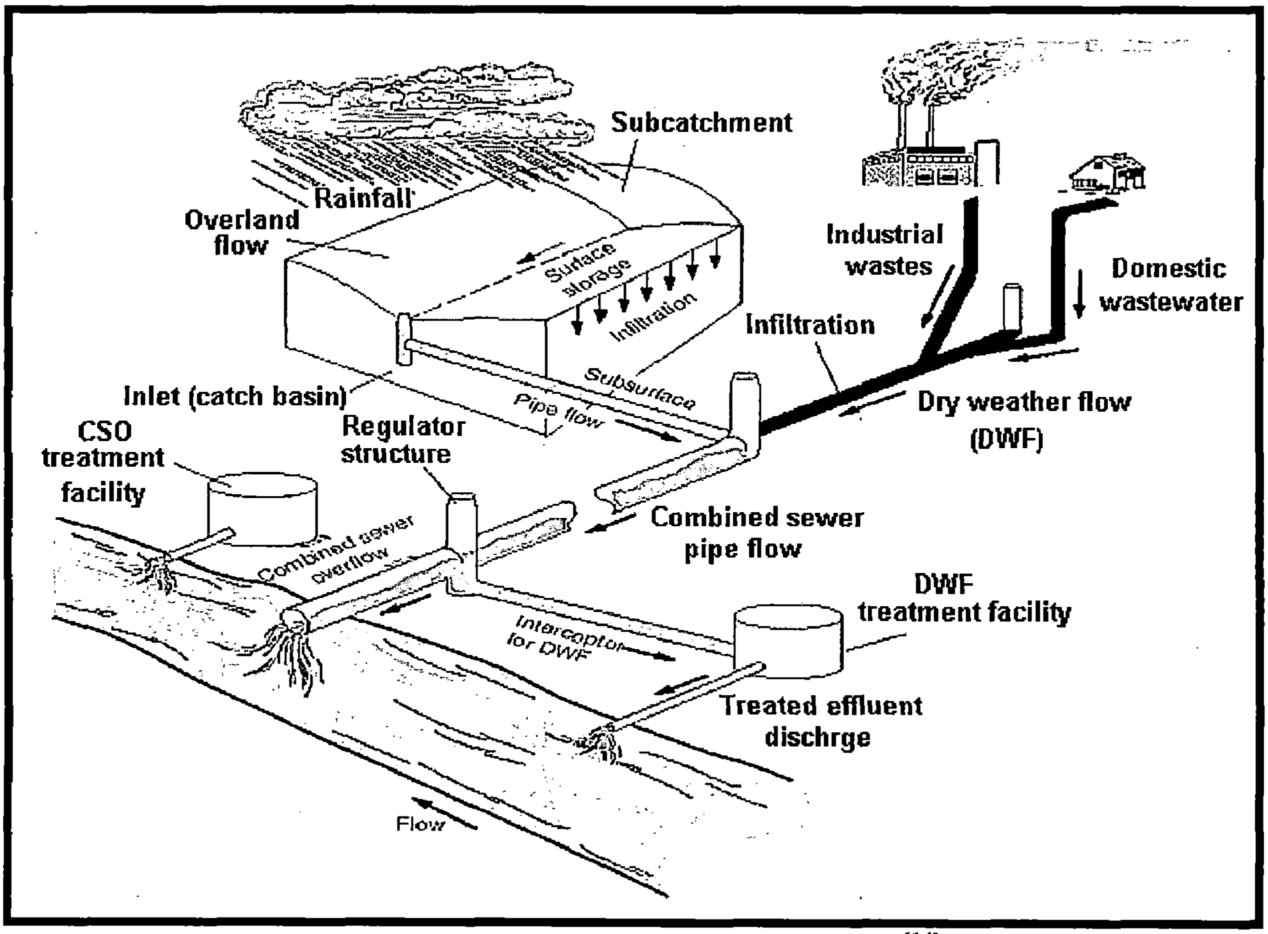


Figure 2.1: Sources of wastewater[14]

Wastewater quality may be defined by its physical, chemical, and biological characteristics. Physical parameters include colour, odour, temperature, and turbidity. Insoluble contents such as solids, oil and grease, also fall into this category. Solids may be further subdivided into Suspended and dissolved solids as well as organic (volatile) and inorganic (fixed) fractions. Chemical parameters associated with the organic content of waste-water include biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). Inorganic chemical parameters include salinity, hardness, pH, acidity and alkalinity, as well as concentrations of ionized metals such as iron and manganese, and anionic entities such as chlorides, sulfates, sulfides, nitrates and phosphates. Bacteriological parameters include coliforms, fecal coliforms, specific pathogens, and viruses. Both constituents and concentrations vary with time and local conditions. Annexure – I, shows typical concentration ranges for various constituents in untreated domestic waste-water. Wastewater is classified as strong, medium or weak, depending on its contaminant concentration. The effects of the discharge of untreated wastewater into the environment are manifold and depend on the types and concentrations of pollutants. Important contaminants in terms of their potential effects on receiving water and treatment concerns are outlined in Annexure - I.

2.2 NEED FOR WASTEWATER TREATMENT

The problem of wastewater disposal developed with man's use of water as a vehicle for carrying away the waste products of human life. Prior to that the volume of wastes, without the water vehicle, was small and disposal was largely restricted to the individual's or family's excreta. The earliest practice was simply to leave body waste and garbage on the surface of the ground where it was gradually decayed by bacteria, mostly the saprophytic anaerobic type. This caused the production of foul odors. Later, experience showed that if these wastes were promptly buried the odors could no longer be detected. Burial of human waste is a very ancient practice and even has biblical references. The next logical step was the development of the earth privy or outhouse, a method for the disposal of excremental wastes which is still widely used.

With urbanization and the development of community water supplies and the use of water to flush or transport wastes from habitations, it became necessary to find disposal methods not only for the wastes themselves, but for the water which carried them. All of the three possible methods:- irrigation, subsurface disposal and dilution, were employed. As urban communities increased in population, with proportional increase in the volume of wastewater and in the amount of organic waste, all methods of disposal resulted in such unsatisfactory conditions that remedial measures became essential and the development of methods of treatment of wastewaters prior to ultimate disposal was started.

The objectives originally sought in wastewater treatment:

1. Protection and maintenance of sources for use as domestic water supplies.
2. Prevention of disease and spread of diseases.
3. Maintenance of clean waters for bathing and other recreational purposes.
4. Protection and maintenance of the environment. For example, maintaining natural waters for the propagation and survival of fish life.

A wastewater treatment plant is designed to remove from the wastewater enough organic and inorganic solids so that it can be disposed of without contravening or affecting the objectives sought. Treatment devices merely localize and confine these processes to a restricted, controlled, suitable area or environment and provide favorable conditions for the acceleration of the physical and biochemical reactions. The extent or degree of treatment needed varies greatly from place to place and is regulated by law. In general, the following are the determining factors.

1. The character and amount of the solids carried by the wastewater, i.e. BOD and suspended solids present.
2. The objectives sought.
3. The ability or capacity of the land (in disposal by irrigation and subsurface disposal) or the receiving water (in disposal by dilution) to handle by self-purification or dispersal the water and solids in the wastewaters.
4. Legal aspects and constraints.

The degree of wastewater treatment required to satisfy the first three conditions above is variable and is highly dependent on the local conditions and needs. Simple settling or even the mere removal of floating solids by screens may be adequate for wastewaters under certain conditions, while a very high removal of suspended solids, decomposition of dissolved organic solids and destruction of pathogenic organisms may be required before discharge to a river which is used downstream as a source of public water supply. After the disposal of the wastewater effluent from a treatment plant, there still remains in the plant the solids and water constituting the sludge which has been removed from the wastewater. This too must be disposed of safely and without nuisance. The progress of self-purification of a stream can be measured by appropriate physical, chemical and biological laboratory tests.

2.3 WASTEWATER TREATMENT METHODS

As treatment methods range from the physico-chemical to the biological, from the aerobic to anaerobic, wastewater treatment methods are broadly classifiable into physical, chemical and biological processes. Figure 2.2 lists the unit operations included within each category.

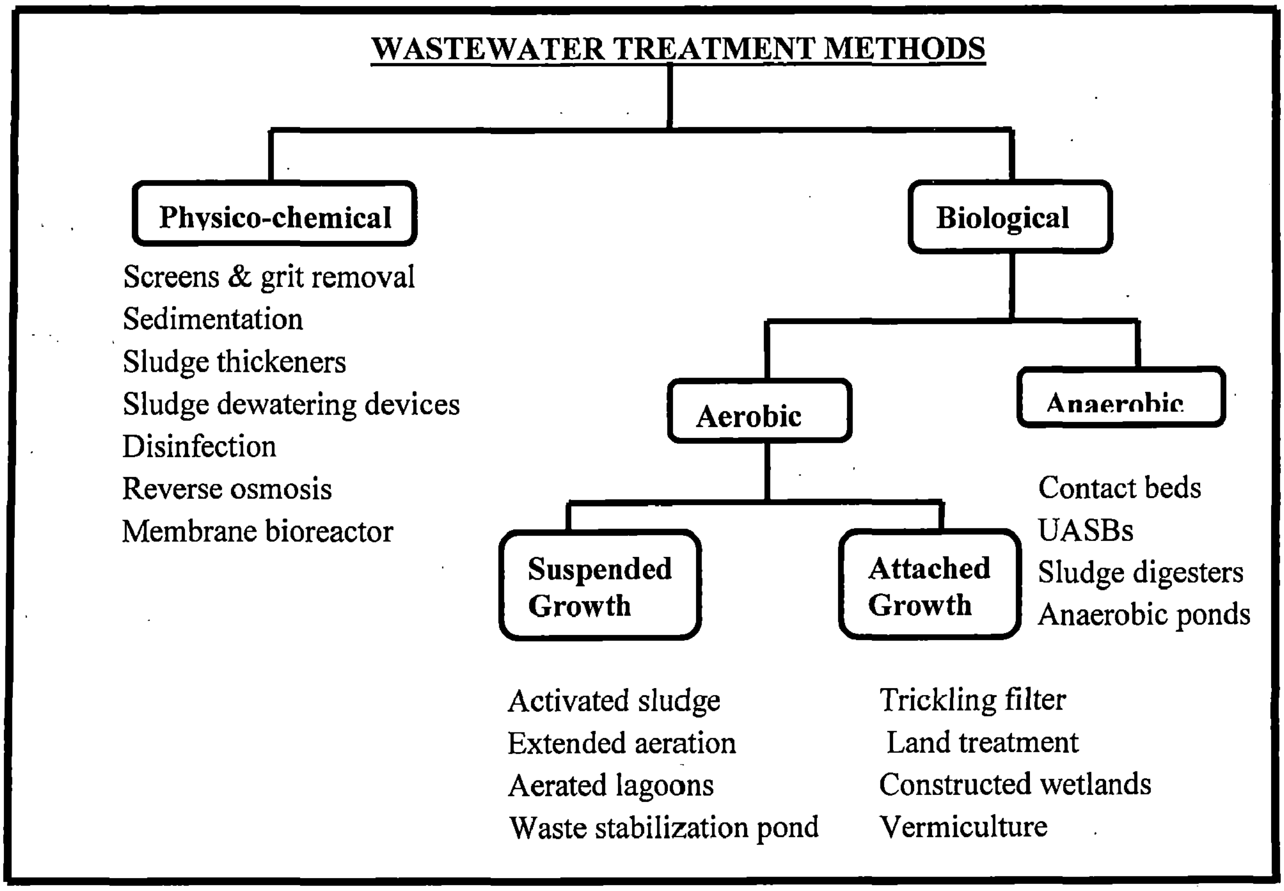


Figure 2.2: Wastewater treatment methods

2.3.1 Physico-Chemical Unit Operations

Among the first treatment methods used were physical unit operations, in which physical forces are applied to remove contaminants. Today, they still form the basis of most process flow systems for wastewater treatment. This section briefly discusses the most commonly used physical unit operations.

Screening

The screening of wastewater, one of the oldest treatment methods, removes gross pollutants from the waste stream to protect downstream equipment from damage, avoid interference with plant operations and prevent objectionable floating material from entering the primary settling tanks. The material retained from the manual or mechanical cleaning of bar racks and screens is referred to as "screenings", and is either disposed of by burial or incineration, or returned into the waste flow after grinding.

Sedimentation

Sedimentation, a fundamental and widely used unit operation in wastewater treatment, involves the gravitational settling of heavy particles suspended in a mixture. This process is used for the removal of grit, particulate matter in the primary settling basin, biological floc in the activated sludge settling basin, and chemical flow when the chemical coagulation process is used. Sedimentation takes place in a settling tank, also referred to as a clarifier. There are three main designs, namely, horizontal flow, solids contact and inclined surface. Four types of settling occur, depending on particle concentration: discrete, flocculent, hindered and compression. It is common for more than one type of settling to occur during a sedimentation operation.

Sludge dewatering devices: flotation

Flotation is a unit operation used to remove solid or liquid particles from a liquid phase by introducing a fine gas, usually air bubbles. The gas bubbles either adhere to the liquid or are trapped in the particle structure of the suspended solids, raising the buoyant force of the combined particle and gas bubbles. Particles that have a higher density than the liquid can thus be made to rise. In wastewater treatment, flotation is used mainly to remove suspended matter and to concentrate biological sludge. The chief advantage of flotation over sedimentation is that very small or light particles can be removed more completely and in a shorter time. Once the particles have been floated to the surface, they can be skimmed out. Flotation, as currently practiced in municipal wastewater treatment, uses air exclusively as the floating agent.

Disinfection

Disinfection refers to the selective destruction of disease-causing micro-organisms. This process is of importance in waste-water treatment owing to the nature of waste-water, which harbours a number of human enteric organisms that are associated with various waterborne diseases. Commonly used means of disinfection include the following:

1. Physical agents such as heat and light;
2. Mechanical means such as screening, sedimentation, filtration, and so on;
3. Chemical agents including chlorine and its compounds, bromine, iodine, ozone, phenol and phenolic compounds, alcohols, heavy metals, dyes, soaps and synthetic detergents, quaternary ammonium compounds, hydrogen peroxide, and various alkalis and acids. The most common chemical disinfectants are the oxidizing chemicals, and of these, chlorine is the most widely used.

2.3.2 Biological Unit Processes

Biological unit processes are used to convert the finely divided and dissolved organic matter in wastewater into flocculent settleable organic and inorganic solids. In these processes, micro-organisms, particularly bacteria, convert the colloidal and dissolved carbonaceous organic matter into various gases and into cell tissue which is then removed in sedimentation tanks. Biological processes are usually used in conjunction with physical and chemical processes, with the main objective of reducing the organic content (measured as BOD, TOC or COD) and nutrient content (notably nitrogen and phosphorus) of waste-water. Biological processes used for waste-water treatment may be classified under three major headings:

1. Aerobic processes;
2. Anaerobic processes;
3. Anoxic processes;

Aerobic Process:

A biological process, in which, organisms use available organic matter to support biological activity. The process uses organic matter, nutrients, and dissolved oxygen, and produces stable solids, carbon dioxide, and more organisms (shown in figure 2.3). The microorganisms which can only survive in aerobic conditions are known as aerobic organisms.

Anoxic process:

In sewer lines the sewage becomes anoxic if left for a few hours and becomes anaerobic if left for more than 1.5 days. Anoxic organisms work well with aerobic and anaerobic organisms. A biological process in which a certain group of microorganisms use chemically combined oxygen such as that found in nitrite and nitrate. These organisms consume organic matter to support life functions (Figure 2.4). They use organic matter, combined oxygen from nitrate, and nutrients to produce nitrogen gas, carbon dioxide, stable solids and more organisms.

Anaerobic decomposition:

A biological process, in which, decomposition of organic matter occurs without oxygen. Two processes occur during anaerobic decomposition, shown in Figure 2.5. First, facultative acid forming bacteria use organic matter as a food source and produce volatile (organic) acids, gases such as carbon dioxide and hydrogen sulfide, stable solids and more facultative organisms. Second, anaerobic methane formers use the volatile acids as a food source and produce methane gas, stable solids and more anaerobic methane formers. The methane gas produced by the process is usable as a fuel. The methane former works slower than the acid former, therefore the pH has to stay constant consistently, slightly basic, to optimize the creation of methane. The anaerobic processes generate energy in the form of biogas, and produce sludge in significantly lower amounts than those resulting from aerobic systems.[27]

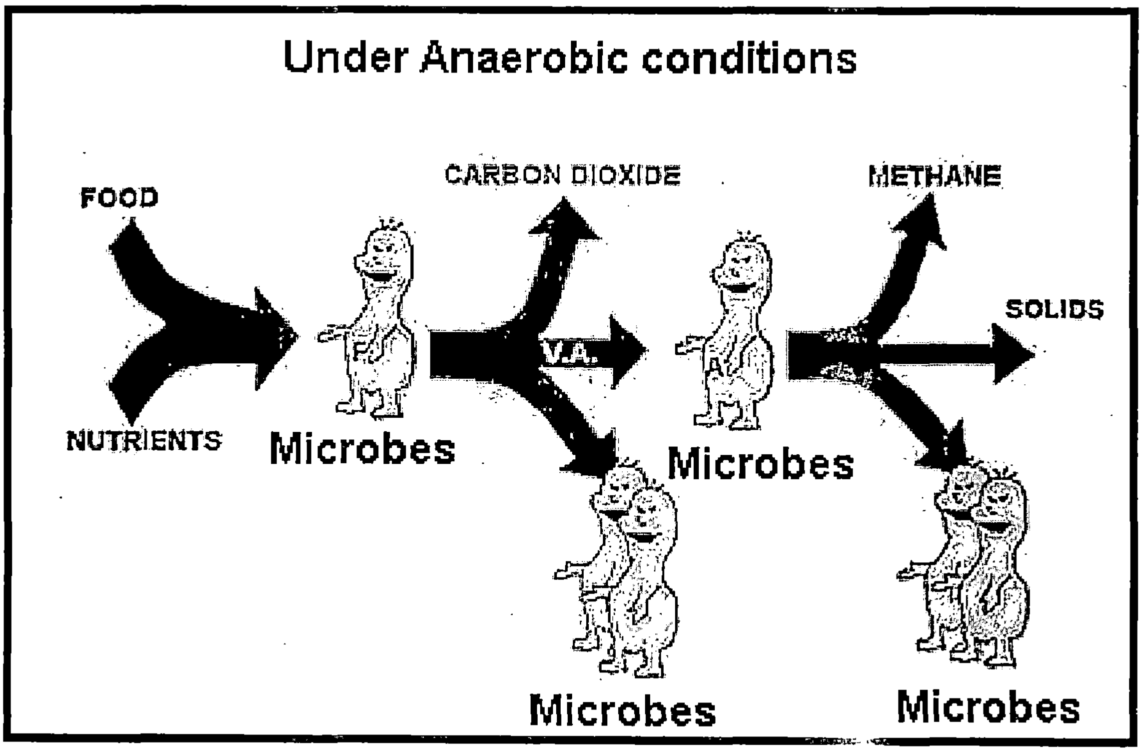


Figure 2.3: Process of aerobic decomposition

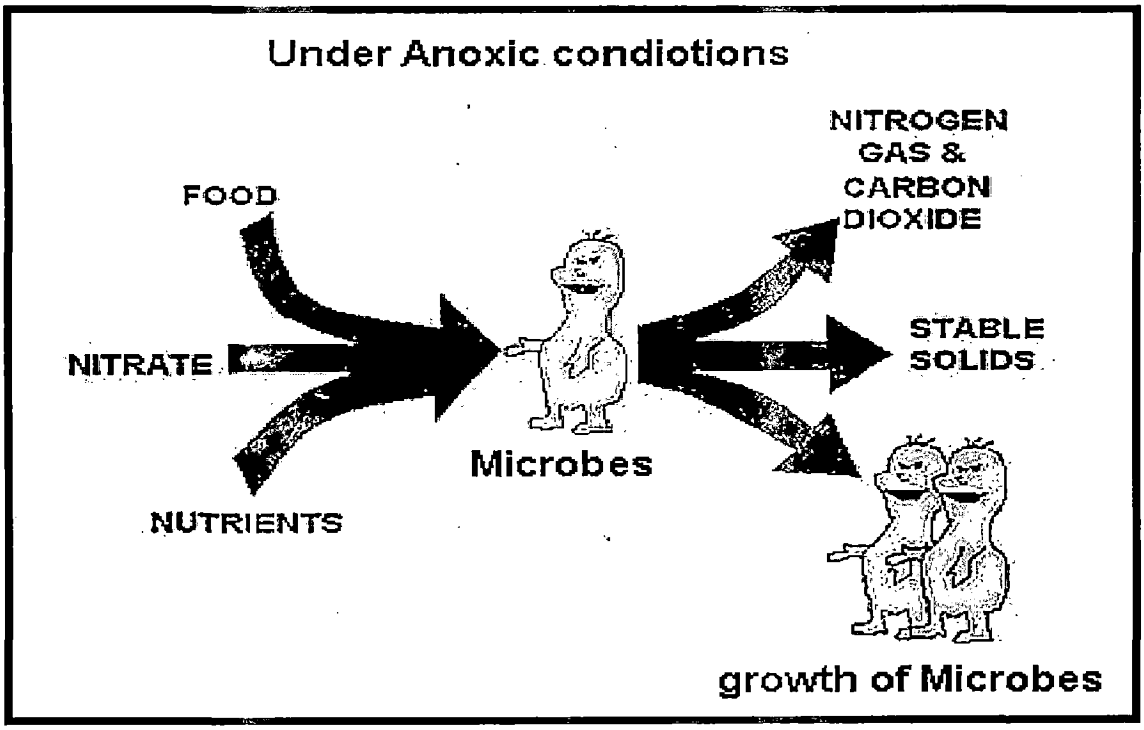


Figure 2.4: Process of anoxic decomposition

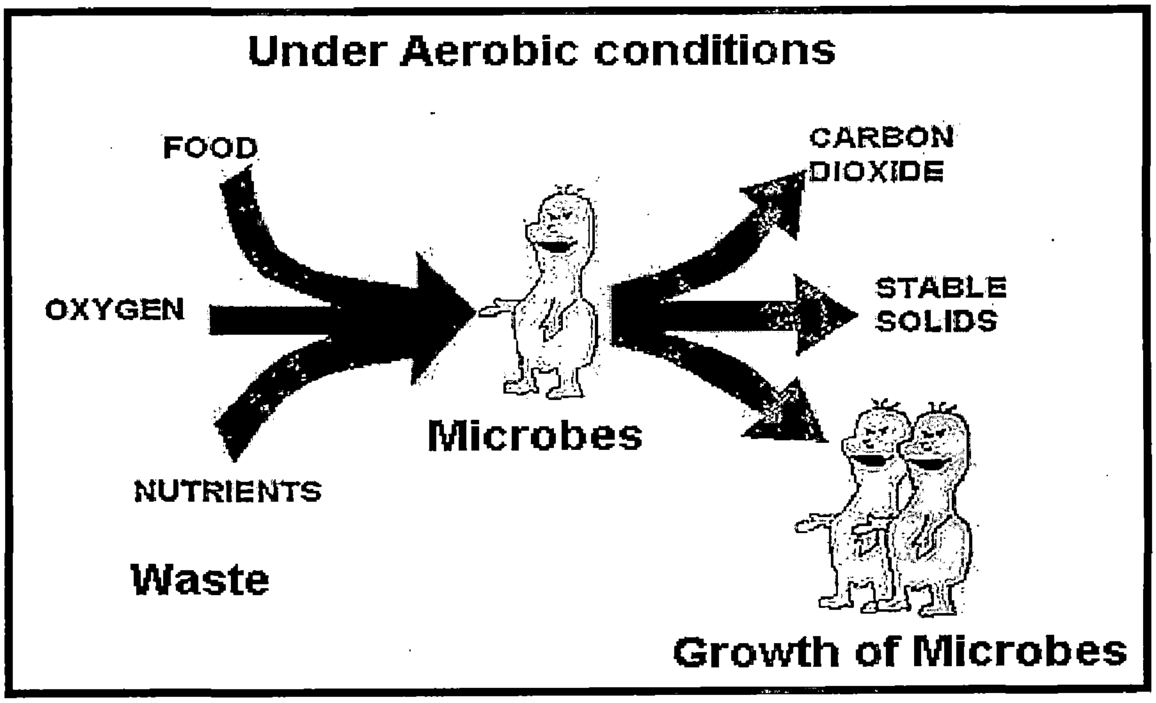


Figure 2.5: Process of anaerobic decomposition

2.4 WASTEWATER TREATMENT TECHNOLOGIES

Physical, chemical and biological methods are used to remove contaminants from waste-water. In order to achieve different levels of contaminant removal, individual waste-water treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary waste-water treatment. More rigorous treatment of waste-water includes the removal of specific contaminants as well as the removal and control of nutrients. Natural systems are also used for the treatment of waste-water in land-based applications. Sludge resulting from waste-water treatment operations is treated by various methods in order to reduce its water and organic content and make it suitable for final disposal and reuse. There are various conventional and advanced technologies in current use which explains how they are applied for the effective treatment of municipal waste-water.

The selection technologies should be environmentally sustainable, appropriate to the local conditions, acceptable to the user, and affordable to those who have to pay for them. Simple solution that are easily replicable, that allow further upgrading with subsequent development, and that can be operated and maintained by the local community, are often considered the most appropriate and cost-effective. (WHO/UNEP, 1997).

As treatment methods range from the physico-chemical to the biological, from the aerobic to anaerobic, the following technologies are considered for study.

1. Activated Sludge Process (ASP).
2. UASB Technology with post treatment final polishing pond (UASB+FPP).
3. Fluidized Aerobic Bed Reactor (FAB).
4. Sequencing Batch Reactor (SBR).
5. Waste Stabilization Pond (WSP).

2.4.1 Activated Sludge Process (ASP)

The activated sludge process is an anaerobic suspended growth process generally used in mechanized plants. In a complete mixing activated sludge system, the raw water undergoes screening, grit removal and primary settling before aeration. The wastewater is then aerated and the mixed liquor from the aeration tank is settled to give a clear supernatant which may be disinfected and discharged or treated further depending upon intended end-uses. The sludge withdrawn from settling tank is called the activated sludge. It is recycled to aeration tank, while a small fraction wasted in order to keep the system in steady state. The fraction wasted is generally mixed with primary sludge, thickened and digested, anaerobically, before being dewatered.

Wastewater is aerated in a tank where bacteria are encouraged to grow by providing oxygen, food (BOD), Nutrients, correct temperature and time. As bacteria consume BOD, they grow and multiply. Treated wastewater flows into secondary clarifier while bacterial cells settle, removed from clarifier as sludge and part of sludge is recycled back to activated sludge tank to maintain bacteria population and remainder of sludge is wasted. It is probably the most widely used biological process for the treatment of organic and industrial waste waters. This process simply creates an agitated environment where the same microbes are able to stabilise the degradable material at a fast rate than before suspended and colloidal material is removed rapidly from the waste water by adsorption and agglomeration on to the microbial flocs.

Advantages:-

1. The treated effluent is of very good quality.
2. Methane gas can be recovered having energy value, can be utilised as fuel.
3. It is very flexible and can be adopted to almost any type of biological waste treatment problem.

Disadvantages:-

1. The major problems encountered in the operation of an ASP are sludge bulking, rising sludge and Nacardia foam.
2. The cost for installation is higher than UASB plant.
3. For operating ASP large electric power is required.
4. It involves a large no. of electro-mechanical equipment which need high technical and skilled personnel.

2.4.2 Upflow Anaerobic Sludge Blanket (UASB).

Upflow Anaerobic Sludge Blanket (UASB) technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used in the treatment of wastewater. It is an anaerobic treatment system wherein the organic matter is digested, absorbed and metabolized into bacterial cell mass and bio gas. Anaerobic digestion is the degradation of organic material without the aid of oxygen. The UASB process is a combination of physical and biological processes. The main feature of physical process is separation of solids and gases from the liquid and that of biological process is degradation of decomposable organic material under anaerobic conditions. The bio gas produced is collected in a gas collector (gas holder) from where it is withdrawn, the remaining water sludge mixture enters a settling compartment where the sludge can settle and flow back into the digestion compartment. after settling, the water is collected in the effluent gutters and discharged out of the reactor to the final polishing unit (FPU) to meet discharge standards.

The domestic waste water treated in a UASB reactor is suitable for discharge in river water or for irrigation after polishing in a high rate pond. the bio gas generated can be utilised for generating electricity. Sludge cakes after de-watering and drying on sludge dry beds is suitable for use as manure

Advantages:-

1. The cost of UASB plant is significantly lower than that of aerobic plant.
2. This has a negligible number of electrical and mechanical components, thus requiring low degree of maintenance and saves operational and maintenance cost.
3. This also eliminates possibilities of problem that may arise in case of brake down of highly maintained intensive process.
4. The energy requirement in the UASB reactor is very low.
5. UASB system generates energy in the form of bio gas which can be used for the production of electricity and which can make UASB plants self sustaining for power requirement.
6. This system reduces the space requirement, which is a big advantage for developing cities.
7. The production of excess sludge in a UASB reactor is very low. This reduces the load on the sludge treatment system. However, the sludge from UASB plant is very stabilized and can be used as manure.
8. Final polishing pond can be used for fish culture, which can be source of revenue.

Disadvantages:-

1. The capital cost of the UASB system will be higher if post-treatment is required for meeting discharge standards.
2. The corrosive potential of anaerobic system is a major negative point and makes it important to choose the right construction materials.

3. The optimum pH range is from 6.6 to 7.6. The wastewater temperatures should not be <5°C because low temperatures can impede the hydrolysis rate of phase 1 and the activity of methanogenic bacteria. Therefore in winter season, methane gas may be needed to heat the wastewater to be treated in the reactor.
4. The SS concentration in the feed to the reactor should not exceed 500 mg/l.

2.4.3 Fluidized Aerobic Bed Reactor (FAB)

This Sewage Treatment Plant is based on the Fluidized Aerobic Bed (FAB) technology. Since the process is aerobic hence air is supplied to sewage in which micro organism metabolize the soluble and suspended organic matter. Part of the organic matter is synthesis in to new cells and part is oxidized to carbon dioxide and water, so this procedure does not exit any foul gases. Hence no odor problem occurs by this STP. In fluidized bed reactors, cells are "immobilized" in small particles, which move with the fluid. The small particles create a large surface area for cells to stick to and enable a high rate of transfer of oxygen and nutrients to the cells. The fluidized bed reactor is most suitable when a high viscosity substrate solution and a gaseous substrate or products are used in a continuous reaction system.

Advantages:-

The sewage treatment has following advantages over conventional activated sludge processes.

1. Small space requirement:- This occupy much less space, making the plants more manageable.
2. Lower operating power requirements: The system utilizes aeration tanks of much smaller size, thereby reducing the overall power required in aeration the raw sewage.
3. Low temperature sustaining capability: It operates in low temperatures too, which are experienced for the least 2-3 months in a year.
4. Simplicity: The system adopted has much less moving part (only pumps blowers) and all the pumps / blowers are manufactures in India only, and hence there is no problem of availability of spaces.
5. E-Coli: The bio-reactor system adopted in STPs is provided with removal of disease causing E-coli bacteria.

6. Coliform removal: Most of the coliform are killed in the reactor itself and remaining coliforms are killed by nominal chlorine dosing (of the order of 2-3 mg/l).
7. Sludge handling: The sludge generated in the bio-reactors is totally digested & it does not envisage any sludge digestion.
8. Sludge production: It produced much small quantity of sludge which requires no further treatment such as digestion, so biogas can not be produced by this technology.

Disadvantages:-

1. There is no N, P removal in FAB.
2. Treated effluent is not as good as SBR.
3. It requires highly trained and skilled personnel for operating the plant.

2.4.4 Sequencing Batch Reactor (SBR)

The sequencing batch reactor (SBR) is a fill-and-draw activated sludge system for wastewater treatment. In this system, wastewater is added to a single "batch" reactor, treated to remove undesirable components, and then discharged. Equalization, aeration, and clarification can all be achieved using a single batch reactor. To optimize the performance of the system, two or more batch reactors are used in a predetermined sequence of operations. SBR systems have been successfully used to treat both municipal and industrial wastewater. They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions. Fill-and-draw batch processes similar to the SBR are not a recent development as commonly thought.

The SBR system can be designed with the ability to treat a wide range of influent volumes whereas the continuous system is based upon a fixed influent flowrate. Thus, there is a degree of flexibility associated with working in a time rather than in a space sequence. An appropriately designed SBR process is a unique combination of equipment and software. Working with automated control reduces the number of operator skill and attention requirement. The availability of artificial intelligence has now made the option of a SBR process more attractive thus providing better controls and results in wastewater treatment. This is coupled by the flexibility of a SBR in the treatment of variable flows, minimum operator interaction required, option for anoxic or anaerobic conditions in the same tank, good oxygen contact with microorganisms and substrate, small floor space, and good removal efficiency. SBRs produce sludges with good settling properties providing the influent wastewater is admitted into the aeration in a controlled manner.

Advantages:-

1. Sequencing Batch Reactor (SBR) is a tool to Combat Against the Bulking Sludge
2. Equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved in a single reactor vessel.
3. Operating flexibility and control and it's operation is more stable.
4. Minimal footprint.
5. Potential capital cost savings by eliminating clarifiers and other equipment as no separate settling tank, pump or pipings are required.

Disadvantages:-

1. A higher level of sophistication is required (compared to conventional systems), especially for larger systems, of timing units and controls.
2. Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches, and automated valves.
3. Potential of discharging floating or settled sludge during the DRAW or decant phase with some SBR configurations.
4. Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.
5. Potential requirement for equalization after the SBR, depending on the downstream processes.

2.4.5 Waste Stabilization Pond (WSP)

A waste stabilization pond is a relatively shallow body of wastewater contained in an earthen basin, using a completely mixed biological process without solids return. Mixing may be either natural (wind, heat or fermentation) or induced (mechanical or diffused aeration). Stabilization ponds are usually classified, on the basis of the nature of the biological activity that takes place in them, as aerobic, anaerobic, or aerobic-anaerobic.

Aerobic ponds are used primarily for the treatment of soluble organic wastes and effluents from waste-water treatment plants. Aerobic-anaerobic (facultative) ponds are the most common type and have been used to treat domestic waste-water and a wide variety of industrial wastes. Anaerobic ponds, for their part, are particularly effective in bringing about rapid stabilization of strong concentrations of organic wastes. Aerobic and facultative ponds are biologically complex. The bacterial population oxidizes organic matter, producing ammonia, carbon dioxide, sulfates, water and other end products, which are subsequently used by algae during daylight to produce oxygen. Bacteria then use this supplemental oxygen and the oxygen provided by wind action to break down the remaining organic matter. This is a treatment process that is very commonly found in rural areas because of its low construction and operating costs.

Advantages:-

1. Stabilization pond can be cost-effective to design and construct in areas where land is inexpensive.
2. They use less energy than most wastewater treatment methods.
3. They are simple to operate and maintain and generally require only part-time staff.
4. The effluent from lagoon systems can be suitable for irrigation (where appropriate), because of its high-nutrient and low pathogen content.

Disadvantages:-

1. They are less efficient in cold climates and may require additional land or longer detention times in these areas.
2. Odor can become a nuisance during algae blooms, spring thaw in cold climates, or with anaerobic ponds and ponds that are inadequately maintained.
3. Unless they are property maintained, lagoons can provide a breeding area for mosquitoes and other insects.
4. They are not very effective at removing heavy metals from wastewater effluent from some types of lagoons contains algae and often requires additional treatment or "polishing" to meet local discharge standard.

2.5 CRITERIA FOR TECHNICAL EVALUATION OF WASTEWATER TREATMENT TECHNOLOGY[14]

The selection of suitable method for sewage treatment for a given situation depends upon the following factors: volume of daily flow to be treated, area of land required for the installation of the plant, the method of supply of oxygen to the microorganisms, mechanical equipment involved in the method, ease of operation and maintenance, capital cost for the installation of the plant, and annual operation and maintenance cost etc. The amount of sludge produced by each technology and the cost of its disposal also can be considered. As the sewage treatment technology is a combination of various unit operations and processes, the following important factors must be considered when evaluating and selecting the unit operations and processes as stated in Table 2.1 and accordingly evaluation of various technologies is presented in Table 2.2. The selection of an appropriate sewage treatment technology is a method or a technique, which provides a socially and environmentally acceptable level of service or quality of project with full health benefits and at the least economic cost. The factors to be considered in technology selection are:-

1. Common scale to compare the overall performance of alternatives.
2. The progressive aspiration of the community, and
3. The effects of inequalities in the levels of society and technology.

Table: 2.1: Factors for evaluating and selecting the unit operations and processes.

Sl.No.	Parameters	Objectives
1.	Process applicability	The applicability of a process is evaluated on the basis of past experience, data from full-scale plants, published data, and from pilot-plant studies. If new or unusual conditions are encountered, pilot-plant studies are essential.
2.	Performance	Performance is usually measured in terms of effluent quality and its variability, which must be consistent with the effluent discharge requirements.
3.	Treatment residuals	The types and amounts of solid, liquid, and gaseous residuals produced must be known or estimated.
4.	Sludge processing	Are there any constraints that would make sludge processing and disposal infeasible or expensive? How might recycle loads from sludge processing affect the liquid unit operations or processes? The selection of the sludge processing system should go hand in hand with the selection of the liquid treatment system.

Sl.No.	Parameters	Objectives
5.	Chemical requirements	What resources and what amounts must be committed for a long period of time for the successful operation of the unit operation or process?
6.	Energy requirements	The energy requirements, as well as probable future energy cost, must be known if cost-effective treatment systems are to be designed.
7.	Other resource requirements	What, if any, additional resources must be committed to the successful implementation of the proposed treatment system using the unit operation or process being considered?
8.	Personnel requirements	How many people and what levels of skills are needed to operate the unit operation or process? Are these skills readily available? How much training will be required?
9.	Operating and maintenance requirements	What special operating or maintenance requirements will need to be provided? What spare parts will be required and what will be their availability and cost?
10.	Reliability	What is the long-term reliability of the unit operation or process being considered? Is the operation or process easily upset? Can it stand periodic shock loadings?
11.	Complexity	How complex is the process to operate under routine or emergency conditions? What levels of training must the operators have to operate the process?
12.	Compatibility	Can the unit operation or process be used successfully with existing facilities? Can plant expansion be accomplished easily?
13.	Adaptability	Can the process be modified to meet future treatment requirements?
14.	Economic life-cycle analysis	Cost evaluation must consider initial capital cost and long-term operating and maintenance costs. The plant with lowest initial capital cost may not be the most effective with respect to operating and maintenance costs.

Sl.No.	Parameters	Objectives
15.	Land availability	Is there sufficient space to accommodate not only the facilities currently being considered but possible future expansion? How much of a buffer zone is available to provide landscaping to minimize visual and other impacts?

Table 2.2: Evaluation of various available technologies

Description	WSP	UASB+FPP	ASP	FAB	SBR
Type of Process	Aerobic Suspended growth process.	Anaerobic Suspended growth process	Aerobic Suspended growth process	Aerobic. Fixed film attached growth process.	Aerobic, suspended growth process.
Principle of operation	Organic matter converted to new cell mass with the aid of sunlight algal growth photosynthesis	Organic matter is reduced by anaerobic bacteria present in the sludge blanket.	The organic matter is brought in contact with bacteria in suspension.	Organic matter is brought in contact with bacteria attached to plastic media, which is in suspension.	Filling, Aeration, Settling and decanting carried out in a single or more Tank in batches.
Mode of Oxygen supply	No external supply of oxygen is required.	No oxygen supply is required.	Oxygen is supplied by surface aerators.	Oxygen is supplied by blowers through air grid system.	Oxygen is supplied by blowers through diffusers.
Sludge recirculation in the reactor	Not required.	Not required	Sludge recirculation to maintain MLSS in aeration tank	Not required.	Optional.
Process variables	No monitoring Natural process depends on Temperature Wind.	Volatile fatty acids, sludge blanket levels, alkalinity, pH must be checked on daily basis.	MLSS, SVI, F/M ratio must be monitored. Sludge recycle and wastage shd be controlled	No sludge volume index / recycle need be checked. System is self sustaining Excess biomass automatically gets wasted off.	Oxygen requirement monitoring by sensor. All operations are done by PLC system.

Description	WSP	UASB+FPP	ASP	FAB	SBR
Cost for installation	Less, easy construction	Medium	Higher than USAB	Slightly higher than ASP	High
Annual Maintenance	Less, easy to maintain, no skilled personnel required.	Slightly higher than WSP Requires Skilled personnel.	High, Requires technical and skilled personnel.	Slightly lower than ASP but higher than UASB requires skilled personne	Very high. High technical & skilled personnel required
Area requirement	Large area is required.	Moderately larg area required.	Medium area	Very small area required.	Small area is required
Power requirement	No power	Almost negligible power.	Large power required.	Less power required than ASP as no recirculation of sludge, but higher than UASB.	Large power Requirement For aeration. Power optimization is done by PLC.
Total coliform in treated sewage	10^4-10^5 MPN/100 ml	10^4-10^5 MPN/100 ml	10^4-10^5 MPN/100 ml	10^3-10^4 MPN/100 ml	10^3-10^4 MPN/100 ml
Effluent quality	Meets the standard.	Meets the Standard.	Very Good Quality.	Meets the standard.	Best Quality.
Sludge production	less	medium	more	medium	medium
Methane recovery	Methane recovery is possible but no reference in India	Yes.	Yes.	No methane recovery.	No methane recovery.
Expandability	Higher loads possible by providing aerators	Limited	Limited	Higher loads accepted with extra media filling.	Easy
Moving parts	Nil	Nil	High	Less than ASP	High
Sensitivity of process	Less sensitive	Highly sensitive.	Moderately sensitive.	Sensitivity Low, due to high bacterial population.	Less Sensitive

MLSS- Mixed Liquor Suspended Solids, SVI- Sludge Volume Index, F/M Ratio – Food to Microorganism Ratio, PLC- Programmable Logic Controller.

2.6 CRITERIA FOR ECONOMIC EVALUATION OF WASTEWATER TREATMENT TECHNOLOGY[2]

Finally, among the few selected options the overall costs (capital and operating) have to be determined in order-to arrive at the most optimum solution,

1. Capital costs include all initial costs incurred upto plant start up, such as Civil construction, Equipment supply and erection costs, Land purchase costs including legal fees (if any), Engineering design and supervision charges and Interest charge on loan during construction period.
2. Operating costs after start up of include direct operating costs and fixed costs. such as amortization and interest charges on capital borrowings and direct operation and maintenance costs on staff, chemicals, fuel and electricity, transport, maintenance and repairs and insurance overheads.

2.7 SELECTION OF WASTEWATER TECHNOLOGY ON EVALUATION BASIS[2]

The technology selection process results from a multi-criteria optimization considering technological, logistic, financial and institutional factors within a planning horizon of 10-20 years. Key factors are the size of the community to be served, characteristics of the sewer system, sources of wastewater, future opportunities to minimize pollution loads, discharge standards for treated effluents, availability of local skill (for design, construction and O&M) and environmental conditions such as land availability, geography and climate.

For the sustainability of any project, special attention has to be given to the selection of appropriate technology with participatory approach. Appropriate technology must be a cost-effective technology that provides adequate treatment, affordable in capital cost and operation and maintenance, operable at a reasonable cost and with locally available labour and reliable enough to consistently meet effluent quality requirements. All the stake holders should be actively involved from the project formulation stage and technology selection process. Such a selection should be based on knowledge of initial capital investment, land requirement, energy consumption, treatment efficiency and reliability and operation and maintenance costs of different technological options used for treatment of wastewater.

The important parameters that are used in the selection of biological treatment methods are land, power requirements and their performance. The expected BOD removal efficiency is not the only parameter to be considered. In several instances, equally careful attention has to be paid to the required removal of nutrients, nitrogen and phosphorous and to the micro organism like coliforms, helminthes etc. Foul odour potential, sludge handling and disposal difficulties, other operational characteristic and dependability of performance are the other factors that need to be addressed. The factors that affect the choice of treatment method are its design criteria and related requirements such as wastewater flow and its characteristics, degree of treatment required, performance dependability and, other process requirements such as land, power consumption, operating equipment requirement and its availability, availability of skilled staff, nature of maintenance problem, extent of sludge production and its disposal, loss of head expected and easy of stage wise extension of plant with time. Between land and power requirements a trade-off is often possible, based on actual cost of the two items. This could be well exploited to get an optimum solution for meeting treatment requirements and giving a dependable performance.

The extent of mechanization adopted should generally be the minimum possible so as to ensure sustainability. As far as possible, the operating equipment and its ancillary control equipment should be easy to operate and maintain. Conversion of waste to energy (by methane gas collection, scrubbing to remove hydrogen sulfide from the gas, wherever necessary and its conversion to electricity) imposes a requirement of higher level of skills of operation and maintenance. Wherever possible, during the site selection stage itself, the option of gas collection with direct supply to a nearby industry or area should be favored over conversion to electricity.

CHAPTER 3

PERFORMANCE EVALUATION OF EXISTING STPs BASED ON DIFFERENT TECHNOLOGIES

3.1 INTRODUCTION

Technology evaluation depends upon wastewater characteristics and on the treatment objectives as translated into desired effluent quality. Effluent quality control is typically aimed at public health protection, preservation of the oxygen content in the water, prevention of eutrophication, prevention of sedimentation, preventing toxic compounds from entering the water and food chains and promotion of water reuse. The selected technologies should be environmentally sustainable, appropriate to the local conditions, acceptable to the user, and affordable to those who have to pay for them. Simple solution that are easily replicable, that allow further upgrading with subsequent development, and that can be operated and maintained by the local community.

In this regard existing STPs of various technology were visited and based on the observations on the status of O&M of individual STPs on the basis of physical inspection, and information given at site by operating staff/officers, techno evaluation have been prepared. As treatment methods range from the physico-chemical to the biological, from the aerobic to anaerobic and accordingly the following treatment plants based on different technologies were studied, as shown in Table3.1.

Table 3.1: Various treatment plants selected for performance study

Sl. No.	Sewage Treatment Technologies	Location of Site
1.	Activated Sludge Process (ASP)	Haridwar (ttarakhand
2.	Upflow Anaerobic Sludge Bed with Final Polishing Pond (UASB + FPP)	Karnal, Haryana.
3.	Fluidized Aerobic Bed (FAB) Reactor	Lucknow, Uttar Pradesh.
4.	Sequencing Batch Reactor (SBR)	Panjim, Goa.
5.	Waste Stabilization Pond (WSP)	Titagarh, West Bengal.

3.2 PERFORMANCE EVALUATION OF ASP, HARIDWAR (UTTARAKHAND)

3.2.1 Details of ASP

The plant is using Activated Sludge process (ASP) and was commissioned in the year

1993 with a capacity of 18 MLD spread over an area of 2.9 hectare, and of initial project cost of Rs.15.00 crores. The current sewage generation is approximately 25-30 MLD but during festive season it goes even higher upto 45MLD (Peak designed capacity) and beyond 18MLD sewage is being bypassed and is mixed with treated effluent, used for irrigation purpose. Lay out plan is shown in Figure 3.1.

Design parameter		Influent	Effluent
BOD_5 (in mg/l)	:	250-300	< 30
TSS (in mg/l)	:	450-600	< 50
MPN No. / 100ml	:	10^6 - 10^9	< 10^3
Annual maintenance cost	:	Rs. 79.00 lacs in the year 2006.	

The technical data are shown in Table 3.2.

Table 3.2: Technical Features of ASP

Sl.No	Units	Values
Preliminary / Primary Treatment		
1	Screen chamber Mechanically operated Manual operated	1 no 3 nos. Width:- 600mm; Opening:- 20mm Inclination:- 30°-45°C. 1 no vertical, 6-10mm opening.
2	Grit chamber	3 no Size:- 4m x 4m x 1.50m. Detention period:- 1.0 min.
3	Distribution box	3 no.
4	Primary settling tank	3 nos. Size:- 16 m dia x 7 m depth. Capacity:- 6 MLD each. Detention time:- 2 to 3 hrs.
Secondary Treatment		
1	Aeration tank	3 units continuous flow Size:- 16m x 16m x 5.75m depth. Hydraulic detention time:- 4 to 5hrs. Capacity of aerator (3 nos.):- 40HP.

Sl.No	Units	Values
2	Secondary settling tank	3 units with HRT-2 to 3 hrs Size:- 20m dia x 4m depth. Surface loading rate:- 20 m^3/m^2/day HRT:- 3-4hrs. Recirculated sludge:- 33%. Effluent used for irrigation purpose.
3	Sludge thickener	2 units Size:- 12m dia x 3.5m depth. To reduce the moisture content- before biodigester
4	Return sludge pump	4 nos. Capacity:- 200m^3/hr.
5	Sludge digester	2 units Size:- 18m dia. Detention period:- 25 days. Anaerobic digestion period:-7 days Digester sludge storage period:- 15 days.
6	Gas holder	2 units Size: 11m dia. Effective movement of dome:- 5.0m.
7	Sludge drying bed	12 no. Size: 34.8m X 24m.
8	Gas Engine	368 kV x 1.2 = 441.6 kW Started with diesel and then run with 40% diesel and 60% gas generated.

3.2.2 Performance Evaluation

The performance of STP has been studied for various parameters such as pH, TSS, BOD, COD etc. the test result are well within norms. In the STP, the domestic sewage with BOD and SS characteristics of about 150 mg per liter and 350 mg per liter respectively, is treated and these parameters are brought down to less than 20 mg per liter (as shown in Table 3.3 and graphical represented in Figure 3.2), respectively, which is better than the norms laid down for pollution control standards.

Table 3.3: Performance of ASP#

Parameters ⟹	pH	BOD_5 in (mg/l)	COD in (mg/l)	TSS in (mg/l)	Total Coliform (MPN/100ml)
Influent	7.3	150	300-350	300-350	$1.2x10^9$
Effluent	7.5	10-15	20-30	15-20	$7x10^4$
Standards for discharge in streams	5.5-9	30	250	100	
Efficiency in %		90 - 93.33	91.43 - 93.33	94.30 - 95	99

 # Data collected in Dec'2007.

3.2.3 Observations

1. ASP unit is being fed with low organic loading and it is performing well.
2. Gas generated in anaerobic sludge reactor is not being utilized fully.
3. Plant is able to comply with the discharge standards.
4. One out of three nos. of mechanical screens is under repair.
5. No facility is provided to measure the quantity of bio-gas being produced daily.
6. Lot of greenery/plants have been grown inside the STP campus.
7. Treated effluent is meeting the design standards for BOD & TSS.

3.3 PERFORMANCE EVALUATION OF (UASB + FPP), KARNAL (HARYANA)

3.3.1 Details of UASB

The STP is using Upflow Anaerobic Sludge Blanket Process with Final Polishing Pond (UASB + FPP) and was commissioned in the year 2000 with a capacity of 40MLD (Zone-I) and 8MLD (Zone-II) of project cost of Rs.12.71 crores spread in an area of 25 acres under Yamuna action plan. A layout diagram of the UASB is shown in Figure 3.3, the technical features are shown below. Against a design capacity of 40 MLD, flow varying from 30-38 MLD (average 35 MLD) is being received at the STP. The effluent from the system is being used for irrigation.

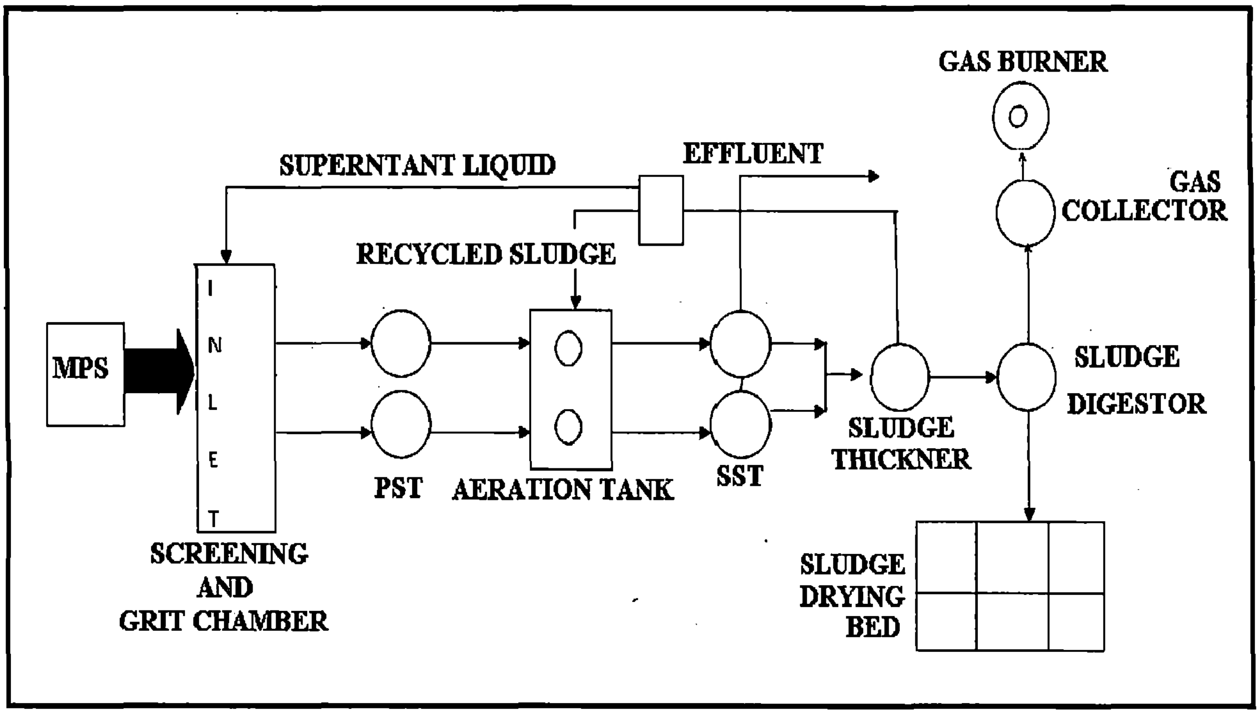


Figure 3.1: Layout plan of ASP, Haridwar

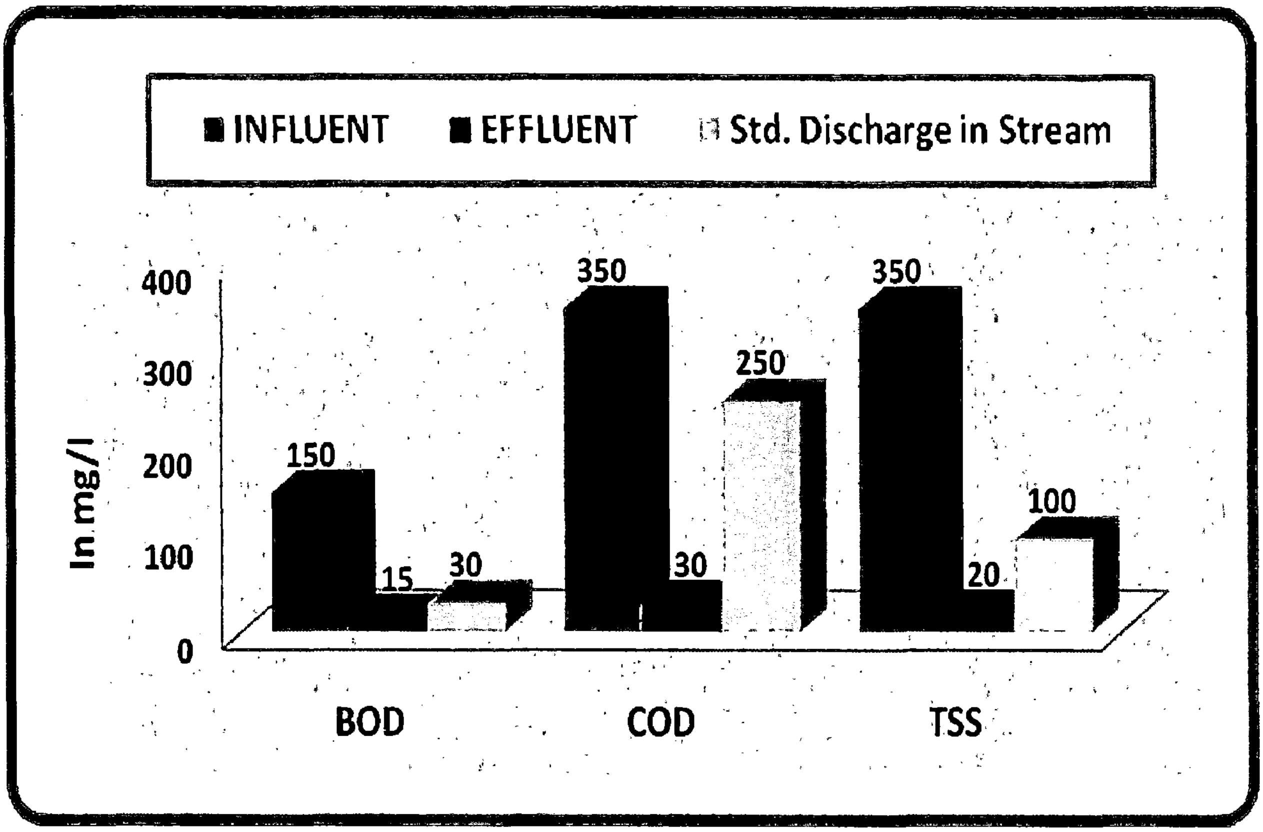


Figure 3.2: Performance evaluation of ASP, Haridwar

Design parameter		Influent	Effluent
BOD_5 (in mg/l)	:	150	< 30
TSS (in mg/l)	:	275	< 50
Sewage temp (°C)	:	20	
Annual maintenance cost	:	54.00lacs. in the year 2003.	

Technical features of sewage treatment plant:-

Primary Treatment

Screen Chamber : 2 nos. of size 6.00 x 2.47 x 1.30 Mtr.

Grit Channels : i) 4 nos. of size 15.32 x 2.00 x 1.47 Mtr.

ii) Average grit removal per day:- 1.00m^3.

Secondary Treatment

UASB Reactors : i) 4 nos. of 10MLD each,

Size of each Reactor:-24m x 32m x 4.58m (depth).

Height of the Reactor:- 5.51m.

Distribution Box :- 2nos. (size 2.50m x 1.90m).

Feeding Boxes:- 16nos.

Gas Domes:- 8nos.

ii) Hydraulic Retention Time:- 8hrs.

iii) Average Gas produced/day:- 200m^3.

iv) BOD_5 Reduction:- 80%.

Sludge Drying Bed : i) 20nos. (size 18.00m x 18.00m each)

ii) Drying cycle:- 10 days.

iii) Dry sludge or Manure production / day:- 6m^3.

Final Polishing Unit (FPU) : i) Size:- 241m x 135m x 1.25m.

ii) Hydraulic Retention Time:- 1 day.

Gas Holder : Size:- 10.98m dia.

Capacity:- 378 m^3.

Gas Production (Theoretical value):- 1135m^3/day.

Actual value:- 200m^3/day.

Methane content:- 65% - 75%.

Other Machinery : i) Sludge withdrawal pump:- 2 nos. of 7.5 HP each.

iii) Dual Fuel Power Generator Set:- 2 nos.

Capacity:-50KVA,

Gas : Fuel ratio:- 60:40.

3.3.2 Performance Evaluation

The Govt. of India, MOEF (NRCD), have appointed BHEL (Pollution Control Research Institute) as a third party evaluator, who regularly collects samples of STP. The test result presented in Table 3.4 & 3.5, indicate that the value of BOD, COD, TSS, pH are well within prescribed limit i.e. $BOD_5 < 30$mg/l, $TSS < 100$mg/l, (Figure 3.4).

Table 3.4: Performance of (UASB +FPU)

Date of sampling	Parameters	BOD in mg/l	COD in mg/l	TSS in mg/l	pH
March,05	Raw water	172.30	430.30	208.15	7.14
	UASB effluent	53	182.69	52.76	6.79
	Final effluent	25.38	75.30	28.53	7.40
	Efficiency in %	85.26	82.50	86.29	--
May,05	Raw water	118.95	359	195.33	7.04
	UASB effluent	48.5	157.58	53.25	6.84
	Final effluent	22.04	77.41	27.25	7.22
	Efficiency in %	81.47	78.44	86.05	--
June,05	Raw water	127.29	341.91	192	7.05
	UASB effluent	52.08	193.08	48.23	6.83
	Final effluent	25.66	76	26.25	7.23
	Efficiency in %	79.84	77.77	86.33	--
August,05	Raw water	132.72	310.72	219	7.27
	UASB effluent	54.27	135.72	54.36	7.19
	Final effluent	26.31	75.45	29.90	7.48
	Efficiency in %	80.18	75.72	86.35	--
September,05	Raw water	135.26	296	216.42	7.33
	UASB effluent	58.42	132.84	47.68	7.25
	Final effluent	26.47	72.31	28.15	7.56
	Efficiency in %	80.43	75.57	87.00	--
November,05	Raw water	129.23	310	177.23	7.20
	UASB effluent	51.07	130.76	40.76	7.12
	Final effluent	26.15	71.69	23.69	7.25
	Efficiency in %	79.74	76.87	86.63	--

Date of sampling	Parameters	BOD in mg/l	COD in mg/l	TSS in mg/l	pH
January,06	Raw water	60.83	187.66	--	7.35
	UASB effluent	22.85	100.83	--	7.23
	Final effluent	11.41	52	--	7.41
	Efficiency in %	81.24	76.87	--	--
February,06	Raw water	74.26	213.2	92.8	7.22
	UASB effluent	25.66	99.73	37.06	7.19
	Final effluent	12.26	55.6	21.6	7.37
	Efficiency in %	83.49	73.92	76.72	--
March,06	Raw water	107.18	293.8	230.6	7.29
	UASB effluent	34.25	128.75	70.75	4.49
	Final effluent	19.12	73.25	47	7.39
	Efficiency in %	82.16	75.07	79.62	--

Table 3.5: Summary of performance of (UASB +FPU)

Parameters	pH	BOD in mg/l	COD in mg/l	TSS in mg/l	Total Coliform (MPN/100ml)
Raw sewage	7.35	172.30 - 60.83	430.30 -187.66	219 – 92.8	$1.3x10^7$
UASB reactors effluent	7.23	58.42 – 22.81	182.69 – 99.73	70.75 – 37.1	
Final effluent	7.41	26.31 – 11.41	75.30 - 52	47 – 21.6	$4x10^5$
Standard for discharge in streams	5.5-9	30	250	100	
Efficiency in %	O.K.	80 - 86	74 - 83	77 – 87	97

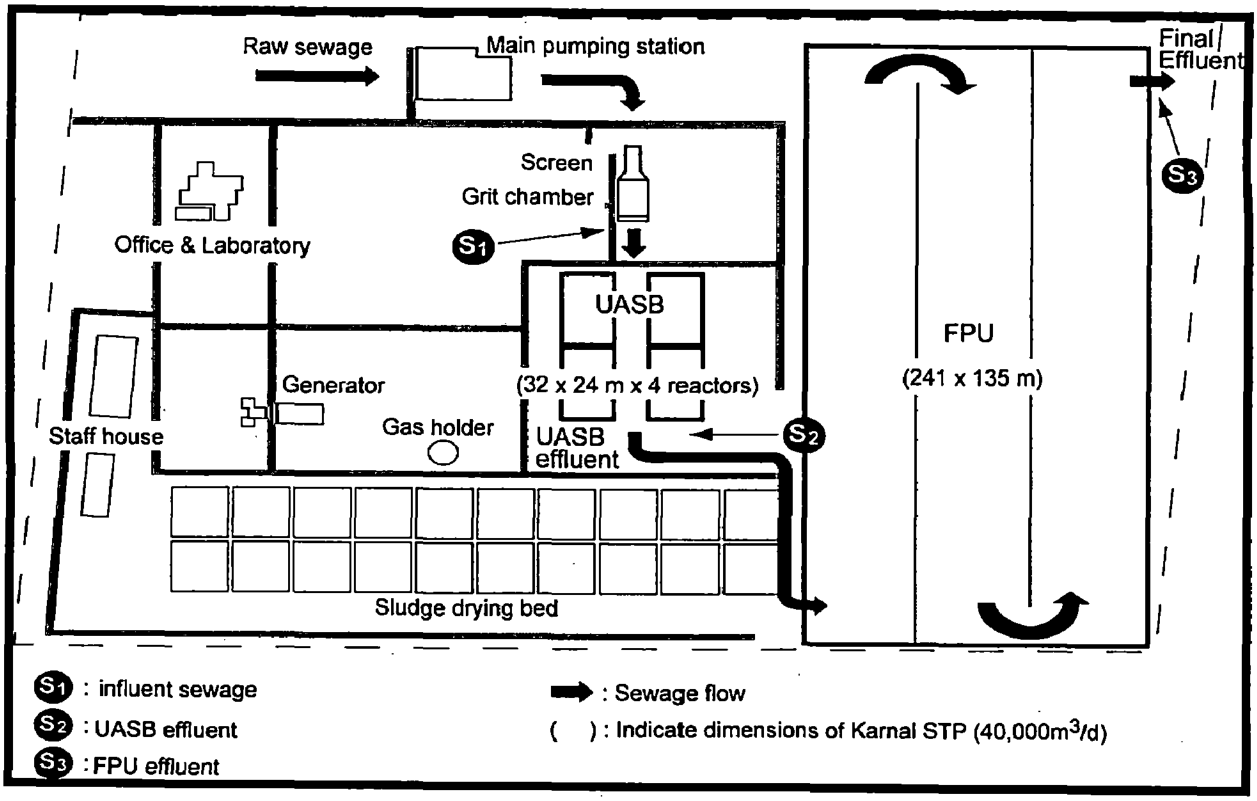
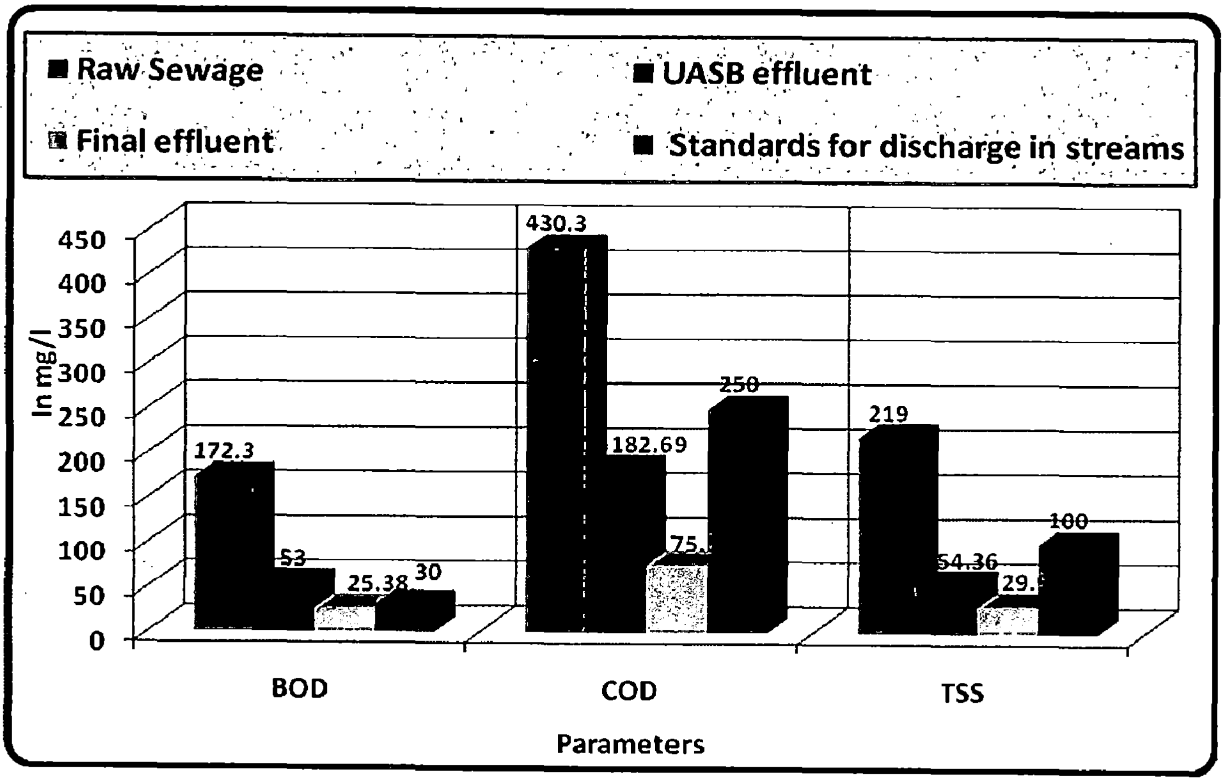
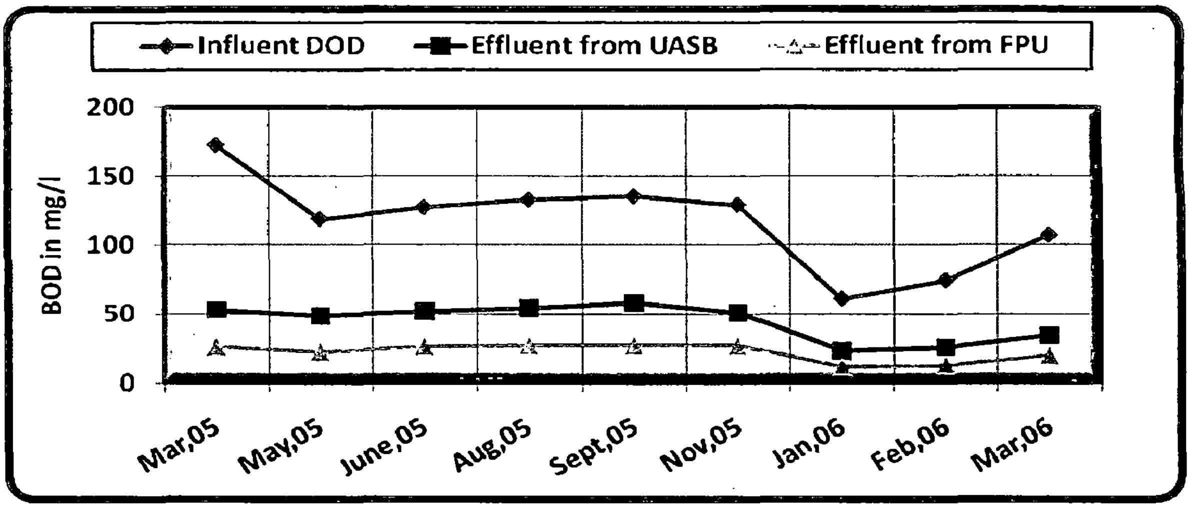


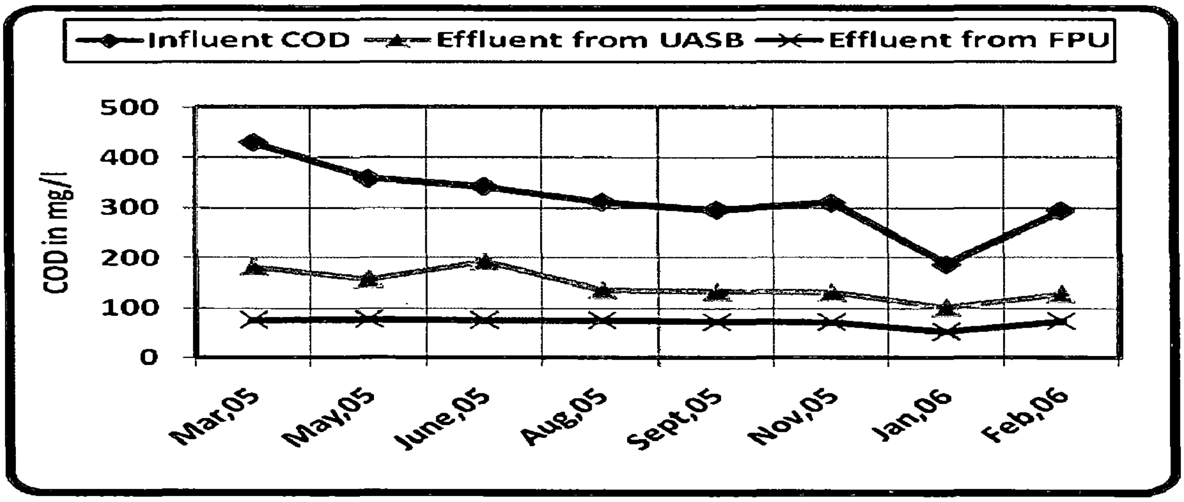
Figure 3.3: Layout diagram of UASB + FPU at Karnal



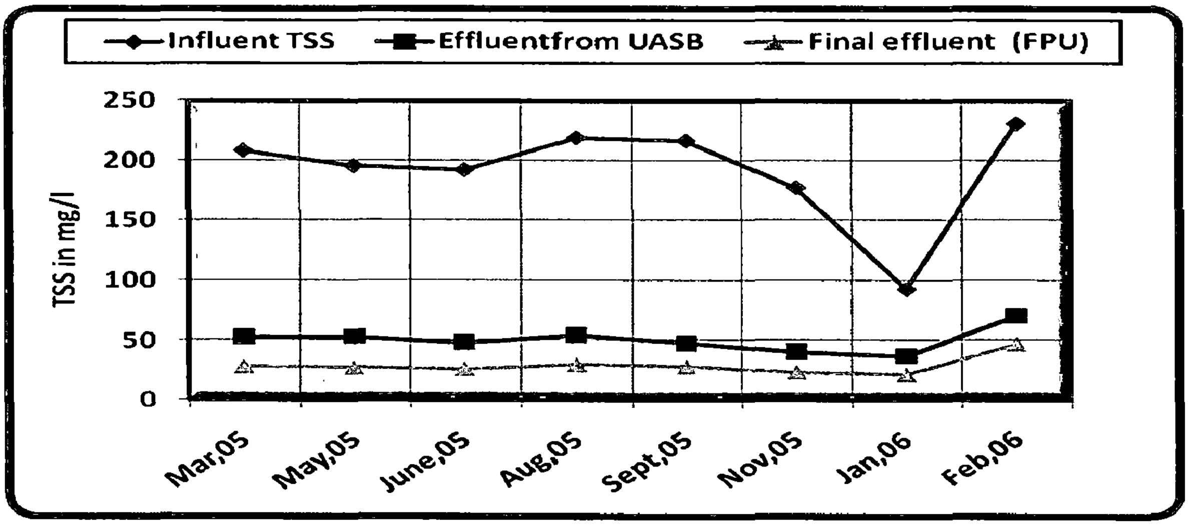
(a) : Effluent quality at different stages



(b) : BOD removal



(c) : COD removal



(d) : TSS removal

Figure 3.4(a), (b) & (c): Performance evaluation of (UASB+FPP), Karnal

3.3.3 Observations

1. Treated effluent is meeting the design standards for BOD and SS and there is lot of greenery/plantation inside the STP.
2. The bio-gas produced is mostly, being flared up.
3. Unequal flow is observed through V-notch/weir along with closing of feed inlet \pipes which need to be more regularly cleaned.
4. Growth of weeds/plants at some places at the water surface on the embankments and scum/algae accumulation on the corners/sides of ponds is observed.
5. Excess sludge is removed from time to time and sent to a simple sand bed drying.
6. The nutrients, nitrogen and phosphorous are not removed, but are conserved to make the irrigational use of the effluent more valuable.
7. Performance of demonstration scale DHS bio-tower of 1MLD shows, as promising post treatment alternative for UASB treating municipal wastewater. Needlessness of aeration, negligible excess sludge, tolerance to temperature variance, low maintenance and consistency in performance makes it a low cost and ideal wastewater treatment system.
8. The corrosion potential of anaerobic system is a major weak point which can ruin a UASB in no time and it needs special attention for better upkeepment of plant.

3.4 PERFORMANCE EVALUATION OF FAB, LUCKNOW (UTTAR PRADESH)

3.4.1 Details of FAB

This Sewage Treatment Plant is based on the Fluidized Aerobic Bed (FAB) technology. It works on the principles of attached growth process where Media supports the biomass. Media is in suspension has Specific gravity < water and fluidization takes place by virtue of hydraulic currents set by aeration. The STP was commissioned in the year 2003 with a capacity of 42MLD of project cost of Rs.14.36 crores spread in an area of 4.60 hectare. A layout diagram of the FAB is shown in Figure 3.5, the technical features are shown below in Table 3.6.

Design parameter		Influent	Effluent
BOD_5 (in mg/l)	:	100-250	< 30
TSS (in mg/l)	:	200-250	< 30
MPN No. / 100ml	:	10^6 - 10^9	< 10^3
Annual maintenance cost	:	Rs.198.00 lacs in the year 2006.	

Table 3.6: Technical Features of FAB

Sl.No	Units	Nos.	Dimensions
1	Settling chamber	1 No.	4.6mx6.4mx2.5m SWD
2	Screens (3 mechanical +1 manual)	4 Nos.	1.0mX6.8mX0.566m
3	Grit Chamber (Mechanical)	3 Nos.	6.0m x 6.0 m x 1.0 SWD
4	Distribution Chamber	1 No.	3.4m x 3.4m x 1.0 SWD
5	Inlet chamber for FAB reactor	3 Nos.	1.0m x 0.50m SWD
6	FAB Reactors	6 Nos.	10.6m dia & 5.50 SWD
7	Feed Chambers	3 Nos.	2.0m x 2.0m x 4.85m SWD
8	Secondary clarisettler	3 Nos.	17.5m dia x 3.75m SWD
9	Chlorine contact tank	3 Nos.	21.50m dia x 2.75n SWD
10	Sludge sump	1 No.	8.30m dia x 3.0 SWD
11	Sludge Thickener	1 No.	14.40m dia x 3.0 SWD
12	Sludge Drying Beds	11 Nos. 3 Nos.	15m x 16m 12.5m x 16m 7.5m x7.5m
13	Filtrate sump	1 No.	2.0m x 2.0m x 2.0 SWD
14	Outer chamber	1 No.	3.00m dia x3.5m ht.
17	Filtrate/overflow transfer sump	1 No.	3.0m x 3.0m x 3.0m SWD
18	Sludge pump	2 Nos.	45m /hr 15 m head
19	Filtrate pump	2 Nos.	8 m /hr. 12m head

3.4.2 Performance Evaluation

The treatment scheme proposed to treat the raw sewage from various areas is first collected in a raw sewage sump & then pumped for further treatment, into three distinct parts:

1. Pre-treatment, which comprises of screening and grit removal,
2. Biological treatment comprising of moving bed aerobic bioreactors, followed by clarification, and
3. Tertiary treatment comprising of addition of chlorine to remove the E- coli.

It reduces the E-Coli in the wastewater with a very nominal chlorination and is the most successful and cost effective technology which reduces the E-coli count from an inlet level of $10^6 - 10^7$ MPN to less than 10^3 MPN at the outlet [20], as seen from Table 3.7.

Table 3.7: Performance of FAB

Date of sampling	Parameters	BOD in mg/l	COD in mg/l	TSS in mg/l	Total Coliform in MPN/100ml
Aug,03	Influent	180	N.A.	276	2400000000
	Effluent	22.5		26	700
	Efficiency	87.5		90.58	99.99
Nov,03	Influent	130	N.A.	162	900000000
	Effluent	21		26	110
	Efficiency	83.84		83.95	99.99
Jan,04	Influent	125	N.A.	138	500000000
	Effluent	24		28	270
	Efficiency	80.8		79.71	99.99
April,04	Influent	110	N.A.	202	5000000000
	Effluent	26		26	330
	Efficiency	76.36		87.13	99.99
Aug,04	Influent	120	274.4	142	6000000000
	Effluent	28	66.64	28	700
	Efficiency	76.67	75.71	80.28	99.99
Feb,05	Influent	110	342.6	306	9000000000
	Effluent	42.5	119.5	98	1400
	Efficiency	61.36	65.12	67.97	99.99
April,05	Influent	110	282.08	210	270000000
	Effluent	29	99.76	38	800
	Efficiency	73.63	64.63	81.90	99.99
June,05	Influent	120	247	160	110000000
	Effluent	27.5	83.6	26	940
	Efficiency	77.08	66.15	83.75	99.99
Aug,05	Influent	80	213	172	14000000
	Effluent	25	72.16	28	800
	Efficiency	68.75	66.12	83.72	99.99
Feb,06	Influent	168	310	300	N.A.
	Effluent	32	80	80	
	Efficiency	80.95	74.19	73.33	
March,06	Influent	115	224	222	240000000
	Effluent	25	96	36	700
	Efficiency	78.26	57.14	83.78	99.99
Nov,06	Influent	85	202.2	118	220000000
	Effluent	32.5	93.6	54	700
	Efficiency	61.76	53.71	54.24	99.99

Table 3.8: Summary of performance of FAB

Parameters	BOD in mg/l	COD in mg/l	TSS in mg/l	Total Coliform (MPN/100ml)
Raw sewage	180 - 80	342.6 – 202.2	306 - 118	$90x10^8$ - $22x10^7$
Final effluent	32 - 21	119.5 – 66.64	98 - 26	1400 -110
Standards for discharge in streams	30	250	100	
Efficiency in %	62.00 - 87.50	65.12 - 76	68.00 – 73.00	99.99

3.4.3 Observations

1. Treated effluent does conform to the standards for discharge in streams, as per the data received from *Industrial Toxicology Research Centre, (constituent lab of C.S.I.R.) Lucknow* which indicates the excellent performance of the plants.
2. Treated effluent is discharged into the river Gomti and the digested sludge is used for dumping in low-lying areas as there is no scope for sale of sludge as manure.
3. As the plant is not running since Dec,06, so no test results are available after November, 06
4. Chlorination is provided for coliform removal but has not been working for want of chlorine gas.
5. Sprayers / sprinklers have been installed to arrest the foam formation but these are mostly out of order.

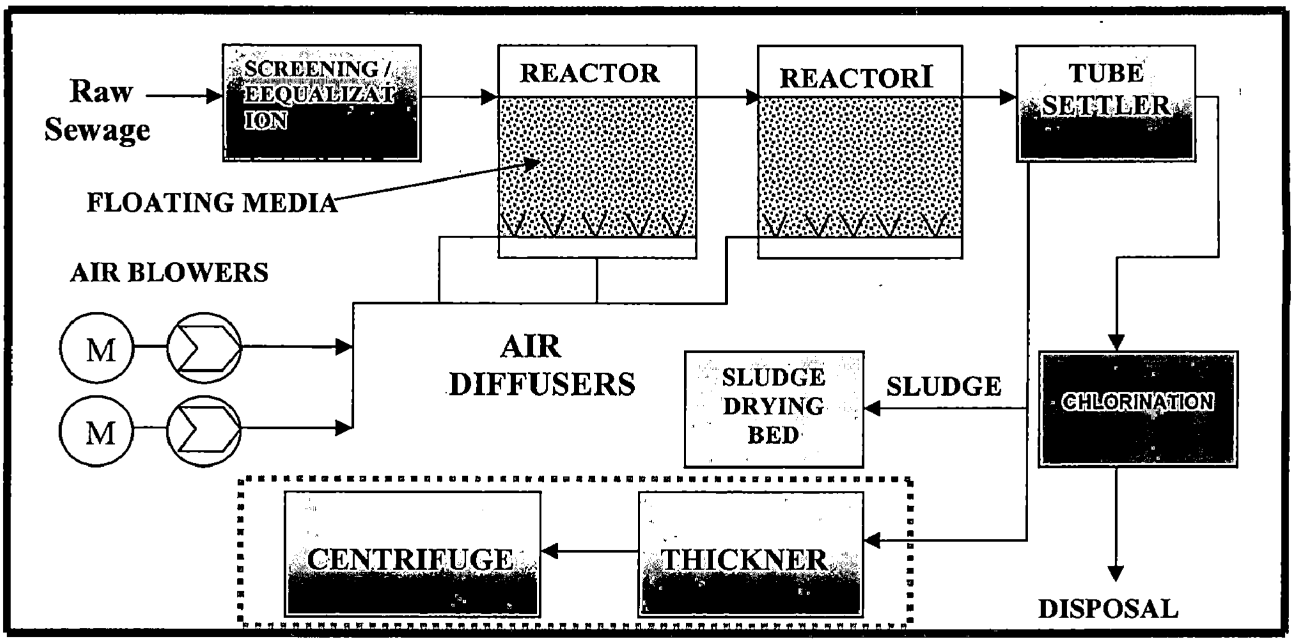
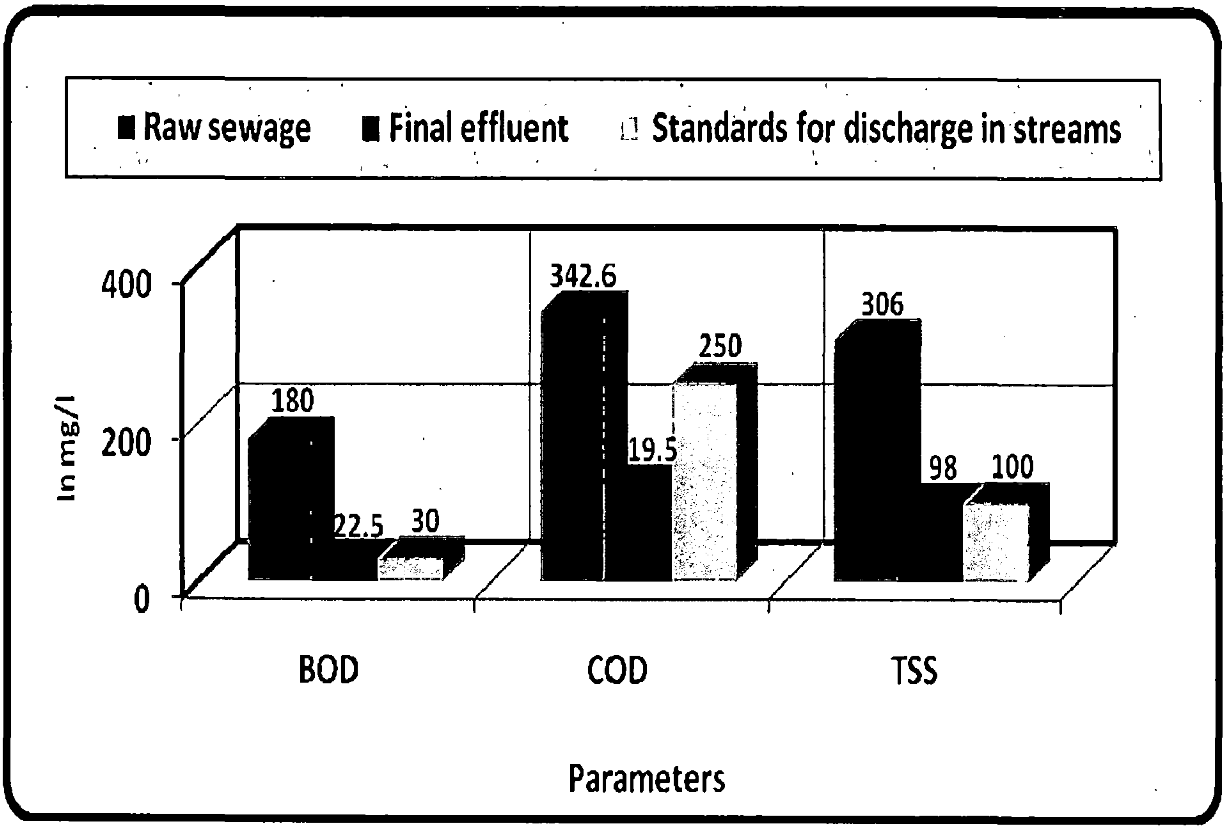
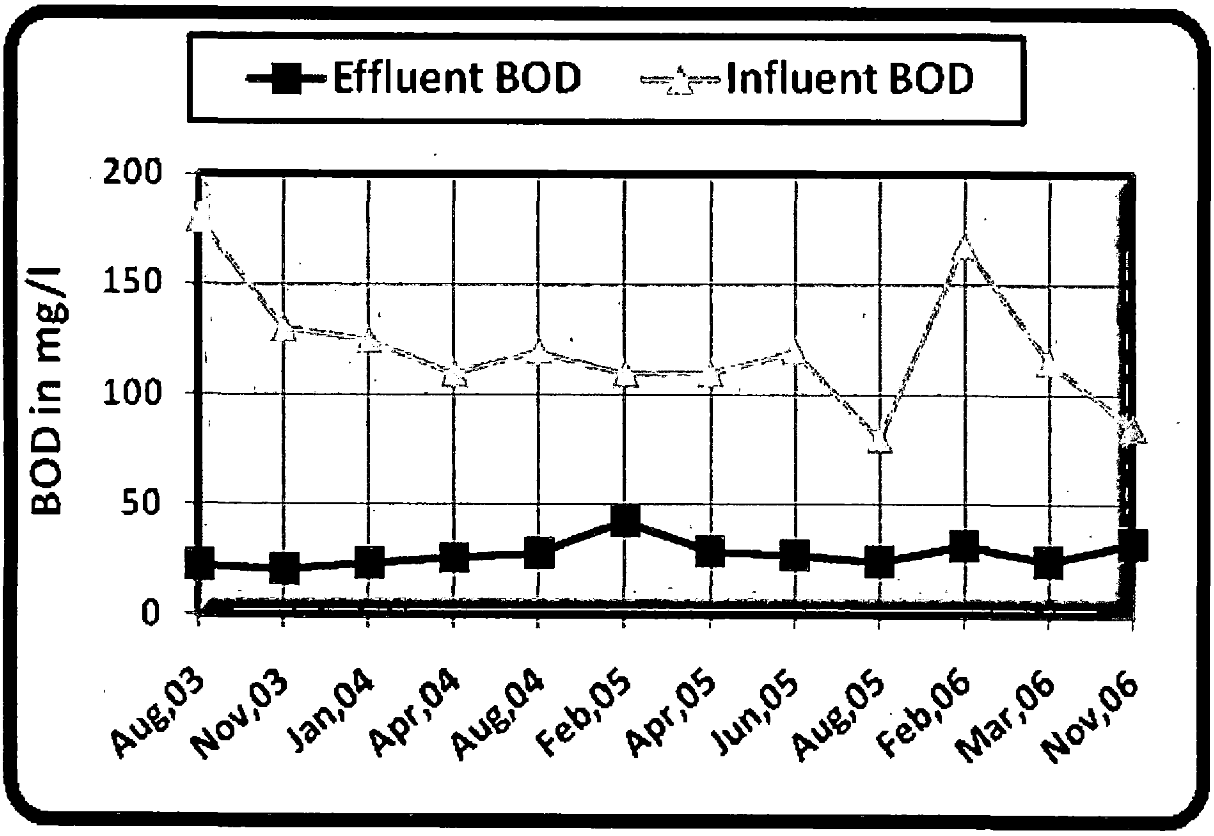


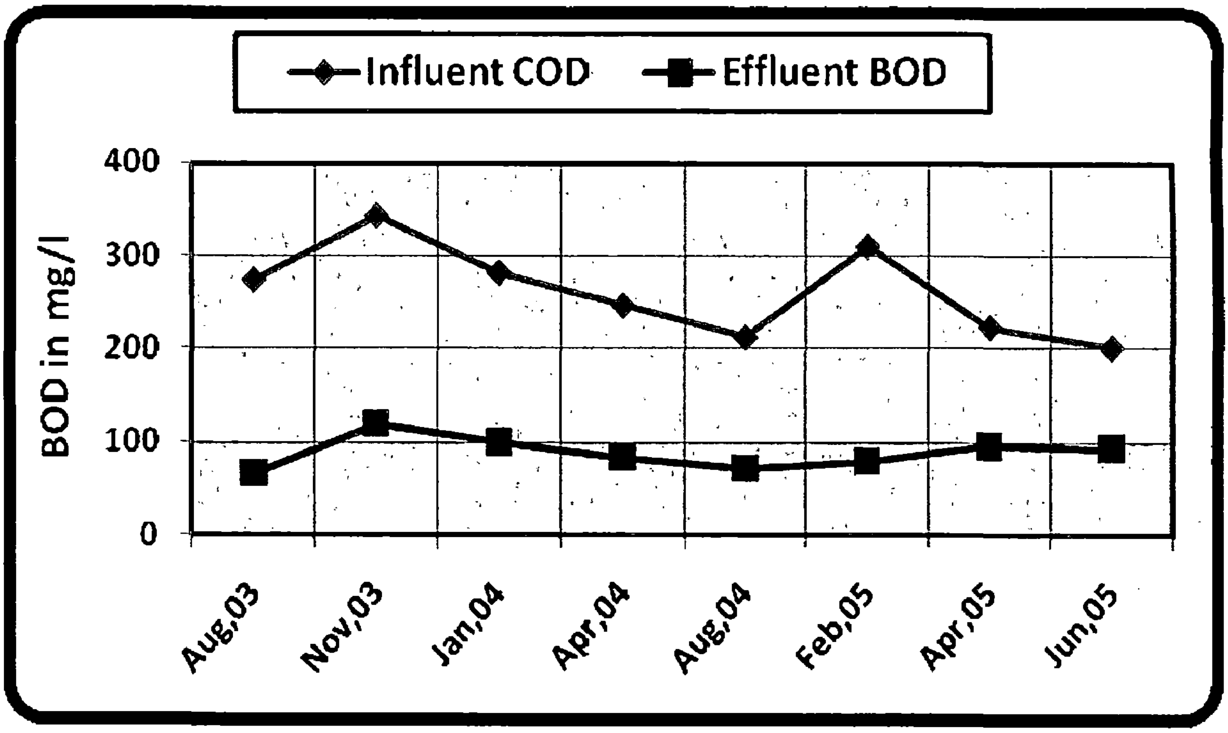
Figure 3.5: Layout diagram of FAB Reactor plant at Lucknow.



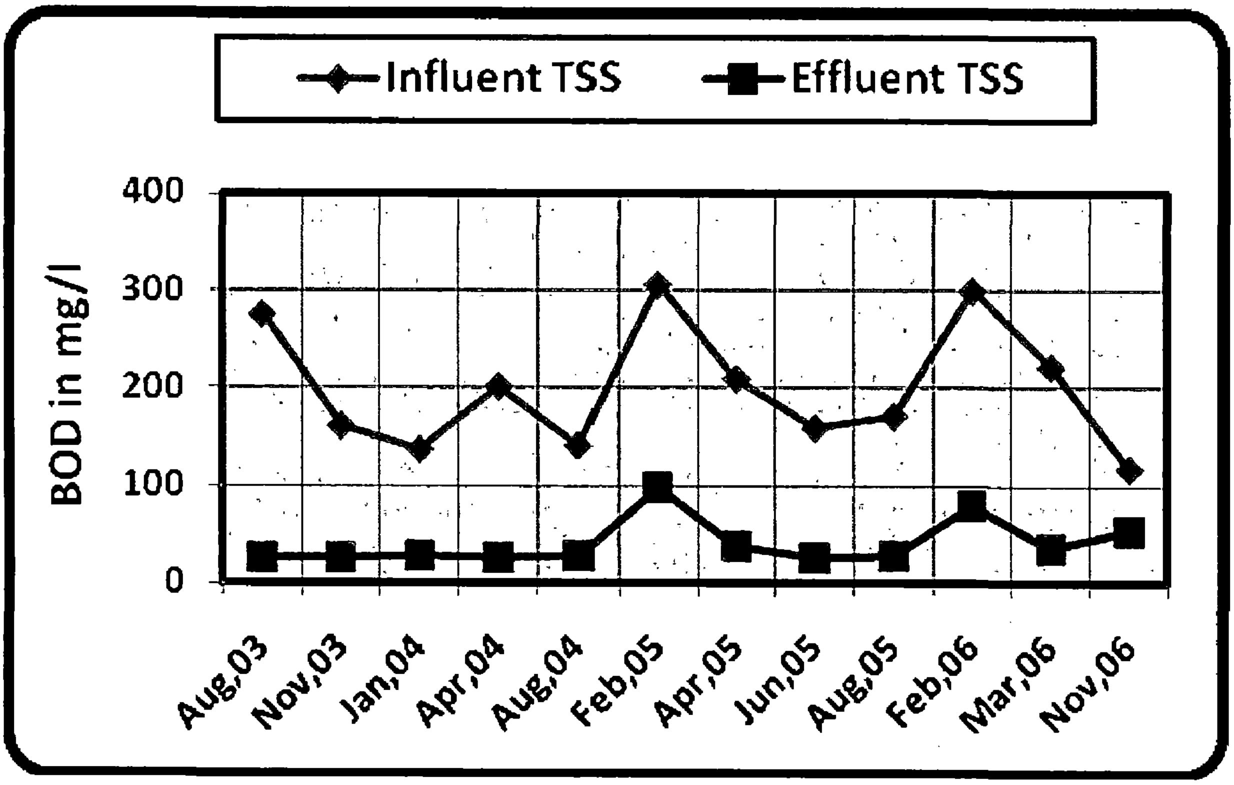
a) : Treated effluent quality



(b) : BOD removal



(c) : COD removal



(d) : TSS removal

Figure 3.6(a), (b) & (c): Performance evaluation of FAB, Lucknow

3.5 PERFORMANCE EVALUATION OF SBR, PANJIM (GOA)

3.5.1 Details of SBR

The STP is using Sequencing Batch Reactor (SBR / C-Tech), and was commissioned in the year 2005 with a capacity of 12.50MLD of project cost of Rs.15.00 crores spread in an area of 4.00 hectare. A layout diagram of the SBR is shown in Figure 3.8, the technical features are shown in Table 3.9.

Annual maintenance cost : Rs. 48.00 lacs in the year 2007.

Cycle completion period : 180 minutes (90+45+45).

A typical process flow schematic for a municipal wastewater treatment plant using an SBR is shown in Figure 3.7. Influent wastewater generally passes through screens and grit removal prior to the SBR. The wastewater then enters a partially filled reactor, containing biomass, which is acclimated to the wastewater constituents during preceding cycles. The complete biological operation is divided into cycles, each of 3hrs duration, during which all treatment steps takes place in a sequence constitute a cycle, which is then repeated.

Table 3.9: Technical Features of SBR

Sl.No	Unit	Nos.	Dimensions
1	Receiving Chamber	1 No.	1.4mx1.4mx1.5m SWD
2	Screens (1 mechanical +1 manual)	2 Nos.	3.0mx0.75mx0.55m SWD
3	Stilling Chamber	1 Nos.	1.4mx1.4mx1.5m SWD
3	Grit Chamber	1 Nos.	3.0m x 1.0 m x 1.0m SWD
4	C-Tech Basin	2 No.	14.80m x 7.3m x 4.0m SWD
5	C-Tech Air Blower	2 Nos.	840 Nm^3/hr @0.50kg/cm^2
6	Return Activated Sludge Pump	2 Nos.	85 m^3/hr @0.50kg/cm^2
7	Surplus Activated Sludge Pump	2 Nos.	3 m^3/hr @1.00kg/cm^2
8	Chlorination Tank	1 Nos.	8.5m x 2.0 m x 2.0m SWD
9	Sludge Drying Bed	5 Nos.	7.0m x 7.0 m x 1.0m TD
10	Effluent Tank	1 No.	4.0m x 4.0 m x 35.1m SWD

3.5.2 Performance Evaluation

The performance of SBRs is typically comparable to conventional activated sludge systems and depends on system design and site specific criteria as seen from Table 3.10 & 3.11. SBRs can achieve good BOD and nutrient removal. For SBRs, the BOD removal efficiency is generally 85 to 95 percent. SBR produces an effluent of less than:

10 mg/l of BOD	10 mg/l TSS	5 - 8 mg/l TN	1 - 2 mg/l TP

Table 3.10: Performance of SBR

No. of samples	Parameters	BOD in mg/l	COD in mg/l	TSS in mg/l	pH	Total Coliform in MPN/100ml
I	Influent	480	940	340	5.7	
	Effluent	2.6	37.6	24	7.2	
	Efficiency in %	99.46	96	92.94	--	
II	Influent	325	674	260	7	
	Effluent	3.4	26.2	19	7.56	
	Efficiency in %	98.95	96.11	92.69	--	
III	Influent	391	778	278	6.9	$46x10^8$
	Effluent	3	32	24	7.4	240
	Efficiency in %	99.23	95.89	91.37	17.39	99.99
IV	Influent	460	930	274	6.8	$1.1x10^8$
	Effluent	5.1	54.8	22	7.3	2400
	Efficiency in %	98.89	94.11	91.97	--	99.99
V	Influent	285	533	174	7.0	46×10^6
	Effluent	1.80	14.80	14	7.4	75
	Efficiency in %	99.36	97.22	91.95	--	99.99
VI	Influent	260	492.3	172	6.8	21×10^6
	Effluent	1.35	12	22	6.9	21
	Efficiency in %	99.48	97.56	87.20	--	99.99

Table 3.11: Summary of performance of SBR

Parameters	BOD in mg/l	COD in mg/l	TSS in mg/l	Total Coliform (MPN/100ml)
Raw sewage	480 - 260	940 – 492.3	340 -170	$46x10^8$ - $21x10^6$
Final effluent	1.35 – 5.1	54.80 – 12	14 - 24	2400 - 21
Standards for discharge in streams	30	250	100	
Efficiency in %	98.89 – 99.48	94 -96	87 - 93	99.99

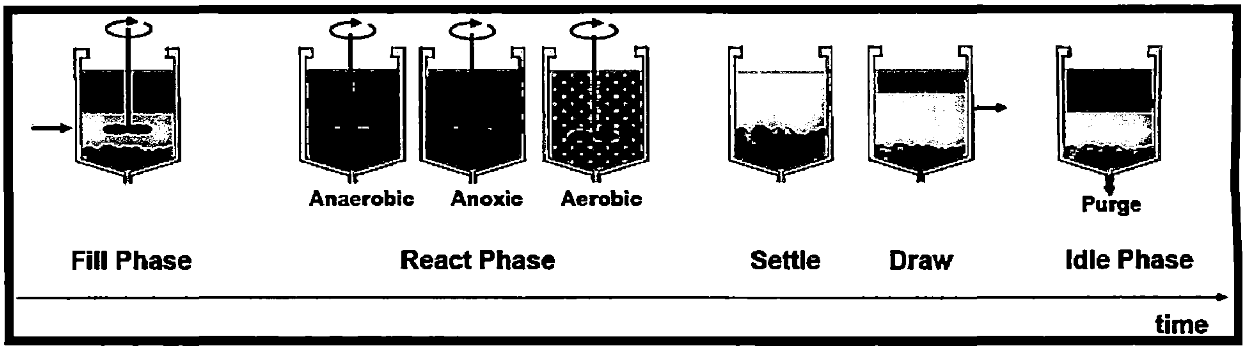


Figure 3.7: Operating sequence of SBR

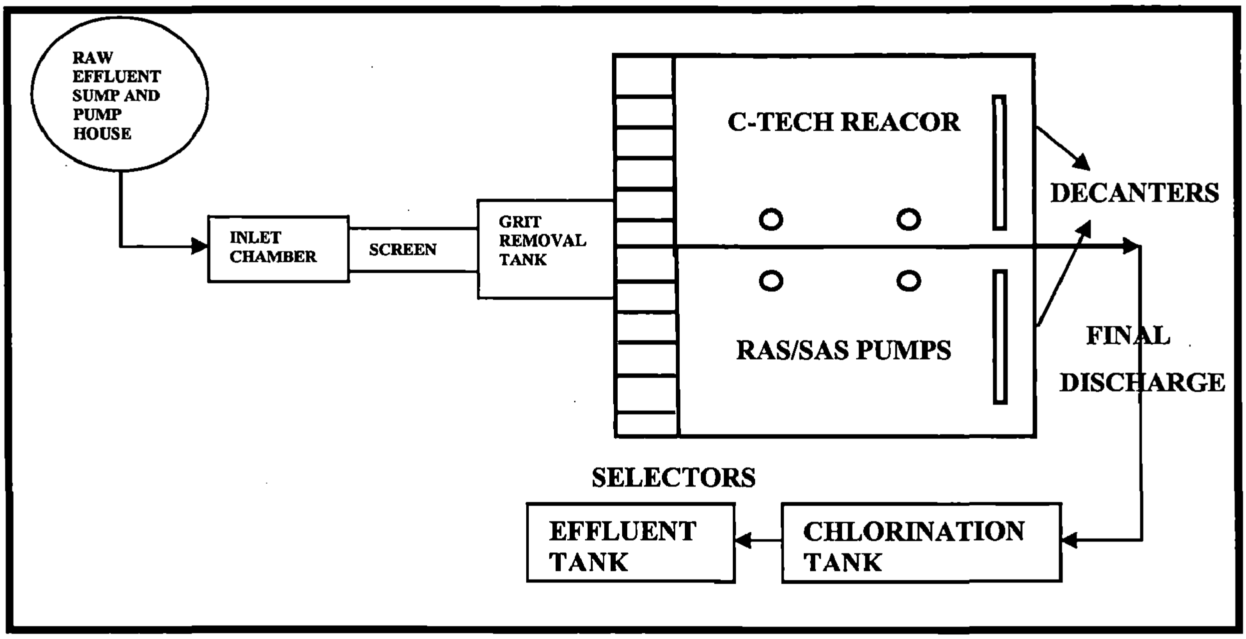
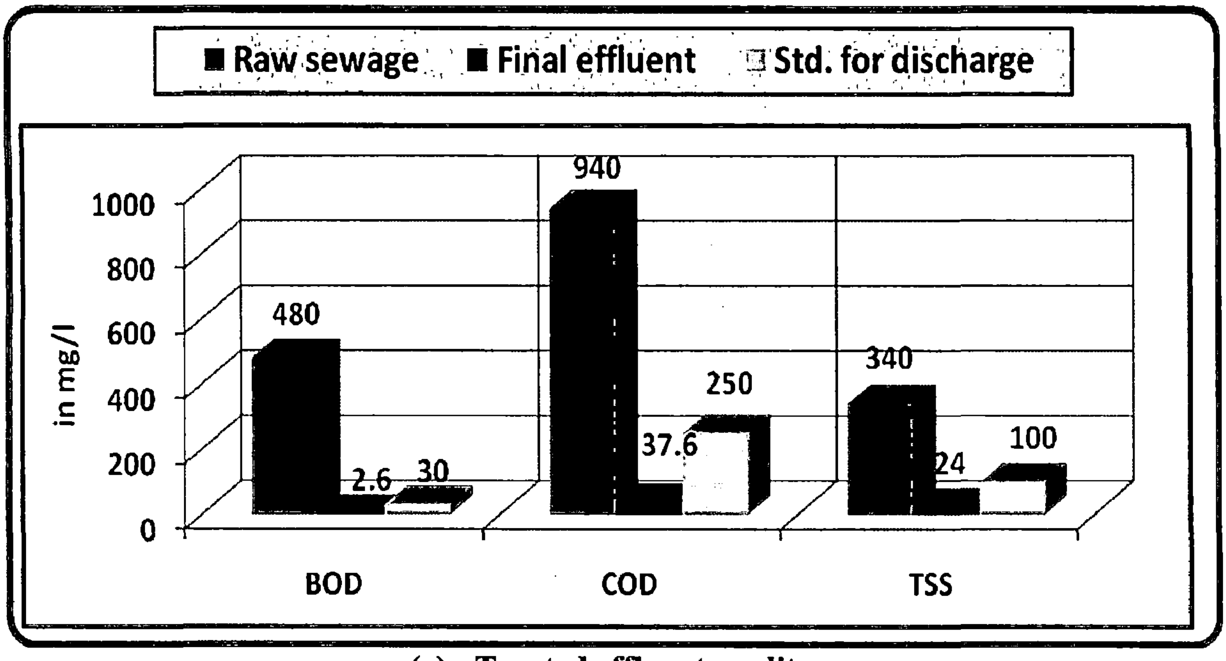
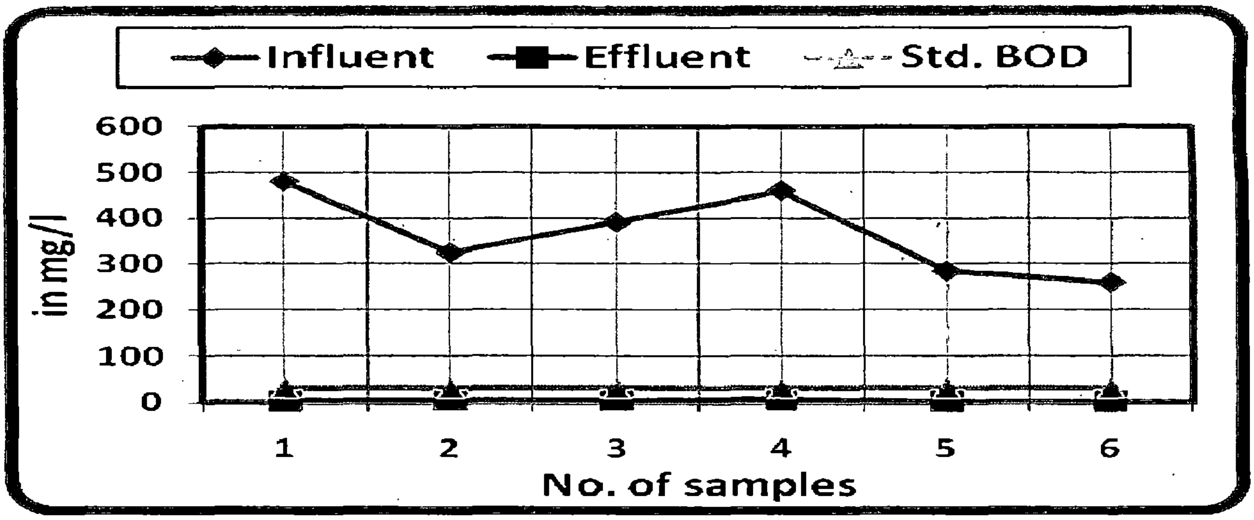


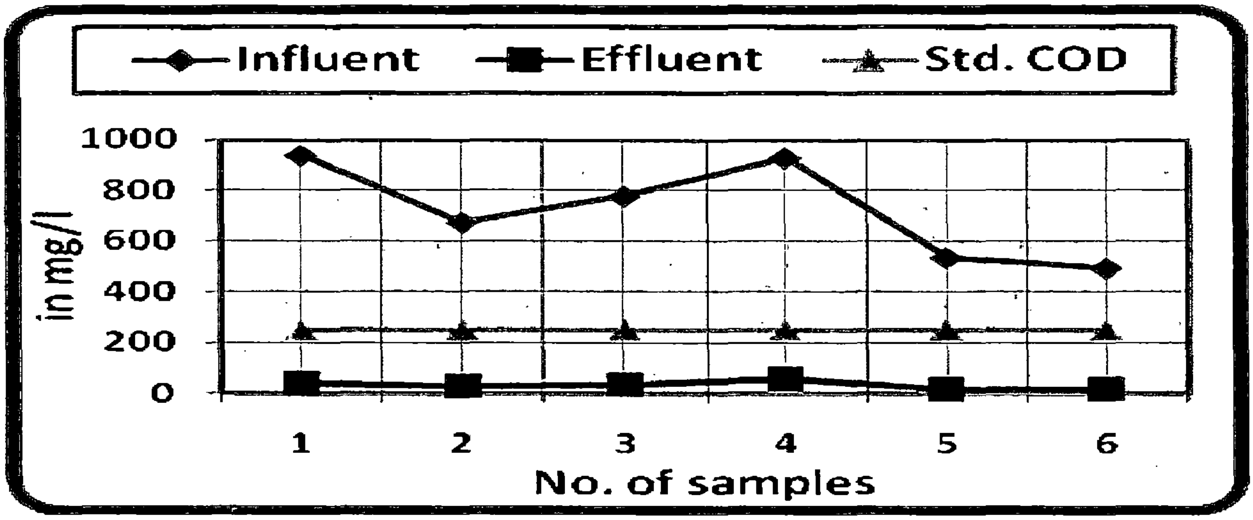
Figure 3.8: Basic process diagram of SBR



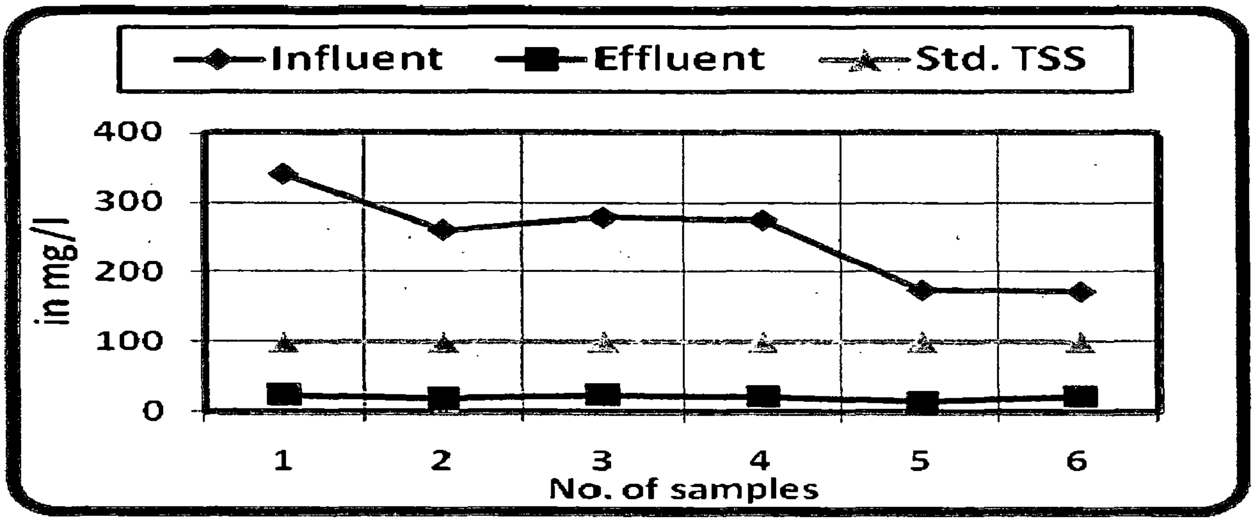
(a) : Treated effluent quality



(b) : BOD removal



(C) : COD removal



(D) : TSS removal

Figure 3.9(a), (b) & (c): Performance evaluation of FAB, Lucknow

3.5.3 Observations

1. Complete plant operation is automatically controlled through a PLC system, where all key functions like RAS, Sludge wasting, Aeration intensity, Cycle time control, Decanting rate etc. are automatically controlled as well as data logged, which is a major factor in reducing operating cost.
2. Complete system is capable of handling variable flow and load conditions by automatically adjusting to the new feed condition by changing cycle times, aeration intensity etc.
3. Chlorination is being done for coliform removal and treated effluent is being discharged into Mandavi river .
4. Sludge from drying beds is being used for filling low-lying areas as there is no demand for its use as manure.
5. The plant is well maintained with high quality of treated effluent as seen from Table 3.10.
6. Equalization, primary clarification (in most cases), biological treatment, and secondary clarification is being achieved in a single reactor vessel.

3.6 PERFORMANCE EVALUATION OF WSP, TITAGARH (WEST BENGAL)

3.6.1 Details of WSP

The STP is using Waste Stabilization Pond (WSP) process, and was commissioned in the year 1993 with a capacity of 14.10MLD of project cost of Rs.1.571 crores spread in an area of 10.8 hectare. A layout diagram of the WSP is shown in Figure 3.10 and technical features are shown in Table 3.12.

Design parameter		Influent	Effluent
BOD_5 (in mg/l)	:	200	< 30
TSS (in mg/l)	:	400	< 100
MPN No. / 100ml	:	$10^5 - 10^7$	$< 10^4$

The system is for treatment of raw sewage discharged by the people of Titagarh and parts (50%) of Barrackpore municipality, the sewage available being mainly from commercial and domestic sources. It is designed for the waste water treatment and reuse for aquaculture, which is termed as the "Resource Efficient Stabilization Tank System", based on the past ten years experience with the sewage fed fisheries in east Calcutta. Fish culture is currently practiced in both the facultative and maturation ponds. It comprises two series of anaerobic, facultative and a single maturation pond.

Technical features:

Design capacity of STP : 14.1 MLD;

Average flow reaching STP : 12 MLD

Table 3.12: Technical Features of WSP

Treatment unit	Size	HRT
Grit chamber		
Anaerobic pond 2 in parallel	0.7 Hectare area x 2.5 m depth	1 day
Facultative ponds 3 in parallel	4.8 Hectare area x 1.5 m depth	4 day
Maturation pond 2 in parallel	4.8 Hectare area x 1 m depth	4 day

3.6.2 Performance Evaluation

It is seen from performance report in Table 3.13, that the treated effluent is meeting the discharge standards in streams for BOD and SS graphical representation is being done in Figure 3.11.

Table 3.13: Performance of WSP

Parameters ⇨	pH	BOD in mg/l	COD in mg/l	TSS in mg/l
Influent	7.37	94	303	284
Final effluent	7.40	15	57	57
Efficiency in %	o.k.	84.04	82.7	91.55
Standards for discharge in streams	5.5-9	30	250	100

3.6.3 Observations:

1. Plant receives very low strength sewage and treated sewage quality is meeting the discharge standards, about 90% of the treated sewage is used for irrigation and reuse for aquaculture.
2. Accumulated sludge from the ponds has never been cleaned since the plant was established in 1993. Anaerobic ponds were filled with accumulated sludge.
3. Bunds between the ponds have been damaged at few places and need repair.

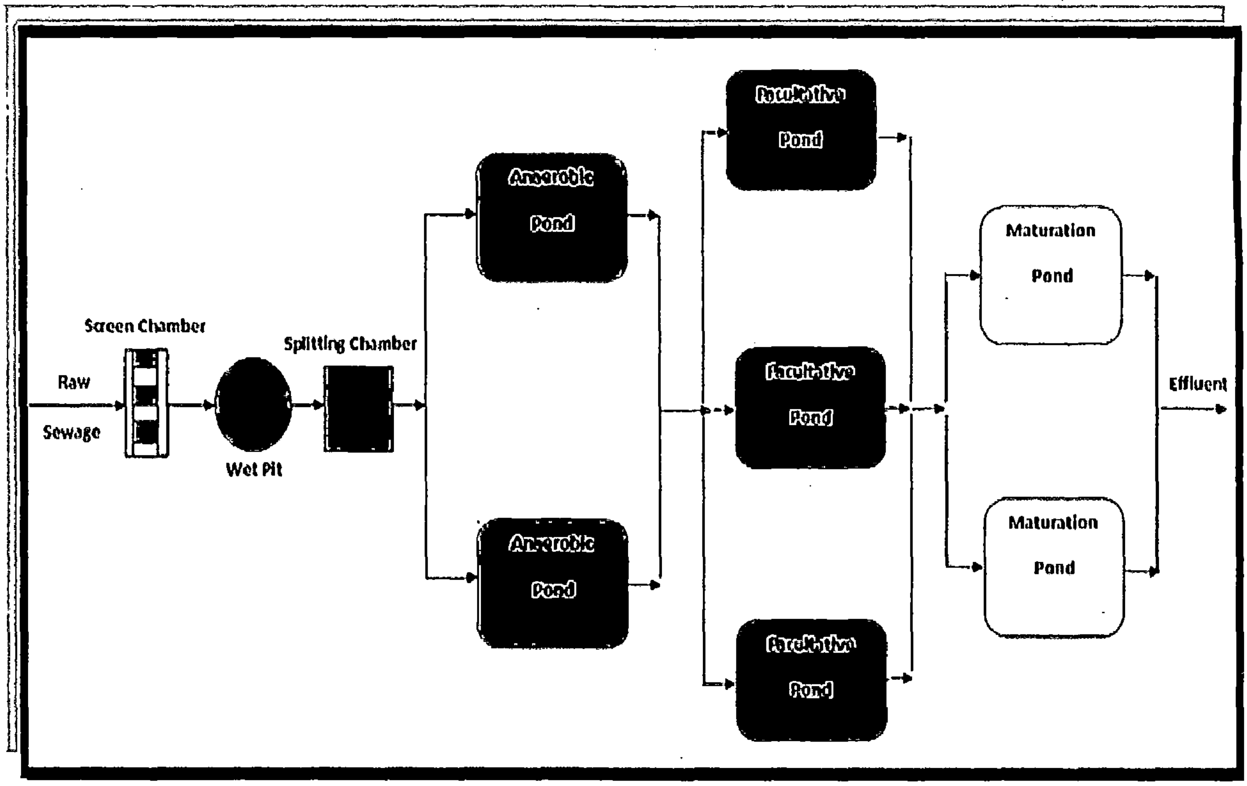


Figure 3.10: Layout diagram of WSP

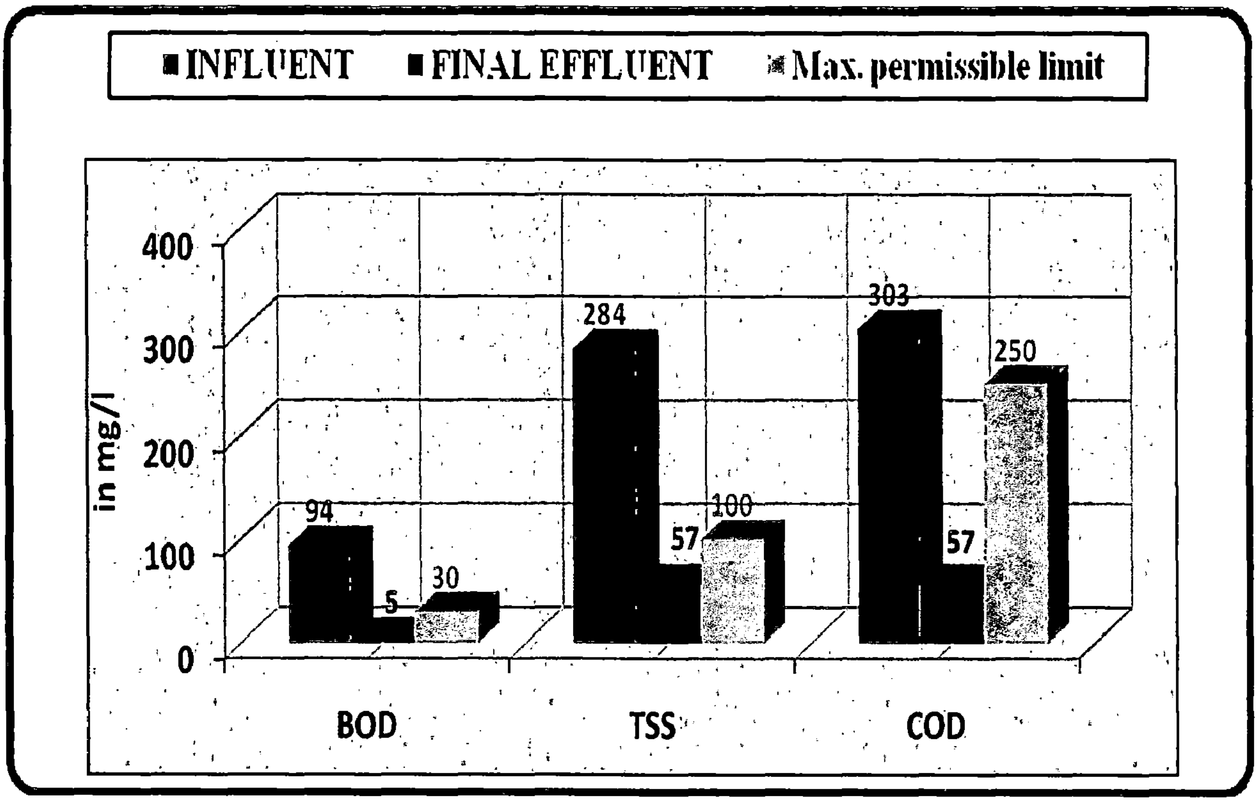
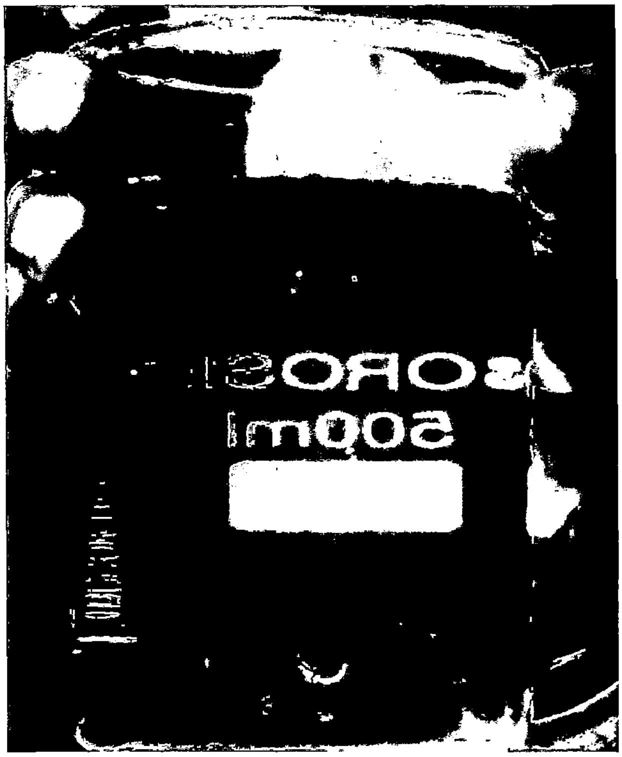


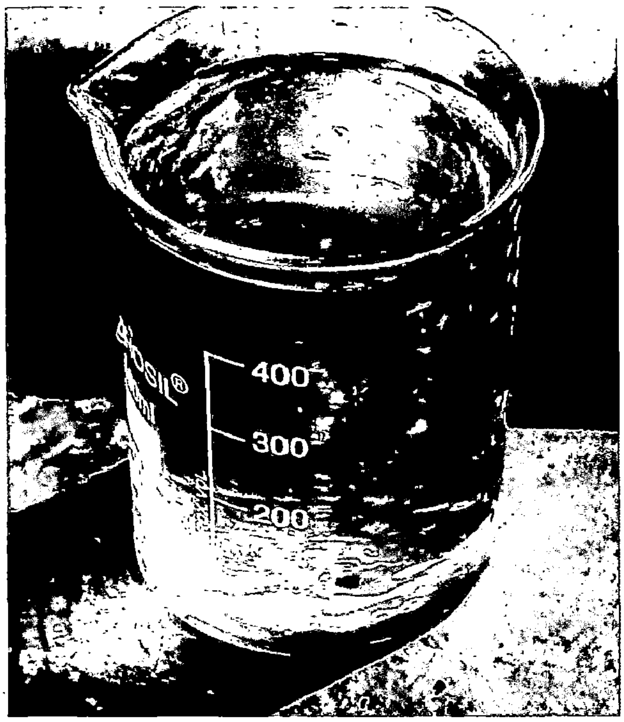
Figure 3.12: Performance evaluation of WSP, Titagarh

3.7 RESULT AND DISCUSSION

The effluent of various STPs are shown in Figure 3.13.

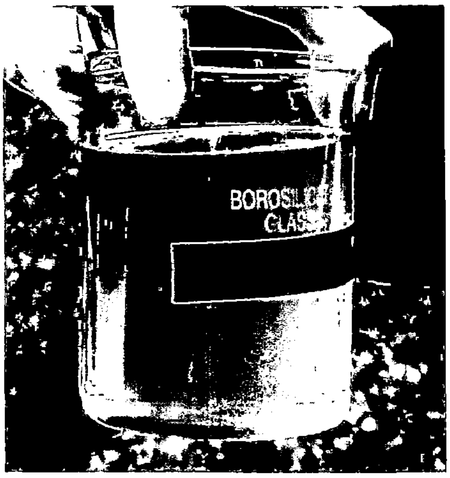


(a): Effluent from ASP, Haridwar

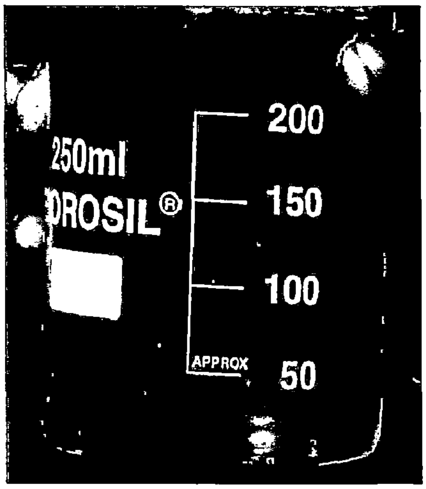


(b): Effluent from SBR, Goa

(c): Effluent from FAB, Lucknow



(d): Effluent from UASB+FPU, Karnal



(e): Effluent from WSP, Tikiapara

Figure 3.13(a), (b) & (c): Effluents of various STPs

The summary of performance for the various sewage treatment processes (STPs) have been presented in the following Table 3.14.

Table: 3.13: Summary of performance of various STPs

Item	WSP	UASB+FPP	ASP	FAB	SBR
BOD Removal, %	77-85	79-86	85-93	65-88	98-99
COD Removal, %	63-83	72-83	90-93	55-75	94-97
TSS Removal, %	78-92	80-87	90-95	55-91	87-93
Coliform Removal, %	60-99.99	99.99	99.99 after chlorination	99.99 after chlorination	99.99 after chlorination
Helminth Removal, %	Yes	Yes	-	-	-
Sludge handling	Manual desilting once in 5 -10 years	Directly dry on sludge drying beds or mechanical devices	First digest then dry on sludge drying beds or mechanical devices	Mechanical devices	Mechanical devices
Equipment requirement (except screening and grit removal which are required for all cases)	Nil	Nil(except gas collection and flaring; gas conversion to electricity is optional)	Aerators, Recycle pumps, Scapers, Thickeners, digestors, driers, gas equipment	Blowers, sludge pumps	Aerators, PLC, Decanters, sludge pumps.
Operational characteristics	Simplest	Simpler than ASP	Skilled operation is required	Skilled operation is required	More skilled personnel required

CHAPTER 4

DESIGN OF STPs BASED ON DIFFERENT TECHNOLOGIES

4.1 INTRODUCTION

In order to calculate the capital cost of various STPs, detailed design of various STPs have been prepared showing the typical sectional drawings of each. The cost estimate for the construction (Annexure – IV) based of design has been prepared to arrive the capital cost of various STPs, as required for the life cycle cost analysis in subsequent chapter. Here detailed design criteria has been mentioned based on which detail designing has been prepared for the following:

1) Activated Sludge Process (ASP).
2) UASB Technology with post treatment final polishing pond (UASB+FPP).
3) Fluidized Aerobic Bed (FAB) Reactor.
4) Sequencing Batch Reactor (SBR).
5) Waste Stabilization Pond (WSP).

The design of STP has been divided in two parts involving with

1) Primary treatment of wastewater, where design of inlet chamber, screen chamber and grit chamber have been done, which are common to all STPs and,
2) Secondary treatment (Biological) of wastewater.

4.2 GENERAL DESIGN PARAMETERS

The plant based on different technologies have been designed to treat to raw sewage having following characteristics:

Average Flow	:	10,000m^3/d (10MLD)
	:	0.116m^3/sec
Peak Flow	:	22,500m^3/d
BOD	:	300mg/l
COD	:	450mg/l
TSS	:	600mg/l
pH	:	7 – 7.5
Coliform count	:	$10^7 - 10^8$ MPN/100ml.

Treated sewage characteristics will be as following considering STP design:

BOD	:	< 30mg/l

COD	:	< 100mg/l
TSS	:	< 50mg/l
pH	:	7 – 9
Coliform count	:	< 10^3 MPN/100ml.

4.3 DESIGN OF PRIMARY TREATMENT UNIT

4.3.1 Design Criteria

4.3.1.1 Inlet Chamber

This chamber is designed for peak flow to accommodate the inlet pipes. The chambers of size length 2.0m, width 2.0m and of total depth 1.5m were provided , assuming 10sec as retention period.

4.3.1.2 Screen Chamber

Design of screen chamber was done as per specification stated below.

1) Flow velocity at average flow.
2) Clear space in screen as 20mm
3) Inclination of screen as $30^{\circ} - 45^{\circ}$.
4) Depression of channel where screen mounted : 75mm to 150mm.

The width of screen calculated by formula

$$W_s = (Q \sin\alpha) / (d * V_s)$$

Where,

Q = Peak flow rate in m^3/sec ;

α = Angle of inclination = 45°

4.3.1.3 Grit Chamber

In design of grit chamber, the minimum size of particle to be removed was assumed to be 0.15mm.

The settling velocity is evaluated by Hazen's modified formula:

$$V_s = 60.60(S_s - 1) * d * [(3T+70) / 100]$$

Where,

d = Size of particle in metre, 0.015m;

T = Temperature, $20^{\circ}C$;

S_s = Sp. Gravity of particle, 2.50;

V_s = Settling velocity in m/sec.

Now, The horizontal settling velocity should be less than 0.3m/sec. The dimensions of Parshall flume was obtained from Table11.2[5] of "Manual of sewerage and sewage treatment".

4.3.2 Detailed Design

4.3.2.1 Inlet chamber

Average flow	=	10	MLD or
	=	0.116	m^3/sec
Peak flow (2.25 X avg. flow)	=	22.50	MLD or
	=	0.260	m^3/sec
Assuming a retention time of 10 seconds			
Volume of inlet chamber	=	2.60	m^3
Assuming a depth of 1.0 m and a free board of 0.5 m			
Area of inlet chamber	=	2.60	m^2
Providing a width of 2m, length	=	1.30	m

Provide Size of inlet chamber 2 X 2 X 1.5 m.

4.3.2.2 Screen chamber

The velocity through the screen	=	0.9	m /sec
Area of screen	=	0.29	m^2
Assume a depth of flow in screen	=	0.90	m
Width of screen	=	0.32	m
Providing a clear spacing of 25mm no. of spacing	=	13	
Using 20mm dia. bars width of screen	=	581.50	mm or
Say,	=	600mm	

Provide a screen of width 0.75m with one no. as standby.

4.3.2.3 Grit chamber

Settling velocity/ surface overflow rate	=	0.75	m/min
Area of grit chamber	=	20.83	m^2
Assuming width of channel	=	1	m
So, length of channel	=	20.83	m
Providing length of chamber	=	12	m

Provide 2nos. of grit chamber.

Assuming depth of grit chamber	=	1	m

The horizontal velocity	=	0.15	m/sec
Horizontal settling velocity	=	0.09	m/sec < 0.3 m/sec O.K.
Check for HRT	=	80.00	Sec i.e. 60<80<120 O.K.

Provide 2 nos. of grit chambers of size 1m x 12m x 1.5m each (including 0.5m free board).

Typical layout of sectional drawing is shown in Figure 4.1

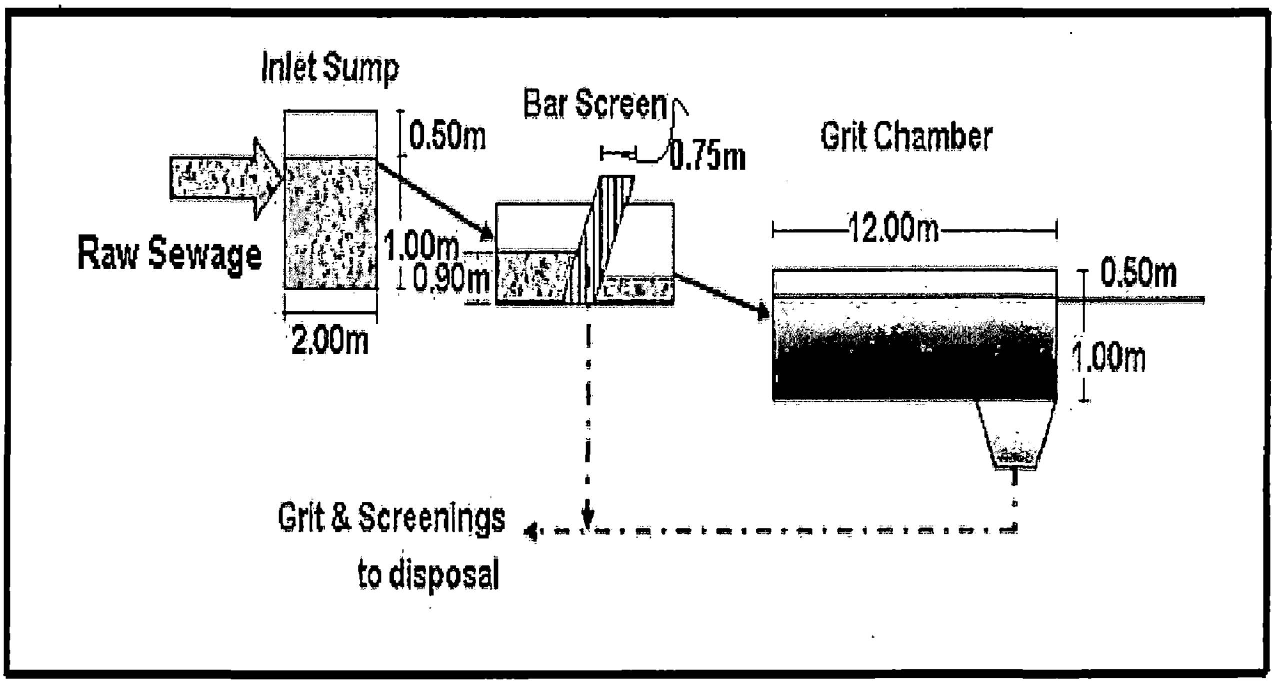


Figure 4.1: Primary treatment unit of wastewater treatment process

4.4 DESIGN OF SECONDARY TREATMENT UNITS OF ASP

4.4.1 Design Criteria

4.4.1.1 Primary Clarifier

Design criteria:- Design parameters has been taken from Table12.1[5]"Manual of sewerage and sewage treatment".

1) Overflow rate for average flow rate : 35 - 50m^3/m^2/day.
2) Detention period : 2.0 - 2.5hrs.
3) Straight water depth : 2.5 – 3.5m.

4.4.1.2 Aeration Tank

Parameters for Aeration Tank design are selected from Table 13.1[5]"Manual of sewerage and sewage treatment".

1) F/M ratio : 0.3 - 0.4 kg BOD/kg MLSS.day.
2) MLSS : 1500 – 3000mg/l

3) D.O. level : 1.0ppm.

4) Temperature : 25°C

5) Normal O_2 required : 0.8 - 1.0kg O_2/kg BOD removed.

6) Hydraulic retention time : 4 – 6hrs.

4.4.1.3 Secondary Clarifier

Design criteria:- Design parameters has been taken from Table12.1[5]"Manual of sewerage and sewage treatment".

1) Overflow rate for average flow rate : 15 - 35m^3/m^2/day.

2) Straight water depth : 3.5 – 4.5m.

3) Sludge recirculation ratio : 33.33% .

4.4.1.4 Sludge Thickener

Design parameters were taken from Table 17.1[5] "Manual of sewerage and sewage treatment".

1) Hydraulic loading rate : 0.8m^3/m^2/hr

2) Solid surface loading rate : 30 - 50kg/m^2/day.

3) Suspended solid removed : 60% (from primary clarifier).

4) Excess activated sludge solid : 50% of BOD removed in ASP.

5) Solid consistency of sludge fed : 1.5%

Higher cross sectional area considered among area calculated on the basis of Sl.No.1 & Sl. No.2.

4.4.4.5 Sludge Digester

The sludge digester volume must be sufficient to prevent the process from failing under all accepted conditions. Design parameters were taken from Table 17.3[5] & Table 17.4[5] "Manual of sewerage and sewage treatment".

1). Solid retention time : 25days

2) VSS in sludge solid : 70% of PSS + 60% of SSS.

3) Sludge conc. : 6.0%

4) VSS destroyed during digestion : 60%

5) Moisture content of digested sludge : 8.0%

The capacity of digester tank was calculated using volume reduction formula:

$$V = [V_f - 2/3(V_f - V_d))]*t$$

Where,

V = Volume of digester, m^3,

V_f = Volume of fresh sludge, m^3/day,

V_d = Volume of digested sludge, m^3/day,

and t = digestion time, days.

So, 1nos. sludge digester of 18m dia. was provided.

4.4.1.6 Sludge Drying Bed

Sludge drying bed has been designed assuming the following data (Appendix 17.2[5]):

1) Dewatering, drying and sludge removal cycle : 10days.
2) Depth of application of sludge solution : 0.4m.

4.4.2 Detailed Design

4.4.2.1 Primary clarifier

Nos. of clarifier provided	=	2	
Specified overflow rate (Avg.)	=	35 - 50 m^3/m^2/day	
Detention period	=	2 - 2.5 hrs	
Assume overflow rate (Avg.)	=	50	m^3/m^2/day
Average design flow in each	=	5	MLD or
	=	208.33	m^3/hr
Minimum diameter of clarifier reqd.	=	0.28217	m
Diameter of primary clarifier provided	=	14	m
Providing water depth of clarifier as	=	3	m
Effective volume of clarifier	=	461.58	m^3
Detention period in clarifier	=	2.22	hrs < 2.50 hrs O.K

Provide 2 nos. of primary clarifier of dia. 14 m and water depth of 3mwith free board 0.5m.

4.4.2.2 Aeration tank

Nos. of aeration tank provided	=	2	
Assuming BOD removed in clarifier	=	40%	of raw sewage BOD
BOD at inlet	=	180.00	mg/L
Hydraulic detention time	=	2.88	hrs
Volume of aeration tank	=	1800	m^3
So, volumetric load	=	1	kg BOD/m^3
BOD removed by aerobic process in reactor	=	75.00	kg/hr
Normal O_2 required	=	0.8	kgO_2 / kg of BOD
O_2 required	=	60.00	kg/hr

Oxygenation capacity of oxyrator (at std. cond.)	=	1.8	kg/SHP/HR
Correction factor	=	0.67	
Oxygenation capacity at field condition	=	1.21	kg/hr
Total SHP required	=	49.75	
SHP required in each aerator	=	24.88	
10% margin for motor rating, so dividing factor	=	0.9	
HP of motor aerator	=	27.64	

Motor for aeration in each aerator of 20 H.P capacity should be provided.

Effective volume of each compartment	=	900	m^3	
Volume of aeration tank provided (V)	=	1015	m^3	> 900 m^3 O.K

Free board of 500mm and platform should be at an elevation of 1.30 m from top water level.

4.4.2.3 Secondary clarifier

Aeration tank provided	=	2		
Assume clarifier surface loading rate	=	20	m^3/m^2/day or	
	=	0.833	m^3/m^2/hr	
Dia. of clarifier	=	17.85	m	
Diameter of clarifier	=	18	m	
Straight water depth of clarifier	=	3.5	m	
Volume of clarifier zone	=	890.19	m^3	
Considering the flow as recirculation (in %)	=	33.33%		
Sludge recirculation flow	=	69.44	m^3/hr	
Detention period in clarifier	=	3.20	hr	It is safe.

Provide 18m dia. secondary clarifier 3.50m depth having detention period 3.5hrs.

4.4.2.4 Sludge thickener

No. of thickener provided	=	1	
Raw sewage flow rate	=	6000	kg/day
Suspended solid removed in primary clarifier	=	60%	
Total suspended solid removed in primary clarifier	=	3600	kg/day
BOD removal in ASP	=	1600	kg/day
Excess activated sludge solid	=	800	kg/day
Total solid to be fed in gravity thickener	=	4400	kg/day

Solid consistency of sludge fed to thickener	=	1.50%	
Volume of sludge fed to thickener	=	293.33	m^3/day
Thickened sludge consistency from thickener	=	6.00%	
Volume of thickened sludge from thickener	=	73.33	m^3/day
Volume of raw sludge fed to digester	=	73.33	m^3/day
Consider hydraulic loading rate	=	0.80	m^3/m^2/day
Cross-sectional area of Thickener	=	15.28	m^2
Assume solid loading rate	=	40	kg/m^2/day
Diameter of thickener	=	11.84	m
Diameter of thickener provided	=	12.00	m

Provide sludge thickener of12.00 m dia. and 3.0 m surface water depth.

4.4.2.5 Sludge pump

Excess activated sludge solid	=	800	kg/day
Solid consistency of sludge fed to thickener	=	1.00%	
Volume of excess sludge	=	80	m^3/day or
	=	3.33	m^3/hr
Recirculation ratio	=	0.33	
Sludge recirculation rate	=	138.88	m^3/hr
Total sludge handled by sludge pump	=	140.96	m^3/hr

Provide 3 nos. of pumps of capacity 100m3/hr, out of which 2 will be working and 1(one) will remain standby.

4.4.2.6 Sludge digester

Sludge solid fed to digester	=	4400	kg/day

VSS in sludge solid = 70% of primary sludge solid

+ 60% 0f secondary sludge solid.

VSS in sludge solid fed to digester	=	3000	kg/day
Thickened sludge consistency from digester	=	6.00%	
Volume of sludge fed to digester	=	73.33	m^3/day
Assume detention period in sludge digester	=	25	days
Sludge digester volume for digestion	=	1833.33	m^3
VSS destroyed in digestion = 60% of VSS fed	=	1800	kg/day

Fixed solid from VSS destroyed = 25% of VSS destroyed

	=	450	kg/day

Total digested sludge = fixed solid in feed + undestroyed VSS			
+ fixed solid due to destroyed VSS	=	3050	kg/day
Digested sludge consistency from digester	=	8%	
Digested sludge volume	=	38.13	m^3/day
Assume sludge storage period	=	15	days
Total digested sludge volume	=	571.88	m^3
Total liquid volume of sludge digester	=	2405.21	m^3
Guaranteed gas produced from digester	=	2300	m^3/day
Gas loading rate allowed as per IS code	=	4.5	m^3/m^2/day
Minimum dia. should be	=	18.04	m
Volume of sludge digester selected	=	2583.15	$m^3 > 2405.21 m^3$ O.K.

Provide dia. of sludge digester as 18 m.

4.4.2.7 Sludge drying bed

Digested sludge volume	=	38.13	m^3/day
Digested sludge volume per year	=	13915.6	m^3
Assume no. of drying cycle in a year	=	10	
Digested sludge volume per drying cycle	=	1291.64	
Thickness of sludge layer on drying bed / year	=	0.25	
Sludge drying bed area reqd.	=	5566.25	m^2
Area for size, 35m (L) X 25m (W)	=	875	m^2
No of sludge drying bed	=	5.896	≅ 6

Provide 6 nos. of sludge drying bed of size 35m(L) X 25m (W).

4.4.2.8 Gas holder

No. of gas holder	=	1	
Capacity of each gas holder	=	460	m^3
Assume effective movement of dome	=	5	m
Dia. of gas holder	=	10.8	m

Provide gas holder as 11m diameter of total height as 6.0m, where 0.5m is free board .

Sectional drawing of typical arrangement of ASP has been shown in Figure 4.2 as per detailed design.

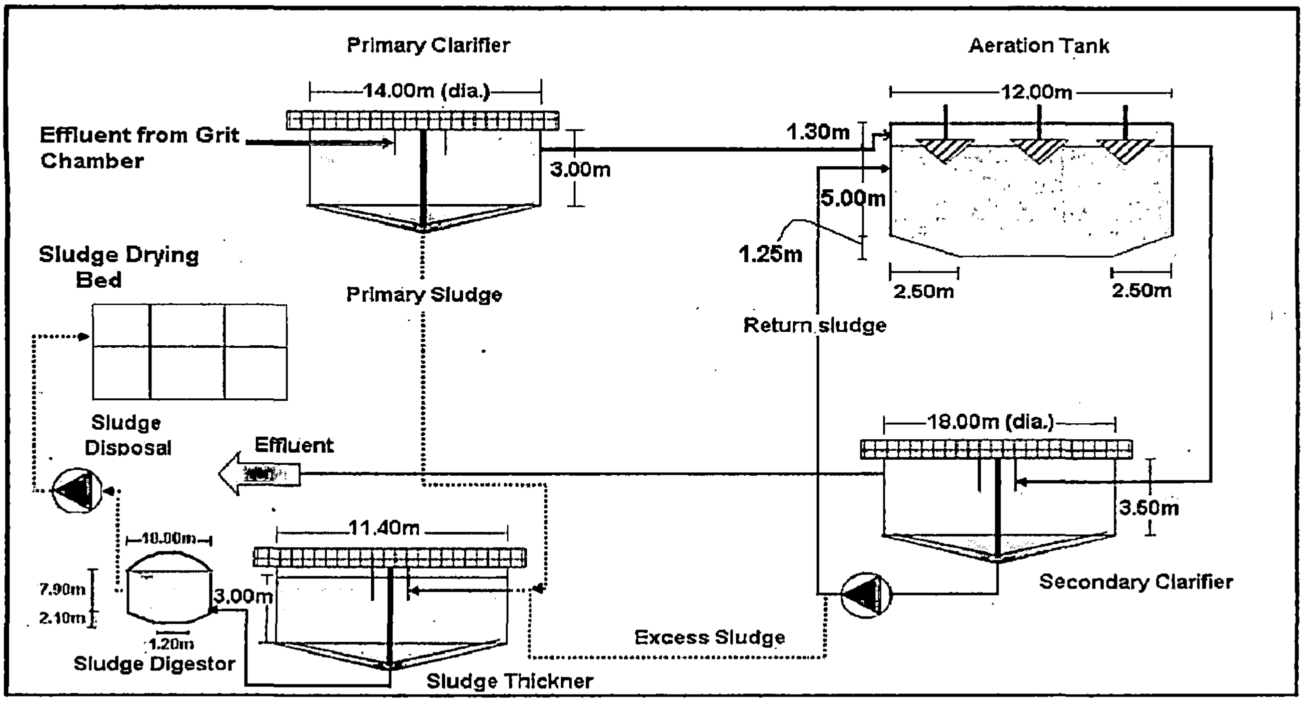


Figure 4.2: Typical layout of sectional drawing of ASP

4.5 DESIGN OF SECONDARY TREATMENT UNITS OF UASB

4.5.1 Design criteria[2]

UASBs are considered where temperature in the reactor will be above 20°C. Between 20° to 26°C, a solid retention time (SRT) of around 30 to 38 days in India gives a stabilized sludge for disposal on open sand beds. At equilibrium conditions, the sludge withdrawn daily has to be equal top the sludge produced daily.

1) Hydraulic Retention Time (HRT) = Reactor Volume / Flow rate
 = 8 – 10hrs. at average flow.

2) Solid Retention Time = $\frac{\text{Total sludge present in the reactor, kg}}{\text{Sludge withdrawal per day, kg/d}}$
 = 30 – 50days or more.

3) Height of reactor = 4.5 – 5m.

4) Sludge blanket depth = 2 – 2.5m

5) Organic loading on sludge blanket = 0.3 – 1.0 kg COD / kg VSS day.

6) Average conc. of sludge in the blanket = 70 kg / m^3.

7) BOD / COD Removal Efficiency = 75 – 85%

8)	Sludge production	= 0.15 – 0.25kg TS/$m^3$of sewage treated
9)	Sludge drying period	= 7days.
10)	Gas production	= Theoretical 0.38m^3/kg COD removed.
		Actual 0.1 – 0.3 m^3/kg COD removed.
11)	Biogas yield	= 0.08 m^3/kg COD removed.
12)	Methane content	= 60 – 70%.

In order to retain flocculent sludge in reactor all times, the upflow velocity should not be more than 0.5m/hr at average flow and not more than 1.2m/hr at peak flow.

4.5.2 Detailed Design

4.5.2.1 Division box

The flow is divided into two streams and is conveyed to distribution box.

Assume a HRT	=	10	sec
Total volume of division box	=	2.60	m^3
Total width of division box	=	2	m
Assume a depth of division box	=	1	m
Surface area	=	2.60	m^2

Size of division box = 2 x 1.5 x 1.5 m (including 0.5m free board)

Assume velocity in pipe	=	1	m/sec
Dia. of pipe	=	0.407	m or
Say,	=	450	mm

4.5.2.2 Distribution box

The flow from the division box is received in the central compartment of the distribution box. The flow is distributed over 8 compartments through flow weirs. The flow to the feeding boxes placed on the top of the UASB reactors is carried through 200mm OD HDPE pipes.

Assume HRT	=	10	sec
Assume depth of distribution box	=	1	m
Volume of distribution box	=	1.302	m^3
Area of distribution box	=	1.302	m^2

Size of distribution box = 1.5 x1.5 x 1.5 m (including 0.5m free board) 2 nos.

No. of feed pipe	=	8	
Flow per pipe	=	0.016	m^3/sec

Assume velocity in pipe	=	1	m/sec
Dia. of feed pipe	=	0.144	m or
	=	150	mm

4.5.2.3 UASB Reactors

Inlet BOD in UASB reactor	=	270	mg/ L
Inlet TSS in UASB reactor	=	420	mg/ L

Provide 2 nos. of reactors of capacity 5MLD or 5000m^3/day

Capacity of one reactor	=	5000	m^3/day or
	=	208.33	m^3/hr
Peak flow	=	468.75	m^3/hr
Assume max upflow velocity	=	1.2	m/hr
Adopt upflow velocity	=	0.54	m^3/m^2/hr
Surface area of one reactor	=	385.80	m^2

Provide 2 nos. of reactor of size 35 x 12 m each.

Total area provided	=	420	m^2
Upflow velocity	=	1.215	m/hr < 1.5m/hr O.K.
No. of bays required of 4m of depth	=	3	
Assume height of reactor	=	5	m
Volume of reactor	=	2100	m^3
Volumetric loading	=	1.19	kg COD /m^3/d i.e.
		0.8<1.19< 1.2 kg COD /m^3/d O.K.	
HRT	=	10.08	hr 8<10.08< 12 hr O.K.

4.5.2.4 Sludge Production

Expected BOD Removal Efficiency	=	70%	
	=	140	mg/L
Ash Content in TSS	=	30%	
	=	180	mg/L
VSS Content	=	70%	of TSS
	=	420	mg/L
New VSS Produced in BOD removal	=	10%	of BOD rem.
	=	14	mg/L
Sludge Produced (A)	=	210	Kg/d
Non-Degradable VSS = 60% of VSS	=	252	mg/L

Sludge Produced (B)	=	2520	Kg/d
Ash Received in flow = 30% of TSS	=	180	mg/L
Sludge Produced (C)	=	1800	Kg/d
Total Sludge Production A+B+C	=	4530	Kg/d
Sludge bed concentration	=	65	kg TSS /m3
Volume of sludge to be removed	=	69.69	m^3/day or 70.00 m^3/day

4.5.2.5 Sludge drying bed

Sludge application depth	=	0.4	m
Digested sludge volume	=	68.62	m^3/day
Sludge drying period	=	7	day
Sludge drying bed area reqd.	=	1200.77	m^2
Providing the size of one drying bed	=	320.00	m^2
No of sludge drying bed	=	3.75	$\cong$ 4

Provide 4 nos. of sludge drying beds of size 20m x 16m.

4.5.2.6 Biogas production

Biogas yield	=	0.08	m3 / kg COD removed
COD	=	500.00	mg/ L
COD removed	=	70%	
COD load	=	5000	kg /d
COD removed	=	3500	kg /d
Theoretically gas produced /kg COD removed	=	0.38	m^3
Actual gas produced /kg COD removed	=	0.1-0.3	m^3
Theoretically gas produced	=	1330	m^3
Actual gas produced	=	700	m^3
Biogas production	=	280	m^3/day
Methane content	=	60 - 70 %	
Methane gas produced from biogas	=	60%	
	=	168.00	m^3/day

4.5.2.7 Energy/Electricity production

Energy Equivalent of methane	=	33810	kJ/m^3 of methane
COD removed	=	3500	kg/d
Methane generated	=	1225.00	m^3/day

Biogas production	=	280 m^3/day
Energy production per day	=	571.20 KWh/day
Energy produced	=	13.25 x 107 KJ/d
Theoretical Electricity produced	=	1533 KW
Efficiency of generator	=	10 % - 20 % (generally 10 %)
Actual Electricity Produced:	=	153.3 KWh

Accordingly Sectional drawing of typical arrangement of UASB has been shown in Figure 4.3.

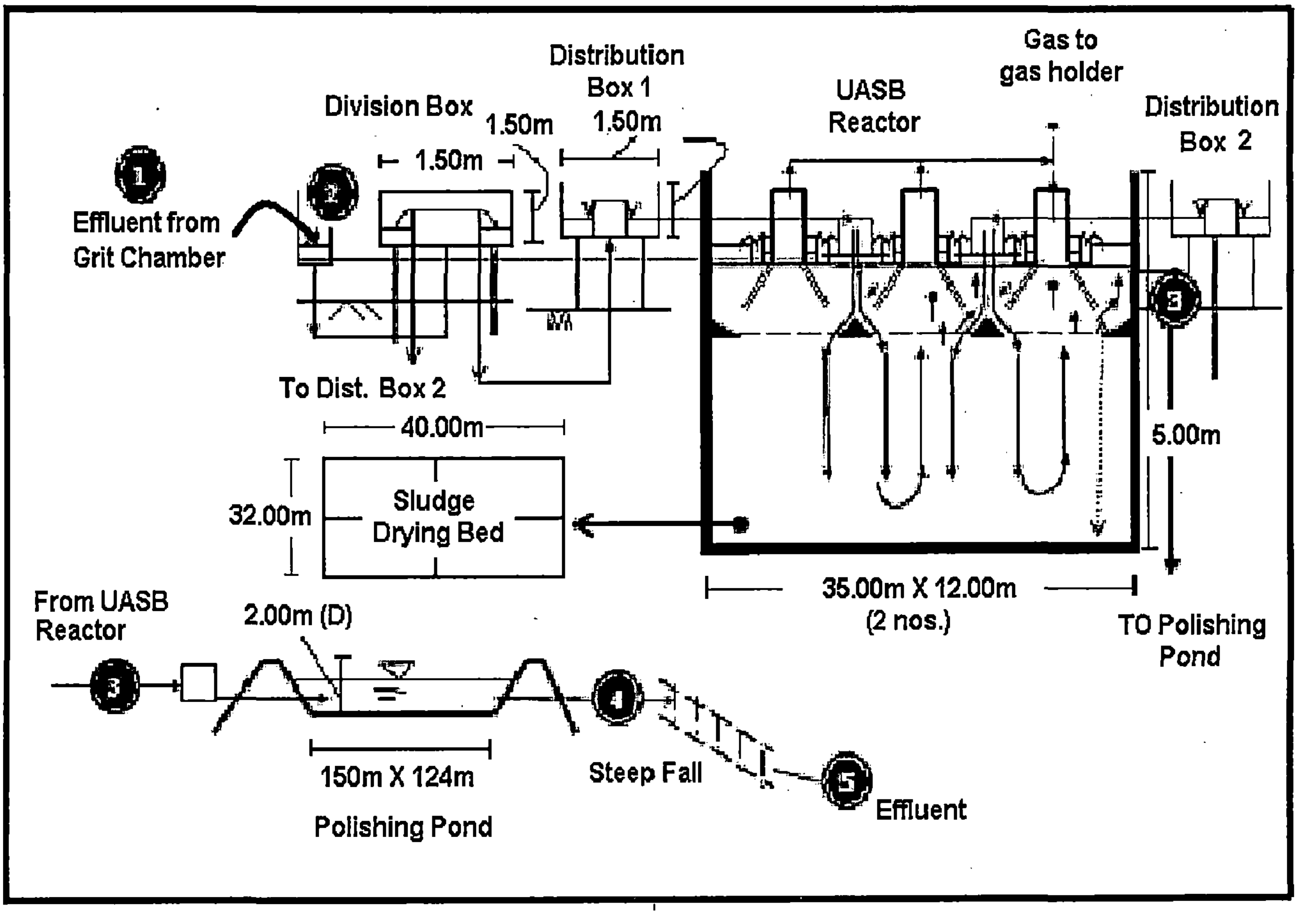


Figure 4.3: Typical layout of sectional drawing of (UASB+FPP)

4.6 DESIGN OF SECONDARY TREATMENT UNITS OF FAB

4.6.1 Design criteria

It is a hybrid system consisting of both suspended & fixed biomass growth, and it is achieved by incorporating a biofilm support media, into the existing aerobic zone of an activated sludge plant.

Surface water depth in Reactor	:	5m
Specific weight of air	:	1.21
Percentage of 02 in air	:	23%
Oxygen transfer efficiency	:	15-20%
Hydraulic Loading of secondary Clarisettler	:	10-15 m3/m2/day
Surface Area of Tube Module	:	4.4 m^2 / m^2 of plan area
Sludge Consistency	:	3.50% (Underflow of Thickener)

4.6.2 Design Details

4.6.2.1 FAB Reactors

Total BOD load	=	3000	kg/day
No. of FAB Reactors	=	2	nos.
HRT	=	3	hrs
Volume of each reactor	=	625.0	m^3
Assume, Surface water depth	=	5	m
Diameter	=	12.6	m

Provide 2 nos. of reactors of dia. 13m and depth of 6m including 1m FB.

4.6.2.2 Oxygen requirement

For BOD removal	=	0.8 - 1 kg/ kg of BOD,	
Specific weight of air	=	1.21	
Percentage of 0_2 in air	=	23%	
Oxygen transfer efficiency	=	15-20%	
Air Blower required	=	1242	m^3/hr
Say,	=	850	m^3/hr

4.6.2.3 Secondary Clarisettler

Assume hydraulic loading	=	11	m^3/m^2/day
Plan Area	=	909.09	m^2
Surface Area of Tube Module	=	4.4	m^2 / m^2 of plan area
Actual Plan Area	=	206.6	m^2
Diameter of clarisettler	=	16	m
Surface water depth	=	3.75	m

Provide 16 m dia claritube settler 3.75m depth.

4.6.2.4 Chlorine Contact Tank

HRT	=	30	min
Volume of CCT	=	208.3	m^3
depth	=	2.5	m
Area	=	83.33	m^2

Provide 1 no. of circular CCT in annular construction around claritubesettler.

4.6.2.5 Sludge production

Inlet BOD	=	300	mg/ L
Inlet TSS	=	600	mg/ L
	=	6000	kg/day
Total non VSS load due to SS (A)	=	3600	kg/day
Inlet BOD	=	300	mg/ L
	=	3000	kg/day
Sludge yield coefficient	=	0.15	kg/kgBOD removed
Sludge due to BOD removal (B)	=	450.00	kg/day
Total Sludge after FAB System (A+B)	=	3900	kg/day
Sludge Consistency	=	1.00%	(Underflow of Clarisettler)
Density of Sludge	=	1020.00	kg/m^3
Volume of Sludge	=	397.06	m^3/day

4.6.2.6 Sludge Sump

Inlet Sludge Load	=	4050	kg/day or
	=	397.06	m^3/day
HRT	=	4	hrs
Volume of sump	=	66.18	m^3
depth	=	2.50	m
Area	=	26.47	m^2
Diameter	=	5.81	m

Provide sump of 6m dia. and depth of 2.5 m.

4.6.2.7 Sludge Thickener

Inlet Sludge Load	=	4050	kg/day
Solids Loading	=	60	kg/m^2/day
Area of Thickener	=	67.5	m^2
Diameter of Thickener	=	9.3	m

Depth	=	3.50	m
Sludge Consistency	=	3.50%	(Underflow of Thickener)
Density of Sludge	=	1020	kg/m^3
Volume of Sludge	=	113.45	m^3/day (Underflow of thickener)
Depth	=	3.50	m
Area	=	31.41	m^2
Diameter	=	6.42	m

Provide 6.5m dia. and 3.5 m depth.

4.6.2.8 Centrifuge

Inlet Sludge Load	=	4050	kg/day
Inlet Sludge Consistency	=	3.50%	
Volume of Sludge	=	113.45	m^3/day
Operating hrs per day	=	20	hrs
Centrifuge Capacity	=	5.67	m^3/hr
Provide centrifuge capacity	=	6	m^3/hr

4.6.2.9 Filtrate sump

Flow	=	393.09	m^3/day
HRT	=	2	hrs
Volume	=	32.76	m^3
Depth	=	2.5	m
Area	=	13.10	m^2
Diameter	=	4.08	m

Provide 4.5 m dia. and 2.5 m depth.

Accordingly Sectional drawing of typical arrangement of FAB has been shown in Figure 4.4.

4.7 DESIGN OF SECONDARY TREATMENT UNITS OF SBR

4.7.1 Design criteria[2]

This process is based on activated sludge extended aeration principle, which serves double purpose of aeration and settling in the same tank, batchwise and the typical operating schedule is shown in Figure 4.5.

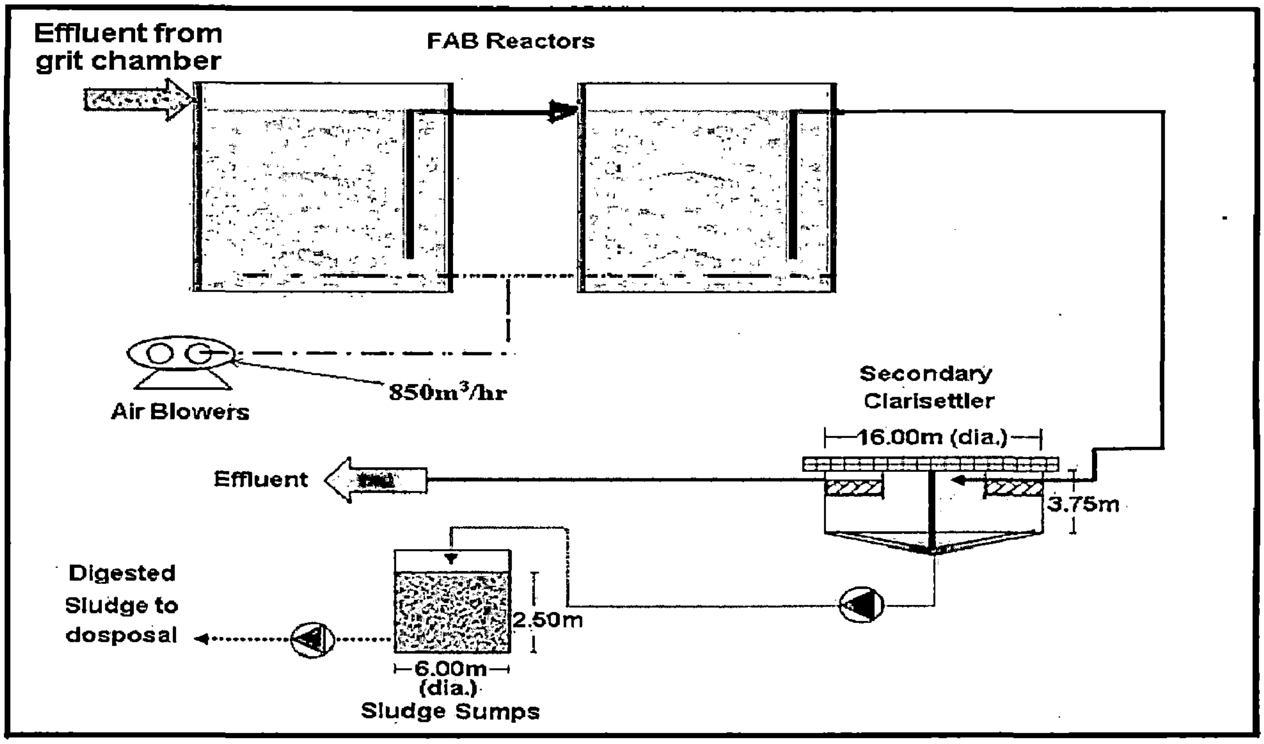
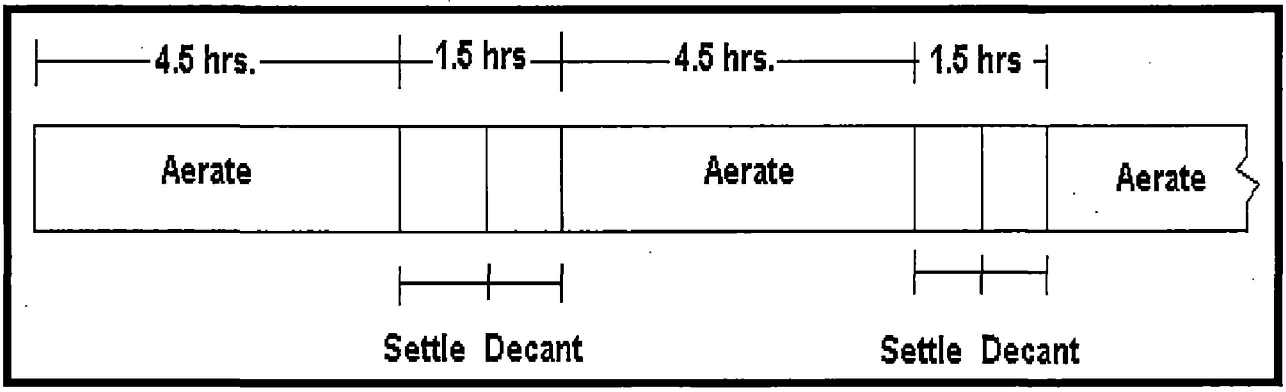
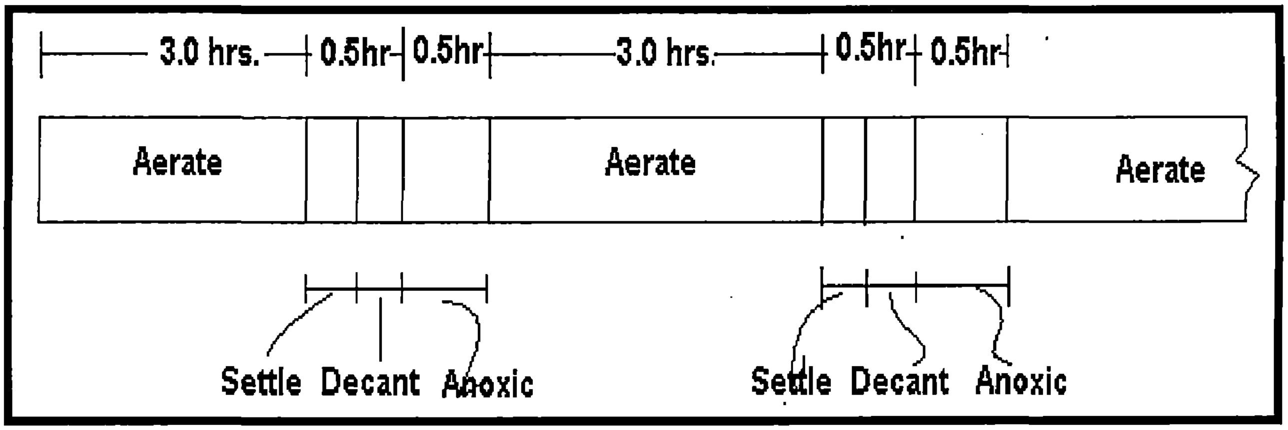


Figure 4.4: Typical layout of sectional drawing of FAB



(a): Operating schedule required without nitrogen removal



(b) Modified operating schedule where Denitrification required

Figure 4.5: Typical operating schedule with & without nitrogen removal of SBR

1) Volume of settled sludge : 70% of depth (after 1 hr.)

2) Excess sludge : 0.4 g/g BOD removed.

3) Denitrification rate (17 – 23°C) : 0.25-0.6 mg NO_3-N/g MLSS/hr.

4) Oxygenation rate for 12 hr aeration : 2.4 kgO_2 / kg BOD_5 applied.

5) Expected BOD removal efficiency : 95%

It is to mention that , the anoxic period should be such that only denitrification occurs in it without touching sulphate. The anoxic period required for denitrification is usually the 1.0 to 1.5 hr, as seen from Figure 4.5.

4.7.2 Detailed Design

4.7.2.1 Aeration Basin

Decanting period	=	6	hr
Decanting frequency per day	=	4	
Loading rate	=	0.05	kg BOD / kg MLSS
Assume MLSS at low water level	=	5000	mg/L or
	=	5	kg/m3
Assume volume of settled sludge	=	70%	of depth (after 1 hr)
Excess sludge	=	0.4	g/g BOD removed
Assume denitrification rate	=	0.25-0.6	mg NO3-N /g MLSS /hr
Oxygenation rate for effective 12 hr aeration	=	2.4	kg O2/ kg BOD applied
Assume F/M ratio as	=	0.15	kg BOD / kg MLSS
BOD	=	200	mg/L
So, M	=	1333.33	kg MLSS
Assume MLSS conc. at mixing condition	=	3000	mg/L
So, lagoon volume at low water level	=	266.67	m^3
Add 10% volume, so volume	=	293	m^3
Volume between the maximum & minimum	=	2500	m^3
Total volume for 4 decanting per day	=	2793	m^3
Assume depth of lagoon	=	5	m
So, area	=	558.67	m^2
Provide the no of Basin	=	2	

So, provide 2 nos. Basin of 16m x 16m x 5.3 m (including freeboard).

4.7.2.2 Sludge production calculation

Inlet TSS	=	6000	kg/day
Total non VSS load due to SS (A)	=	3600	kg/day
Inlet BOD	=	300	mg/ L
	=	2000	kg/day
Sludge yield coefficient	=	0.15	kg/kgBOD removed
Sludge due to BOD removal (B)	=	300	kg/day
Total Sludge after Basin (A+B)	=	3900	kg/day
Sludge Consistency	=	0.01	
Density of Sludge	=	1020	kg/m3
Volume of Sludge	=	382.35	m3/day

4.7.2.3 Aeration & Mixing calculation

For BOD removal	=	0.8 - 1	kg/ kg of BOD,
Specific weight of air	=	1.21	
Percentage of 0_2 in air	=	23%	
Oxygen transfer efficiency	=	15-20%	
Air Blower required	=	828	m^3/hr
or say	=	850	m^3/hr

4.7.2.4 Sludge Drying Bed

Total VSS load due to SS	=	2400	kg/day
Total solid content in sludge	=	1%	
Excess sludge volume	=	24	
Liquid sludge is spread to a depth of	=	0.25	cm
Assume sludge drying cycle	=	12	days
Sludge drying bed area reqd. / day	=	96	m^2
Total area required	=	1152	m^2

Provide sludge drying bed size of 40m X 30m of 2no.

Sectional drawing of typical arrangement of SBR has been shown in Figure 4.6.

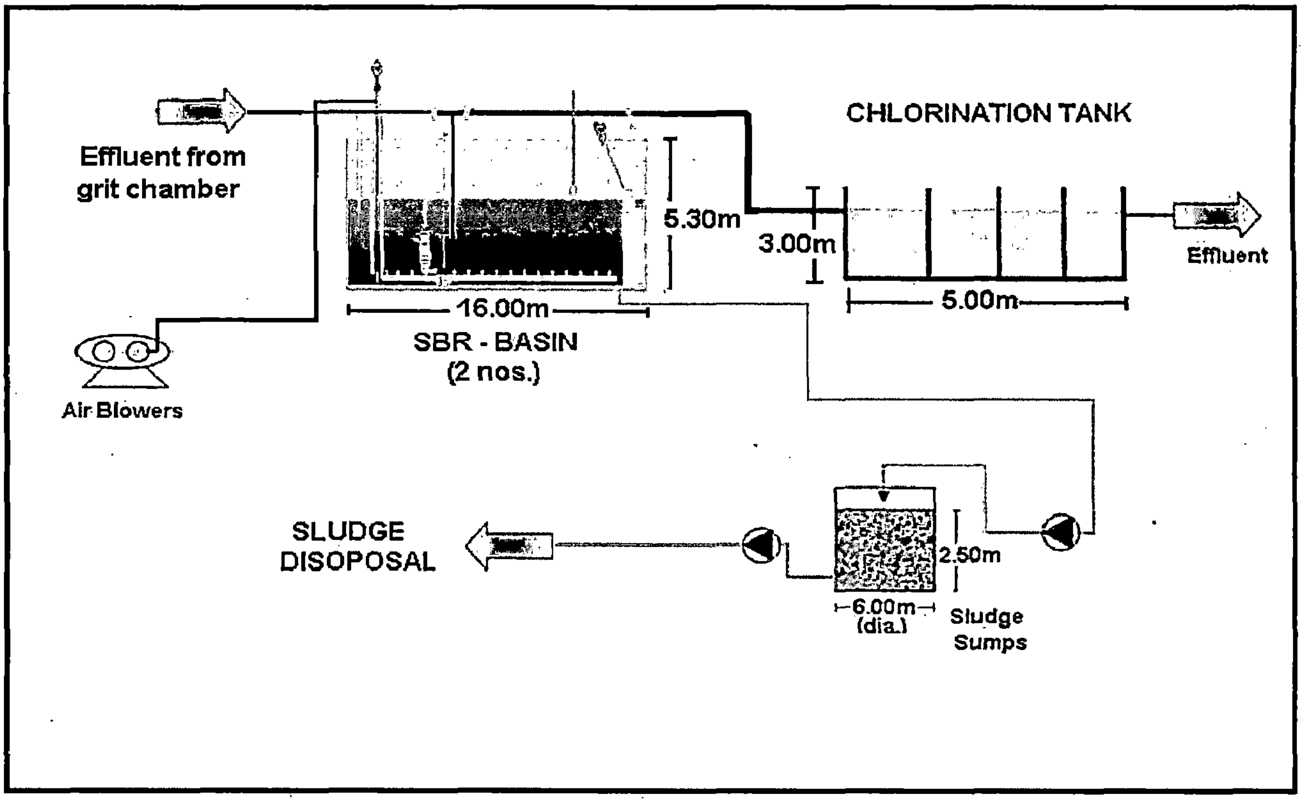


Figure 4.6: Typical layout of sectional drawing of SBR

4.8 DESIGN OF SECONDARY TREATMENT UNITS OF WSP

4.8.1 Design Criteria

There are four important design parameters for WSP, including temperature, net evaporation, flow and BOD. The climate also is important in as much as the processes responsible for BOD_5 and fecal bacterial removal are temperature-dependent. Further, algal photosynthesis depends on solar radiation, itself a function of latitude and cloud cover.

4.8.1.1 Anaerobic Ponds

The design of anaerobic ponds is based on volumetric loading (λv, $g/m^3/d$), which is given by:

$$\lambda v = L_i \, Q / V_a$$

Where L_i is influent BOD (mg/l), Q is flow rate (m^3/day), and V_a is anaerobic pond volume (m^3). Once the organic loading is selected, the volume of the pond is then determined with the using the above equation. The hydraulic retention time is given by the following equation:

$$HRT = V_a / Q$$

A retention time less than one day should not be used for anaerobic ponds; if it occurs, however, a retention time of one day should be used, and the volume of the pond should be recalculated. Table 4.1 illustrates the permissible loadings to the anaerobic ponds.

Table: 4.1: Design value of permissible volumetric BOD loadings on, and percentage BOD removal in, anaerobic ponds at various temperatures

Temperature (^{0}C)	**Volumetric loading (g/m^3.day)**	**BOD removal (%)**
< 10	100	40
10 - 20	20T – 100	2T+20
20-25	10T+100	2T+20
>25	350	70

4.8.1.2 Facultative Ponds

The facultative ponds are designed based on the surface BOD loading, (λ_s, kg/ha.day), which is give by: $\lambda_s = 10 * L_i * Q / A_f$

Where L_i is the concentration of influent sewage (mg/l), and A_f is the facultative pond area (m^2).

As per CPHEEO Manual on Sewerage and sewage treatment there are 2 methods for selecting the permissible design values for surface BOD loading λ_s, one based on latitude and another based on temperature.

Surface BOD loading S_L based on latitude.

The variation of design value for λ_s, with latitude in India is given in the Table 4.2. The mathematical relation is expressed as below

$\lambda_s = 375 - 6.25L$; where L is latitude.

Table: 4.2: Variation of design BOD loading on facultative ponds in India with latitude

Latitude in ^{0}C	**Design BOD loading λ_s in kg / ha.d)**
36	150
32	175
28	200
24	225
20	250
16	275
12	300
8	325

Surface BOD loading S_L based on temperature.

The design value for surface BOD loading λ_s based on temperature is given by the eqn

$$\lambda_S = 20T - 120, \text{ for } S_L = 225 \text{ kg/ha.day (for } 24^\circ \text{ latitude).}$$

Once a suitable value for surface BOD loading has been selected , the pond area can be calculated by the following eqn and its HRT is

$$\text{HRT} = \theta_f = A_f * D / Q_m$$

Where,

D = Depth of facultative pond

Q_m = Mean flow

= (Qi+Qe) / 2 where

Qi = influent flow

Qe = effluent flow

$$\text{HRT} = \theta_f = A_f * D/[(1/2)/(Q_i + Q_e)]$$

$$Qe = Qi - 0.001 * A_f * e$$

Where; e = net evaporation rate in mm / day

$$\text{HRT} = \theta_f = 2 * A_f * D/(2Q_i - 0.001 * A_f * e)$$

4.8.2.3 Maturation Ponds

The design of maturation pond is is to remove feacal coliform. The faecal coliform removal can be modelled by first order kinetics and is given by the eqn. for a single pond

$$N_e = N_i / (1 + K_T\theta) \quad \text{where}$$

N_i = no of FC per 100 ml of influent,

N_e = no of FC per 100 ml of effluent,

K_T = First order rate constant for FC removal in d^{-1},

θ = Retention time in days,

For a series of anaerobic, facultative and maturation ponds the above eqn becomes

$$\theta_m = \{[N_i / N_e(1 + K_T\theta_a)(1 + K_T\theta_f)]^{1/n} - 1\} / K_T$$

Where,

N_i = no of FC per 100 ml of influent,

N_e = no of FC per 100 ml of effluent,

K_T = First order rate constant for FC removal in d^{-1},

θ = Retention time in days,

4.8.3 Detailed Design

Detailed design has been prepared based on design criteria mentioned in Para 4.8.2. of this chapter and typical layout of sectional drawing showing details of various unit is being shown. Based on designed data land area required for various STPs has been prepared needed for life cycle cost analysis.

Input details:-

Latitude L (of Asansol, W.B)	23^0 68'	=	24	
Design temperature (T)		=	25	^0C
Net evaporation		=	5	mm/day
BOD of influent (Li)		=	200	mg/L

4.8.3.1 Anaerobic Pond

Volumetric BOD loading =10T+100	=	350	g/m^3d
Volumetric BOD loading	=	350	g/m^3d
HRT = Va / Q			
HRT = Li / Vol. loading	=	0.57	day or say
	=	1	day.
Va = HRT * Q	=	5714.29	m^3

Table 4.3: Details of anaerobic pond of different depth

Depth ⇨	**3m depth**		**4m depth**		**5m depth**	
Area of pond	1904.76	m^2 or	1428.57	m^2 or	1142.86	m^2 or
(1 acre= 4046.9 m^2)	0.471	acres	0.353	acres	0.282	acres

Provide anaerobic pond area with a depth of 3m of area 1904.76m^2 or 0.471acres.

4.8.3.2 Facultative Pond

Surface BOD loading S_L based on latitude

S_L=375-6.25L

where L is latitude which is 23^0 68' or 24°

S_L = 225kg / ha.day

A_f = 10* Li *Q / S_L

Li for facultative pond is 70% of BOD	=	60	
A_f	=	26666.7	m^2 or
	=	26667	m^2 based on latitude

Surface BOD loading S_L based on temperature

D = Depth of facultative pond nornally		=	1.5	m
HRT		=	4.03	days or
		=	4	days
Area of pond	A_f	=	26490.1	m^2

Provide 4 days retention period for the facultative ponds and 1.5 m depth of Area 26491m^2.

4.8.3.3 Maturation Ponds

i) For restricted irrigation

The retention time for anaerobic and facultative ponds are 1 and 4 days respectively from Table 4.7 the percentage of helminth egg removals in the pond are

Anaerobic pond	=	74.67
Facultative pond	=	93.38

Assuming the wastewater contains 750 helminth eggs/litre, the anaerobic pond effluent contains (0.2533*750) i.e 190 eggs per litre, and the facultative pond effluent contains (0.066*190) i.e. 13 eggs per litre. A maturation pond is therefore required to reduce the number of eggs to 1 per litre for restricted irrigation (Table 10.1)

The required percentage egg removal in the maturation pond is

θ_m		=	100[(13-1)/13]	
i.e. 92% . So from Table 4.7 , choose		=	3.6	days.
D = depth of maturation pond		=	1	m
Qi		=	9987	m^3/day

Therefore taking the depth of pond as

1m	A_m	=	35632	m^2

The final effluent flow for restricted irrigation is given by

Qe	=	9809	m^3/day

Thus 1.3 % of the flow is lost due to evaporation .

Table 4.4: Details of maturation pond for restricted irrigation

Area of anaerobic pond	1905	m^2 or	0.47	acres
Area of facultative pond	26491	m^2 or	6.55	acres
Area of maturation pond	35632	m^2 or	8.80	acres
Total area	64027	m^2 or	15.82	acres

ii) For unrestricted irrigation

$K_T = 2.60(1.19)^{T-20}$ = 6.20 days

θ_f = 4 days

Substituting all the above values = 43.19 days for n=1

θ_m = 2.48 days for n=2

≅ 2.5 days or 3 days

Depth = 1 m

λ_m = 133 kg/ha.day

Satisfactory as it is < 75% of permissible design loading on facultative ponds at 25° C (350 kg / ha day)

The area of first maturation pond is given by the following eqn.

$$A_{m1} = 2Q_i \theta_m / (2D + 0.001e\, \theta_m)$$

Where, Q_i :- effluent flow from facultative pond = 60000 m3/day

e :- net evaporation rate in mm / day. = 5 mm/day

D :- depth of maturation pond = 1 m

θ_m :- Retention time in days for maturation pond = 3 days

A_{m1} = 29737 m^2

The effluent flow from first maturation pond is

$Q_e = Q_i - 0.001\, A_{m1} * e$ = 9838 m^3/day

The area of second maturation pond is

A_{m2} = 29294 m^2

Q_e = 9750 m^3/day

For unrestricted irrigation the area requirements of pond is given below

Table 4.5: Details of WSP (For unrestricted irrigation)

Description	Mid depth Area				Depth (m)
Area of anaerobic pond 1 day HRT	1905	m^2 or	0.47	acres	3.0
Area of facultative pond 1 day HRT	26491	m^2 or	6.55	acres	1.5
Area of 1st maturation pond 1 day HRT	29737	m^2 or	7.35	acres	1.0
Area of 2nd maturation pond 1 day HRT	29294	m^2 or	7.24	acres	1.0
Total	87427	m^2 or	21.60	acres	

Sectional drawing based on detailed design summarized in Table 4.5, of WSP is shown in Figure 4.7:

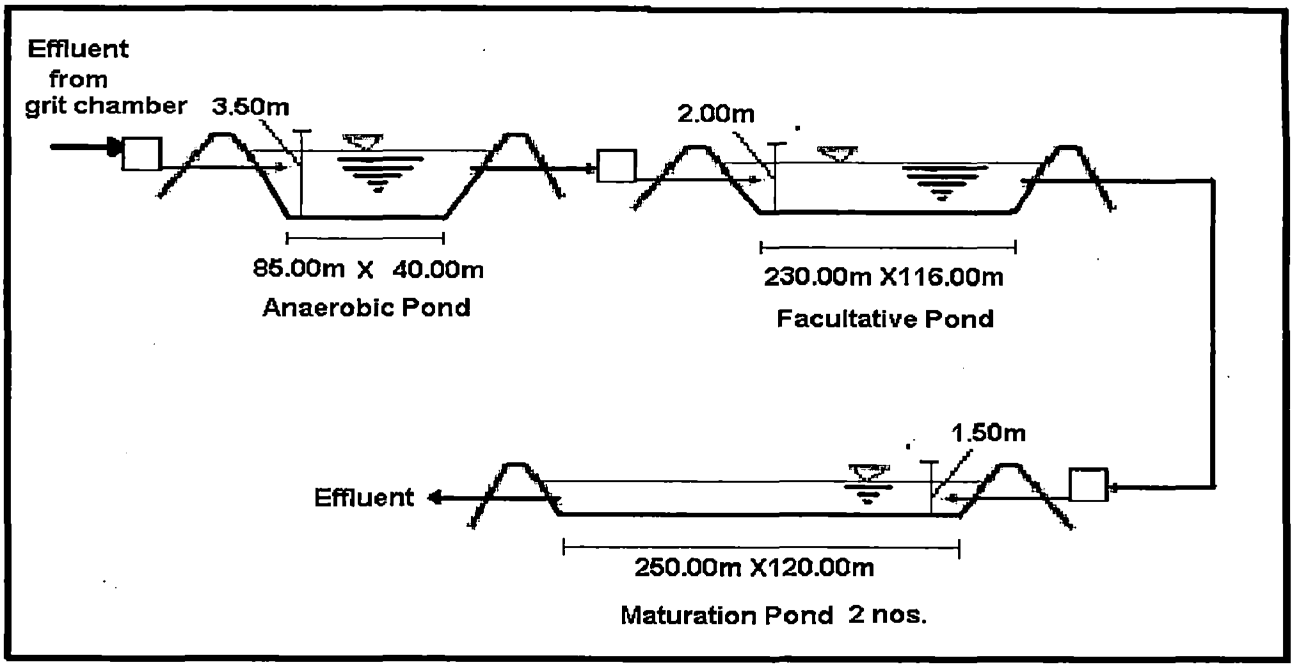


Figure 4.7: Typical layout of sectional drawing of WSP plant

CHAPTER 5

ECONOMIC EVALUATION OF STPs DESIGNED ON VARIOUS TECHNOLOGIES

5.1 INTRODUCTION

The economic evaluation for selection of appropriate technology is very important and is governed by several factor like availability and cost of land. The various financial management tools are used for economic evaluation of various Sewage Treatment Technologies using net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR) calculations. In the present work Life Cycle Cost Analysis has been used. In this method, the present worth of a technology assuming an infinite life is computed, i.e., the capitalized cost is the initial cost plus the present value of an infinitely lived technology. The technology with the lowest capitalized cost is the best technology from an economic standpoint.

5.2 COMPONENT OF LIFE CYCLE COST

The life cycle cost analysis (LCCA) has the following component used for economic evaluation of various STPs technologies

1) Capital cost of construction.
2) Required land area.
3) Annual operation & maintenance cost.

5.3 CAPITAL COST OF CONSTRUCTION

In order to estimate the capital cost of construction and land area for various STPs technology, a wastewater treatment plants of 10MLD have been designed in Chapter 4, and cost estimate has been prepared based on PWD schedule of rate of West Bengal, for selecting the most viable, reasonable and cost-effective alternatives.

5.3.1 Cost Estimate of STPs

In order to calculate the capital cost of various STPs, detailed cost estimate has been prepared for WSP, UASB and ASP (enclosed in Annexure –II). The capital cost of FAB and SBR has been enquired from Ms. Thermax India, Pune and M/s C-Tech, Mumbai respectively and presented in Table 5.1 in the form of Capital cost per MLD and is compared with the existing plants (shown in Table 5.2) in different parts of India, bringing the cost on a common scale i.e. year 2008.

Table 5.1: Capital Cost comparison per MLD of various STPs

Sl. No.	Type of Plant	Capital cost in Rs. lacs.	Remarks
1	ASP	48.00	Referred from Table A.5.1 of Annex.-V.
2	UASB + FPP	44.00	Referred from Table A.5.2 of Annex.-V.
5	WSP	20.50	Referred from Table A.5.3 of Annex.-V.
4	SBR	55.00	Referred from M/s C-Tech, Mumbai.
3	FAB	50.00	Referred from M/s Thermax India, Pune

Table 5.2: Capital Cost comparison per MLD of existing STPs

Sl. No.	Description of Items	ASP Haridwar	UASB+FPP Karnal	FAB Lucknow	SBR Panjim	WSP Titagarh
1	Year of Commissioning	1991	2000	2003	2005	1995
2	Capacity of plant in MLD	18	40	42	12.5	18.64
4	Capital cost in lacs	300	1271	1436.14	650	157.1
5	NPV considering inflation rate as 6%	2.69	1.59	1.34	1.19	2.13
6	Capital cost in lacs in the year 2008	807.83	2025.78	1921.88	774.16	335.08
7	Capital cost in lacs per MLD in the year 2008	44.88	50.64	45.76	61.93	17.98
8	Estimated capital cost in lacs per MLD	48.00	44.00	50.00*	55.00#	20.50

** Data obtained from Ms. Thermax India, Pune; # Data obtained from M/sC-Tech, Mumbai.*

5.4 REQUIRED LAND AREA OF STPs

Land area required per MLD of different STPs have been prepared from the designed data (shown in Annexure - VIII) and same is shown in Table 5.3 and in Figure 5.1.

Table 5.3: Required land area comparison per MLD of various STPs

Area / Technology	WSP	UASB+FPU	ASP	FAB	SBR
Area in m^2 for 10 MLD	91666.7	22620	10352.25	1935	3150.35
Area in m^2 for 1 MLD	9166.67	2262	1035.2	193.5	315.035
Area in ha for 1 MLD	0.91667	0.2262	0.10352	0.0194	0.03150
Area in ha per MLD	**0.917**	**0.226**	**0.104**	**0.019**	**0.032**

Note : For FAB and SBR centrifuge assumed in stead of Sludge drying beds.

5.5 OPERATION AND MAINTENANCE COST OF DIFFERENT STPs

Careful / accurate attention is needed in the calculation of AM cost as it is highly sensitive in technology selection in the life cycle cost analysis. The annual operation and maintenance charges have been prepared based on the energy required, personnel, chemicals required and other repair etc (shown in annexure -VI). The details of annual revenue generation from existing STPs and designed STPs have been shown in Annexure -IV & V, respectively. A comparative study has been done regarding actual and potential of annual revenue generation from existing STPs, and of designed 10MLD plant (shown in Table 5.6), in Table 5.5 with graphical representation in figure 5.2. Annual O&M cost with and without full potential of annual revenue generation for each type of STP has been prepared based on 10MLD plant, in Table 5.4.

Table 5.4: Annual O&M cost (per MLD) of 10MLD STPs in Rs. lacs.

Sl. No.	Description of Items	ASP	UASB+FPP	FAB	SBR	WSP
1	Capital cost in lacs per MLD	48.00	44.00	50.00	55.00	20.50
2	Annual O&M cost in lacs per MLD	9.02	7.16	8.47	8.70	5.07
3	Revenue generation potential per MLD	1.69	1.69	1.07	1.07	1.19
4	Net annual O&M cost in lacs per MLD	7.48	5.47	7.40	7.63	3.88

Table 5.5: Annual revenue generation from existing plants in Rs. lacs.

Sl. No.	STPs ⟹	Haridwar (ASP)		Karnal (UASB+FPP)		Lucknow (FAB)		Panjim (SBR)		Titagarh (WSP)	
	Parameters	Actual	Potential	Actual	Potential	Actual	Potential	Actual	Potential	Actual	Potential
1	From treated effluent#	4.50	18.00	0	40.00	0	42.00	0	12.50	0	18.90
2	From digested sludge cakes	0.90	2.50	0.27	4.94	0	2.89	0	0.86	0	0
3	Aquaculture	0	0	0	0*	0	0	0	0	1.89	1.89
4	Due to power generation from methane	0	9.63	16.04	26.20	0	0	0	0	0	0
5	Total	5.40	24.94	16.31	71.14	0	44.89	0	13.36	1.89	20.79
6	Total revenue generation per MLD	0.30	1.39	0.40	1.78	0	1.06	0	1.07	0.1	1.1

Table 5.6: Annual revenue generation from 10MLD plant

Sl. No.	Parameters	ASP	UASB+FPP	FAB	SBR	WSP
1	From treated effluent#	10	10	10	10	10
2	From digested sludge cakes	1.39	1.24	0.70	0.70	0
3	Aquaculture	0	0*	0	0	1.89**
4	Due to power generation from methane	5.47	5.69	0	0	0
5	Total	16.86	16.93	10.70	10.70	11.89
6	Total revenue generation per MLD	1.69	1.69	1.07	1.07	1.19

 # Considering cost Rs. 1/- per m^3 of treated sewage.   ** Depends upon the actual resource generation.* *** Data taken from WSP, Titagarh, West Bengal.*

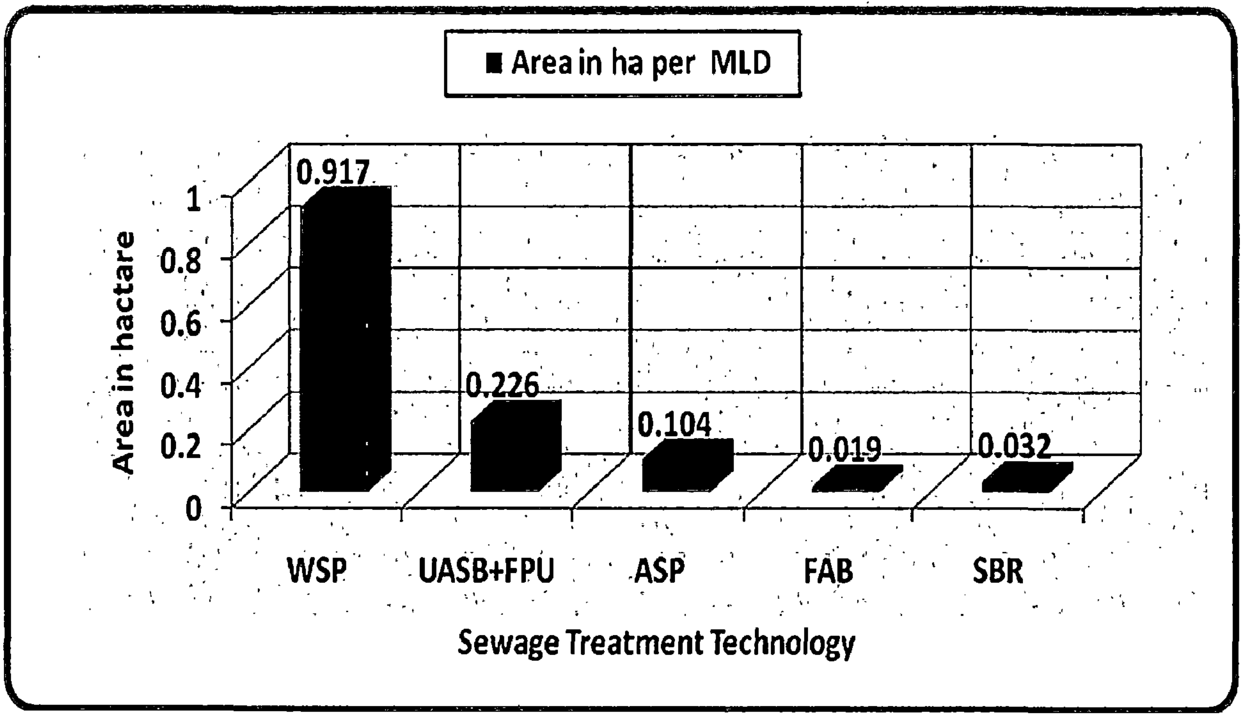


Figure 5.1: Required land area for various technologies

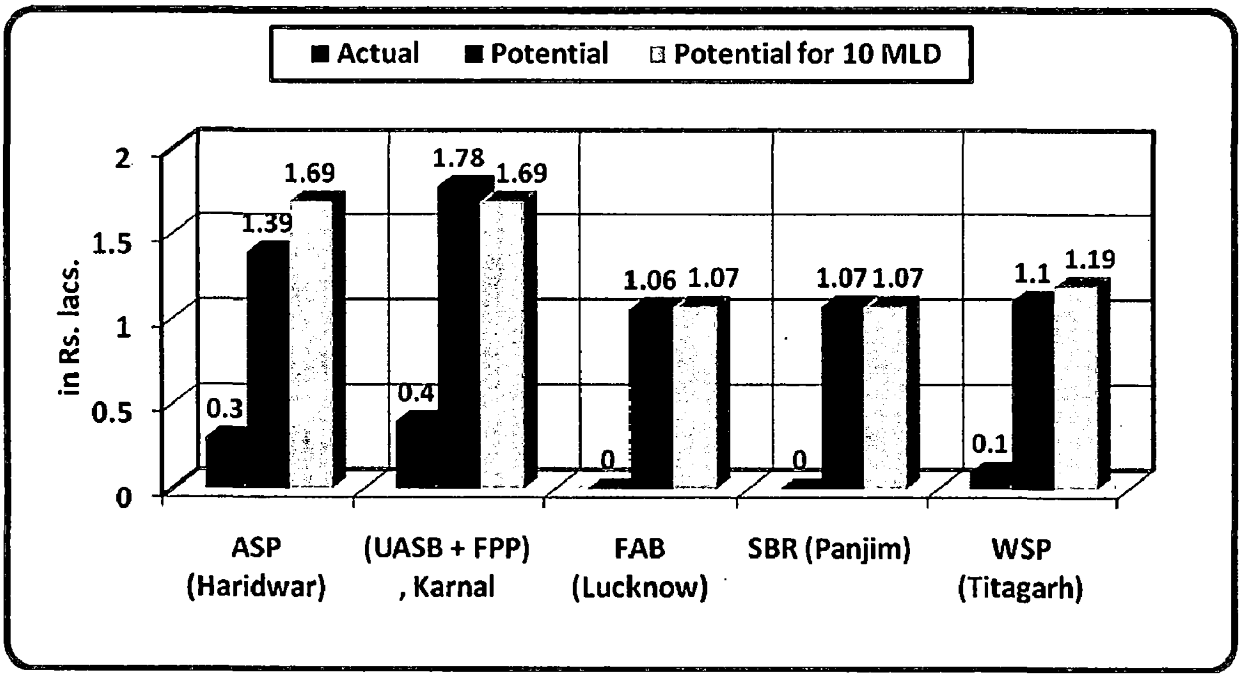


Figure 5.2: Comparison of annual revenue generation

5.6 LIFE CYCLE COST ANALYSIS

Life Cycle Cost Analysis is an essential design process for controlling the initial and the future cost of building ownership. LCCA can be implemented at any level of the design process and can also be an effective tool for evaluation of existing building systems. LCCA can be used to evaluate the cost of a full range of projects, from an entire site complex to a specific building system component. Life Cycle Cost (LCC) is defined as "the total discounted cost of owning, operating, maintaining, and disposing of a building or a building system" over a period of time. Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a facility over period of time.

The sum of initial and future costs associated with the construction and operation of a building over a period of time is called the life cycle cost of a facility, taking into consideration the future maintenance and replacement costs in their selections. In this method, the present worth of a technology assuming an infinite life is computed, i.e., the capitalized cost is the initial cost plus the present value of an infinitely lived technology. The technology with the lowest capitalized cost is the best technology from an economic standpoint.

Life cycle cost for 20 years = Capital Cost including land cost + Present Worth of AM cost for 20 years.(assuming interest rate of 10%)

Present worth of AM cost for 20 years = AM cost*$[\{1-1/(1+i)^n\}/i]$

Where, i = interest rate (10% assumed) &

n = Total life or period (20 years assumed).

Life cycle cost has been done based on data arrived from:-

1) Land requirement per MLD of sewage has been furnished from design of 10MLD capacity pant, as shown in Table 5.3.
2) Unit cost of annual O&M per MLD of STP has been referred from Table 5.6.
3) Cost of land is considered as Rs. 1.00 lacs per hectare.
4) Unit cost of construction of STP per MLDhas been shown in Table 5.1.

The life cycle cost for each technology for various capacities of STP with land cost as Rs.1.00 lakhs per ha has been prepared in Table 5.8 and plotted in graph (Figure 5.4) and the life cycle cost for each technology has been presented in Table 5.7 and plotted in graph. The graph showing the LCC for each technology is furnished in Figure 5.3.

Table 5.7: LCC analysis of different technologies

Sl.No.	Description	Unit	WSP	UASB+FPP	FAB	ASP	SBR
1	Design Flow	MLD	1.00	1.00	1.00	1.00	1.00
2	Unit area of STP required	ha	0.917	0.226	0.019	0.104	0.032
3	Area required for design flow	ha	0.92	0.23	0.02	0.10	0.03
4	Rate of land	Rs. in Lakhs / ha	1.00	1.00	1.00	1.00	1.00
5	Unit cost of construction of STP	Rs. in Lakhs / MLD	20.50	44.00	50.00	48.00	55.00
6	Unit cost of annual O&M of STP	Rs. in Lakhs / MLD	3.88	5.47	7.40	7.48	7.63
7	Cost of land	Rs. in Lakhs	0.92	0.23	0.02	0.10	0.03
8	Cost of construction of STP	Rs. in Lakhs	21.42	44.23	50.02	48.10	55.03
9	Total cost of annual O&M of STP	Rs. in Lakhs	3.88	5.47	7.40	7.48	7.63
10	Capitalised cost of O&M for 20 years @ 10% int.	Rs. in Lakhs	33.03	46.57	63.00	63.68	64.96
11	**Life cycle cost of STP for 20 years**	**Rs. in Lakhs**	**54.45**	**90.80**	**113.02**	**111.79**	**119.99**

Table 5.8: Life cycle cost analysis of varying capacity for land cost

CAPACITY in MLD	WSP	UASB+FPP	FAB	ASP	SBR
	Rs. In crores				
1	0.54	0.91	1.13	1.12	1.20
10	5.44	9.08	11.30	11.18	12.00
20	10.89	18.16	22.60	22.36	24.00
30	16.33	27.24	33.91	33.54	36.00
40	21.78	36.32	45.21	44.71	48.00
50	27.22	45.40	56.51	55.89	60.00
60	32.67	54.48	67.81	67.07	71.99
70	38.11	63.56	79.11	78.25	83.99
80	43.56	72.64	90.42	89.43	95.99
90	49.00	81.72	101.72	100.61	107.99
100	54.45	90.80	113.02	111.79	119.99

Table 5.9: Life cycle cost analysis for different sewage treatment technologies

Land cost Rs in Lakhs	WSP	UASB+FPP	FAB	ASP	SBR
	Rs. In crores				
0	0.54	0.91	1.13	1.12	1.20
50	0.99	1.02	1.14	1.17	1.22
75	1.22	1.08	1.14	1.19	1.22
100	1.45	1.13	1.15	1.22	1.23
125	1.68	1.19	1.16	1.25	1.26
150	1.91	1.24	1.16	1.27	1.25
175	2.14	1.30	1.16	1.30	1.26
200	2.37	1.36	1.17	1.32	1.26

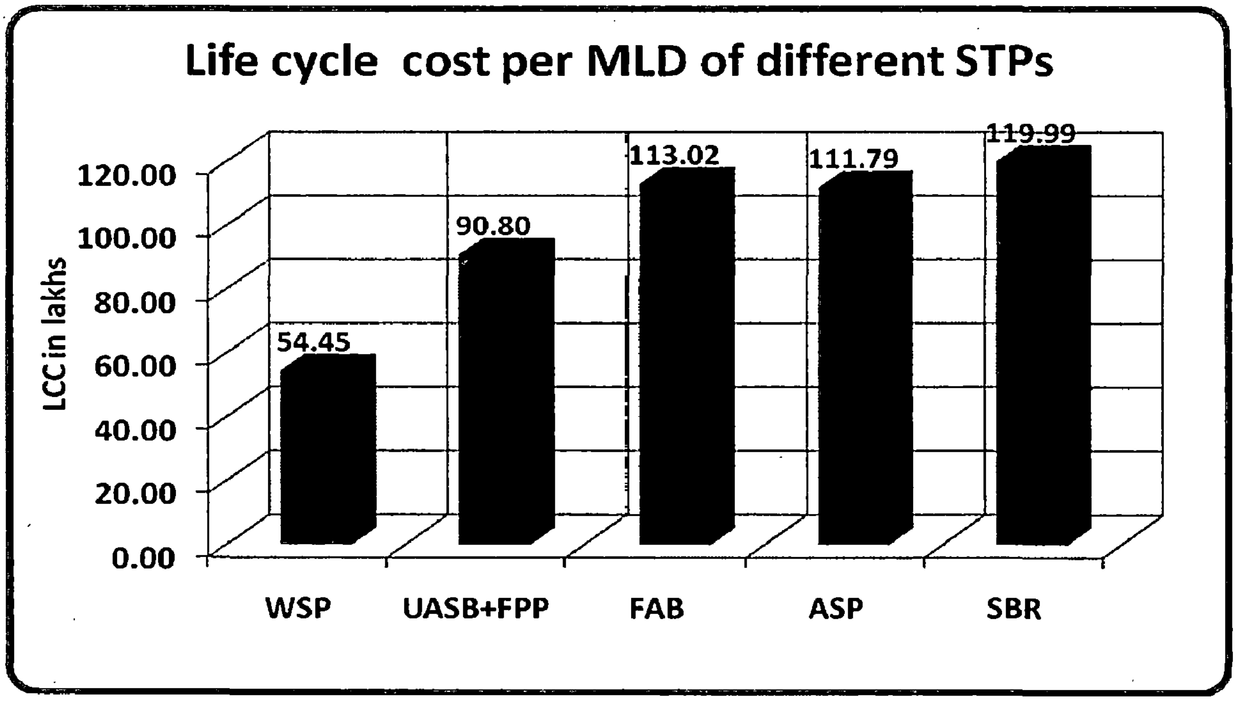


Figure 5.3: Life cycle cost per MLD of different STPs

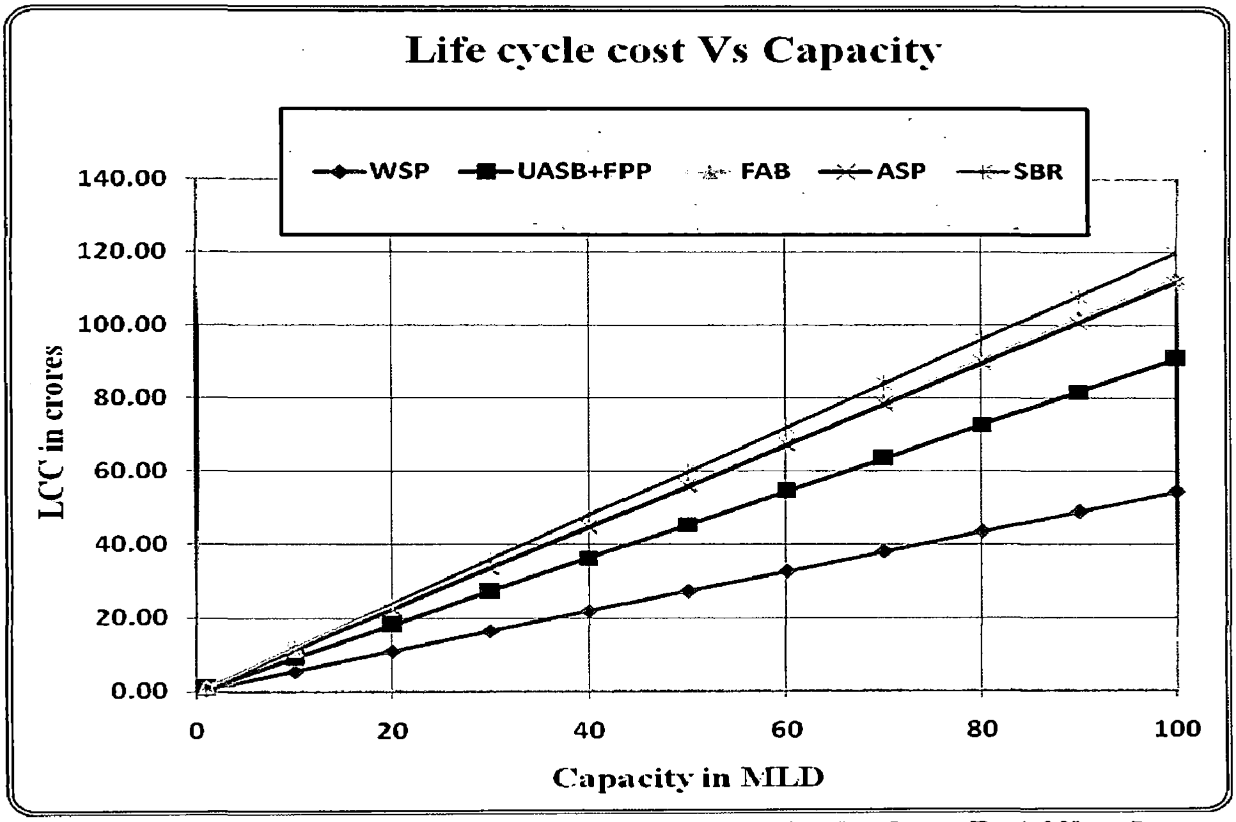


Figure 5.4: Life cycle cost Vs capacity, considering land cost Rs.1.00lacs/ha

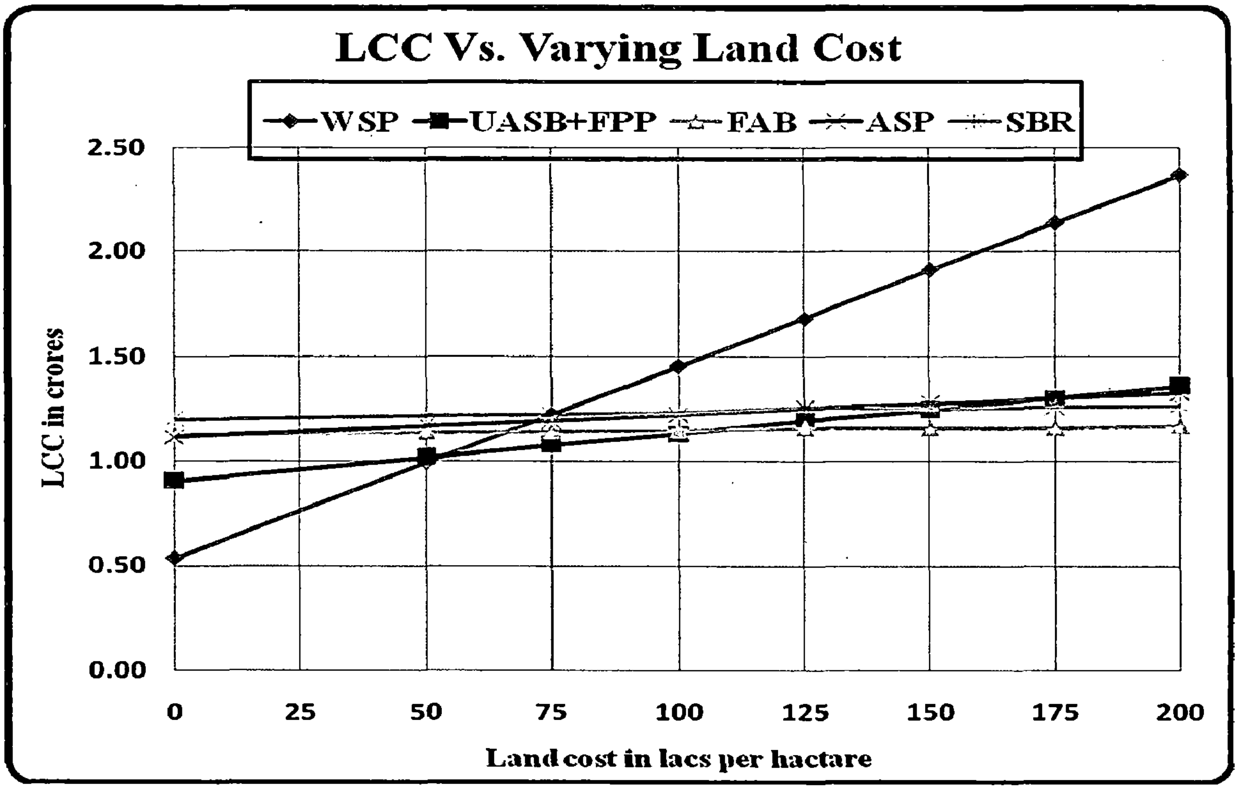


Figure 5.9: Life cycle cost Vs land cost for 1.00 MLD plant

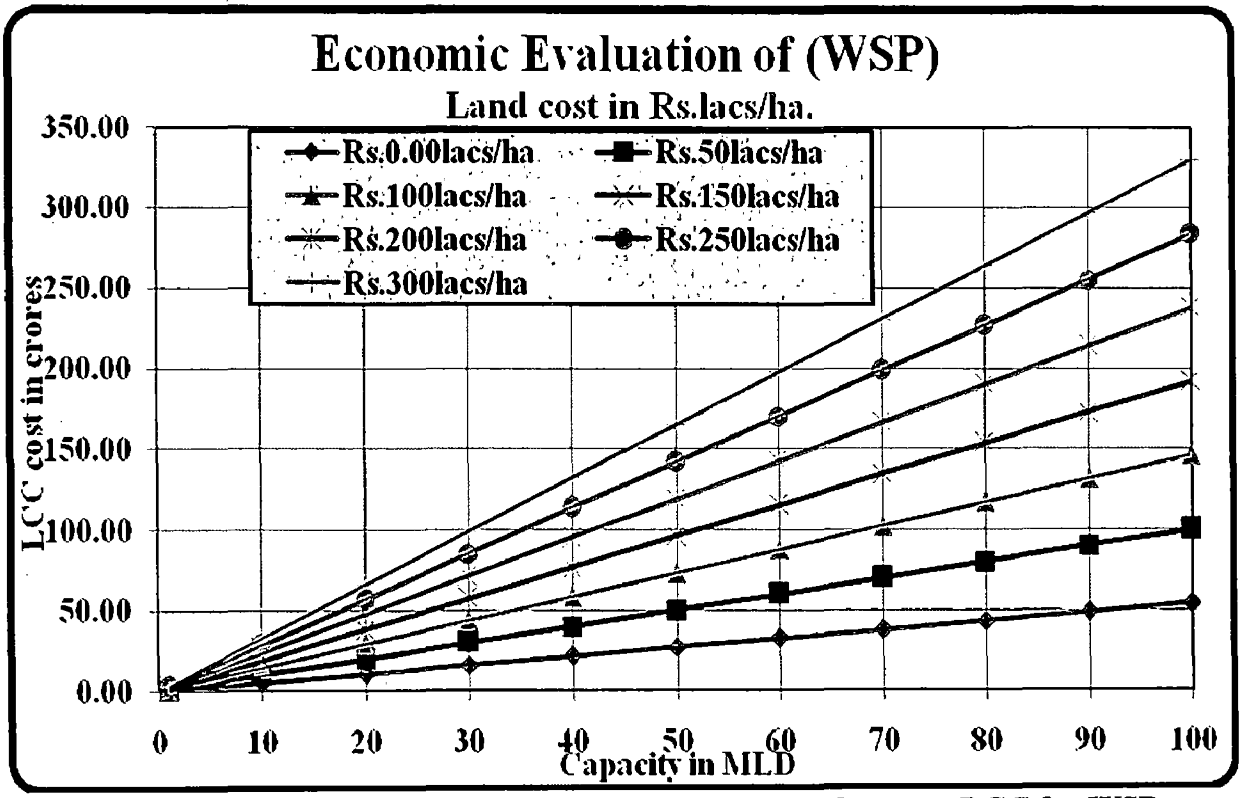


Figure 5.10: Analysis of effect of capacity and land cost on LCC for WSP

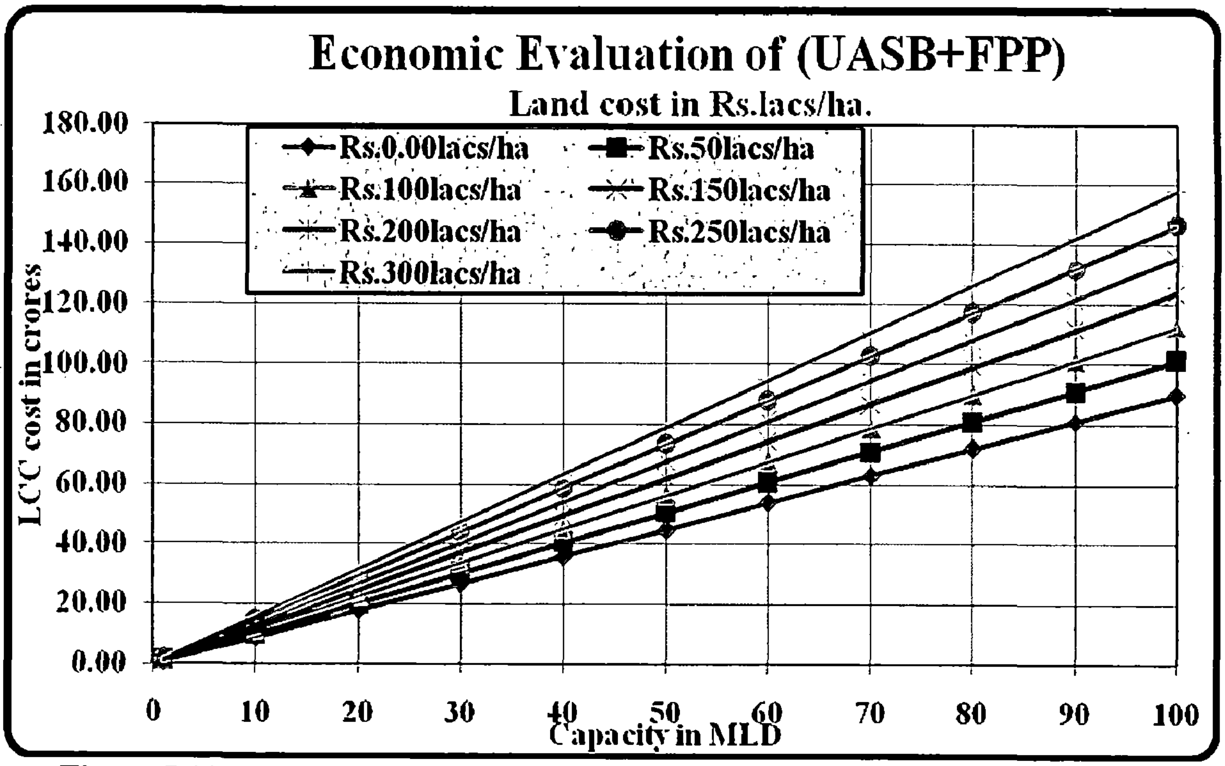


Figure 5.11: Analysis of effect of capacity and land cost on LCC for (UASB +FPP)

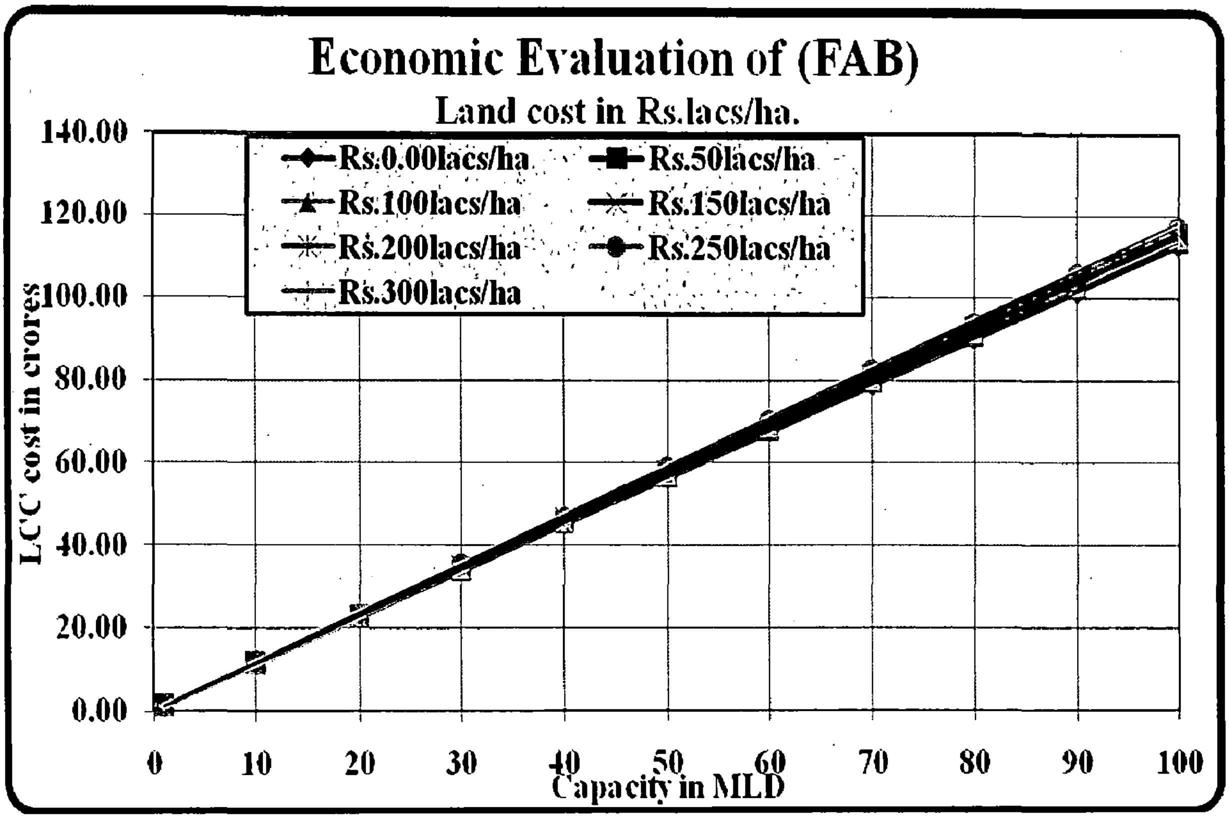


Figure 5.12: Analysis of effect of capacity and land cost on LCC for FAB

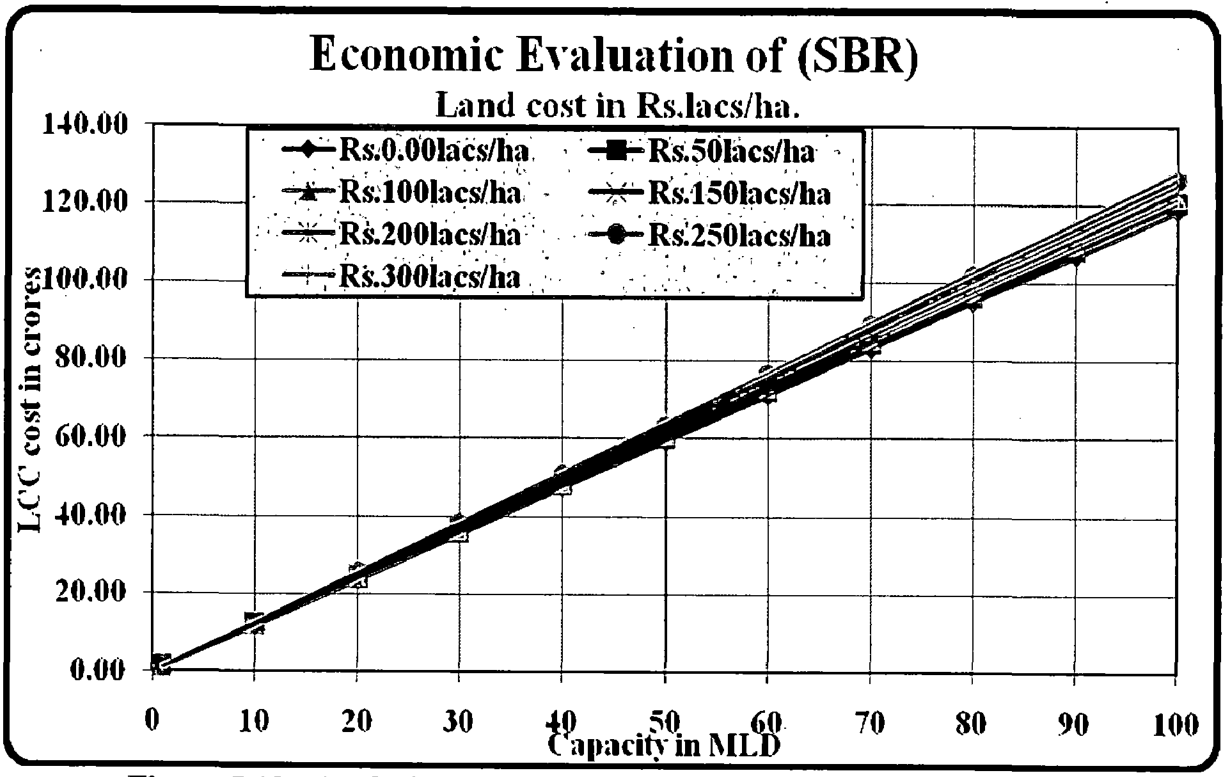


Figure 5.13: Analysis of effect of capacity and land cost on LCC for SBR

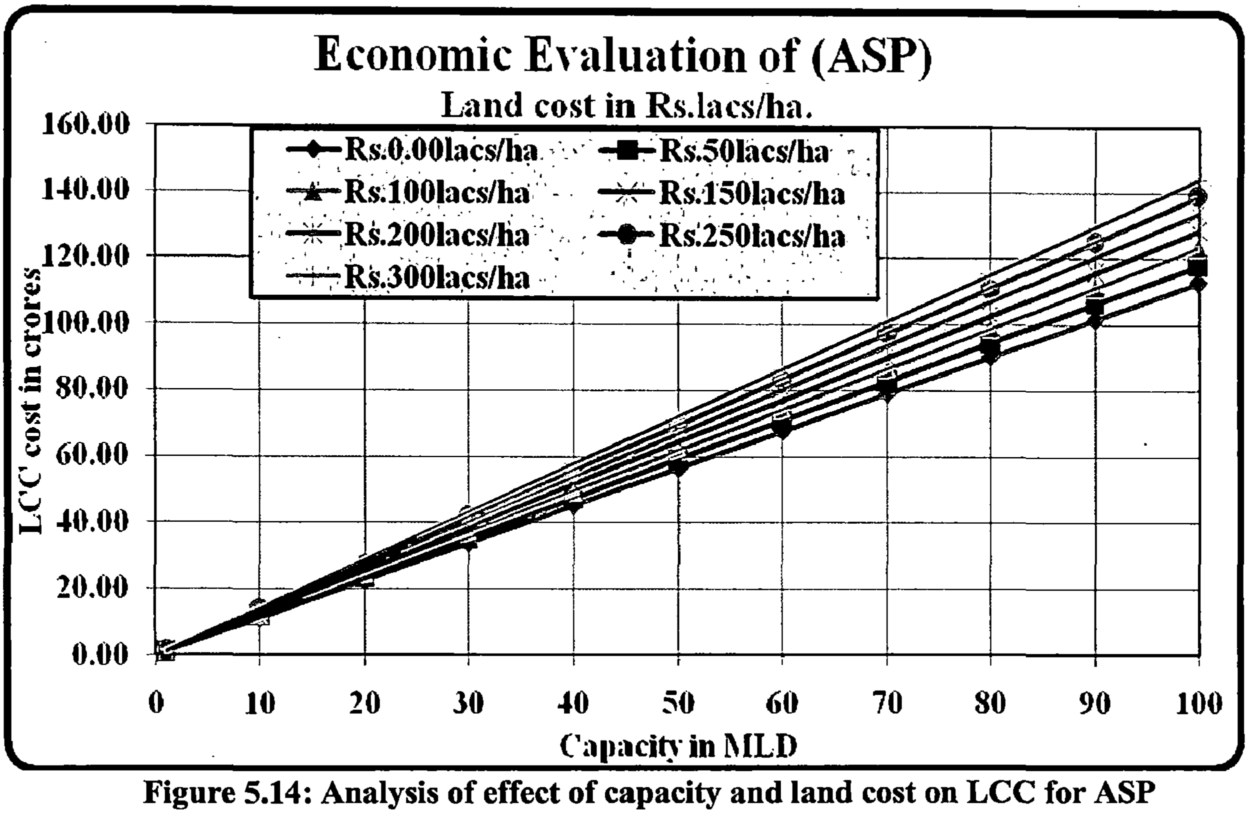


Figure 5.14: Analysis of effect of capacity and land cost on LCC for ASP

5.7 RESULT AND DISCUSSION

From LCC analysis, an attempt has been made to correlate the life cycle cost with capacity and land cost for all STPs, shown in Figure 4.11. to Figure 4.15. for WSP, UASB + FPP, FAB, ASP and SBR respectively. Herein it has been observed that LCC cost of WSP and UASB has wide range of variation while that of FAB and SBR, it has been very limited range of variation. The linear relationship has been seen from the graph. Life cycle cost of any capacity with land cost can be derived from graph of respective STP (see Annexure -VII).

Based on the study, evaluation based on different parameters has been summarized to make a choice for selection for appropriate technology, as shown in Table 5.10.

Table 5.10: Evaluation of Wastewater Treatment Technology

Sl. No.	Evaluation Parameter	WSP	UASB + FPP	ASP	FAB	SBR
		Rank (1 = Best)				
1.	Capital cost of Construction	1	2	3	4	5
2.	Revenue generation potential	3	1	2	5	4
3.	Land area requirement	5	4	3	1	2
4.	Operation & Maintenance cost	1	2	4	3	5
5.	Operability	1	2	3	4	5
6.	Reliability	1	2	5	4	3
7.	Power use	1	2	5	4	3
8.	Effluent quality	5	4	2	3	1
9.	Life Cycle Cost Analysis (for fixed land cost)	1	2	5	3	4

CHAPTER 6

CONCLUSIONS

From the present study the following conclusions are drawn in terms of performance and economical basis, useful for selection of appropriate technology.

6.1 TECHNO ECONOMIC EVALUATION

1. From life cycle cost analysis it is observed that:-
   - i) WSP is the most economical and cost effective technology for low cost of land (approx. Rs.50.00lacs / ha) & a suitable option for Urban and Semi-urban areas where land is inexpensive, climate favourable and a simple method of treatment is desired not requiring equipment and operating skills
   - ii) The UASB with FPP comes to the next option for medium cost of land (upto Rs.100lacs / ha) & is a suitable technology for all medium and small size cities / towns where required land can be made available, and treated effluent can be used for irrigation purpose along with aquaculture in Final Polishing Pond.
   - iii) For high cost of land or land scarcity areas where huge area is not available, FAB, SBR and ASP are found to be economical in order, a suitable option in Mega & Metropolitan areas.

3. The Sequencing Batch Reactor (SBR) is a most preferred technology, as treated effluent can be reused for non-potable purpose like, gardening, car washing, toilet flushing, as effective option to conserve the potable water.

3. The revenue generation potential from UASB with FPP is the highest, as the treated effluent preserving N, K, & P, is suitable for irrigation, use of dry sludge as manure, utilization of bio-gas generated for power saving and encouraging aquaculture in FPP.

4. The treated effluent from ASP, WSP and UASB is suitable for irrigation, while that of from FAB and SBR can be directly discharged into waterbodies / streams or can be reused.

5. UASB technology is the least demanding on resource in terms of land, energy and finances.

6. Based on the potential of biogas/power generation from STPs, expenditure on O&M can be offset by earning 'carbon credits' on recurring basis.

6.2 LIMITATION OF THE STUDY

1. The five different sewage treatment technology in use in India have been considered in study.
2. Selection of treatment plant (STPs) for study purpose may not be the representative plant of that wastewater treatment technology.
3. The capital cost of construction for FAB and SBR is based on the information received from construction firms M/s. Thermax India, Pune And M/s. C-Tech, Mumbai, as these are their patented technology.
4. The annual salary of personnel required for each STPs is based on pay scale approved by Govt. of West Bengal.
5. Annual operation and maintenance cost has been calculated on common scale but in actual it may vary from place to place.
6. Reusing of treated effluent option is not considered as source revenue generation source.
7. Revenue generation from levying charges from users against treatments cost is not considered.

6.3 FURTHER SCOPE OF WORK

1. Other sources of revenue generation should be investigated so as to make a plant economically self sustainable.
2. Proper utilization of bio-gas generated in ASP & UASB should be studied to save energy and O&M expenditure cost.
4. Tertiary treatment option to make the effluent from AASP, UASB and WSP reusable for non-potable purpose.

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ANNEXURES

ANNEXURE - I

A.1.1: TYPICAL COMPOSITION OF UNTREATED DOMESTIC WASTE-WATER

CONTAMINANTS	UNIT	CONCENTRATION		
		WEAK	MEDIUM	STRONG
Total solids (TS)	mg/l	350	720	1 200
Total dissolved solids (TDS)	mg/l	250	500	850
Fixed	mg/l	145	300	525
Volatile	mg/l	105	200	325
Suspended solids	mg/l	100	220	350
Fixed	mg/l	20	55	75
Volatile	mg/l	80	165	275
Settleable solids	mg/l	5	10	20
BOD5, 20°C	mg/l	110	220	400
TOC	mg/l	80	160	290
COD	mg/l	250	500	1 000
Nitrogen (total as N)	mg/l	20	40	85
Organic	mg/l	8	15	35
Free ammonia	mg/l	12	25	50
Nitrites	mg/l	0	0	0
Nitrates	mg/l	0	0	0
Phosphorus (total as P)	mg/l	4	8	15
Organic	mg/l	1	3	5
Inorganic	mg/l	3	5	10
Chlorides	mg/l	30	50	100
Sulfate	mg/l	20	30	50
Alkalinity (as CaCO3)	mg/l	50	100	200
Grease	mg/l	50	100	150
Total coliforms	No/100 ml	106-107	107-108	107-109
Volatile organic compounds	µg/l	<100	100-400	>400

Source: Adapted from Metcalf and Eddy Inc., Wastewater Engineering, 3rd edition[14].

A.1.2: IMPORTANT CONTAMINANTS IN WASTEWATER

CONTAMINANTS	REASON FOR IMPORTANCE
Suspended solids (SS)	can lead to development of sludge deposits and anaerobic conditions when untreated wastewater is discharged to the aquatic environment.
Biodegradable organics	principally made up of proteins, carbohydrates and fats. They are commonly measured in terms of BOD and COD. If discharged into inland rivers, streams or lakes, their biological stabilization can deplete natural oxygen resources and cause septic conditions that are detrimental to aquatic species.
Pathogenic organisms	found in waste-water can cause infectious diseases.
Priority pollutants	including organic and inorganic compounds, may be highly toxic, carcinogenic, mutagenic or teratogenic.
Refractory organics	that tend to resist conventional waste-water treatment include surfactants, phenols and agricultural pesticides.
Heavy metals	usually added by commercial and industrial activities must be removed for reuse of the waste-water.
Dissolved inorganic	constituents such as calcium, sodium and sulfate are often initially added to domestic water supplies, and may have to be removed for waste-water reuse.

Source: Adapted from Metcalf and Eddy, Inc., Wastewater Engineering, 3rd edition[14].

ANNEXURE - II

A.2 CAPITAL COST ESTIMATION FOR VARIOUS STPS

A.2.1 Cost estimation of preliminary units:-

Estimate for inlet & outlet chamber

Sl.No.	Description of Items	Unit	Quantity	Rate	Amount (Rs)
1	Earth work excavation of foundation trenches or drains of septic tank. Soak well etc. (including mixed soil) but excluding laterite and sand stone) including removing, spreading or stacking the spoils within a lead of 75 metre as directed and including trimming sides of trenches, leveling dressing and ramming the bottom, baling or pumping out water etc. as desired complete: a) Depth of excavation not exceeding 1.5 metre	cum	21.88	27.23	595.79
2	b) Depth of excavation for additional depth beyond 1.5M and upto 3.00 M but not requiring shoring	cum	15.67	50.35	788.98
3	Single brick flat soling of picked jhama bricks including ramming and dressing bed to proper level and filling joints with powdered earth of local sand.	sqm	13.41	100.00	1341.00
4	Nominal mix M15 cement concrete with graded stone chips 20 mm size excluding shuttering and reinforcement, if any, in ground floor, Pakur/Chandil variety	cum	2.01	2242.00	4506.42
5	Brick work with 1st class bricks including mortar (4:1) in foundation and plinth	cum	14.30	1719.00	24581.70
6	(b) Hire and labour charges for shuttering with centering and necessary staging upto 4 m. using approved stout vertical props and thick hard wood planks of approved thickness with required bracing for concrete slab, beams, columns, lintels or straighting, including fitting and striking out after completion of work (upto roof of ground floor).	sqm	2.31	81.30	187.80

Sl.No.	Description of Items	Unit	Quantity	Rate	Amount (Rs)
7	a) Reinforcement (for reinforced concrete work) including distribution bars, stirrups binders etc, including. Supply of rods, initial straightening of bend bars excluding coil bars and removal of loose (if necessary) cutting to requisite length hooking bending to correct shape as per drawing, placing in proper position and binding with 1.626mm. black annealed wire at every intersection as per drawing and direction				
	for the work in foundation basement and upto roof of ground floor/upto 4.00M i) Tor Steel/Mild Steel	MT	0.13	20141.00	2618.33
8	Plaster (to wall floor etc.) with sand and cement mortar including rounding off or chamfering corners as directed and raking out joints or roughening of concrete surface, including throating, nosing and drip course. where necessary (Ground floor): (ii) With 4:1 cement mortar (a) 19 mm thick plaster	sqm	61.60	64.00	3942.40
9	Neat cement punning about 1.5 mm thick in wall dado window sills floor drain etc. Note: cement 0.152 cu.m. per 100 sq.m.	sqm	61.60	14.00	862.40
10	Earth work in filling in foundation trenches or Plinth with good earth, in layers not exceeding 15 cm including watering and ramming etc. layer by layer complete.				
	a)With earth obtained from excavation of foundation	cum	3.04	15.92	48.40
11	Supplying Fitting & fixing CI bend (90°) 600 mm dia.	kg	560.00	26.00	14560.00
12	Supplying Fitting & fixing 600 mm dia. 2.5M long CI	no	1.00	1537.00	1537.00
	TOTAL				55570.23
	Cost for 1 no say Rs.55570/- then Cost for 2 nos. =				
	2x 55570/-	=		Rs.	111140.00

Estimate for grit chamber

Sl. No.	Description of Items	Unit	Quantity	Rate	Amount (Rs)
1	Earth work excavation of foundation trenches or drains of septic tank. Soak well etc. (including mixed soil) but excluding laterite and sand stone) including removing, spreading or stacking the spoils within a lead of 75 meter as directed and including trimming sides of trenches, leveling dressing and ramming the bottom, baling or pumping out water etc. as desired complete: a) Depth of excavation not exceeding 1.5 metre	cum	145.00	27.23	3948.35
2	Earth work in filling in foundation trenches or Plinth with good earth, in layers not exceeding 15 cm including watering and ramming etc. layer by layer complete.				
	a) With earth obtained from excavation of foundation	cum	159.00	15.92	2531.28
3	Single brick flat soling of picked jhama bricks including ramming and dressing bed to proper level and filling joints with powdered earth of local sand.	sqm	85.00	100.00	8500.00
4	Cement concrete with graded stone ballast 40 mm size excluding shuttering.				
	a) 6 : 3 : 1 proportion GF	cum	10.00	1924.00	19240.00
5	Nominal mix M15 cement concrete with graded stone chips 20 mm size excluding shuttering and reinforcement, if any, in ground floor, Pakur/Chandil variety	cum	35.00	2242.00	78470.00
6	Nominal mix M20 cement concrete with graded stone chips 20 mm size excluding shuttering and reinforcement, if any, in ground floor, Pakur/Chandil variety	sqm	69.00	2610.00	180090.00
7	(b) Hire and labour charges for shuttering with centering and necessary staging upto 4 m. using approved stout vertical props and thick hard wood planks of approved thickness with required bracing for concrete slab, beams, columns, lintels or straighten including fitting and striking out after completion of work (upto roof of ground floor).	sqm	1035.00	81.30	84145.50

Sl. No.	Description of Items	Unit	Quantity	Rate	Amount (Rs)
8	a) Reinforcement (for reinforced concrete work) including distribution bars, stirrups binders etc, including. Supply of rods, initial straightening of bend bars excluding coil bars and removal of loose (if necessary) cutting to requisite length hooking bending to correct shape as per drawing, placing in proper position and binding with 1.626mm. black annealed wire at every intersection as per drawing and direction				
	for the work in foundation basement and upto roof of ground floor/upto 4.00M i) Tor Steel/Mild Steel	MT	22.00	20141.00	443102.00
9	Pen Stock Gate (0.50 M wide)	each	12.00	20000.00	240000.00
10	Class LA cast iron pressure pipe (suitable for joining with rubber gasket) at ex-factory situated at Kolkata as IS 1536:1967 300mm dia.	M	81.50	2845.00	231867.50
11	Sand/fly ash filling in foundation or plinth in layers not exceeding 15 cm. as directed and consolidation same by through saturation with water and ramming complete. including the cost of supply of sand/ flyash.				
	a)With silver sand/Fine sand	cum	114.50	204.10	23369.45
13	MS Structural works in columns beams with simple rolled structural members (eg. Joints, angle, channel sections conforming to IS 226,IS 808 of SP(6)-1964 connected to one another with bracket, gasket, cleats as per design direction of Engineer-in-Charge complete including cutting to requisite shape and length, fabrication with necessary bolting, metal are welding conforming to IS 816-1956 & IS 9595 using electrodes of approved make and brand conforming to IS 814-1957,hoisting and erection all complete) for structural members of specified sections weighing not less than 22.5 kg/meter	MT	7.20	27909.00	200944.80

Sl. No.	Description of Items	Unit	Quantity	Rate	Amount (Rs)
14	Providing RCC cast-in-situ bored piles in position as per specifications in all kinds of soils excepts rock of any hardness including cost of boring by any method but using drilling mud to stabilize the bore and flushing the bore of excess mud with freshly prepared drilling fluid by using pumps prior to placing concrete by tremie method in one continuous operation and including the cost of all materials and labour for placing of concrete and also including the cost of hire charges of all implements (i.e., pile rigs and thin mobilization) necessary for boring, placing of concrete wielding of reinforcement cage as necessary and lowering reinforcement cage complete but excluding the cost of reinforcement and labour for bending binding etc. work to be executed as per IS 2911 (part I/Sec-2) (cement concrete should have an ultimate crushing strength of not less than 250kg/cm^2 on 15 cm^3 at 28 days and its cement concrete not less than 400 kg/cum of concrete) 400 mm dia.	M	488.00	915.00	446520.00
15	Hire & labour charges for driving sheet piles	sqm	210.00	308.00	64680.00
16	Withdrawing sheet piles	sqm	210.00	96.00	20160.00
					2047568.88
			say	Rs.	2047569.00

A.3.2 Cost Estimate for 10 MLD WSP

Cost estimate for Anaerobic Pond of 10 MLD 3333m^2

Sl. No.	Description	NO.	L	B	D	QTY	Rate	Amount
	Size at mid depth 85 X 40 X 3.5 M(including FB)		85	40	3.5			
Sl. No.	**Description**	**NO.**	**L**	**B**	**D**	**QTY**	**Rate**	**Amount**
1	Earth work excavation of foundation trenches or drains of septic tank. Soak well etc. (including mixed soil) but excluding laterite and sand stone) including removing, spreading or stacking the spoils within a lead of 75 meter as directed and including trimming sides of trenches, leveling dressing and ramming the bottom, baling or pumping out water etc. as desired complete:	1	3400	1625	1.5	3687.77		
	For clay filling	1	65	25	0.3	487.5		
						4175.27	28	116,907
2	E/W in filling for bunds formation	1	288	5.5	2	3168	10.5	33,264
3	Pre cast slab							
	inside sloping	1	288	7.83		2253.96		
	Top	1	288	1.5		432		
						2685.96	233.51	627,198
4	Turfing outside sloping	1	288	4.47		1287.98	8.75	11,270
5	Supplying & clay filling	1	65	25	0.3	487.5	275	134,063
6	Nominal mix M15 cement concrete with graded stone chips(20 mm size) for structural concrete excluding shuttering and reinforcement if any	1	180	0.3	0.45	24.3		
	Around pipe	2	9	0.6	0.6	6.48		
						30.78	2242	69,009
7	Supply and fixing of pipe	2	20			40	1200	48,000
8	Miscellaneous						LS	21,368
							Total:	**1,061,078**

Cost estimate For Facultative Pond for 10 MLD 26500 m^2

Size at mid depth 230 X 116 X 2 M (including FB)			230	116	2			
Sl.No.	**Description**	**NO**	**L**	**B**	**D**	**QTY**	**Rate**	**Amount**
1	Earth work excavation of foundation trenches or drains of septic tank. Soak well etc. (including mixed soil) but excluding laterite and sand stone) including removing, spreading or stacking the spoils within a lead of 75 meter as directed and including trimming sides of trenches, leveling dressing and ramming the bottom, baling or pumping out water etc. as desired complete:	1	26680	25651	0.75	19622.86		
	For clay filling	1	227	113	0.3	7695.3		
						27318.16	28	764,908
2	Bund formation	1	718	4	1.25	3590	10.5	37,695
3	Pre cast slab							
	inside sloping	1	718	4.47		3210.99		
	Top	1	718	1.5		1077		
						4287.99	233.51	1,001,289
4	Turfing outside sloping	1	752	2.80		2101.90	8.75	18,392
5	Supplying & clay filling	1	227	113	0.3	7695.3	275	2,116,208
6	Nominal mix M15 cement concrete with graded stone chips(20 mm size) for structural concrete excluding shuttering and reinforcement if any	1	680	0.3	0.45	91.8		
	Around pipe	2	9	0.6	0.6	6.48		
						98.28	2242	220,344
7	Supply and fixing of pipe	2	20			40	1200	48,000
8	Miscellaneous						LS	14,872
							Total:	4,221,708

COST ESTIMATE FOR MATURATION POND 10 MLD 29737m²

Size at mid depth 250 X 120 X 1.5 M(including FB)			250	120	1.5			
Sl. No.	**Description**	**NO**	**L**	**B**	**D**	**QTY**	**Rate**	**Amount**
1	Earth work excavation of foundation trenches or drains of septic tank. Soak well etc. (including mixed soil) but excluding laterite and sand stone) including removing, spreading or stacking the spoils within a lead of 75 metre as directed and including trimming sides of trenches, leveling dressing and ramming the bottom, baling or pumping out water etc. as desired complete:	1	30000	29264	0.5	14815.62		
	For clay filling	1	248	118	0.3	8779.2		
						23594.82	28	660,655
2	Bund formation	1	762	3.5	1	2667	10.5	28,004
3	Pre cast slab							
	inside sloping	1	762	3.35		2555.83		
	Top	1	762	1.5		1143		
						3698.83	233.51	863,713
4	Turfing outside sloping	1	800	2.24		1788.85	8.75	15,652
5	Supplying & clay filling	1	248	118	0.3	8779.2	275	2,414,280
6	Nominal mix M15 cement concrete with graded stone chips(20 mm size) for structural concrete excluding shuttering and reinforcement if any	1	732	0.3	0.45	98.82		
	Around pipe	2	9	0.6	0.6	6.48		
						105.3	2242	236,083
7	Supply and fixing of pipe	2	20			40	1200	48,000
8	Miscellaneous						LS	19,707
							Total:	**4,286,093**
						For 2 nos.	Total:	8,572,186

A.2.3 COST ESTIMATE OF ASP

Sl. No.	Description of item	Equation	Design Discharge, Q in l/sec	Cost in $	Cost in Rs. year 2003	Cost in Rs. the year 2008
1	Screening and grit removal with bar screens	$CC = 674Q^{0.611}$	115.74	12287.12	528346	674318
2	Primary sedimentation with sludge pump	$CC = -0.00002Q^2 + 19.29Q + 220{,}389$	115.74	222621.37	9572719	12217485
3	Final clarifier with aeration basin	$CC = 2941Q^{0.609}$	141.78	60094.27	2584053	3297980
4	Sludge pumping	$C.C = -0.00005Q^2 + 44.77Q + 323{,}702$	557.455	25265.42	1086413	1386569
5	Gravity thickener	$CC = 177Q^{0.68}$	354.69	9591.10	412417	526361
6	Sludge digesters	$CC = -0.00002Q^2 + 23.7Q + 208{,}627$	209.05	213580.54	9183963	11721323
7	Sludge drying beds	$CC = 89Q^{0.854}$	1072.10	34451.78	1481427	1890718

Source: Qasim, Wastewater Treatment Plants and USEPA 2003, Detailed Costing Document.

*Q=Qd*24.5/ actual design surface overfloe rate in m3/m2/d.*

A.2.3.1 Abstract of cost estimate for ASP of 10 MLD

Sl. No.	Description	Amount in Rs.
1	Cost of inlet chamber	111,140
2	Screening and grit removal with bar screens	2,047,569
3	Primary sedimentation with sludge pump	12,217,485
4	Cost of outlet chamber	200,000
5	Final clarifier with aeration basin	3,297,980
6	Sludge pumping	1386569
7	Gravity thickener	526,361
8	Sludge digesters	11,721,323
9	Sludge drying beds	1,890,718
10	Filtrate Sump and Filtrate pump	1,000,000
11	Bio gas holder	1,000,000
12	Gas engine room	1,000,000
13	Dual fuel engine	2,500,000
14	Generator room	800,000
15	Gas flaring system and gas flow meter	500,000
16	Sewerage system carrying back wash/overflow/drainage	300,000
17	Water Supply	500,000
18	Internal roads	600,000
19	Internal Surface drain	99,000
20	Office Laboratory, Staff Quarters and Compound Wall	900,000
21	Laboratory Instruments, glass ware , Chemicals and furniture, Equipment and tools	500,000
22	Effluent Channels	111,140
23	Street Light and Flood lighting arrangements	450,000
24	Power Supply	300,000
25	Miscellaneous Items such as Mechanical gas scrubber, Main LT panel, cable etc.,	2,000,000
26	Boundary wall and allied works	1,225,000
27	River training works, Godown hiring, land scaping, clearing STP site etc.	500,000
	Total	47,684,284
	Cost Per MLD	4,768,428
	Say,	4,800,000

A.2.4 ABSTRACT OF COST ESTIMATE FOR UASB OF 10 MLD

Sl. No.	Description	Amount in Rs.
1	Cost of inlet chamber	111,140
2	Screening and grit removal with bar screens	2,047,569
4	Cost of outlet chamber	111,140
5	Cost of Division Box	100,000
6	Cost of Distribution Chambers	180,000
7	Cost of UASB Reactors 2 nos.*	10,000,000
8	Pipes and valves connecting different units	7,000,000
9	Effluent channel from reactors to polishing pond	1,000,000
10	Sludge sump, pump house and Sludge pump	3,500,000
11	Sludge drying bed	1,846,747
12	Polishing pond	2,000,000
13	Filtrate Sump and Filtrate pump	1,000,000
14	Bio gas holder	1,000,000
15	Gas engine room	1,000,000
16	Dual fuel engine	2,500,000
17	Generator room	800,000
18	Gas flaring system and gas flow meter	500,000
19	Sewerage system carrying back wash/overflow/drainage	300,000
20	Water Supply	500,000
21	Internal roads	500,000
22	Internal Surface drain	500,000
23	Office Laboratory, Staff Quarters and Compound Wall	1,500,000
24	Laboratory Instruments, glass ware , Chemicals and furniture, Equipment and tools	500,000
25	Effluent Channels	1,500,000
26	Street Light and Flood lighting arrangements	1,000,000
27	Power Supply	500,000
28	Miscellaneous Items such as Mechanical gas scrubber, Main LT panel, cable etc.,	2,000,000
29	River training works, Godown hiring, land scaping, clearing STP site	500,000
	Total	43,996,596
	Cost Per MLD	4,399,660
	Say,	4,400,000

A.2.5 ABSTRACT OF COST ESTIMATE FOR WSP 10 MLD

Sl. No.	Description	Amount in Rs.
1	Construction of Anaerobic pond of size 100 x 51 x 3.5 m	1,061,078
2	Construction of facultative pond of size 285 x 140 x 2 m	4,221,708
3	Construction of maturation ponds 2 nos. of size 310 x 145 x 1.5 m each	8,572,186
4	Inlet chamber	111,140
5	Screening grit and outlet chamber	2,047,569
6	Provision for Office, Laboratory, internal Roads	2,500,000
7	Provision for Water supply compound wall/ fencing	1,500,000
8	Provision for Tree planting as buffer zone	480,000
	Total	20,493,681
	Cost Per MLD	2,049,368
	Say,	2,050,000

<u>ANNEXURE - III</u>

A.3 ANNUAL MAINTENANCE COST OF DIFFERENT TECHNOLOGIES

A.3.1: Requirement of Personnel in Various STPs of 10MLD

Sl. No.	Description	Annual salary* in Rs.	WSP	UASB	ASP	FAB	SBR
1	AE	338,280	1	1	1	1	1
2	JE	258,360	1	2	2	2	2
3	Fitter I class	73,800		1	1	1	1
4	Electrician I class	73,800		1	1	1	1
5	Fitter II class	61,560	1				
6	Electrician II class	61,560	1	1	1		1
7	Gardener	49,200	1	1	1	1	1
8	Jr. Acct.	123,000	1	1	1	1	1
9	UDC Sr. Asst	110,760	1	1	1	1	1
10	LDC Typist/Jr. Asst	98,400	1	1	1	1	1
11	Peon	73,800		1	1	1	1
12	Lab Asst.	73,800	1	1	1	1	1
13	Lab Attendant	61,560	1	1	1	1	1
14	Sweeper	36,960	1	1	1	1	1
15	Operators	73,800		10	12	5	5
16	Labors / Beldars	36,960	10	20	20	10	10

* *Based on pay scale approved by Govt. of West Bengal.*

A.3.2: Annual O&M Cost in Various STPs IN Rs. lacs

Sl. No.	Cost Component	WSP	UASB	ASP	FAB	SBR
1	Establishment cost	16.43	31.69	33.16	23.69	24.30
2	Electric energy charges	10.63	15.11	43.61	43.15	24.30
3	Minor repairs, spares, grease, etc	0.85	6.10	7.20	8.75	10.45
4	Consumables, Chemicals, Chlorine	18.43	1.43	7.48	8.64	8.64
5	Miscellaneous	0.20	0.32	0.20	0.47	0.54
6	Others desilting of ponds in WSP	4.20	0.00	0.00	0.00	0.00
	Total cost.	50.74	54.65	91.65	84.69	68.24
	Annual O&M cost per MLD	**5.07**	**5.46**	**9.17**	**8.47**	**6.82**

ANNEXURE – IV

A.4 RESOURCE GENERATION FROM EXISTING STPs

PARAMETERS	VALUES	REACTOR VOL.	PST VOL	SST VOL	TOTAL (V)	SRT	Sludge (KG/D)	Primary Sludge (KG/D)	Total Sludge (KG/D)
CONVENTIONAL ACTIVATED SLUDGE PROCESS									
F/M (day-1)	0.3								
Q (m3/d)	10000								
S0 (kg/m3)	0.25	3125	1250	1250	5625	5	468.75	1750	2218.75
V (m3)								Include Inert	
X (kg/m3)	2								
Inf. SS kg/m3	0.25								
Inorganic SS	0.075								
UASB PROCESS									
COD Loading	1								
Q (m3/d)	10000								
S0 (kg/m3)	0.25	4000			4000		1225	750	1975
X (kg/m3)	65								
X (kg/m3)	3.2								
Inf. SS	0.25								
Inorganic SS	0.075								
VSS	0.175								

A.4.1 Revenue Generation from Sludge Production

A.4.1.1 ASP (Haridwar)

Mass of sludge in ASP based STP = 221.88 kg/MLD (Table A.4)

Sludge concentration =65 to 75 kg/ m^3 (say) 70 kg/ m^3

Volume of sludge = 221.88 /70 kg/ m^3 = 3.17 m3/MLD

Sludge production per day = 18 MLD X 3.17m3/MLD =57.06 m^3

Quantity of dry sludge=15% of wet sludge =57.06 X 0.15 = 8.559 m^3

Sludge production per year = 8.559 m3 X 365 days = 3124.0 m^3

Cost of sludge @ Rs. 80.00 per m^3 = Rs. 2.50 lakhs.

A.4.1.2 FAB (Lucknow)

(Assuming the quantity of sludge produced by FAB based STP is 50% as in ASP based STP)

Mass of sludge in FAB based STP = 110 kg/MLD

Sludge concentration =65 to 75 kg/ m^3 (say) 70 kg/ m^3

Volume of sludge = 110 /70 kg/ m^3 = 1.57 m3/MLD

Sludge production per day = 42 MLD X 1.57m3/MLD =65.94 m^3

Quantity of dry sludge =15% of wet sludge=65.95 X 0.15 = 9.89 m^3

Sludge production per year = 9.89 m^3 X 365 days = 3610 m^3

Cost of sludge @ Rs. 80.00 per m^3 = Rs. 2.89 lakhs.

.1.3 SBR (PANJIM)

' is 50% as in ASP based STP)

s of sludge in FAB based STP = 110 kg/MLD

lge concentration =65 to 75 kg/ m^3 (say) 70 kg/ m^3

ıme of sludge = 110 /70 kg/ m^3 = 1.57 m3/MLD

lge production per day = 12.5 MLD X 1.57m3/MLD = 19.63 m^3

ntity of dry sludge =15% of wet sludge=19.63 X 0.15 = 2.95 m^3

lge production per year = 2.95 m^3 X 365 days = 1074.47 m^3

t of sludge @ Rs. 80.00 per m^3 = Rs. 0.86 lakhs.

1.4 UASB (Karnal)

s of sludge in UASB based STP = 197.5 kg/MLD (Appendix 5)

lge concentration =65 to 75 kg/ m^3 (say) 70 kg/ m^3

ıme of sludge = 197.5 /70 kg/ m^3= 2.82 m3/MLD

lge production per day = 40 MLD X 2.82 m^3/MLD =112.8 m^3

ntity of dry sludge =15% of wet sludge=112.8X0.15=16.92m3

lge production per year = 16.92 m^3 X 365 days = 6175.8 m^3

t of sludge @ Rs. 80.00 per m^3 = Rs. 4.94 lakhs.

2 Revenue Generation from Gas Production

2.1 ASP, Haridwar

ıl suspended solids in the influent =255 mg/l.

ıl suspended solids in the effluent = 20 mg/l.

ıl suspended solids removed =235 mg/l.

ıming volatile solids to be equal to 70 % of suspended solids, we have

ıtile solids removed = 70 % X 235 mg/l. = 164.5 mg/l.

/ assuming that the volatile solids (matter) are reduced by 65% in the sludge by digestion,

ıave Volatile solids reduced = 65% X 164.5= 106.93 mg/l.

ıtile matter reduced per million litre of sewage = 106.93 X10^6/10^6 = 106.93 kg

/ assuming that 0.9 m3 of gas is produced per kg of volatile matter reduced, we have, the

produced per million litre of sewage = 0.9X106.93=96.23 m^3(Say)=96 m^3

Haridwar STP (18 MLD) = 18 X 96 = 1728 m^3

ıal Biogas production = 430 m^3

ırific Value of Biogas

-=65vol%; CO_2=32vol%

Calorific value of pure CH_4 =50,000kJ/kg

Calorific value of biogas

(0.65 X16 X 50,000)/ (0.65 X 16 +0.32X44) =21241.8kJ/m3= 21.24 MJ/kg

Projected energy production from biogas:-

Biogas production from STP = 430 m^3

Energy production per day =430 X2.04 = 877.2 kWh/day

=0.88 MWh/day

Cost of Electricity r savings (0.88 MWh/day X365 days X 3.00 X1000)

= Rs.9.64 lakhs/year

Cost of Electricity savings per 1MLD = Rs. 9.64 lakhs / 18 MLD

= 0.54 lakhs/year

A.4.2.2 UASB, Karnal

Total suspended solids in the influent = 400 mg/l.

Total suspended solids in the effluent = 50 mg/l.

Total suspended solids removed = 350 mg/l.

Assuming volatile solids to be equal to 70 % of suspended solids,

We have, Volatile solids removed = 70 % X 350 mg/l. = 245 mg/l.

Now assuming that the volatile solids (matter) is reduced by 65% in the sludge by digestion, we have, Volatile solids reduced = 65% X 245= 159.25 mg/l.

There fore Volatile matter reduced per million litre of sewage

($159.25 \times 10^6/10^6$) = 159.25 kg

Now assuming that 0.9 m3 of gas is produced per kg of volatile matter reduced, we have, the gas produced/MLD of sewage (0.9 X 159.25) = 143.33 m^3 (or) = 143 m^3

Projected gas production = 40 X 143 = 5720 m^3.

Actual flow 35 MLD / day

Gas production for flow23.15 MLD = 35 X 143 = 5005 m^3

Actual gas production from STP = 900 m^3

C.V.of Biogas = 21.24 MJ/kg

Projected energy production from biogas:-

Biogas production from STP = 900 m^3

Energy production per day (900 X2.04) = 1836 kWh/day =1.84 MWh/day

Cost of Electricity savings (1.84 MWh/day X365 days X 3.90 X1000)

= Rs.26.20 lakhs/year

ANNEXURE - V

A.5 REVENUE GENERATION POTENTIAL FROM DESIGNED STPs

PARAMETERS	VALUES	REACTOR VOL.	PST VOL	SST VOL	TOTAL (V)	SRT	Sludge (KG/D)	Primary Sludge (KG/D)	Total Sludge (KG/D)
CONVENTIONAL ACTIVATED SLUDGE PROCESS									
F/M (day-1)	0.3								
Q (m3/d)	10000								
S0 (kg/m3)	0.25	3125	1250	1250	5625	5	468.75	1750	2218.75
V (m3)								Include Inert	
X (kg/m3)	2								
Inf. SS kg/m3	0.25								
Inorganic SS	0.075								
UASB PROCESS									
COD Loading	1								
Q (m3/d)	10000								
S0 (kg/m3)	0.25	4000			4000		1225	750	1975
X (kg/m3)	65								
X (kg/m3)	3.2								
Inf. SS	0.25								
Inorganic SS	0.075								
VSS	0.175								

A.5.1 Revenue Generation from Sludge Production

A5.1.1 In ASP

Mass of sludge in ASP based STP = 2218.8 kg (Appendix 5)

Sludge concentration =65 to 75 kg/ m^3 (say) 70 kg/ m^3

Volume of sludge per day = 2218.8 /70 kg/ m^3 = 31.7 m3

Quantity of dry sludge =15% of wet sludge

Quantity of dry sludge=15% of wet sludge =31.7 X 0.15 = 4.755 m^3

Sludge production per year = 4.755 m3 X 365 days = 1735.575 m^3

Cost of sludge @ Rs. 80.00 per m^3 = Rs. 1.39 lakhs.

A.5.1.2 In FAB and SBR

(Assuming the quantity of sludge produced by FAB based STP is 50% as in ASP based STP)

Mass of sludge in FAB based STP = 1110kg

Sludge concentration =65 to 75 kg/ m^3 (say) 70 kg/ m^3

Volume of sludge produce per day = 1110 /70 kg/ m^3 = 15.86 m3

Quantity of dry sludge =15% of wet sludge=15.86 X 0.15 = 2.38 m^3

Sludge production per year = 2.38 m^3 X 365 days = 868.70 m^3

Cost of sludge @ Rs. 80.00 per m^3 = Rs.0.695 lakhs.

A.5. 1.3 In UASB

Mass of sludge in UASB based STP = 1975 kg (Appendix 5)

Sludge concentration =65 to 75 kg/ m^3 (say) 70 kg/ m^3

Volume of sludge produce per day = 1975 /70 kg/ m^3= 28.2 m3

Quantity of dry sludge =15% of wet sludge=28.20X0.15=4.23m3

Sludge production per year = 4.23 m^3 X 365 days = 1543.95 m^3

Cost of sludge @ Rs. 80.00 per m^3 = Rs. 1.23 lakhs.

A.5.2 Revenue Generation from Gas Production

A.5.2.1 In ASP & UASB

Total suspended solids in the influent =300 mg/l.

Total suspended solids in the effluent = 50 mg/l.

Total suspended solids removed =250 mg/l.

Assuming volatile solids to be equal to 70 % of suspended solids, we have

Volatile solids removed = 70 % X 250 mg/l. = 175 mg/l.

Now assuming that the volatile solids (matter) are reduced by 65% in the sludge by digestion, we have Volatile solids reduced = 65% X 175= 113.75 mg/l.

Volatile matter reduced per million litre of sewage = 113.75 $X10^6/10^6$ = 113.75 kg

Now assuming that 0.9 m3 of gas is produced per kg of volatile matter reduced, we have, the gas produced per million litre of sewage = 0.9X113.75=102.37 m^3(Say)=102 m^3

For STP of 10 MLD capacity = 10 X 102 = 1020 m^3

Theoritical Biogas production = 1020 m^3

Actual gas production = 245 m^3

Calorific Value of Biogas

CH4=65vol%; CO2=32vol%

Calorific value of pure CH4 =50,000kJ/kg

Calorific value of biogas

(0.65 X16 X 50,000)/ (0.65 X 16 +0.32X44) =21241.8kJ/m3= 21.24 MJ/kg

A.5.2.2 PROJECTED ENERGY PRODUCTION FROM BIOGAS

Biogas production from STP = 245 m^3

Energy production per day =245 X2.04 = 499.8 kWh/day

=0.50 MWh/day

Cost of Electricity r savings (0.50 MWh/day X365 days X 3.00 X1000)

= Rs.5.47 lakhs/year

Cost of Electricity savings per 1MLD = Rs. 5.47 lakhs / 10 MLD

= 0.55 lakhs/year

ANNEXURE - VI

A.6 ANNUAL O & M COST OF DIFFERENT STPs TECHNOLOGIES

A.6.1: REQUIREMENT OF PERSONNEL IN VARIOUS STPs OF 10MLD*

Sl. No.	Description	Annual salary* in Rs.	WSP	UASB	ASP	FAB	SBR
1	AE	338,280	1	1	1	1	1
2	JE	258,360	1	2	2	2	2
3	Fitter I class	73,800		1	1	1	1
4	Electrician I class	73,800		1	1	1	1
5	Fitter II class	61,560	1				
6	Electrician II class	61,560	1	1	1		1
7	Gardener	49,200	1	1	1	1	1
8	Jr. Acct.	123,000	1	1	1	1	1
9	UDC Sr. Asst	110,760	1	1	1	1	1
10	LDC Typist/Jr. Asst	98,400	1	1	1	1	1
11	Peon	73,800		1	1	1	1
12	Lab Asst.	73,800	1	1	1	1	1
13	Lab Attendant	61,560	1	1	1	1	1
14	Sweeper	36,960	1	1	1	1	1
15	Operators	73,800		10	12	5	5
16	Labors / Beldars	36,960	10	20	20	10	10

* *Based on pay scale approved by Govt. of West Bengal.*

A.6.2: ANNUAL O&M COST IN VARIOUS STPs in Rs. lacs

Sl. No.	Cost Component	WSP	UASB	ASP	FAB	SBR
1	Establishment cost	16.43	31.69	33.16	23.69	24.30
2	Electric energy charges	10.63	15.11	43.61	43.15	24.30
3	Minor repairs, spares, grease, etc	0.85	6.10	7.20	8.75	10.45
4	Consumables, Chemicals, Chlorine	18.43	1.43	7.48	8.64	8.64
5	Miscellaneous	0.20	0.32	0.20	0.47	0.54
6	Others desilting of ponds in WSP	4.20	0.00	0.00	0.00	0.00
	Total cost.	50.74	54.65	91.65	84.69	68.24
	Annual O&M cost per MLD	**5.07**	**5.46**	**9.17**	**8.47**	**6.82**

ANNEXURE-VII

A.7: LIFE CYCLE COST OF VARIOUS STPs WITH VARIABLE LAND COST AND CAPACITY

A.7.1: LCC of WSP (Land Cost in lacs. Per ha)

Capacity in MLD	Rs.0.00	Rs.50.00	Rs.100.00	Rs.150.00	Rs.200.00	Rs.250.00	Rs.300.00
1.00	0.54	1.00	1.46	1.92	2.38	2.84	3.29
10.00	5.43	10.01	14.60	19.18	23.77	28.35	32.94
20.00	10.86	20.03	29.20	38.37	47.54	56.71	65.88
30.00	16.29	30.04	43.80	57.55	71.31	85.06	98.82
40.00	21.72	40.06	58.40	76.74	95.08	113.42	131.76
50.00	27.15	50.07	73.00	95.92	118.85	141.77	164.70
60.00	32.58	60.09	87.60	115.11	142.62	170.13	197.64
70.00	38.01	70.10	102.20	134.29	166.39	198.48	230.58
80.00	43.44	80.12	116.80	153.48	190.16	226.84	263.52
90.00	48.87	90.13	131.40	172.66	213.93	255.19	296.46
100.00	54.30	100.15	146.00	191.85	237.70	283.55	329.40

A.7.2: LCC of UASB with FPP, (Land Cost in lacs. per ha)

Capacity in MLD	Rs.0.00	Rs.50.00	Rs.100.00	Rs.150.00	Rs.200.00	Rs.250.00	Rs.300.00
1.00	0.90	1.01	1.12	1.24	1.35	1.46	1.58
10.00	8.99	10.12	11.25	12.38	13.51	14.64	15.77
20.00	17.98	20.24	22.50	24.76	27.02	29.28	31.54
30.00	26.97	30.36	33.75	37.14	40.53	43.92	47.31
40.00	35.96	40.48	45.00	49.52	54.04	58.56	63.08
50.00	44.94	50.59	56.24	61.89	67.54	73.19	78.84
60.00	53.93	60.71	67.49	74.27	81.05	87.83	94.61
70.00	62.92	70.83	78.74	86.65	94.56	102.47	110.38
80.00	71.91	80.95	89.99	99.03	108.07	117.11	126.15
90.00	80.90	91.07	101.24	111.41	121.58	131.75	141.92
100.00	89.89	101.19	112.49	123.79	135.09	146.39	157.69

A.7.3: LCC of FAB, (Land Cost in lacs. per ha)

Capacity in MLD	Rs.0.00	Rs.50.00	Rs.100.00	Rs.150.00	Rs.200.00	Rs.250.00	Rs.300.00
1.00	1.13	1.14	1.14	1.15	1.16	1.17	1.18
10.00	11.26	11.35	11.44	11.54	11.64	11.73	11.83
20.00	22.51	22.70	22.89	23.08	23.27	23.46	23.65
30.00	33.77	34.06	34.34	34.63	34.91	35.20	35.48
40.00	45.03	45.41	45.79	46.17	46.55	46.93	47.31
50.00	56.29	56.76	57.24	57.71	58.19	58.66	59.14
60.00	67.54	68.11	68.68	69.25	69.82	70.39	70.96
70.00	78.80	79.47	80.13	80.80	81.46	82.13	82.79
80.00	90.06	90.82	91.58	92.34	93.10	93.86	94.62
90.00	101.32	102.17	103.03	103.88	104.74	105.59	106.45
100.00	112.57	113.52	114.47	115.42	116.37	117.32	118.27

A.7.4: LCC of SBR, (Land Cost in lacs. per ha)

Capacity in MLD	Rs.0.00	Rs.50.00	Rs.100.00	Rs.150.00	Rs.200.00	Rs.250.00	Rs.300.00
1.00	1.19	1.20	1.22	1.23	1.25	1.27	1.28
10.00	11.86	12.02	12.18	12.34	12.50	12.66	12.82
20.00	23.72	24.04	24.36	24.68	25.00	25.32	25.64
30.00	35.58	36.06	36.54	37.02	37.50	37.98	38.46
40.00	47.44	48.08	48.72	49.36	50.00	50.64	51.28
50.00	59.30	60.10	60.90	61.70	62.50	63.30	64.10
60.00	71.16	72.12	73.08	74.04	75.00	75.96	76.92
70.00	83.02	84.14	85.26	86.38	87.50	88.62	89.74
80.00	94.88	96.16	97.44	98.72	100.00	101.28	102.56
90.00	106.74	108.18	109.62	111.06	112.50	113.94	115.38
100.00	118.60	120.20	121.80	123.40	125.00	126.60	128.20

A.7.5: **LCC of ASP, (Land Cost in lacs. per ha)**

Capacity in MLD	Rs.0.00	Rs.50.00	Rs.100.00	Rs.150.00	Rs.200.00	Rs.250.00	Rs.300.00
1.00	1.13	1.18	1.23	1.29	1.34	1.39	1.44
10.00	11.30	11.82	12.34	12.86	13.38	13.90	14.42
20.00	22.59	23.63	24.67	25.71	26.75	27.79	28.83
30.00	33.89	35.45	37.01	38.57	40.13	41.69	43.25
40.00	45.18	47.26	49.34	51.42	53.50	55.58	57.66
50.00	56.48	59.08	61.68	64.28	66.88	69.48	72.08
60.00	67.78	70.90	74.02	77.14	80.26	83.38	86.50
70.00	79.07	82.71	86.35	89.99	93.63	97.27	100.91
80.00	90.37	94.53	98.69	102.85	107.01	111.17	115.33
90.00	101.66	106.34	111.02	115.70	120.38	125.06	129.74
100.00	112.96	118.16	123.36	128.56	133.76	138.96	144.16

ANNEXURE –VIII

A.8 LAND AREA REQUIRED PER MLD OF VARIOUS STPs

4.8.1 For ASP

Sl. No.	Particulars of Units	Area in m^2
1.	Pretreatment unit	300
2.	Primary Clarifier	310
3.	Aeration Tank	330
4.	Secondary Clarifier	510
5.	Sludge Thickener	260
6.	Sludge Drying Bed	5125
7.	Gas Holders	125
	Total	6960
	Additional Area (50% extra)	3480
	Grand Total	10440
	Per MLD	1044
Land required per MLD in hectare		**0.1044**

A.8.2 For UASB + FPU

Sl. No.	Particulars of Units	Area in m^2
1.	Pretreatment unit	300
2.	Distribution box & division	25
3.	UASB Reactor	550
4.	Sludge Drying Bed	1080
5.	FPU	13105
	Total	15060
	Additioal Area (50% extra)	7530
	Grand Total	22590
	Per MLD	2259
Land required per MLD in hectare		**0.2259**

A.8.3 For FAB

Sl. No.	Particulars of Units	Area in m^2
1.	Pretreatment unit	300
2.	FAB Reactor	250
3.	Secondary Clarisettler	525
4.	Chlorine Contact Tank	110
5.	Sludge Thickener	50
6.	Sludge Sump	50
	Total	1285
	Additioal Area (50% extra)	642.5
	Grand Total	1927.5
	Per MLD	192.75
Land required per MLD in hectare		**0.019275**

A.8.4 For SBR

Sl. No.	Particulars of Units	Area in m^2
1.	Pretreatment unit	300
2.	Area of Basin	1300
3.	Chlorine Contact Tank	200
4.	Filtrate Sump	100
5.	Centrifuge Room	200
	Total	2100
	Additioal Area (50% extra)	1050
	Grand Total	3150
	Per MLD	315
Land required per MLD in hectare		**0.0315**

A.8.5 For WSP

Sl. No.	Particulars of Units	Area in m^2
1.	Pretreatment unit	200
2.	Anaerobic Pond	1905
3.	Facultative Pond	26491
4.	Maturation Pond	58588
	Total	87184
	Additioal Area	4500
	Grand Total	91684
	Per MLD	9168.4
Land required per MLD in hectare		**0.91684**