TECHNO-COMMERCIAL COMPARISON OF MEMBRANE BIO-REACTOR WITH ACTIVATED SLUDGE PROCESS AND MOVING BED BIO-FILM REACTOR

A PROJECT REPORT SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER IN TECHNOLOGY

IN

ENVIRONMENTAL ENGINEERING

Research Supervisor

Mrs. GEETA SINGH

Submitted by

Meena Seema Ramhari (2K14/ENE/010)

Department of Environmental Engineering

Delhi Technological University

Delhi-110042

June 2016

CERTIFICATE

This is to certify that the work which is being presented in thesis entitled "**TECHNO-COMMERCIAL COMPARISON OF MEMBRANE BIO-REACTOR WITH MOVING BED BIO-FILM REACTOR AND ACTIVATED SLUDGE PROCESS"** is submitted by MEENA SEEMA RAMHARI, ROLL NO- 2K14/ENE/010 in the partial fulfillment of the requirement for the award of the degree of MASTER OF TECHNOLOGY in ENVIRONMENTAL ENGINEERING to DEPARTMENT of ENVIRONMENTAL ENGINEERING, DELHI TECHNOLOGICAL UNIVERSITY. It is the record of students's own work carried under the supervision and guidance

Mrs. Geeta Singh

(Supervisor)

Assistant Professor

Department of Environmental Engineering

Delhi Technological University,

Delhi

ACKNOWLEDGEMENT

I would like to express my hearty gratitude to my project guide Mrs. Geeta Singh, Assistant Professor, Delhi Technological University, Delhi for giving me the opportunity to work under her insightful and substantial guidance and bestowing me with her constant guidance, encouragement, kind suggestions and tireless endeavors for this project thesis.

I wish to thank my HOD, Prof. A.K. Gupta. I am highly grateful to all the Faculty and laboratory staffs of Department of Environmental Engineering for their cooperation.

Meena Seema Ramhari
Roll No. 2K14/ENE/010
M.TECH (ENVIRONMENTAL ENGINEERING)
Department of Environmental Engineering
Delhi Technological Univeristy
Delhi-110042

DECLARATION

I, hereby declare that the work being presented in the project entitled "**TECHNO-COMMERCIAL COMPARISON OF MEMBRANE BIO-REACTOR WITH MOVING BED BIO-FILM REACTOR AND ACTIVATED SLUDGE PROCESS**" is an original work and an authentic report carried out as apart of my major project. The contents of this report have not been previously formed the basis for the award of any degree, diploma or other similar title or recognition and is being utilized by me for the submission of my Major-2 Report to complete the requirements of Master's degree of Examination in Environment Engineering, as per Delhi Technological University curriculum.

Meena Seema Ramhari

Roll No. 2K14/ENE/010

M.TECH (ENVIRONMENTAL ENGINEERING)

Department of Environmental Engineering

Delhi Technological Univeristy

Delhi-110042

Table of Contents

List of Figures

List of Tables

ABSTRACT

The wastewater from industries varies so greatly in both flow and pollutional strength. In general, industrial wastewaters may contain suspended, colloidal and dissolved solids. In addition, they may be either excessively acid or alkaline and may contain high or low concentrations of coloured matter. These wastage may contain inert, organic or toxic materials and possibly pathogenic bacteria. These wastes may be discharged into the sewer system provided they have no adverse effect on treatment efficiency or undesirable effects on the sewer system. It may be necessary to pretreat the wastes prior to release to the municipal system or it is necessary to a fully treatment when the wastes will be discharged directly to surface or ground waters. The technologies discussed in the project are Membrane Bio-reactor (MBR), Activated Sludge Process (ASP) and Moving Bed Bio-film Reactor (MBBR).

Membrane Bio-reactor (MBR) is a wastewater treatment technology that offers many advantages including excellent effluent quality, stable operation performance, a small footprint, reduction of excess sludge production, reuse of effluent, reduction of risk substances and so on. When one takes into consideration that fresh water serves as a precious resource for human brings, the ability to reuse treated water is one of the biggest advantages of using MBR technology.

The activated sludge process (ASP), found in the wastewater treatment plants, consists basically of a biological reactor followed by a sedimentation tank, which has one inlet and two outlets. The purpose of the ASP is to reduce organic material and dissolved nutrients (substrate) in the incoming wastewater by means of activated sludge (microorganisms). The major part of the discharged flow thrugh the bottom outlet of the sedimentation tank is re-circulated to the reactor, so that the biomass is reused.

The moving bed bio-reactor (MBBR) technology is an attached growth biological treatment process based on a continuously operating, non-clogging bio-film reactor with the low head loss, a hig specific bio-film surface area, and no requirement for backwashing. Moving bed technology presents several operational advantages, compared to other conventional biological treatments.

CHAPTER – 1
INTRODUCTION

1. INTRODUCTION

Industrial waste water is one the important pollution sources in the pollution of the water environment. During the last century a huge amount of industrial wastewater was discharged into rivers, lakes, and coastal areas. This resulted in serious pollution problems in the water environment and caused negative effects to the eco-system and human’s life. There are many types of industrial wastewater based on different industries and contaminants, each sector produces its own particular combination of pollutants. Like the various characteristics of industrial wastewater, the treatment of industrial wastewater must be designed specifically for the particular type of effluent produced.

The amount of wastewater depends on the technical level of process in each industry sector and will be gradually reduced with the improvement of industrial technologies. The increasing rates of industrial in developing industries are thought to be much higher than those in developed industries. This fact predicts that industrial wastewater pollution, as a mean environment pollution problem, will move from developed countries to developing countries in the early 21st century.

Basically, the problems such as high eutrophication of the water bodies due to high nutrient contains of waste water, depletion of dissolved oxygen level due to toxic contaminants such as heavy metals and emerging pollutants, breeding of various pathogenic microorganism indicators such as E-coli, salmonella and some viruses, are more challenging. Wastewater treatment is needed fundamentally to eliminate environmental contaminations that would have added by the wastewater so that we can use natural rivers and streams for swimming, fishing and drinking water. The population and the industrial growth have increased stress on our natural resources and create vulnerable situation dramatically. The technological advances, land-use and land-use change, business innovations along with the urbanization and industrialization may produce highly fluctuating and complex wastes are a huge challenge for traditional waste treatment technologies indeed.

The initiative of modern wastewater treatment system was commenced during 19th century due to the rapid urbanization and industrialization. However, during those days the collected wastewater from sewerage system was fed directly to the streams and rivers without adequate treatment and the self-purification process was only the cleaning maneuver. Since majority of cities achieved their drinking water from those natural sources receiving untreated wastewater; there was a huge epidemic of typhoid and waterborne diseases. Right after, sanitary engineers were engaged in rigorous trials and implemented filtration at the intake of water supplies for the solution to the problem. Even after, the struggle for treatment of wastewater has been challenging in the social regime.

In this study, effluent and influent characteristics for different industries is analyzed and techno-commercial technologies like membrane bioreactor, activated sludge process, moving bed bioreactor are used for designing. In the design, parameters such as flow rate, Mixed liquor suspended solids (MLSS), Sludge retention time (SRT), MBR flux are taken as constant. Constants such as decay constant (Kd), yield coefficient (Y), and self- debris constant (Fd) are used for the analysis. Also, a comparative study is done between these technologies for the industries and removal efficiencies is analyzed for the technologies.

1.1 Motivation

They can classified in two main categories:

1. Environmental motivation. Because water is something special and we want to preserve it.
2. Economic motivations. Because a wastewater treatment plant can be considered as the largest industry in terms of raw material treated.Therefore, such an industry should always work near to its maximum efficiency. Mostly because, in some countries recent evolution of the legislation concerning surface or groundwater use is such that total recycling of process water has become an issue. In such a context, the wastewater treatment becomes part of a

production process where the quality control of the effluent is very important since poor operation of the treatment process can lead to important production losses and environmental problems.

1.2 Membrane Bio-reactor (MBR)

The term ‘membrane bioreactor’ (MBR) is generally used to define wastewater treatment processes where a perm-selective membrane eg microfiltration or ultrafiltration is integrated with a biological process – a suspended growth bioreactor.MBRs differ from ‘polishing’ processes where the membrane is employed as a discrete tertiary treatment step with no return of the active biomass to the biological process.All commercial MBR processes available today use the membrane as a filter, rejecting the solid materials which are developed by the biological process, resulting in a clarified and disinfected product effluent.A membrane bio reactor is essentially a version of the conventional activated sludge (CAS) system. While the CAS process uses a secondary clarifier or settlement tank for solid/liquid separation, an MBR uses a membrane for this function. This provides a number of advantages relating to process control and product water quality.Membrane bioreactors (MBRs) have been considered as one of the most promising for wastewater treatment and water reclamation. The main features of MBR process include the high quality effluent from the treated wastewater for reclamation or reuse, operation at higher mixed liquor suspended solids (MLSS) concentrations, compact and modular system (small plant footprint) and excellent performance on removal of organics, solids, nutrients, pathogens and emerging pollutants.

1.3 Activated Sludge Process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process. In activated sludge process wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter. Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy. In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge. The conventional system maintains a plug flow hydraulic regime. Over the years, several modifications to the conventional system have been developed to meet specific treatment objectives. In step aeration settled sewage is introduced at several points along the tank length which produces more uniform oxygen demand throughout. Tapered aeration attempts to supply air to match oxygen demand along the length of the tank. Contact stabilization provides for reaeration of return activated sludge from from the final clarifier, which allows a smaller aeration or contact tank.Completely mixed process aims at instantaneous mixing of the influent waste and return sludge with the entire contents of the aeration tank. Extended aeration process operates at a low organic load producing lesser quantity of well stabilized sludge.

1.4 The Moving Bed Biofilm Reactor (MBBR)

The Moving Bed Biofilm Reactor (MBBR) technology is a leading-edge biological solution for wastewater treatment, based on a core understanding of microbiology and treatment processes. This simple and robust biological treatment process is suitable for specific wastewater treatment processes – nitrogen reduction, high BOD/COD removal, including difficult industrial wastewater requirements.At the core of the technology, specially designed polyethylene biofilm carriers provide a large surface area for micro-organisms to grow on and perform specific biological treatment functions. Carriers are kept in suspension in the reactor either by the aeration system (aerobic zone) or mixers (anoxic zone). Bacteria from the wastewater attach themselves to the floating carriers.The very compact configuration helps to achieve a highly active biomass concentration in the reactor and a low settling load in the downstream solids separation process. Biofilm wastewater treatment technologies are very robust, especially when compared to conventional technologies like activated sludge.

1.5 OBJECTIVE OF THE STUDY

The study focuses on a case study comparison of the three technologies with considering effluent from 9 different effluent generating bodies. The effluent characteristics of these 9 industries have been taken from the test certificates provided by these respective industries.

The objective of the study is

1. To compare the techno-commercial aspects of the three renowned treatment plants
2. The comparison of cost with the technical feasibility, land requirement and overall efficiency
3. The three technologies have been designed on varying judging parameters like Sludge retention time, hydraulic retention time, food to micro-organisms ratio, dissolved oxygen set point, ambient temperature, etc.

Our main objective is to understand that which industry should adopt a particular technology in consideration with their limiting factors.

CHAPTER – 2
LITERATURE REVIEW

2. LITERATURE REVIEW

This chapter deals with the literature review of the three technologies considered for the designing i.e. Membrane bio-reactor, activated sludge process and moving bed-bio-film reactor

2.1 Membrane Bio-reactor (MBR)

MBRs are most prominent and proven processes these days to achieve relatively clean water from wastewater through the combination of membrane and biological treatment **(Lee, 2012).** Coupling membrane separation with biochemical conversion has emerged a high range of environmental biotechnology applications such as biosolids separation, gas-diffusion, extractive, biocatalytic and electrochemical membrane biological reactors. Membranes are rarely used to filter untreated wastewater directly due to the possible fouling which can break the steady state and poor water recovery. However, combination of membrane with biological process can treat raw wastewater containing dissolved organic matter to suspended biomass thus reducing the membrane fouling with increased size of solid fractions **(Hai et al., 2014).**

There are various historical milestones that have been leading the present development of membrane bioreactors. Various MBRs have been studied since 1960s. The era between 1960s and 1980s often considered as golden age of membrane science. The first historical application of membrane, coupling with activated sludge bioreactor was the cross-flow membrane filtration looped sidestream MBRs, suggested by **(Smith et al., 1969).** Nevertheless, those first generation MBRs had more difficulties due to high cost of membranes and high energy consumptions. The breakthrough in MBR technology emerged in 1989 when first submerged membranes were introduced. Eventually, submerged or immersed MBRs (iMBR) technologies have become more cost effective for large scale lower strength uses and sidestream MBRs (sMBR) for smalle scale higher strength applications **(Hai et al., 2014).** Similarly, commercial aerobic and anaerobic MBRs have already been in use with small footprint over conventional biological processes, creating high quality effluent to reuse options at high organic loading rates **(Brindle & Stephnson, 1995)** footprint over conventional biological processes, creating high quality effluent to reuse options at high organic loading rates **(Brindle & Stephnson, 1995).**

The robustness of the MBR is exemplified in its ability to handle many different types and qualities of incoming waste yet maintain a high quality effluent. For example, a study performed on the biological degradation of landfill leachate showed that in a recent retrofit, the MBR/RO coupled system achieved acceptable effluent quality wherebiological oxidation alone failed **(Ahn et al., 2002).** Prior to the retrofit, the BOD and COD removal efficiencies were 79% and 66% respectively. After the retrofit wasimplemented, the MBR BOD and COD removal efficiencies both increased to 97%.Simulated groundwater with high nitrate concentrations was treated using a sequencing membrane bioreactor **(Rezania et al., 2005).** The two-membrane system utilized one membrane to diffuse hydrogen into the mixed liquor and the second to separate water from the biomass. This novel approach completely denitrified the groundwater while retaining 95% of soluble microbial products.

The effectiveness of membranes actually increases with time. In 2003, **Klatt and LaPara** saw increased bioreactor performance due to the bacterial community in the MBR adapting its physiology. In the laboratory setting, the complete retention of the membrane separation unit allowed faster and more complete adaptation to influent wastewater. This may or may not be valid for real world application however, it was also stated that these rapid physiological adaptations occurred within the first few days of operation. This has implications for rapid and efficient system startup.

Several studies have been performed on the applicability of membrane bioreactors to treat wastewater for reuse **(Durham et al., 2001; Xing et al., 2001; Liberti et al., 2003; Coté et al., 2004).** The obligation to sustain our water resources has also driven research and development in many technologies, including membranes. Water reuse can be used to mitigate water shortages and provide a measure of certainty to long term water forecasts. The excellent effluent quality and integral pathogen barrier provided by MBRs makes it an ideal candidate for water reuse schemes. A 2001 report by Schaefer highlighted several water reuse success stories in Australia, Mexico and the US. Industrial and municipal wastewater was used to recharge aquifers and reused in industrial processes. However, the vast majority of MBRs are employed as one unit operation of a wastewater reuse scheme.

2.2 Activated Sludge Process (ASP)

The activated sludge process has already been used in practice for almost eighty years. Originally, it was developed in England by Arden and Lockett in 1914 **(Metcalf and Eddy, 1979)** and since then it has been subjected to many improvements throughout the years. It is rather a unique biotechnological process which consists of an aerated suspension of mixed bacterial cultures which carry out the biological conversion of the contaminants in the wastewater. The aeration tank, while having many possible configurations, basically retains the influent wastewater for a number of hours (or days) in a well mixed/aerated environment, before forwarding the effluent for further settling to the secondary clarifier. The end products of the clarification process are clarified effluent that is discharged to the open water bodies and sludge. A fraction of the sludge is returned to the aeration tank and is called returned activated sludge. The sludge contains a high density of biomass and an active population of microorganisms is always maintained in the tank. The influent wastewater provides the basic food source for the microorganisms in the aeration tank. This biodegradable organic material is converted into new bacterial cells and other end products include CO_2, NO_3 and SO_4. **(Eckenfelder and Grau, 1992)**

When a biodegradable organic food source is supplied to a heterotrophic microorganism population in a well-aerated environment the following phenomena occur **(Kiely, 1997):**

1. The readily soluble biodegradable particulate COD goes through the cell wall and is metabolized quickly;
2. The slowly biodegradable particulate COD is adsorbed on to the organisms and stored. This action removes all the particulate and colloidal COD which than over time is broken down and transferred through the cell wall and metabolized
3. Some of the COD metabolized is converted to new cells while the remainder is lost as heat in the energy process required for the new cell synthesis

4. At the same time there is a net loss of biomass, termed endogenous mass loss, where some of the organisms utilize as food their own stored food materials and dead cells.

The activated sludge process is governed by the microorganism characteristics and the physical configuration of the aeration tank. As such, the biological kinetics and the process kinetics are closely interconnected. **(Metcalf and Eddy, 1979; Eckenfelder and Grau, 1992).**

According to the literature review conducted by **Rybicki (1997)** the evolution of biological phosphorus removal started with Levin and Shapiro **(1965)** who reported on extensive investigations into phosphorus uptake and release. They named the observed high phosphorus removal " a luxury uptake". They also observed that uptake and release of phosphorus are reversible processes; an observation of great importance for the development of the process. After many years of an extensive research it was found that under certain anaerobic - anoxic conditions, activated sludge microorganisms can contain more then the normal 2-3% phosphorus.

2.3 The Moving Bed Biofilm Reactor (MBBR)

The use of MBBR has been reported in both pilot plant studies and full-scale plants They are usually employed in carbonaceous BOD removal and nitrification, but nutrient removal is possible with different system configurations and conditions**. (Gilmore et al., 1999; Rusten et al., 1997; Sunner et al.,1999).** The system is currently used in 16 different countries all over the world and over 60 plants are either in operation or under construction. The system consists of a reactor vessel containing mixed liquor suspended solids with specially designed carrier media suspended and kept in constant circulation. A screen is provided at the outfall end of the reactor to keep media from clogging the effluent spout or passing out of the reactor.

Experiments are currently underway to increase the carrier media size. This will enable screens with larger openings to be used and thus prevent the use of primary settlers in most MBBR system configurations **(Odegaard et al., 1994).** The system finds several uses in both industrial and municipal wastewater treatment. Several configurations are possible to meet different treatment objectives.

The high specific area of the carrier media, which allows very high biofilm concentrations in a small reactor volume, controls the system performance. It was reported that typical biofilm concentrations range from 3000 to 4000 g TSS /m3 **(Odegaard et al., 1994),** which is similar to values obtained in activated sludge processes with high sludge ages. It was inferred that, since the volumetric removal rate in the MBBR is several times higher than that in the activated sludge process, the biomass in the former are much more viable **(Odegaard et al., 1994).**

The nature of the carrier media used requires development of a very thin, evenly distributed and smooth biofilm to enable transport of substrate and oxygen to the biofilm surface. In this regard, thick and fluffy biofilms are not desired for this system. Adequate turbulence sloughs off excess biomass and maintains adequate thickness of biofilm. Biofilm thickness less than 100 μm for full substrate penetration is usually preferred. Adequate turbulence also maintains flow velocities necessary for effective system performance **(Odegaard et al., 1994).**

MBBRs have been applied for organic matter removal **(Rusten et al, 1995).** The process quickly degrades biodegradable, soluble organic matter. It is reported by **(Odegaard et al. 1994)** that particulate organic matter is partly trapped in biofilm, hydrolyzed and utilized although the hydrolyzed fraction is not significant compared to the readily soluble biodegradable organic matter utilized in the process.

MBBRs have been used to upgrade existing activated sludge (AS) systems. In one example, the MBBR was proposed to replace a pretreatment system composed of biological filters and humus tank **(Sunner et al., 1999).** The effluent from the MBBR was fed directly into the AS reactor without an intermediate settling tank. It was anticipated that the sludge age of the AS could be influenced by the solids from the MBBR effluent. Additionally, it was reported that the direct feed improved the settling properties of solids in the secondary clarifiers. MBBRs have been used for nitrification **(Hem et al., 1994; Odegaard et al., 1994; Rusten et al., 1995a).** MBBR systems have been very useful in upgrading schemes. The small footprint of the reactor saves the cost of acquiring land at a high premium for conventional reactors. It has also been used in treating industrial wastewaters from food processing and paper and pulp industries **(Broch-Due et al., 1994; Odegaard et al.,**

1994; Rusten et al., 1992.). Where phosphorus removal is desired, chemical coagulation is incorporated in a pretreatment or post treatment step. If coagulation is used in the pretreatment stage, it was found that suspended solids were removed, leaving low molecular weight soluble organic matter in the influent wastewater stream. The low influent suspended solid concentration increases the overall system efficiency **(Odegaard et al., 1994.)**

CHAPTER - 3

METHODOLOGY

3. METHODOLOGY

This chapter deals with working of the three techniques, factors taken into consideration for designing and study of the industries for which designing is carried out. Also, it includes the constants which are considered in designing

3.1 Membrane Bio-reactor (MBR)

Membrane Bioreactors (MBR) are treatment processes, which integrate a perm-selective semi-permeable membrane with a biological process. There are two configurations which exits.

3.1.1 MBR Process Configurations

Internal/submerged

The filtration element is installed in either the main bioreactor vessel or in a separate tank. The membranes can be flat sheet or tubular or combination of both, and can incorporate an online backwash system which reduces membrane surface fouling by pumping membrane permeate back through the membrane. In systems where the membranes are in a separate tank to the bioreactor, individual trains of membranes can be isolated to undertake cleaning regimes incorporating membrane soaks, however the biomass must be continuously pumped back to the main reactor to limit MLSS concentration increase. Additional aeration is also required to provide air scour to reduce fouling. Where the membranes are installed in the main reactor, membrane modules are removed from the vessel and transferred to an offline cleaning tank.

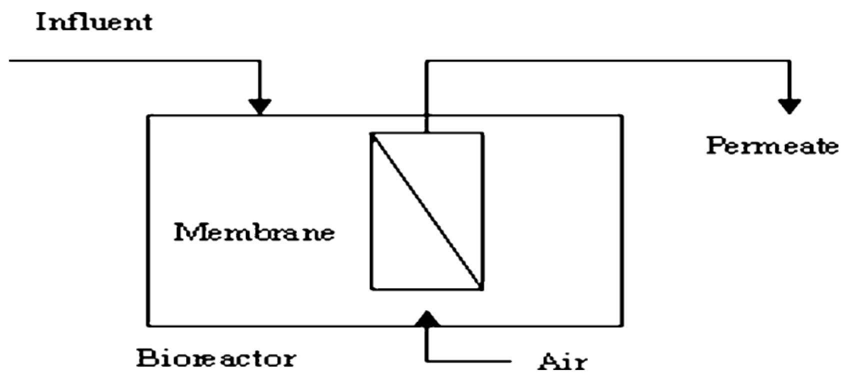


Fig 3.1: Internal submerged MBR

External/sidestream

The filtration elements are installed externally to the reactor, often in a plant room. The biomass is either pumped directly through a number of membrane modules in series and back to the bioreactor, or the biomass is pumped to a bank of modules, from which a second pump circulates the biomass through the modules in series. Cleaning and soaking of the membranes can be undertaken in place with use of an installed cleaning tank, pump and pipework.

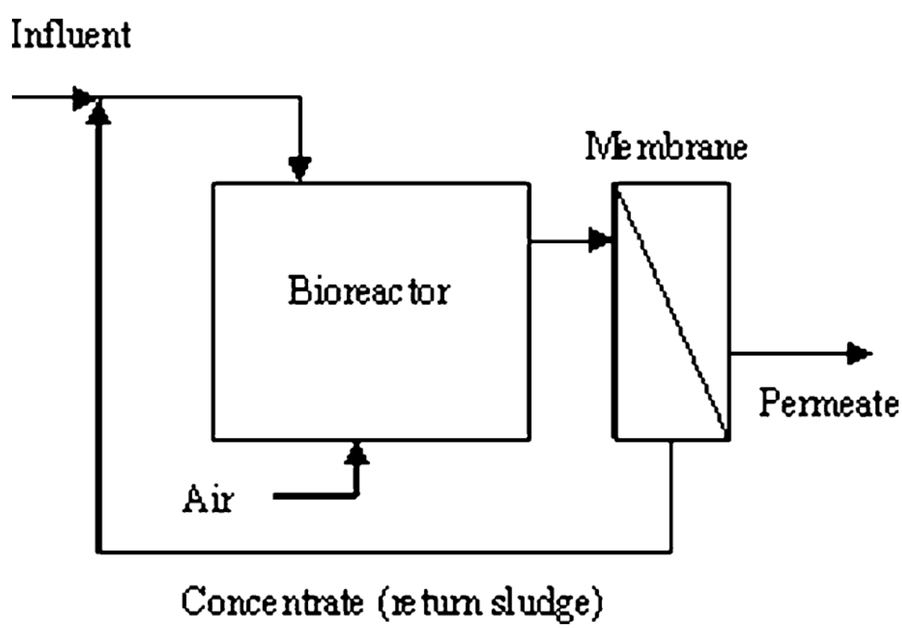


Fig 3.2: External submerged MBR

3.1.2 Types of Membranes

There are five principal membrane employed in practice:

1. Hollow fiber (HF)
2. Spiral-wound
3. Plate-and-frame (i.e., flat sheet (FS)
4. Pleated filter cartridge
5. Tubular.

In the HF module, large amounts of HF membranes make a bundle, and the ends of the fibers are sealed in epoxy block connected with the outside of the housing (Fig. 3). The water can flow from the inside to the outside of the membrane, and also from the outside to the inside, which is produced differently by different manufacturers. These membranes can work under pressure and under vacuum

Fig. 3.3: Hollow-fiber (HF) membrane module

The spiral-wound configuration is mostly used for the NF and RO process. The membranes are wound around the perforated tube through which permeate goes out The spiral-wound modules aremanufactured in standard dimensions by all major manufacturers, which makes their installation easier and membrane production less costly. Many membrane modules can be installed together in series or parallel in plants with high capacity

Fig. 3.4: Spiral-wound membrane module

Plate-and-frame membrane modules comprise of FS membranes with separators and/or support membranes. The pieces of these sheets are clamped onto a plate. The water flows across the membrane and permeate is being collected through pipes emerging from the interior of the membrane module in a process that operates under vacuum

Fig. 3.5: Plate-and-frame immersed membrane module

3.1.3 Merits and Demerits of MBR

Merits

- Small footprint
- Complete solid removal
- Removal of organic, nutrient & solid

- High loading rate capability
- Low/zero sludge production
- Rapid start up
- Sludge bulking not a problem
- -Modular/retrofit

Demerits

- Aeration limitation
- Membrane fouling
- Membrane costs

3.2 Activated Sludge Process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process as shown in figure:

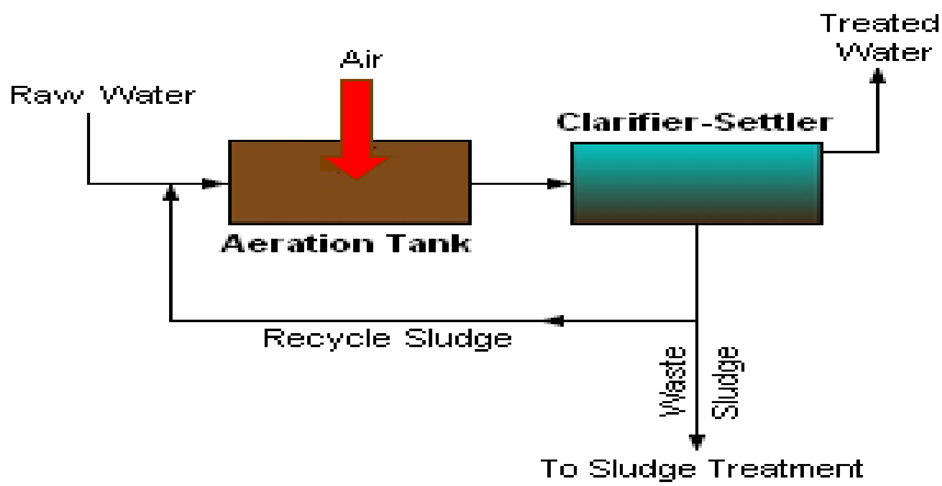


Fig. 3.6: Activated sludge process

Activated sludge plant involves:

1. wastewater aeration in the presence of a microbial suspension,
2. solid-liquid separation following aeration,

3. discharge of clarified effluent,
4. wasting of excess biomass, and
5. return of remaining biomass to the aeration tank.

3.2.1 Activated Sludge Process Variables

The main variables of activated sludge process are

- the mixing regime
- loading rate
- the flow scheme.

Mixing Regime

Generally two types of mixing regimes are of major interest in activated sludge process: plug flow and complete mixing**.**

In the first one, the regime is characterized by orderly flow of mixed liquor through the aeration tank with no element of mixed liquor overtaking or mixing with any other element. There may be lateral mixing of mixed liquor but there must be no mixing along the path of flow.

In complete mixing, the contents of aeration tank are well stirred and uniform throughout. Thus, at steady state, the effluent from the aeration tank has the same composition as the aeration tank contents.The type of mixing regime is very important as it affects oxygen transfer requirements in the aeration tank susceptibility of biomass to shock loads,local environmental conditions in the aeration tank, and the kinetics governing the treatment process

Loading Rate

A loading parameter that has been developed over the years is the hydraulic retention time (HRT). Another empirical loading parameter is volumetric organic loading which is defined as the BOD applied per unit volume of aeration tank per day. A similar loading parameter is mean cell residence time or sludge retention time (SRT).

Flow Scheme

The flow scheme involves:

- the pattern of sewage addition
- the pattern of sludge return to the aeration tank
- the pattern of aeration.

Sewage addition may be at a single point at the inlet end or it may be at several points along the aeration tank. The sludge return may be directly from the settling tank to the aeration tank or through a sludge reaeration tank. Aeration may be at a uniform rate or it may be varied from the head of the aeration tank to its end.

3.2.2 Merits and Demerits of ASP

Merits

- Resistant to organic and hydraulic shock loads
- Can be operated at a range of organic and hydraulic loading rates
- High reduction of BOD and pathogens
- High nutrient removal possible
- Can be modified to meet specific discharge limits

Demerits

- High energy consumption
- High capital and operating costs
- Requires operation and maintenance by skilled personnel
- Prone to complicated chemical and microbiological problems
- Not all parts and materials may be locally available
- Sludge and possibly effluent require further treatment and/or appropriate discharge

3.3 Moving Bed Bio-film (MBBR)

A Moving Bed Bio-film MBBR reactor consists of a tank with submerged but floating plastic (usually HDPE, polyethylene or polypropylene) media having specific gravity less than 1.0. The large surface area of the plastics provide abundant surface for bacterial growth. Biomass grows on the surface as a thin film whose thickness usually varies between 50-300 microns. Medium or coarse bubble diffusers uniformly placed at the bottom of the reactor maintains a dissolved oxygen (DO) concentration of > 2.5-3 mg/L for BOD removal. Higher DO concentrations are maintained for nitrification. To retain the media flowing out of the tank, screens are placed on the downstream walls. A clarifier is placed downstream of the MBBR tank to separate the biomass and the solids from the wastewater. No sludge recycle is required for this process. For denitrification, anoxic Moving Bed Biofilm Reactor MBBR tanks are used. The anoxic tank is similar to aerobic Moving Bed Biofilm Reactor MBBR tank described above except that no oxygen is supplied. The tank contains no diffusers and the media is kept in suspension in the reactor through submersible mixers. Other feature such as the screen is the same as aerobic reactor although the design may be slightly different. A schematic of the Moving Bed Biofilm Reactor MBBR process for BOD removal and/or nitrification is shown. Wastewater enters the Moving Bed Biofilm Reactor MBBR where the biomass attached to the surface of the media degrades organic matter resulting in BOD removal and/or nitrification depending on the type and characteristic of the wastewater. Organic carbon is converted to carbon dioxide and leaves the system while the ammonia and nitrogen in the organics are converted to nitrates through nitrification process. Oxygen required for the process is provided through the diffusers installed at the bottom of the reactor. The treated wastewater then flows through the screens to the downstream clarifier where the biomass and solids are separated from the wastewater. There are more than a thousand Moving Bed Biofilm Reactor MBBR installations worldwide. Moving Bed Biofilm Reactor technology can be used for wastewater treatment for the following industries: food and beverage plants, steel mills, oil refineries, petrochemicals, chemical plants, paper mills and any industries requiring wastewater treatment for BOD removal, nitrification and denitrification.

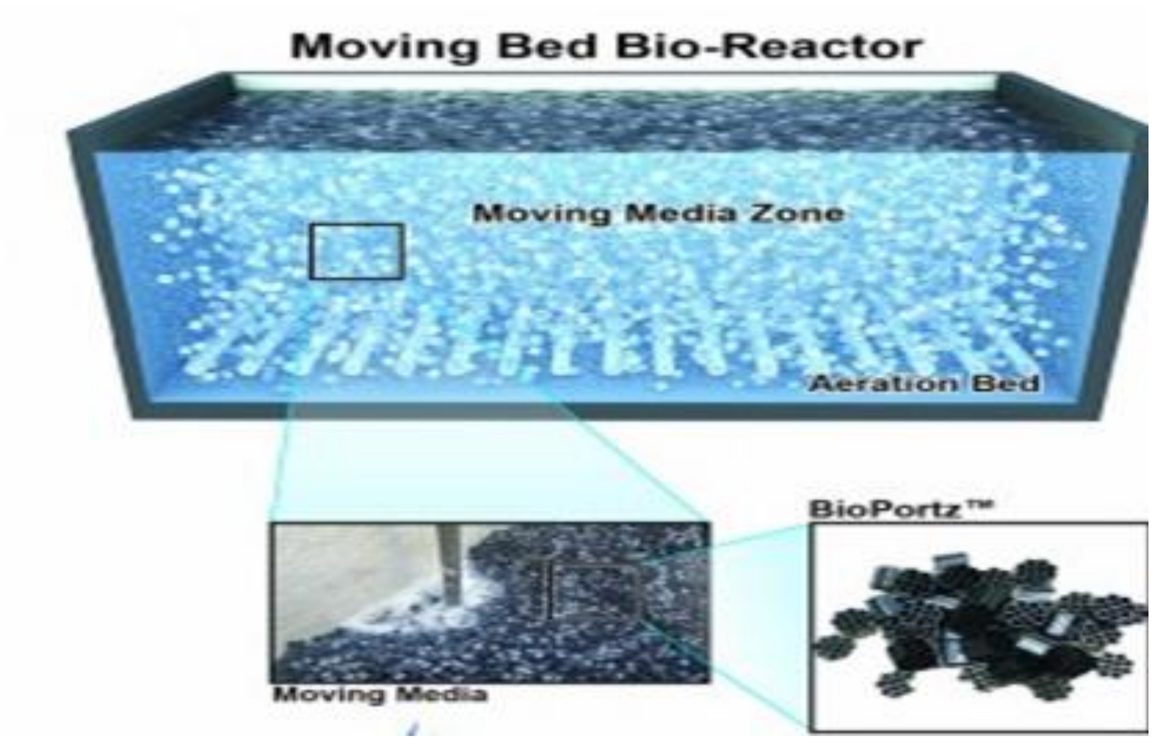


Fig.3.7: The Moving Bed Bio-film Reactor

3.3.1 Merits and Demerits of MBBR

Merits

- Robust – It is stable under load variations, insensitive to temporary limitation and provides consistent treatment results
- Efficient – It generates low solids and requires no or minimum polymer for solid/liquid separation
- Compact – It requires a small footprint. Typically it requires 1/3rd the space required for Activated Sludge Process.

- Cost – It requires a low capital cost and is comparable to cost of Activated Sludge Process. It is cheaper than the MBR process.
- Flexible – Existing plants can be upgraded easily with MBBR. New MBBR plants can be upgraded to handle higher loads with no or minimum cost and construction.
- Trouble Free- It is easy to operate, has automatic sludge wasting, has no sludge Return and no MLSS, and there no issue of media clogging.

Demerits

- Change of media after sometime
- Odour
- Higher running cost

3.4 Factors taken into consideration for designing

1. F/M

Organic loading rate is an important design and controlling parameter in biological wastewater treatment process. It is measured by the amount of food provided to a unit amount of biomass (or reactor volume) for a unit period of time. Food-to-microorganisms (F/M) ratio is based on the amount of biomass

2. Oxygen Uptake Rate (OUR)

Oxygen uptake rate (OUR) represents the volumetric oxygen consumption rate. It can be directly correlated with food to mass (F/M) ratio since the amount of substrate to be decomposed is proportional to the amount of oxygen required at steady state. By definition, volumetric oxygen dissolution rate must exactly match with OUR unless dissolved oxygen (DO) level changes

3. Hydraulic Retention Time (HRT)

It is defined as volume of aeration tank to the rate of flow of waste water in the system excluding recirculation

4. Biological O2 demand estimation

In biological wastewater treatment, oxygen is consumed by microorganisms to treat mainly carbonaceous oxygen demand and nitrogenous oxygen demand. Although some inorganic ions in their reduced form also need oxygen to be oxidized, the amount is negligible comparing to the others. carbons convert to heterotrophs and CO_2 while consuming O_2, which is the most dominant mechanism in carbon-rich wastewater treatment. The nitrogen measured as TKN is oxidized to NO_3-N by autotrophs while the autotrophs utilize the the energy from the oxidation reaction to fix CO_2. Eventually the carbon in CO_2 is used as building blocks of autotrophs. A portion of TKN is also used to build hetrotrophs and autotrophs without being oxidized.

5. Blower system design

In general, blower systems should be designed for a minimum 5:1 turndown ratio, meaning that a system should be capable of operating at 1/5th of its full capacity. Some common arrangements that provide for efficient blower operation with back up are to design for four blowers at 33 percent each of design flow, or two blowers at 25 percent each of design flow plus two blowers at 50 percent each of design flow. As noted here, the aeration process can account for 25 to as much as 60 percent of total plant energy use

6. Oxygen transfer efficiency (OTE)

Standardized oxygen transfer efficiency (SOTE)

SOTE represents the oxygen transfer efficiency (OTE*)* at 20 ^oC, zero dissolved oxygen, and zero salinity. SOTE tends to decline if air flow rates increase. The increased bubble coalescence and the increased bubble rising velocity cause diminished bubble surface area and contact time, which in turn causes lower SOTE. Therefore the SOTE for a specific diffuser is usually reported as a function of air flow rate to the diffuser.Since SOTE is only valid only for the water depth that the diffuser was tested, SOTE is often reported as specific SOTE ($SOTE_s$ by dividing the diffuse submergence by the depth assuming $SOTE_s$ is constant regardless of the water depth. The $SOTE_s$ is used to estimate the SOTE in the tanks with various depths. Although oxygen transfer from bubbles to water decreases gradually while the bubble rises due to the depleting oxygen content and the decreasing static pressure. However, the errors caused by neglecting these effects are relatively not significant comparing to the uncertainties caused by the fluctuation of biological condition, unique diffuser placement, etc

Table 3.1: Typical SOTE of various diffusers (Cote et al.)

Diffuser type place in grid	**SOTE at 4.5 m submergence**	**$SOTE_s$ (/m)**
Ceramic dics	0.26-0.33	0.058-0.073
Ceramic domers	0.27-0.29	0.06-0.064
Porous plastic disc	0.28-0.32	0.062-0.071
Non rigid porous plastic disc	0.26-0.36	0.058-0.08
Single spiral roll	0.19-0.37	0.042-0.082
Perforated membrane tubes	0.22-0.29	0.049-0.064
Coarse bubble diffusers	0.09-0.13	0.02-0.029

3.5 Equations used for designing

1. Air requirement (m^3/hr)

$$\frac{\text{BOD} * \text{Flow} * \text{Specific gravity of air} * 100}{21 * \text{Rate coefficient} * \text{AOTE}}$$

2. Actual oxygen transfer efficiency (AOTE)

$$= \frac{\text{SOTE}}{2.7}$$

3. Standard oxygen transfer efficiency (SOTE) = Depth*6

Depth = 5 m

4. No. of diffusers

$$= \frac{\text{Air required}}{4}$$

Factor 4 accounts for capacity of fine bubble diffuser

5. Cost of Diffuser = No. of diffuser*900

6. Blower power consumption per day (KW)

$$=\left[\frac{5+1.5+10}{10}^{0.283} - 1\right] * [(4.28 * 10^{-4} * \text{air required per blow} * 0.59 * (\text{temp} * 1.8 + 32) + \quad 460)] * 0.7456 * 24$$

7. Area of MBR

$$= \frac{\text{Average flow rate}}{\text{MBR flux}}$$

8. No. of Modules

$$= \frac{\text{Total MBR Area}}{\text{Area of one module}}$$

The area of one module in hollow fibre membrane is 150 m^2

9. Hydraulic Retention time (HRT)

$$= \frac{\text{BOD} * (1 + \text{Fd} * \text{Kd}) * \text{SRT}}{\text{MLSS} * (1 + \text{Kd} * \text{SRT})}$$

Where,

a. F_d=self-debris coefficient, defined as ratio of cell which are non biodegradable in nature to the total cells

b. K_d= decay constant

c. MLSS= Mixed Liquor Suspended Solids

d. SRT= Sludge Retention Time

10. F/M Ratio

$$= \frac{\text{BOD}}{\text{MLSS} * \text{HRT}}$$

11. Total sludge production = Flow*BOD*0.85
12. Volume of MBR = Discharge*HRT
13. Hydraulic Retention time (HRT) for ASP = HRT FOR MBR*8000/3000
14. Volume of ASP = Discharge*HRT
15. Volume of MBBR

$$= \frac{\text{BOD} * \text{Discharge}}{\text{Loading rate}} * \frac{100}{70}$$

Values assumed

1. F_d=0.12
2. K_d=0.15
3. MLSS for MBR=8000 mg/l
4. SRT= 20 days
5. Y=0.71
6. Q= 1000 m^3/d
7. TEMPERATURE=25^{o}C

3.6 Study Area

1. Stp for Amrapali Mall at Mezaffarpur

Over the past years, Muzaffarpur city, with a sizeable local population (of around 30 lacs), has sustained and is reaching heights in terms of all around development. It is a very old & Holly city and has a great past is now showing itself in new avatar. Amarpali Multiplex Mall, Muzaffarpur is strategically located and positioned to address people's longing for social interaction. Such things as comfortable seating and children's play areas make people feel welcome to socialize in the mall. Especially in environments like those at Bareilly, the mall gives physical definition to residents' sense of community.

Table 3.2: Influent and Effluent characteristics

PARAMETERS	UNITS	INFLUENT	EFFLUENT
PH	-	7.5 to 8.5	6 – 7
BOD_5	mg/l	350	< 20
Suspended solids(SS)	mg/l	400	< 10
Oil & grease	mg/l	150	NIL
COD	mg/l	500	< 100

2. Spanish Hill View, Guwahati

Spanish Hill Vew Apartments spreads across 1.65 acres of land with 81 percent open area. Surrounded by hills, inspired by nature and two G+11 towers overlooking the city. It biasts of 05 Penthouses and 53 flats with beautifully landscaped gardens by the famous Joel Burega of Burega Farnell, Singapore. Located at the junction of Guwahati-Shillong road (GS Road) NH-37, on the hills of Khanapara

Table 3.3: Influent and Effluent characteristics

PARAMETERS	UNITS	INFLUENT	EFFLUENT
PH	-	6.5 to 8.5	6.0 to 7.5
Suspended solids	mg/l	200 - 450	<1
Biochemical Oxygen Demand (BOD)	mg/l	300 - 350	<5
Chemical Oxygen Demand (COD)	mg/l	400-6000	<10
Oil & Grease	mg/l	50	<2

3. **Dr Lal PathLabs Private Limited, Gurgaon, Haryana**

Late Dr. Major S.K. Lal, commenced the business of providing pathology services and maintaining a blood bank in the year 1949 through sole proprietorship M/s Central Clinical Laboratory and M/s Blood Bank Transfusion Centre. The business of diagnostic and related healthcare tests and services now continues to be provided by the Company. The group has built a national network consisting of National Reference Laboratory in New Delhi, 163 other clinical laboratories, 1,340 patient service centers and over 5,000 pickup points as of March 31, 2015. The network has coverage across India, including metropolitan areas such as New Delhi, Mumbai, Bengaluru, Chennai, Hyderabad and Kolkata.

Table 3.4: Influent and Effluent characteristics

PARAMETERS	**UNITS**	**INFLUENT**	**EFFLUENT**
PH	-	Around 6.5 – 8.5	6.5 – 8.5
COD	mg/l	400	<100
BOD @ 20 deg. C	mg/l	250	<20
Suspended solids	mg/l	80	<10
Total dissolved solids	mg/l	1000	1000
Oil & grease	mg/l	20	<10
Color		Objectionable	Unobjectionable

4. **IOCL Panipat**

Panipat Refinery has doubled its refining capacity from 12 MMT/yr to 15 MMT/yr with the commissioning of its Expansion Project. Panipat Refinery is the seventh refinery of IndianOil. It is located in the historic district of Panipat in the state of Haryana and is about 23 km from Panipat City. The original refinery with 6

MMTPA capacity was built and commissioned in 1998 at a cost of Rs. 3868 crore (which includes Marketing&Pipelines installations).

Table 3.5: Influent and Effluent characteristics

PARAMETERS	Units	DESIGN BASIS
BOD	mg/l	270
COD	mg/l	473
OIL & GREASE	mg/l	100

5. Industrial model township, Manesar

Manesar is a fast-growing industrial town in Gurgaon district of the State of Haryana in India, and is a part of theNational Capital Region (NCR) of Delhi. It has transformed from a sleepy village to one of the fastest-growing townships in India. It is an upcoming area of NCR. Some of the developers have added a new tag to Manesar. Proximity to political nerve center - Delhi has also led the government to establish headquarters of some institutes of national importance here like the National Security Guards (and its training center), National Bomb Data Centre and National Brain Research Centre. It has many factories, offices, hotels and educational institutes. There are several sightseeing spots around the area, some overlapping with Gurgaon. Manesar is 32 km from IGI Airport and has some of the best urban infrastructure in northern India. Located on NH 8, the area is well connectedwith Delhi, Rewari, Dharuhera, Jaipur, Ahmedabad and Mumbai;air connectivity is equally good.

Table 3.6: Influent and Effluent characteristics

PARAMETERS	UNITS	INFLUENT	EFFLUENT
PH	-	4.5-9	6.5 – 8.5
COD	mg/l	1500	<150
BOD @ 20 deg. C	mg/l	750	<10
Suspended solids	mg/l	1200	<10
Oil & grease	mg/l	100	<5

6. STP at ESIC Hospital Rohini

Employees' State Insurance (abbreviated as ESI) is a self-financing social security and health insurance scheme for Indian workers. This fund is managed by the Employees' State Insurance Corporation (ESIC) according to rules and regulations stipulated there in the ESI Act 1948. ESIC is an autonomous corporation by a statutory creation underMinistry of Labour and Employment, Government of India.

Table 3.7: Influent and Effluent characteristics

PARAMETERS	UNITS	INFLUENT	EFFLUENT
PH	-	Around 6.5 – 8.5	6.5 – 8.5
COD	mg/l	400	<100
BOD @ 20 deg. C	mg/l	250	<15
Suspended solids	mg/l	100	< 10
Oil & Grease	mg/l	20	-

7. 200 bedded ESI hospital, Manesar

Employees' State Insurance (abbreviated as ESI) is a self-financing social security and health insurance scheme for Indian workers. This fund is managed by the Employees' State Insurance Corporation (ESIC) according to rules and regulations stipulated there in the ESI Act 1948. ESIC is an autonomous corporation by a statutory creation under Ministry of Labour and Employment, Government of India. Manesar is 32 km from IGI Airport and has some of the best urban infrastructure in northern India.

Table 3.8: Influent and Effluent characteristics

PARAMETERS	Units	INFLUENT	EFFLUENT
PH	-	5-9	6.5-8.5
BOD	mg/l	50	<15
COD	mg/l	250	<50
TSS	mg/l	150	<10
OIL & GREASE	mg/l	10	<5

8. Hotel Comrade Inn.

Comrade INN is a plush boutique hotel in Rajbagh area, which is centrally located and close to the major tourist attractions, including the Dal Lake, and marketplaces in Srinagar. The décor seamlessly blends minimalist design elements and functionality with traditional Kashmiri accents like an intricately-carved wood khatambandh ceiling and walnut wood furniture. The hotel takes in 40 tastefully decorated rooms that are sure to appeal to travellers from all over the globe.

Table 3.9: Influent and Effluent characteristics

PARAMETERS	Units	INFLUENT	EFFLUENT
PH	-	Around 6.5 – 8.5	6.5 – 8.5
COD	mg/l	400	<100
BOD @ 20 deg. C	mg/l	250	<20
Suspended solids	mg/l	80	<10
Total dissolved solids	mg/l	1000	1000
Oil & grease	mg/l	20	<10

9. STP for DMRC project at Dwarka.

The Delhi Metro Rail Corporation Limited (DMRC) was registered on 3rd May 1995 under the Companies Act, 1956 with equal equity participation of the Government of the National Capital Territory of Delhi (GNCTD) and the Central Government to implement the dream of construction and operation of a world- class Mass Rapid Transport System (MRTS). Having constructed a massive network of 213 Km with 160 stations in record time, the DMRC today stands out as a shining example of how a mammoth technically complex infrastructure project can be completed before time and within budgeted cost by a Government agency.

Table 3.10: Influent and Effluent characteristics

PARAMETERS	Units	INFLUENT	EFFLUENT
PH	-	Around 6.5 – 8.5	6.5 – 8.5
COD	mg/l	400	<100
BOD @ 20 deg. C	mg/l	250	<20
Suspended solids	mg/l	80	<10
Oil & grease	mg/l	20	<10
Color		Objectionable	Unobjectionable

CHAPTER – 4

RESULTS AND CALCULATIONS

4. RESULTS AND CALCULATIONS

This chapter deals with the parameters calculated using different equations and the comparison of the three techniques

4.1 Calculation of Different Parameters using Different Equations

The below table contains air required for different industries which is calculated using eq.1

Table 4.1: Air required for different industries

S. NO	**INDUSTRIES**	**Air Required (m^3/hr)**
1.	Stp for Amrapali Mall at Mezaffarpur	623
2.	Spanish Hill View, Guwahati	623
3.	Dr Lal PathLabs Private Limited	445
4.	IOCL Panipat	125
5.	Industrial Model Township, Manesar	1335
6.	STP at ESIC Hospital Rohini	445
7.	200 bedded ESI hospital, Manesar	89
8.	Hotel Comrade Inn.	445
9.	STP for DMRC project at Dwarka.	445

From the table, it can be analyzed that air required for industry no. 5 is maximum as BOD load for the industry is maximum while air required is minimum for industry no. 7 as BOD load is minimum. This shows that air required increases with the increase in BOD load

The table 4.2 contains no. of diffusers required and their corresponding cost using eq. 4 and 5

Table 4.2: No. of diffusers and their cost

S. NO	**INDUSTRIES**	NO. of Diffusers	Cost of diffusers
1.	Stp for Amrapali Mall at Mezaffarpur	156	140158
2.	Spanish Hill View, Guwahati	156	140158
3.	Dr Lal PathLabs Private Limited	111	100113
4.	IOCL Panipat	120	108122
5.	Industrial Model Township, Manesar	334	300388
6.	STP at ESIC Hospital Rohini	111	100113
7.	200 bedded ESI hospital, Manesar	22	20023
8.	Hotel Comrade Inn.	111	100113
9.	STP for DMRC project at Dwarka.	111	100113

The no. of diffusers required is maximum for industry no.5 as air required is maximum, which is further dependent on BOD load while industry no. 7 requires minimum diffusers as its air requirement is minimum owing to its minimum BOD load. Therefore, cost of diffusers is maximum for industry no.5 while it is minimum for industry no. 7

The table 4.3 shows blower power consumption for the industries using eq.6

Table 4.3: Blower power consumption required per day

S. NO	INDUSTRIES	Blower Power Consumption/day (KW)
1.	Stp for Amrapali Mall at Mezaffarpur	234
2.	Spanish Hill View, Guwahati	234
3.	Dr Lal PathLabs Private Limited	167
4.	IOCL Panipat	181
5.	Industrial Model Township, Manesar	501
6.	STP at ESIC Hospital Rohini	167
7.	200 bedded ESI hospital, Manesar	33
8.	Hotel Comrade Inn.	167
9.	STP for DMRC project at Dwarka.	167

Blower power consumption is dependent on air required, which further depends on BOD load. Hence, it can be analyzed that blower power consumption is more for industry no.5 as compared to other industries and is less for industry no. 7. Therefore the electricity cost involved is maximum for industry no.5 and it is minimum for industry no.7

The below table 4.4 contains area of MBR and modules required for the industries using eq.7 and 8 resp

Table 4.4: Area of MBR and modules required

S. NO	INDUSTRIES	Area of MBR (m^2)	No. of MBR Modules
1.	Stp for Amrapali Mall at Mezaffarpur	278.78	2
2.	Spanish Hill View, Guwahati	278.78	2
3.	Dr Lal PathLabs Private Limited	278.78	2
4.	IOCL Panipat	278.78	2
5.	Industrial Model Township, Manesar	278.78	2
6.	STP at ESIC Hospital Rohini	278.78	2
7.	200 bedded ESI hospital, Manesar	278.78	2
8.	Hotel Comrade Inn.	278.78	2
9.	STP for DMRC project at Dwarka.	278.78	2

The area required is dependent on flow rate which is assumed constant for all industries. Hence, the area is constant for the industries. The modules required is dependent on flux and area of MBR which is constant. The modules used in designing is hollow fibre membrane as the efficiency is maximum for hollow fibre membrane and is easily available. It has flux of 150 L/m2.h

The table 4.5 contains the the values of HRT and F/M ration which is evaluated using eq. 9, 10 and 13

Table 4.5: HRT and F/M ratio for ASP and MBR

S. NO	INDUSTRIES	F/M For MBR	F/M For ASP	HRT (hrs) for MBR	HRT (hrs) for ASP
1.	Stp for Amrapali Mall at Mezaffarpur	0.2	2	5	14
2.	Spanish Hill View, Guwahati	0.2	2	5	14
3.	Dr Lal PathLabs Private Limited	0.1	1	4	10
4.	IOCL Panipat	0.1	1	1	11
5.	INDUSTRIAL MODEL TOWNSHIP,MANESAR	1.0	7	11	29
6.	STP at ESIC Hospital Rohini	0.1	1	4	10
7.	200 bedded ESI hospital, manesar	0.0	0	1	2
8.	Hotel Comrade Inn.	0.1	1	4	10
9.	STP for DMRC project at Dwarka.	0.1	1	4	10

In order to operate properly there must be a balance between the food (BOD_5, COD, or TOC) entering the biological system, and the microorganisms in the aeration basin. A high F:M ratio means there is a greater quantity of food relative to the quantity of microorganisms available to consume that food. When the F:M ratio is high, the bacteria are active and dispersed and they multiply rapidly. But with a high F:M ratio the bacteria will not form a good floc. Operating with a high F:M ratio will typically result in a poor settling sludge in the clarifier and a turbid effluent.

A low F:M ratio means there are many microorganisms but there is a limited amount of food. Only when the food supply is limited do bacteria begin to develop a thicker slime layer, lose their motility, and begin to clump together to form floc that will settle well in the clarifier.

From the table, it can be analyzed that F/M ratio is maximum for ASP in industry no.5 which is almost impossible to maintain while for MBR it is 1, which can be easily maintained. Also HRT is more for ASP as compared to MBR

The table contains the sludge generated for different industries using eq. 11

Table 4.6: Total sludge generation

S. NO	INDUSTRIES	Total Sludge Generation (kg/d)
1.	Stp for Amrapali Mall at Mezaffarpur	298
2.	Spanish Hill View, Guwahati	298
3.	Dr Lal PathLabs Private Limited	213
4.	IOCL Panipat	60
5.	INDUSTRIAL MODEL TOWNSHIP,MANESAR	638
6.	STP at ESIC Hospital Rohini	213
7.	200 bedded ESI hospital, manesar	43
8.	Hotel Comrade Inn.	213
9.	STP for DMRC project at Dwarka.	213

The sludge generated is maximum for the 5^{th} industry while it is minimum for the 7^{th} industry. All other industries have intermediate values. The sludge generated in MBR can be disposed directly after dewatering as while in ASP it needs treatment using methods like stabilisation, thickening, drying and incineration.

The table shown below contains values for volume aeration tank required for MBR, MBBR and ASP using eq. 12, 14 and 15 resp

Table 4.7: Volume required for MBR, MBBR and ASP

S. NO	INDUSTRIES	Volume of MBR (m^3)	Volume of ASP (m^3)	Volume of MBBR (m^3)
1.	Stp for Amrapali Mall at Mezaffarpur	223	594	200
2.	Spanish Hill View, Guwahati	223	594	200
3.	Dr Lal PathLabs Private Limited	159	424	143
4.	IOCL Panipat	172	458	154
5.	INDUSTRIAL MODEL TOWNSHIP,MANESAR	458	1222	429
6.	STP at ESIC Hospital Rohini	159	424	143
7.	200 bedded ESI hospital, manesar	32	85	29
8.	Hotel Comrade Inn.	159	424	143
9.	STP for DMRC project at Dwarka.	159	424	143

The volume required for aeration tank is maximum for ASP as its HRT is maximum while it is minimum for MBBR. MBR has intermediate volume between ASP and MBBR. Hence, the construction cost and land required is maximum for ASP while they are minimum for MBBR. For industry no.5 ASP is not recommended as it involves huge land area and cost.

Table 4.8: Standard cost of different parts

Different parts installed	Cost per Quantity	Quantity per Industry
MBR Modules	600000	2
Feed Pumps of MBR	30000	2
Dosing System of MBR	36000	1
RAS Pumps of MBR	54000	2
Backwash Pumps of MBR	35000	2
Cost of construction of tanks	8000	Per m^3
MBBR Media	12000	Per m^3
RAS Pumps of MBBR	18000	2
RAS pumps of ASP	18000	2

Source: MBR Brochure- Seamaks, GE power and water, Kubota

The table 4.9 shows total cost of MBR, MBBR and ASP for different industries

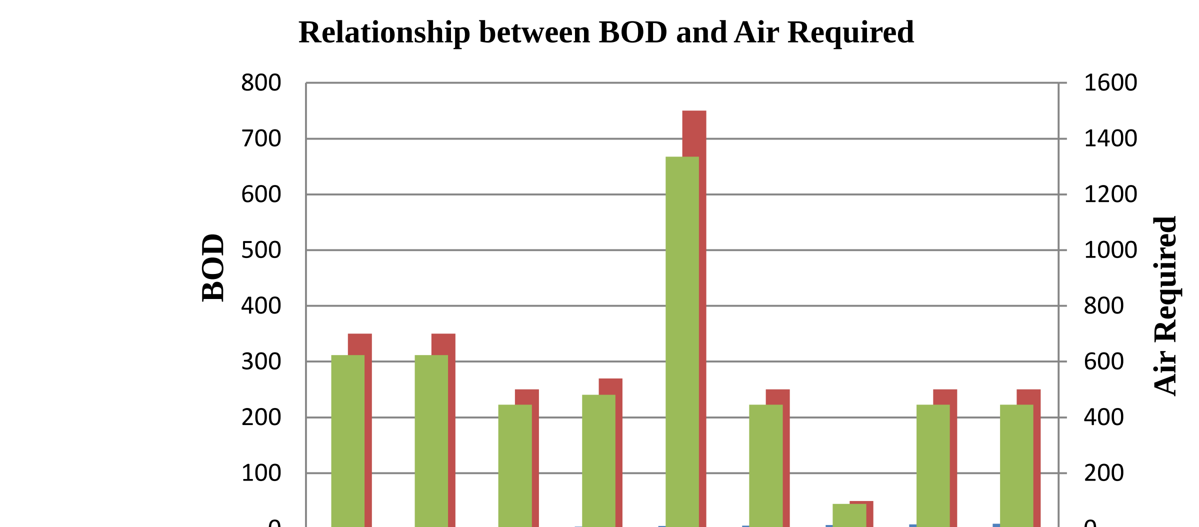
Table 4.9: Total Cost of MBR, MBBR and ASP

S.No.	Industries	Total cost of MBR (Rs)	Total cost of MBBR (Rs)	Total cost of ASP (Rs)
1.	Stp for Amrapali Mall at Mezaffarpur	7,155,500	3,316,000	4,786,667
2.	Spanish Hill View, Guwahati	7,083,500	3,316,000	4,786,667
3.	Dr Lal PathLabs Private Limited	6,574,500	2,378,857	3,429,333
4.	IOCL Panipat	6,676,300	2,566,286	3,700,800,
5.	INDUSTRIAL MODEL TOWNSHIP,MANESAR	8,968,667	7,064,571	9,813,778
6.	STP at ESIC Hospital Rohini	6,574,500	2,378,857	3,429,333
7.	200 bedded ESI hospital, manesar	5,556,500	504,571	714,667
8.	Hotel Comrade Inn.	6,574,500	2,378,857	3,429,333
9.	STP for DMRC project at Dwarka.	6,574,500	2,378,857	3,429,333

The cost involved is maximum for MBR as it involves electricity cost and MBR modules while ASP involves construction cost as it requires more volume for aeration tank but for industry no.5 the total cost for ASP is maximum as compared to MBR and MBBR as the volume required is very large which causes increase in construction cost. Hence, for 5th industry ASP is not recommended while MBR is recommended. In industry no.7 the volume required is minimum hence, cost involved for ASP is minimum as compared to MBR and MBBR. Hence, for 7th industry ASP is recommended

4.2 Variation of different parameters for Different Industries

4.2.1 Variation of BOD with Air required

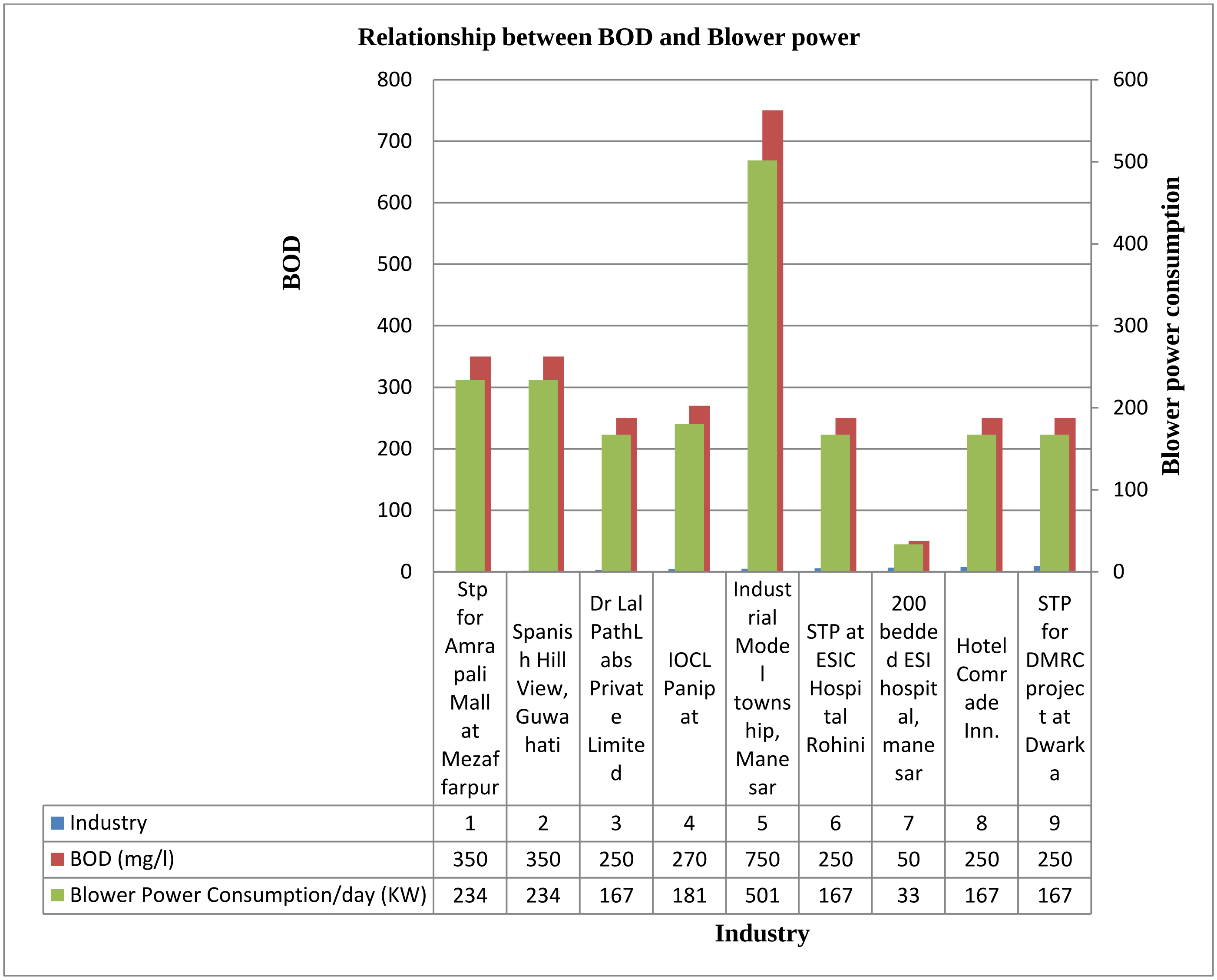


	Stp for Amrapali Mall at Mezaffarpur	Spanish Hill View, Guwahati	Dr Lal PathLabs Private Limited	IOCL Panipat	Industrial Model township, Manesar	STP at ESIC Hospital Rohini	200 bedded ESI hospital, manesar	Hotel Comrade Inn.	STP for DMRC project at Dwarka
Industry	1	2	3	4	5	6	7	8	9
BOD (mg/l)	350	350	250	270	750	250	50	250	250
Air Required (m3/hr)	623	623	445	481	1335	445	89	445	445

Industry

Fig 4.1: Relationship between BOD and Air Required

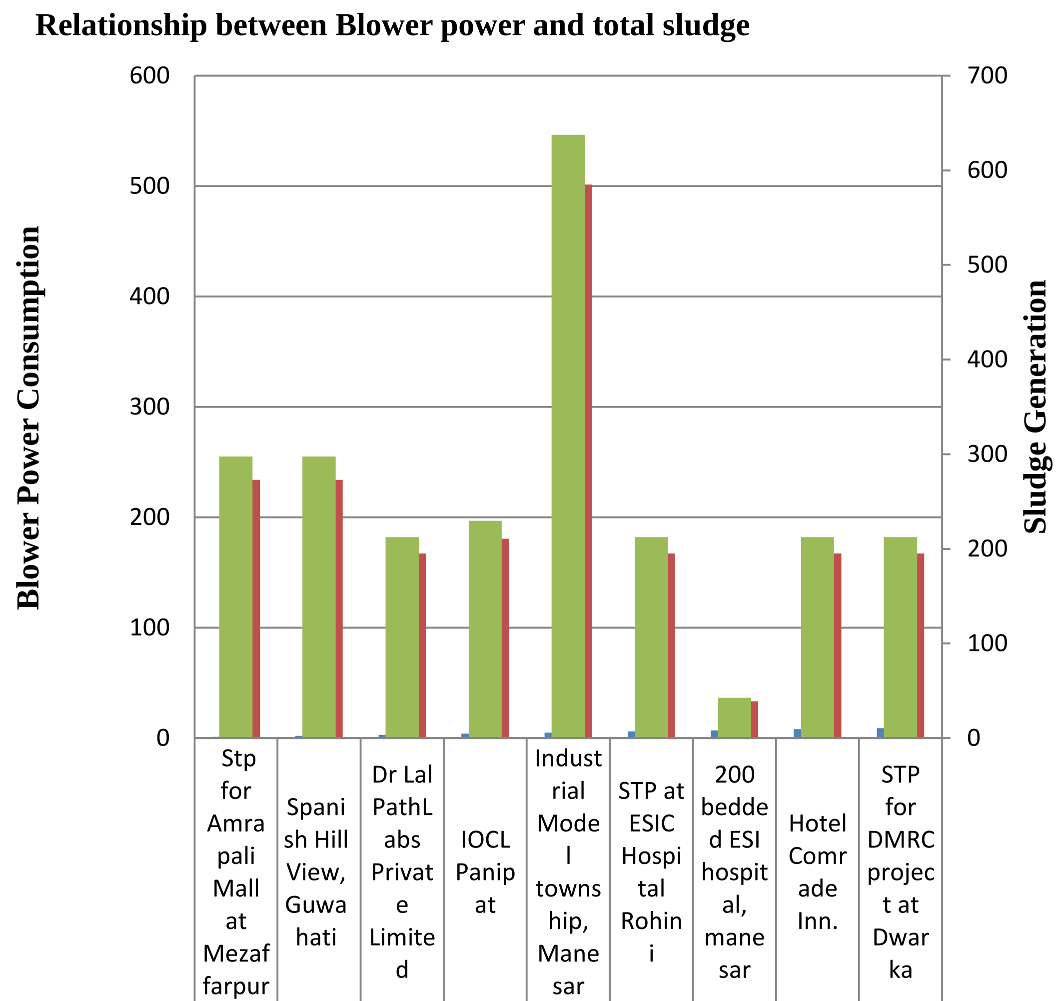
4.2.2 Variation of BOD with Blower power consumption



	Stp for Amrapali Mall at Mezaffarpur	Spanish Hill View, Guwahati	Dr Lal PathLabs Private Limited	IOCL Panipat	Industrial Model township, Manesar	STP at ESIC Hospital Rohini	200 bedded ESI hospital, manesar	Hotel Comrade Inn.	STP for DMRC project at Dwarka
Industry	1	2	3	4	5	6	7	8	9
BOD (mg/l)	350	350	250	270	750	250	50	250	250
Blower Power Consumption/day (KW)	234	234	167	181	501	167	33	167	167

Fig 4.2: Relationship between BOD and Blower power

4.2.3 Variation of Blower Power Consumption with Total Sludge Generation



Industry	Stp for Amrapali Mall at Mezaffarpur	Spanish Hill View, Guwahati	Dr Lal PathLabs Private Limited	IOCL Panipat	Industrial Model township, Manesar	STP at ESIC Hospital Rohini	200 bedded ESI hospital, manesar	Hotel Comrade Inn.	STP for DMRC project at Dwarka
Industry	1	2	3	4	5	6	7	8	9
Blower Power Consumption/day (KW)	234	234	167	181	501	167	33	167	167
Sludge Generation (kg/d)	298	298	213	230	638	213	43	213	213

Fig 4.3: Relationship between Blower power and total sludge generated

4.3 Comparison of MBR with MBBR and ASP for different industries

4.3.1 Comparison of HRT

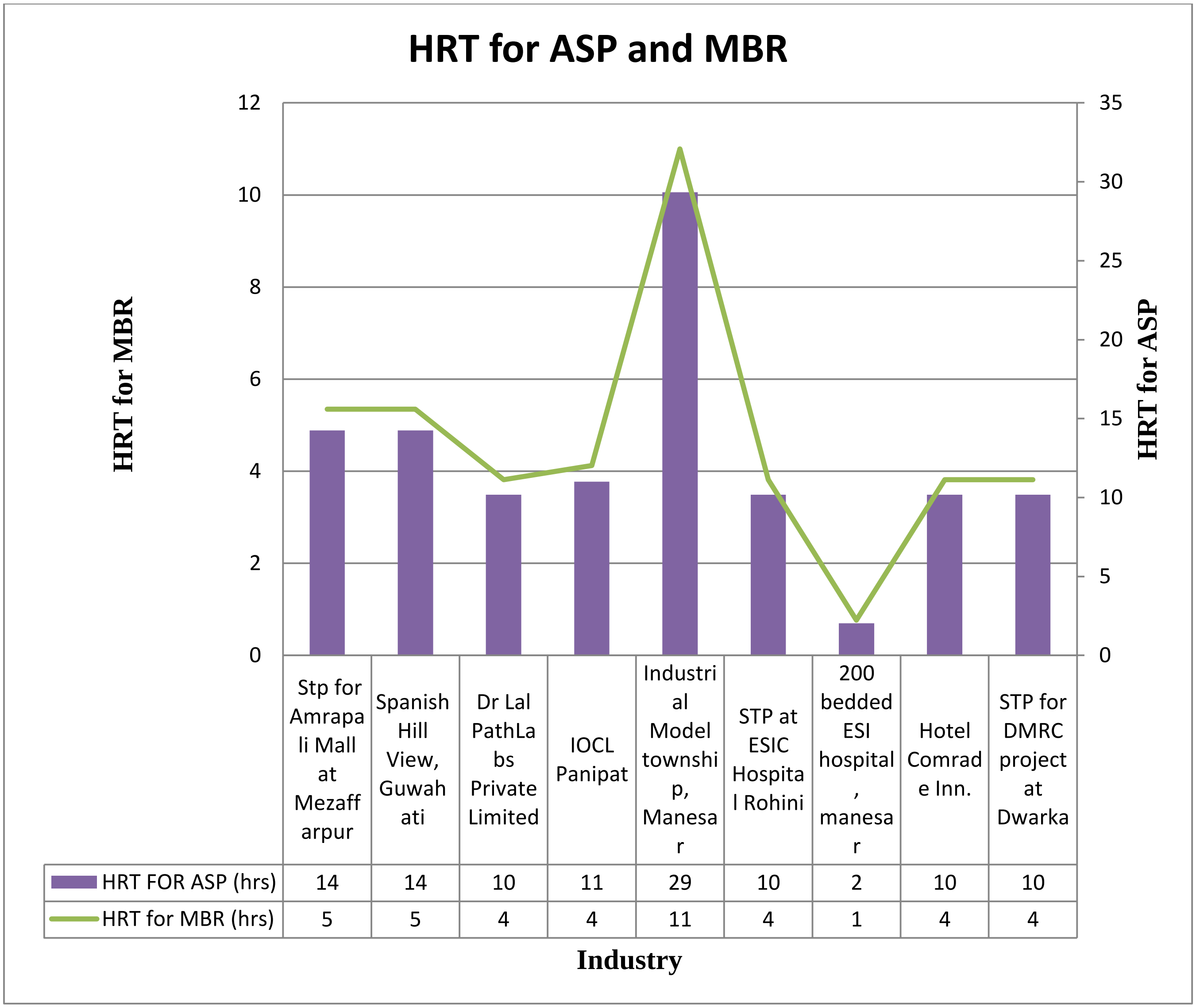


Fig 4.4: HRT for ASP and MBR

4.3.2 Comparison of F/M Ratio

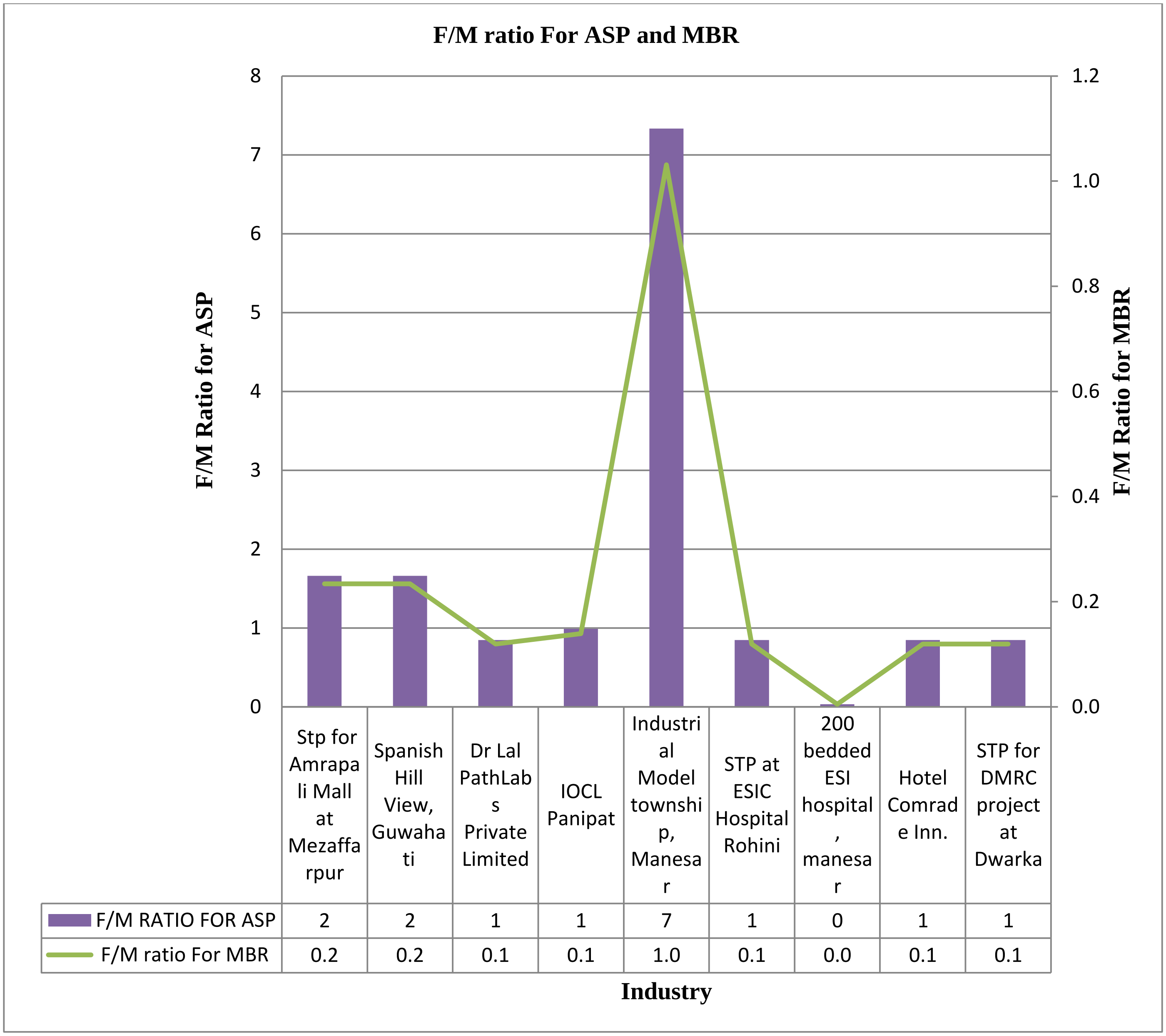
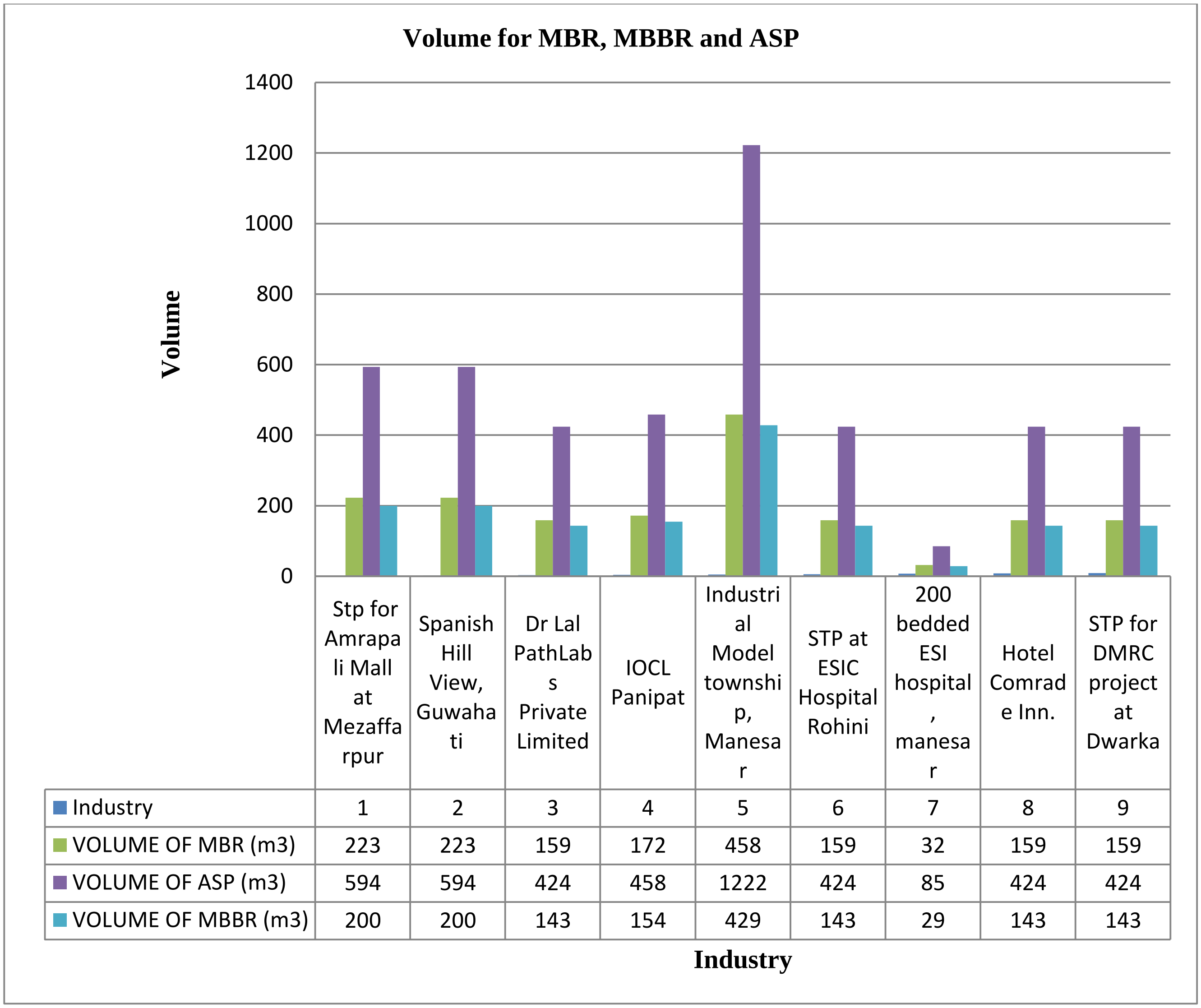


Fig 4.5: F/M ratio For ASP and MBR

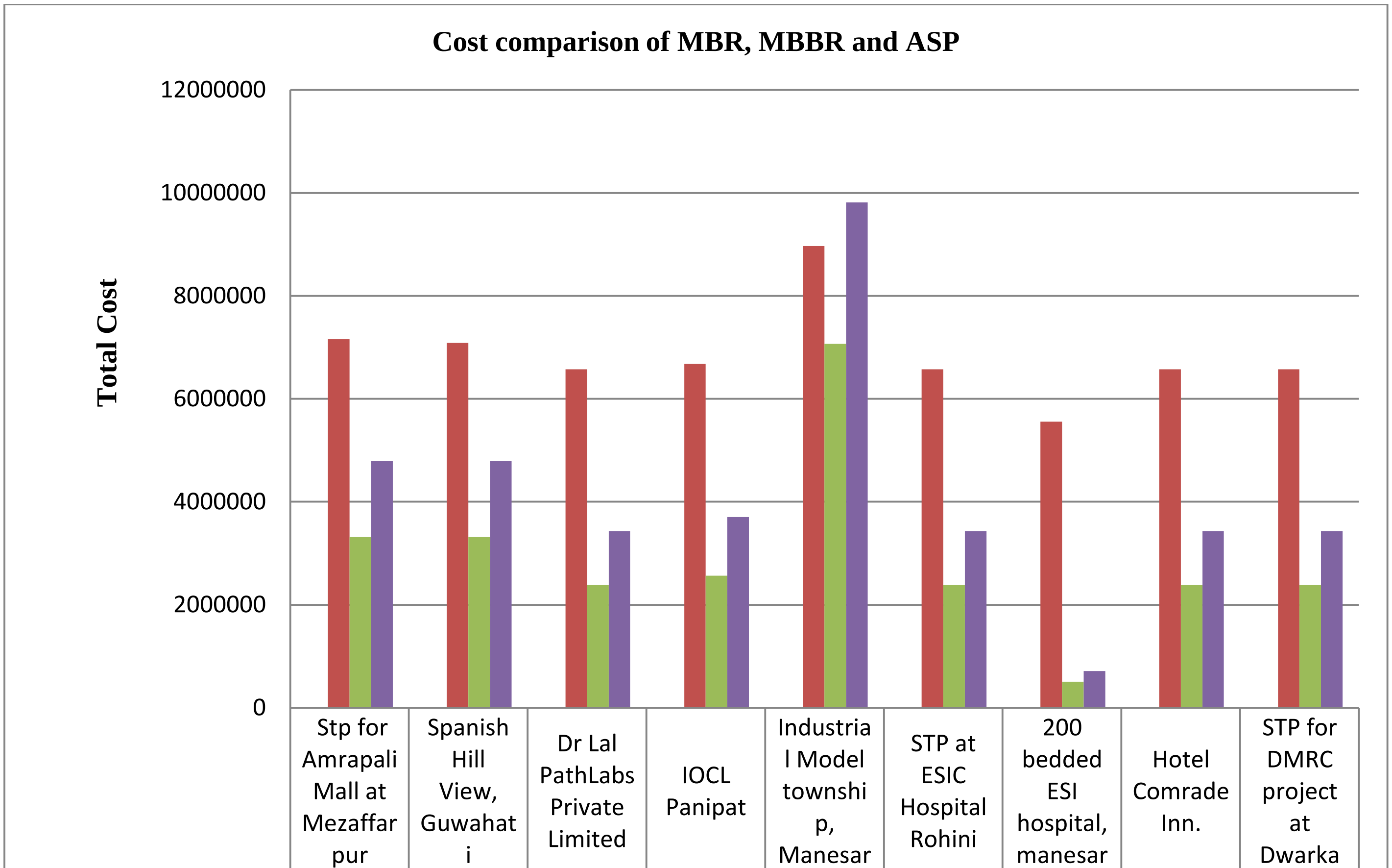
4.3.3 Comparison of volume of MBR, ASP and MBBR



	Stp for Amrapali Mall at Mezaffarpur	Spanish Hill View, Guwahati	Dr Lal PathLabs Private Limited	IOCL Panipat	Industrial Model township, Manesar	STP at ESIC Hospital Rohini	200 bedded ESI hospital, manesar	Hotel Comrade Inn.	STP for DMRC project at Dwarka
Industry	1	2	3	4	5	6	7	8	9
VOLUME OF MBR (m3)	223	223	159	172	458	159	32	159	159
VOLUME OF ASP (m3)	594	594	424	458	1222	424	85	424	424
VOLUME OF MBBR (m3)	200	200	143	154	429	143	29	143	143

Fig 4.6: Volume required for MBR, ASP and MBBR

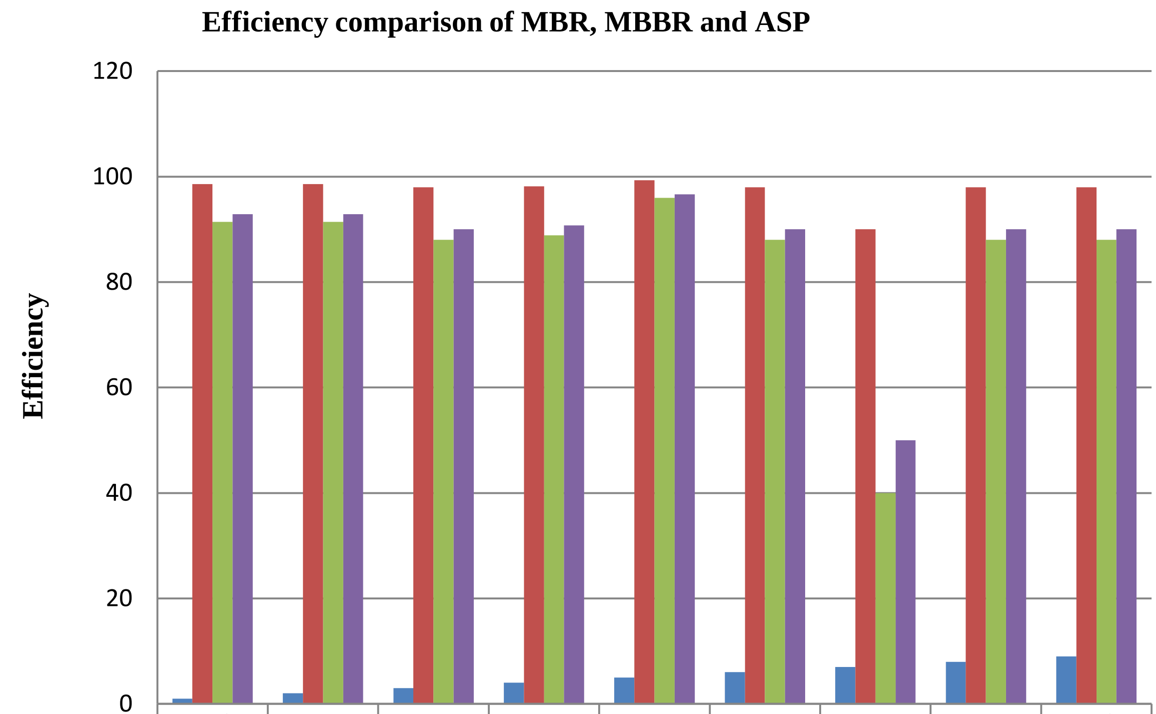
4.3.4 Cost comparison of MBR, MBBR and ASP



	Stp for Amrapali Mall at Mezaffar pur	Spanish Hill View, Guwahat i	Dr Lal PathLabs Private Limited	IOCL Panipat	Industria l Model townshi p, Manesar	STP at ESIC Hospital Rohini	200 bedded ESI hospital, manesar	Hotel Comrade Inn.	STP for DMRC project at Dwarka
Industry	1	2	3	4	5	6	7	8	9
Total Cost MBR	7,155,50	7,083,50	6,574,50	6,676,30	8,968,66	6,574,50	5,556,50	6,574,50	6,574,50
Total Cost of MBBR	3,316,00	3,316,00	2,378,85	2,566,28	7,064,57	2,378,85	504,571	2,378,85	2,378,85
Total Cost of ASP	4,786,66	4,786,66	3,429,33	3,700,80	9,813,77	3,429,33	714,667	3,429,33	3,429,33

Fig 4.7: Cost comparison of MBR, MBBR and ASP

4.3.5 Efficiency comparison of MBR, MBBR and ASP



	Stp for Amrapali Mall at Mezaffarpur	Spanish Hill View, Guwahati	Dr Lal PathLabs Private Limited	IOCL Panipat	Industrial Model township, Manesar	STP at ESIC Hospital Rohini	200 bedded ESI hospital, manesar	Hotel Comrade Inn.	STP for DMRC project at Dwarka
Industry	1	2	3	4	5	6	7	8	9
Efficiency of MBR (%)	99	99	98	98	99	98	90	98	98
Efficiency of ASP (%)	91	91	88	89	96	88	40	88	88
Efficiency of MBBR (%)	93	93	90	91	97	90	50	90	90

Industry

Fig 4.8: Efficiency comparison of MBR, MBBR and ASP

CHAPTER-5

CONCLUSION

5. Conclusion

MBBR is the most cost effective technology. It needs less space and is easy to operate. But the efficiency of pollutant removal is low than MBR. The sludge generated is also less stable and needs further treatment. While ASP has high civil cost and land requirement, it is difficult to execute it in malls or hotels.

MBR becomes the pioneer in these technologies when it comes to re-use of water treated. Otherwise if treated water is to be disposed in drains then there is no point of installing an MBR.

The cost involved in MBR is shooting high. We do believe consideration in future of a hybrid system incorporating advantages of all the three technologies would not only decrease operational and maintenance cost of the system, but it will make the system compact, user friendly and give very high quality treatment.

The main conclusions points are –

1. Air required is directly proportional to the BOD load.
2. The number of diffusers is proportional to the air required, so more the BOD load more is the cost of diffusers.
3. Similarly power consumption of the blowers is also directly proportional to the BOD load.
4. Whereas the number of MBR modules is directly proportional to the flow which in our case study is constant for all cases. Hence MBR number of modules is constant.
5. By looking at the F/M ratios we can see that the recommended values of HRT for ASP doesn't provide the optimum F/M ratio for all industries. While MBR can still achieve optimum F/M ratio for most cases with low HRT.
6. Sludge generation is also directly proportional to the BOD load.
7. Volume required for MBR is lowest followed by MBR and then ASP.
8. The cheapest technology is MBBR whereas the costliest is MBR. We can also see that for high BOD MBR is cheaper than ASP as high civil costs are involved with the latter.
9. The efficiency of pollutant removal for MBR is highest while for MBBR it is the lowest.

CHAPTER-6

REFERENCE

6. References

1. Metcalf & Eddy, Inc. 2003. *Wastewater Engineering*: Treatment and Reuse. Fourth Edition. McGraw-Hill, New York.

2. Punmia, B.C., & Jain, A., 2005. Environmental Engineering-2. *Wastewater Engineering*. New Delhi. ISBN: 81-7008-091-6. pp.655.

3. Qasim, R.S., 1999. *Wastewater Treatment Plants*: Planning, Design and Operation. Second Edtion. CRC Press LLC. pp. 778.

4. EPA, 1997. Environmental Protection Agency. *Wastewater Treatment Manuals*: Primary, Secondary and Tertiary Treatment. EPA, Ireland, pp . 131.

5. Manual on Sewerage and Sewage Treatment (CPHEEO-1993)

6. Coté, P., M. Masini, D, Mourato (2004) Comparison of membrane options for water reuse and reclamation. Desal. 167, 1-11

7. Fane, A. & S. Chang (2002) Membrane bioreactor: Design and operational options. Filt.Sep. June 26-29

8. Frederickson, K. (2002). The current state of wastewater treatment systems on Manitoba First Nations Communities. Biosystems Engineering Undergraduate Thesis, University of Manitoba.

9. LEE, E., KIM, K., LEE, Y., NAM, J., LEE, Y., KIM, H. and JANG, A., 2012. A study on the high-flux MBR system using PTFE flat sheet membranes with chemical backwashing. *Desalination,* **306**(0), pp. 35-40.

10. MBR in Industrial Wastewater Treatment– EU Experience, Examples and Trends, Water Science & Technology, 53(3), 37-44, 2006, P.Cornel, S Krause.

11. Adams, C.E., Wesley, W., Eckenfelder, W.W. and Goodman B.L. (1975). Effects of removal of heavy metals in biological treatment. In *Heavy Metals in the Aquatic Environment*, P.A. Krenkel (Ed.), Pergamon Press, Oxford.Andreadakis, A.D., (1993). Physical and chemical properties of activated sludge flocs. *Wat. Res.*, **27**,12, 1707-1714.

12. ATV (Abwassertechnische Vereinigung) (1973). Arbeitsbericht des ATVFachausschusses 2.5 Absetzverfarhen. Die Bemessung der Nachklärbecken von Belebungsanlangen. *Korrespondenz Abwasser*, **20**, 193-198.
13. ATV Task Group on Bulking (ATV - Arbeitsgruppe 2.6.1) (1988). Blähschlammbildung und -ßekämpfung. Barahona, L. and Eckenfelder, W.W. (1984). Relationships between organic loading and zone settling velocity in the activated sludge process. *Wat. Res*.,**18**, 91-94.
14. Barber, J.B. and Veenstra, J. N. (1986). Evaluation of biological sludge properties influencing volume reduction. *J. WPCF*, **58**, 2, 149-156. Bhargava, D.S. and Rajagopal, K. (1993). Differentiation between transition zone and compression in zone settling. *Wat. Res*., **27**, 3, 457-463.
15. Blackall, L. L., Harbers, A.S., Greenfield, P.F. and Hayward, A.C. (1989). Actinomycete scum problems in Australian activated sludge plants. *Wat. Sci.Technol*., **20**, 493-495.
16. Gudmundsdottir, S. (1993). "Struvite formation in anaerobically digested sludge at the Renton wastewater treatment plant," MS thesis, University of Washington.
17. Kroiss H. and Wabnegg F. P. 1983 Sulfide toxicity with anaerobic wastewater treatment. Proc. Eur. Symp. On Anaerobic Treatment, pp. 72 – 85. The Hague, the Netherlands.
18. Edwards, M., B. Courtney, B., P. S. Heppler, M. Hernandez. 1997. Beneficial discharge of iron coagulation sludge to sewers., Journal of Environmental Engineering, pp 1027- 1032.
19. Reiber, S., R. A. Ryder, and I. Wagner.1996. Corrosion assessment technoloies. Internal corrosion of water distribution systems, 2nd ed., 445-486. Denver, CO: AWWA Research foundation/TZW.
20. Valcke, D., and W. Verstraete. 1983. A practical method to estimate the acetoclastic methanogenic biomass in anaerobic sludge. Journal of Water Pollution Control Fed. 55:1191-1195.