DECENTRALIZED WASTEWATER TREATMENT FOR AN EDUCATIONAL INSTITUTIONS

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MASTER OF TECHNOLOGY

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Dedicated to my mentor…

DELHI TECHNOLOGICAL UNIVERSITY

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Certificate

This is to certify that the thesis entitled, **"DECENTARLIZED WASTEWATER TREATMENT FOR AN EDUCATIONAL INSTITUTIONS"** submitted by Ms Aparna Katiyar in partial requirements for the award of Master of Technology in Environmental Engineering in the Department of Environmental Engineering at the Delhi Technological University, Delhi is an authentic work carried out by her under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

PLACE :

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Place: APARNA KATIYAR

Date

ABSTRACT

Millions of gallons of domestic and industrial wastewater are discharged every day from various sources including sink, kitchens, and toilets. This wastewater is highly contaminated with pathogens that are detrimental to human health and therefore its proper management and treatment is necessary for human health safety point of view.

Traditionally wastewater in many areas has been managed by large Centralized treatment facilities in urban areas and septic tank in rural areas. Today there is an array of innovative and advanced Decentralized wastewater treatment system that collect and treat domestic and institutional wastewater onsite.

These systems sometimes offer benefits over conventional treatment because they reduce the need for energy and large infrastructure, providing recycled water for onsite usage and can expand to meet increasing demand.

Decentralized wastewater treatment is an approach used for the treatment of wastewater just after its discharge on the existing site and thus it is also referred to as onsite treatment unit. The aim of the decentralized treatment unit is to strictly treat the wastewater before it is discharged into the environment to reduce the burden on public sewers and treatment units.

Effluent coming from industrial and commercial facilities with no access to sustainable wastewater treatment systems may contribute to pollution or deterioration in quality of the receiving bodies of water. Commercial facilities, particularly public markets, discharge high strength wastewater which causes these water bodies to be in the state of eutrophication. In order to reduce its strength, building a suitable and effective wastewater treatment facility is done. These treatment systems constitute a lot to pollution reduction as well as mitigation measures for effluents coming from the market. A treated wastewater can be discharged directly into a water body without causing harm to aquatic life and in the quality of water. It may also be for human recreation, e.g., bathing, cleaning, and drinking depending on how advanced a treatment is. Designing a treatment facility that could convert a wastewater back to its usable form will be of compliance to building an innovative approach and to the promotion of sustainable development. One of the advance

processes in treating wastewater that has the ability to convert wastewater to its usable form is called Membrane Bioreactor (MBR) Facility.

The main purpose of this study is to design an MBR facility for an educational institute of Delhi Technological University in order to control and reduce the pollution burden on existing river. It also aims to discharge an effluent complying with the national standards for wastewater. Engineering design considered in this study are: Wastewater Engineering, Environmental Pollution, specifications of membrane bioreactor and its design. The study also highlights the usefulness of membrane bioreactor and the superior quality of the MBR effluent over the conventionally treated effluents.

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LIST OF ABBREVIATIONS

Abbreviation	Title
COD	Chemical Oxygen Demand
HRT	Hydraulic Retention Time
BOD	Biological Oxygen Demand
MBR	Membrane Bioreactor
TSS	Total Suspended Solids
VSS	Volatile Suspended Solids
F/M	Food to Microorganism ratio
DEWAT	Decentralized Wastewater Treatment
OD	Oxidation Pond
WWTP	Wastewater Treatment Plant
CWA	Clean Water Act
LCA	Life Cycle Assessment
OWTS	Onsite Water Treatment System
RF	Recirculating Factor
TDS	Total Dissolved Solids
MPN	Most Probable Number
DO	Dissolved Oxygen
UASBR	Up flow Anaerobic Sludge Blanket
CPHEOO	Central Public Health & Environmental Engineering Organization
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
ZLD	Zero Liquid Discharge
STP	Secondary Treatment Plant
SVP	Sludge Volume Index
FGD	Flue Gas Desulphurization

LIST OF SYMBOLS

Symbol	Description
BOD_5	5 day 20°C BOD
BOD_u	Ultimate BOD
Q_{avg}	Average rate of flow of wastewater
S_o	Amount of BOD entering STP
S_e	Effluent BOD
θ_c	Sludge Age
V	Volume
S	Influent Soluble BOD
P_x	Increase in mass of MLVSS
P_y	Increase in mass of MLSS
Q_{sw}	Sludge wasting flow rate
Cfs	Cubic feet per second

CHAPTER -1

INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Within the years, Delhi the Capital city of India has witnessed many challenges related to environmental pollution, the major one being the water pollution and the air pollution. The main cause associated with the increase in pollution level of the water bodies is the insufficient and improper management and treatment of institutional as well as industrial and domestic waste.

Delhi being a metropolitan city is situated on the bank of Yamuna river and is considered as the major contributor towards its pollution followed by Agra and Mathura. The main source of pollution of Yamuna in National Capital Territory is due to the following reasons.

- Increase in the population density along the bank of river and poor sanitation practices by residing population thereby.
- Discharge of highly polluted domestic waste water
- Untreated industrial effluents
- Religious practices and throwing of idols into the river
- Cattle washing, throwing of dead bodies and agricultural washouts.
- Untreated and undetected pesticides residues leaves a toxic mark all across the river.

The bodies of water, like rivers and lakes, are turning out to be polluted day by day. The nearby establishments and settlements may be contributing to the pollution of the waters. One of the main contributors of pollution are the domestic wastes containing high levels of organic material, suspended solids, fats, oils, and grease. These water contaminants are causes of wastewater of chemicals from laboratories, human waste from houses, kitchen wastes, fruit, and vegetable wastes. Proper treatment plants for these wastewaters must be available in order to meet the effluent standards and not to pollute the bodies of water.

Figure 1.1. Yamuna River at Delhi

STATUS OF SEWAGE TREATMENT PLANTS IN DELHI

It is estimated that out of 3267 MLD of sewage generated in Delhi, the treatment capacity is existing for 2330 MLD of sewage (71% of total sewage generation). However, actual treatment is received to only about 1478 MLD (63%) of sewage in terms of BOD load. Out of 480 tonnes/day of BOD load generated in Delhi, 264 tonnes/day (or 55%) is reduced due to treatment. There are 30 STPs located at 17 locations in Delhi. The total combined treatment capacity of all the STPs is 2,330 MLD. The actual treatment of sewage during November December 2003 was observed only 1478 MLD, about 63% of the installed treatment capacity. Out of total STPs, 20 STPs were running under capacity, 5 STPs were running over capacity, 3 STPs were non-functional while only 2 STPs are running to their capacity. The performance of the STPs is evaluated in terms of percent reduction in pollution load. Average reduction in BOD, COD and TSS load computed based on the study was 87%, 81% and 92% respectively.

Table 1.1. Status of Sewage Treatment Plants in Delhi during Nov – Dec, 2004

S. No	STP's Capacity (MGD)	Design Capacity (MLD)	Actual Flow (MLD)	Type of STP	Present Status
1	Coronation Pillar STP'S (10) (10+20)	45.46 45.46 90.92	40.87 63.46 56.55	Activated Sludge Process(ASP), Trickling Filter & ASP	Over the designed Capacity Under Utilized
2	Delhi Gate	10.00	10.00	High rate biofilters	Running on designed capacity
3	Ghitorni	22.73	Nil	-	Not in operation
4	Keshopur STP's (12) (20) (40)	54.55 90.92 181.84	46.55 95.10 106.46	All the three plants designed on Activated Sludge Process	12 MGD not running properly
5	Kondli STP's (10- Phase I) (25- Phase II) (10 Phase III)	45.46 113.65 45.46	56.55 57.96 28.36	All three Activated Sludge Process	Over the capacity Under- Utilized Under-Utilized
6	Mehrauli STP (5)	22.73	4.95	Activated Sludge Process (ASP)	Under- Utilized
7	Najafgarh STP (5)	22.73	2.27	Activated Sludge Process (ASP)	Under- Utilized
8	Nilothi STP (40)	181.84	15.0	Activated Sludge Process (ASP)	Under- Utilized

9	Narela (10)	45.46	2.50	Activated Sludge Process (ASP)	Under- Utilized
10	Okhla STP's (12) (16) (30) (37) (45)	 54.55 72.73 136.38 168.20 204.57	 39.09 40.91 136.98 159.11 181.84	 All the plants designed on Activated Sludge Process (ASP)	 Under- Utilized Under- Utilized Running in Capacity Under- Utilized Under- Utilized
11	Papankalan STP (20)	90.92	37.73	Activated Sludge Process (ASP)	Under- Utilized
12	Rithala STP's (40) Old (40) New	 181.84 181.84	 46.28 185.07	 ASP UASB	 Under- Utilized Over the designed capacity
13	Rohini STP (15)	68.19	Nil	Activated Sludge Process (ASP)	Not in Operation
14	Dr. Sen N.H. STP (2.2)	10.0	10.0	High Rate Biofilter	Running on Designed Capacity
15	Timarpur O.P. (6)	27.27	4.79	Oxidation Ponds	Under Utilized
16	Yamuna Vihar STP's Ph- I (10) Ph-II (10)	 45.46 45.46	 27.27 14.77	 Activated Sludge Process (ASP)	 Under- Utilized Under- Utilized
17	Vasant Kunj STP's (2.2) (3.0)	 10.00 13.63	 3.18 4.36	 Extended Aeration ASP	 Under- Utilized Under- Utilized
	Total	**2330**	**1478**	----	---

Source CPCB

1.2. OBJECTIVE OF THE STUDY

The study of the project covers the design criteria and construction of a Membrane Bioreactor (MBR) as an advanced and tertiary treatment for treating the domestic and institutional waste of a college in Delhi. The objective of the study includes the following of the specific and general objectives

The general objective of the project is to identify the existing current wastewater disposal and treatment techniques and to design a wastewater treatment facility of an educational institute to discharge an effluent that meets the standard of CPCB (Central Pollution Control Board) data for the regulation and control of pollution and to reduce the burden on existing public sewers.

The specific objectives of the study consists of:

i) To establish the benefits and disadvantages of centralized treatment systems compared to selected onsite technologies. Determine under which circumstances it is advantageous to use centralized over decentralized, and vice versa.
ii) To study an MBR technology for the treatment of wastewater and discharging its effluents overly complying with the effluent standards stated by the Boards.
iii) To design a decentralized wastewater treatment system for Delhi Technological University as a case study.

1.3. SIGNIFICANCE OF THE STUDY

The result of the study will be significant to the following:

i. **To the Beneficiary:** Membrane Bioreactor Technology designed for the treatment of wastewater can help not completely but to a large extent to meet the effluent standards stated by Central Pollution Control Board. The wastewater that is being treated from this technology can also proved to be beneficial to the establishments as a free source of water supply for reuse and consumption for other works

ii. **To the Society:** The level of exposure and risk of people to its harmful effects will be minimized. The society will also benefit from reusing the treated wastewater for domestic water supply.

iii. **To the Department:** The study will benefit the School of Civil, Environmental and Geological Engineering by means of acquiring authority on the publication of the document and in acquiring new knowledge regarding the design of an MBR treatment facility for further studies.

iv. **To the Students:** The result of the study will benefit the Environmental and Sanitary Engineering students by means of having a reference on future designs of a wastewater treatment facility, as well as for the study of the process and innovations

v. **To the Future Researchers:** The design made by the researchers can be a baseline for future researchers in developing and designing a new and advanced way of treating wastewater

1.4. SCOPE AND LIMITATIONS OF THE PROJECT

The work associated with this study will only be limited to the design of the MBR treatment facility, its process and operation, as well. The water supply and sewerage systems will not be covered as part of this study. For the study and design, it will only be used for the beneficiary. Also, it will be dealing with the compliance of the institute to the different standards and sanitation codes stated by the government.

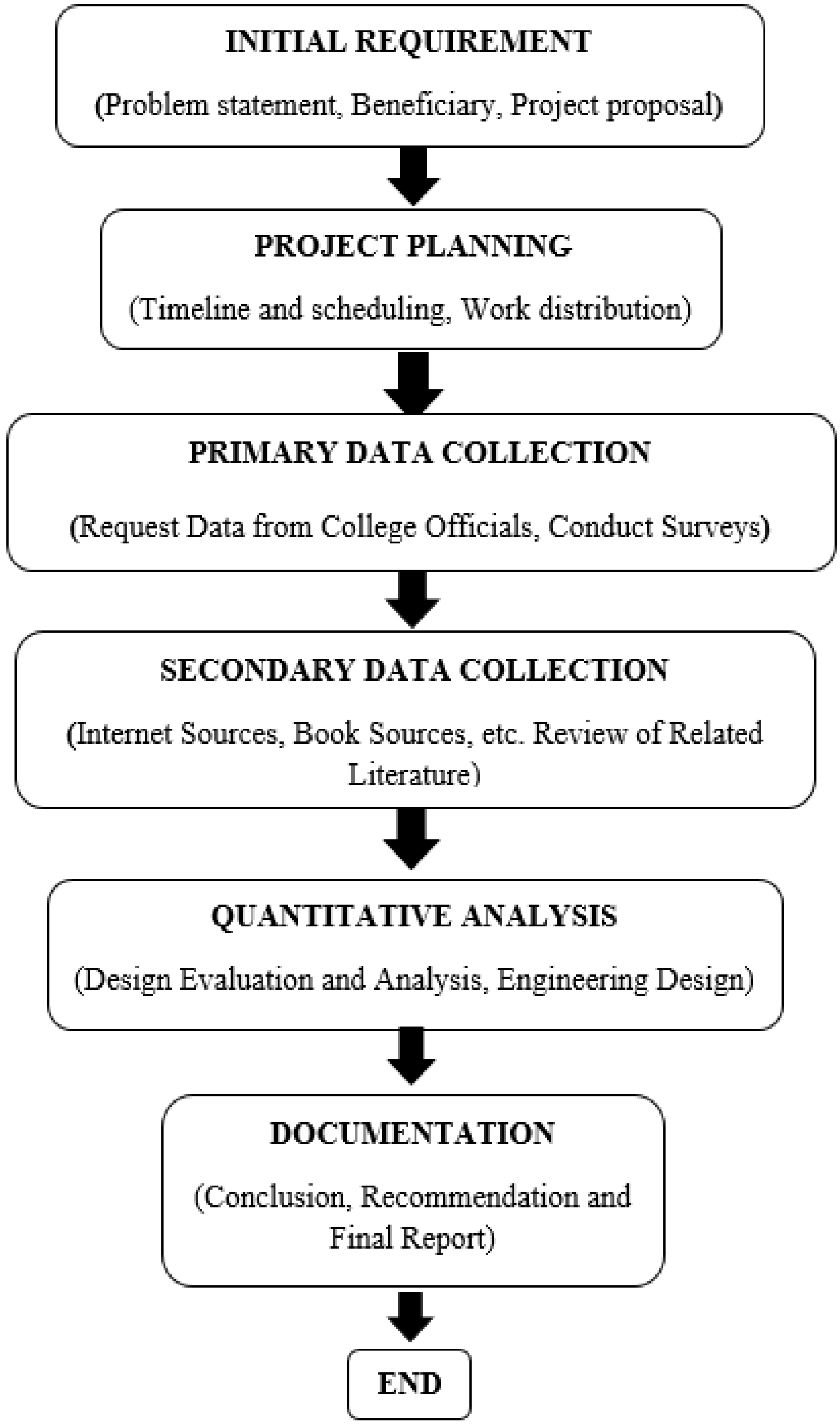

Figure 1.2. Schematic Diagram of Research Methodology

CHAPTER-2

LITERATURE REVIEW

2.1. GENERAL

In this chapter recent work done by the different researchers on this technique is reviewed and highlighted. Decentralized wastewater treatment systems are appropriate for low density communities and varying site conditions and are more cost effective than centralized systems. Applicability of Membrane technology has find a significant use in water treatment for along time. The combination of membrane separation and biological treatment in to one process is called membrane bioreactor. It can be used to remove organic matters, nutrients, pathogens, and potentially micro pollutants in water. Membrane bioreactor is complex and small footprint than conventional treatment technologies. It not only can be operated under aerobic and anaerobic conditions but it is also operated in source with low or high organic loading. Another advantage of membrane bioreactor is the excellent quality of its effluent. Those are reasons why membrane bioreactor is widely used for water and wastewater treatment. At present, membrane bioreactor is considered as auspicious technology that can apply for decentralized treatment system.

2.2. ZERO LIQUID DISCHARGE

2.2.1. CONCEPT OF ZERO LIQUID DISCHARGE

Scarcity of freshwater, is considered one ofthe most serious issues worldwide, that creates a major difficulty in the economic growth, water security, and ecosystem health. The pressure developed due to the economic development and industrialization has led to a severe climatic changes that further complicated the challenge of providing adequate and safe drinking water .Industrialization has led to the development of various large and small scale industries that utilizes huge quantity of fresh water for their manufacturing and in turn discharges enormous amount of untreated wastewater which is much more than the domestic and commercial wastewater. These industries and commercial institutions discharges their wastewater into our natural river streams and land through unauthorized direct discharges that poses a severe impact on aquatic ecosystem and public health. This increase in demand of water for industrial, domestic and commercial purposes and wastewater discharges has led the researchers to move for a better and sustainable approach by recovery and recycling of wastewater that has gained appreciable uniqueness in the past decades in many countries including India. Wastewater reuse not just limits the volume and natural danger of released wastewater, additionally mitigates the weight on biological communities coming about because of freshwater withdrawal. Through reuse, wastewater is never again considered an "unadulterated waste" that conceivably effect the earth, but instead an extra asset that can be tackled to accomplish water supportability.

Figure 2.1 Concept of Zero Liquid Discharge

Zero liquid discharge (ZLD) is a purposeful wastewater treatment technique that eliminates any liquid waste leaving the plant or facility boundary, with the majority of water being recovered for reuse. ZLD deters the danger of contamination related with wastewater release and augments water use efficiency, in this way striking a harmony between misuse of freshwater assets and conservation of sea-going situations. Achieving ZLD, however, is generally characterized by intensive use of energy and high cost. Due to this reason ZLD has not been considered feasible and cost effective for every treatment plant and has been used in limited cases. In recent years, more noteworthy acknowledgment of the double difficulties of water shortage and contamination of aquatic life has gained worldwide enthusiasm for ZLD. More stringent directions, increasing costs for wastewater transfer, and expanding estimation of freshwater are driving ZLD to end up plainly a beneficial or even a vital choice for wastewater administration.

The worldwide market for ZLD is evaluated to achieve a yearly venture of in any event $100−200 million, spreading quickly from created nations in North America and Europe to rising economies, for example, China and India. Early ZLD frameworks depended on remain solitary thermal procedures, where wastewater was regularly vanished in a brine concentrator taken after by a brackish water crystallizer or a dissipation lake. The dense distillate water in ZLD frameworks is gathered for reuse, while the created solids are either sent to a landfill or recouped as important salt byproducts. It's been more than 40 years that these systems are in considerable use but contrary to this their working, operation and maintenance requires much energy consumption and capital cost. To overcome this problem of cost issue and to make them energy efficient, a membrane based process known as Reverse osmosis (RO), widely applied in desalination, has been incorporated into ZLD systems. Even though RO is considered more energy efficient than thermal dissipation, can be connected just to bolster waters with a restricted saltiness go. Appropriately, other salt -concentrating advances that can treat higher saltiness encourage waters, for example, electro dialysis (ED), forward osmosis (FO), and layer refining (MD), have developed as of late as option ZLD innovations to additionally think wastewater past RO. In spite of the fact that ZLD holds incredible guarantee to decrease water contamination and expand water supply, its practicality is dictated by an adjust among the benefits related with ZLD, vitality utilization, and capital/ operation costs. Along these lines, it is basic to comprehend the drivers and benefits that make ZLD a reasonable alternative. Fusing new advances, for example, Membrane based procedures, gives chances to diminish the related vitality utilization and costs and to extend the relevance of ZLD.

ZLD diminishes water utilization, as well as focuses on taking out water release. ZLD prepare purge and reuse plant wastewater, changing fluid waste into expendable dry solids and transferring effluent water again into the plant procedure stream to be reused. In this manner ZLD execution is developing importance as an essential wastewater administration system to lessen water contamination and enlarge water supply. In any case, high cost and escalated energy utilization will remain the fundamental hindrances to ZLD selection. During the process of ZLD treatment the feed water becomes more concentrated thereby increasing the salinity which in turn increases the minimum energy required for their desalination. In this way, the energy consumption of ZLD, alongside its related expenses, will at present be higher than that of traditional wastewater treatment or transfer alternatives. Stricter controls for wastewater transfer are the essential driver for ZLD. All the more exorbitant resistance punishments alongside expanding costs for wastewater disposal can exceed the high costs of ZLD establishment. As water shortage intensifies all around, the ability of ZLD to reclaim wastewater to the biggest degree additionally upgrades its prospects. Increase in the society awareness towards environmental problems constitutes an extra driver, as ZLD maintains a strategic distance from negative natural effects of wastewater release and thereby reducing the problem of public concern. Practically speaking, the motivating forces behind ZLD execution change contingent upon its application and topographical area. Subsequently, the1drivers and benefits of ZLD are talked about in this segment with regards to its worldwide applications.

2.2.2. HISTORY OF ZLD

ZLD has been connected in spots, for example, the European Union, Australia, Canada, the Middle East, and Mexico cases from the United States, China, and India are highlighted, as they speak to the major ZLD markets with the biggest served population and monetary power.

In United States the introduction of ZLD goes back to the1970s when the expanded saltiness of the Colorado River prompted an administrative order of1ZLD for adjacent power plants. Back then, getting endorsement for release understandings for new modern tasks required quite a long while, though reception of ZLD reduced this period to just a couple of months. Today, control plants remain the significant space of ZLD execution in the U.S.where nourish waters, for example, flue gas desulfurization (FGD) wastewater and cooling tower blowdown, are dealt with and reused. For instance, ZLD has been embraced at the Dallman Power Plant in Illinois to stay away from the ecological effects of boron from the FGD wastewater. Among the 82 ZLD plants recorded in a review by Mickley in 2008, more than 60 plants were related with the power business; the rest were disseminated crosswise over regions, for example, gadgets, compost, mining, and compound enterprises. The U.S. EPA as of till date finished its rules over reassessing the current directions on squander water release from warm power plants. This new administer, which sets the first government boundaries on the level of lethal metals and other destructive discharges in wastewater released from control plants, considers zero release as the favored choice for toxins in fly ash debris transport water, bottom ash transport water, and wastewater from flue gas mercury control frameworks. Consistence with these more tightly wastewater release principles gives new administrative motivations to ZLD establishment in U.S. control plants. ZLD can likewise be utilized for salt water administration in inland desalination plants. Contrasted with ocean water desalination, brackish water desalination requires a great deal less vitality and is especially appropriate for semiarid inland areas where seawater is difficult to reach. In any case, the administration of concentrated brine waters speaks to one of the greatest difficulties for inland desalination. Conventional salt water administration works on, including direct release into surface water or publicly owned treatment works (POTW) and in addition deep well infusion can be avoided, because of possibly disastrous effects on surface water and groundwater, insufficient POTW limit, land and legitimate limitations, and expanding disposal costs. As a result, inland desalination is still not installed at many locations where water is critically needed, such as Las Vegas, Phoenix, and Denver. ZLD solved the issues related to saline solution release, subsequently empowering inland desalination in places where there is a scarcity of water. Up until this point, various administrative offices and associations, including the U.S. Department of Reclamation and California Energy Commission, have researched ZLD application to inland desalination under speculative situations in Arizona, California, Colorado, Nevada, and Texas. These developing researches, in any case, have not brought about full-scale ZLD inland desalination plants in the U.S., with cost and vitality utilization giving the principle boundaries to execution. In Chine fast financial improvement and urbanization have prompted rising water utilization and widespread contamination in China. Because of this awesome test, China as of late declared another Action Plan to handle water contamination, planning to a great extent enhance the nature of nearby water assets and biological communities by 2020. This arrangement, authorized by the local government, stresses thorough control of poison release and advances water reusing and reuse, in this manner giving administrative help to ZLD establishment.

The current blast of the coal-to-chemicals industry in China creates another promising specialty for ZLD application. The coal-to-chemicals industry, using coal instead of oil or flammable gas to deliver crude materials for synthetic creation, is right now under pressure to diminish reliance on imported vitality. Coal-to-chemicals plants devour a lot of freshwater yet are located in water scarce areas, for example, Inner Mongolia where plentiful coal holds and naturally delicate field exist together.

As an outcome, ZLD is obligatory at coal-to-chemicals plants in those territories to save both neighborhood water assets and biological systems. A few ZLD offices are as of now introduced or in the phase of outline/development at Chinese coal-to-chemicals plants, with an extensive variety of bolster water salinities (2,000−16,000 mg/L of aggregate broke down salts,TDS) and treatment limit (110−2300 m^3/hour).

India confronting a circumstance like that in China, is taking forceful activities to check extreme water contamination, even in the sacred stream Ganga. The current three-year target set by the Indian government, known as the "Clean Ganga" extend, forces stricter controls on wastewater release and moves high-contaminating businesses toward ZLD. In 2015, the government provided a draft strategy that requires every single material plant creating more than 25 m^3 of wastewater effluent every day to introduce ZLD system. As revealed plants in the city of Tirupur had officially executed ZLD by 2008, which reclaimed water as well as profitable salts from material wastewater for coordinate reuse in the coloring procedure. As indicated by a current specialized report, the ZLD showcase in India was esteemed at $39 million of every 2012 and is required to develop ceaselessly at a rate of 7% from 2012 to 2017. In this market, the material, blending and refining, power, and petrochemical enterprises are the significant application zones.

2.3. DECENTRALIZED WASTEWATER TREATMENT SYSTEM

- **C.Wen et.al. (1999)** They installed a laboratory scale setup which involved anaerobic bioreactor coupled with a membrane filtration device used for the treatment of domestic wastewater at ambient temperature. From their study they concluded that this setup of treatment including the combination of anaerobic bioreactor with membrane filtration was highly capable of removing COD to an effluent concentration of less than 20mg/l and T- COD removal was about 97%. In addition to that the effluent was also free of suspended solids. They also concluded from their experimental test that this combination of treatment has a great ability to stand up for high tolerance for violent organic loading changes from 0.5 up to 12.5 kg/m^3/day and high temperature variations from 12^{0}C to 27^{0}C. Concentration of sludge in the anaerobic reactor was kept at high range between 16 and 21.5 g/l due to the fact of effective retention of biomass within membrane bioreactor. Their analysis also focused that about half of the incoming COD was converted to methane gas. Membrane permeability was largely affected by intermittent suction and membrane flux. A stable operation could be maintained over 2 weeks without any cleaning at operation of 4 min pumping and 1 min non-pumping, and a membrane flux of 5 l m^{-2} h^{-2}.

- **Stave (2003)** constructed a simple Las Vegas water supply system representation to increase public understanding of the value of water conservation. **Passell et al. (2002)** modeled the Middle Rio Grande river basin (New Mexico) and integrated hydrology, ecology, demographics and economics.

- **Shoutang Zang et.al. (2005)** They worked on the application of novel stainless steel membrane module with a 0.2μm nominal pore diameter in an aerated submerged membrane bioreactor to treat synthetic domestic sewage. The pore size of metal membrane was more homogeneous and of tighter distribution than that of organic membrane. The steady membrane flux was more than 17 Lm^{-2}h^{-1}. The mean COD removal efficiency achieved 97.0%. The mean NO_3-N/TN ratio was 74.6% in effluent. There was a certain positive correlation between membrane fouling and extraceller polymeric substances of activated sludge solution. Membrane fouling could be effectively alleviated by the on-line backwash and intermittent running mode. In addition to this they also concluded1that membrane fouling could be eliminated almost entirely by off-line cleaning with 0.25% (wt) NaCLO solution with pH 12. After off-line cleaning, membrane flux could be recovered by about 93.3%. Their results implied that it was economical for using the stainless steel membrane in a membrane bioreactor for wastewater treatment.

- **M.G.Healy et.al. (2007)** Studied on treatment of dairy waste water using constructed wetlands and intermittent sand filters in Ireland. The work discussed the discharge of dairy parlor washing which was creating many problems to the public and natural sources, treating the dairy parlor washing by using constructed wetlands along with intermittent sand filters (ISF) was the traditional method in Ireland. The proposed work concluded that ISF treatment method reduced the pollutant concentration and gave higher efficiency achievement in recirculation system.

- **B.Lew et al. (2008)** The effect of backwash frequency at three different time interval of 15min, 30 min and 60 min and influent flux (3.75, 7.50 and 11.25 L/h/m2) on fouling amelioration in an innovative external side-stream dead-end microfiltration anaerobic membrane bioreactor (AnMBR) for the treatment of domestic wastewater at 25^0C was investigated by them. During 6 month of reactor operation a constant COD removal of 88% and an accumulation1of 350 mg TSS/L/d inert matter in the reactor were observed. Experiments with different backwash frequency and fluxes showed that the increase in transmembrane pressure with time (fouling rate) follows in a two-step manner: a slow linear rise at the beginning, followed by a sudden increase in transmembrane pressure. Based on the fouling rates during the slow linear phase, the best backwash frequency for energy savings and fouling amelioration was determined to be in between 30–60 min. Moreover, the effect of particulate matter load on fouling rate was determined.

- **Petros Gikas and George Tchobanoglous (2008)** studied the use of satellite and decentralized waste water management systems that together offers the significant advantage of treating the waste water close to the waste water generation and to potential water reuse applications. The comparative advantage of satellite and decentralized waste water management system for number of water reuse applications are presented and discussed by them.

- **Massoud, Trahini and Nasr (2008)** They presented a review of the various practices for decentralized wastewater treatment that applies a combination of onsite and cluster system. They studied the limitations and problems incorporated with centralized wastewater treatment. On the basis of their studies they conferred that providing efficient and affordable wastewater treatment facilities in rural areas is one of the most challenging issue that our world is facing specially in developing countries. According to them to cope up with this issue where centralized treatment plants are not economically effective as they are costly to build and operate especially in areas with low densities and dispersed households, it is affordable to switch on to decentralized wastewater treatment facilities. The decentralized system is not only a long term solution for small communities but is more reliable and cost effective.

- **Islam M.A. et.al. (2008)** Shown how the mechanism of biodegradation is successfully used in conventional activated sludge processes for wastewater treatment, and also in advanced technologies as Membrane Bioreactor (MBR). The MBR systems are compared with conventional wastewater treatment systems, and the advantages of the first over the second have been clearly pointed out. Membrane fouling, membrane regeneration, the progress in the design and the application of the MBR system in the developed countries have also been briefly discussed. It is concluded that the replacement of polymeric membrane by locally manufactured filtration units in a MBR could be highly inspiring for small and medium scale industries in the developing world to build their effluent treatment plant based on MBR principle.
- **Neha Gupta et.al. (2008)** They focused on the submerged membrane bioreactor (SMBR) as a promising technology for wastewater treatment and water reclamation. This paper provides an overview of wastewater treatment in a submerged membrane bio-reactor process with a special focus on municipal wastewater systems. SMBRs predict more than 95% organic removal with relative short hydraulic retention times (HRTs) of 1-8 h

and NH_3 removal of more1than 90% in the municipal wastewater treatment. It achieves 30% more removal of organic matter than activated sludge process. The COD can be reduced by 95%. Nitrification was complete and up to 82% of the total nitrogen could be denitrified. Details of the various methods for washing are also included. In his article, new trends in Waste Water recycling with Membrane Technology-Membrane Bioreactor (MBR).

- **Gauang Sun et.al. (2009)** Studied on purification efficiency of sewage in constructed wetlands with different plants in China with different plants and HRT's to treat the wastewater. The plants used for the experiment were Cattails, common reed and Acorus Calamus with a HRT's of 3, 4 and 5 days. The analysis were carried out for the COD, NH_4-N and TN. Overall removal rate of COD 54.9%, NH_4 was 54.8% and TN was 90%. The proposed work concluded that the removal efficiency was higher in the 3 days of HRT as compared to other two HRT's and Cattails and better than common reed and Calamus plant.

- **David Martimez Sosa et.al (2011)** A pilot scale anaerobic submerged membrane bioreactor with an external filtration unit for municipal wastewater treatment was operated for 100 days. Besides gas sparging additional shear stress was created by circulating sludge to control Membrane fouling. During the first 60 days, the reactor was operated under mesophilic temperature conditions. Afterwards the temperature was gradually reduced to 20^0C. A slow and linear increase in the filtration resistance was observed under critical flux conditions (7l/(m^3/h)) at 35^0C .However an increase in fouling rate probably limited to an accumulation of solids, a higher viscosity and soluble COD concentration in the reactor was observed at 20^0C. The COD removal efficiency was close to 90% under both temperature ranges. Effluent COD and BOD_5 concentration were lower than 80 and 25 mg/l respectively. Pathogen indicator microorganism (fecal coliform bacteria) were reduced by $\log_{10}$ 5. Hence the effluent could be used for irrigation purpose in agriculture.

- **J.B.Gimenez et.al (2011)** The aim of their study was to assess the effect of several operational variables on both biological and separation process performance in submerged anaerobic membrane bioreactor pilot plant that treats urban wastewater. The pilot plant is equipped with two industrial hollow-fibre ultrafiltration membrane module (PURON Koch Membrane system, 30 m^2 of filtration surface each). It was operated under mesophilic condition (at 30^0C), 70 days of SRT, and variable HRT ranging from 20 to 6 hour. The effect of the influent COD/SO_4-S ratio (ranging from 2 to 12) and MLSS concentration (ranging from 6 to 22 g/l) were also analyzed. The main performance result were about 87% of COD removed, and blocks methane concentration over 55%. Methane yield was strongly affected by the influent COD/SO_4-S ratio. They concluded that no irreversible fouling were detected even for MLTS concentration above 22 g/l.

- **<u>Thomas Maere et.al. (2011)</u>** Explains that the benchmark simulation model for membrane bioreactors (BSM-MBR) was developed to evaluate operational and control strategies in terms of effluent quality and operational costs. The configuration of the existing BSM for conventional wastewater treatment plants was adapted using reactor volumes, pumped sludge flows and membrane filtration for the water sludge separation. The BSM performance criteria were extended for an MBR taking into account additional pumping requirements for permeate production and aeration requirements for membrane fouling prevention. A comparison with three large scale MBRs showed BSM-MBR energy costs to be realistic.

- **<u>Noor Sabrina Ahmad Mutamin et.al. (2012)</u>** Their studies reviewed the performance of MBR for the treatment of industrial wastewater of high strength. On the basis of their studies they conferred that use of Membrane Bioreactor Technology technology has proved to be highly efficient for the treatment of industrial waste at different constraints depending on the characteristics of wastewater. Industrial wastewater contains high content of fats, oil and grease and a large quantity of organic and inorganic material depending upon the source of their discharge. All these factors along with other aspects are taken into consideration for the designing of an MBR system like Hydraulic Retention time (HRT), Solid Retention1time (SRT), Food to Microorganism ratio, Mixed Liquor Suspended Solids (MLSS), transmembrane pressure and fouling factors because they play major role in the working efficiency of MBR and quality of effluent discharged after the treatment process.

- **Giovanni Libralato, Annamania Volpi Ghirardini (2012)** conferred the recent trends in waste water management concerning the role of centralization and decentralization in waste water treatment. They discussed about the advantages, criticisms and limitations considering social, economic and environmental issues. They further concluded that none of the approaches could be of great importance for a particular area and to achieve greater efficiency in waste water treatment and management, integration of one another on the basis of the specific required situation is necessary.

- **Ramprasad C et.al. (2012)** studied on treatment of waste water generation from the quarters, school, hostel, and college hostel of university campus using reed bed for the treatment of effluent. The work discussed the comparison between the conventional treatment method and the purification using reed bed. Phragmitis australis is the plant that is used for conducting the experiment which is locally known as NANAL. The proposed work shows a remarkable reduction in the concentration of five parameters of wastewater i.e. Ph, BOD, COD by reed bed treatment as compared to the conventional treatment system and simple filter bed system. The studies shows that the root zone treatment can be used enough for discharge into natural water body as the concentrations are below allowable limits.
- **Dohare and Trivedi (2014)** They have studied on the usefulness of Membrane Bioreactor Technology. In their paper they emphasized on MBR as an emerging biological treatment that utilizes benefits of both Activated Sludge Process and Membrane Filtration. Due to the robustness, reliability and flexibility, MBR technology is gaining wide acceptance in field of wastewater treatment. Growing industrialization in emergent nations like India, it is estimated to generate substantial demand for fresh usable water that in turn is likely to fuel market growth in coming recent1years. Conventional ubiquitous technologies are estimated to be replaced by MBR systems in the coming years, owing to low operation and maintenance costs of MBR systems. Presently, the global market for this technology is rapidly growing at a compound annual growth rate (CAGR) of 13.2%. This growth rate is much higher than any other wastewater treatment technologies; also, the market is expected to increase twice over the present growth rate

in the next five years worldwide as this technology offers various advantages over limitations of conventional systems. Historically, high capital cost and operation & maintenance costs (CAPEX & OPMEX) and limited membrane life were barriers in broad application of MBRs. But studies conducted in last two decades and recent advances have helped to overcome such obstacles. Their study also reviews present scenario, potential applications of MBR technology, recent advances in membrane materials and problems of membrane fouling. An attempt also has been made to give a state-of-the art of the technology.

- **Faisal I.Hai et.al.(2014)** They have studied on the efficiency of the Membrane Bioreactor technology for the wastewater treatment. The conferred that the well designed and operating Membrane Bioreactor can efficiently removes suspended solids and microorganisms including protozoa and coliform bacteria. It can significantly removes various viruses and phages. Their studies also highlights the practical issues associated with the installation of Membrane Bioreactor such as the reduction in dosage of chemical disinfectant and enhanced economic and environmental benefits. They have also focused on the issues such as membrane cleaning and microbial growth and the overall performance of Membrane Bioreactor.

- **Dayalan J, Sharon Ann Mathew (2015)** They performed a case study of the two plants that helped them to design a 1 MLD MBR treatment plant with submerged membrane bioreactors. This plant is designed with the basic intention of meeting the space constrain problems. They proposed a treatment process to convert sewage water into potable water by undergoing ultra-filtration and chemical treatment using sodium hypochlorite and hydrogen peroxide. Thus they concluded that the MBR process is a proven technology today for treating domestic and other industrial wastewaters. MBRs produce excellent effluent quality for discharge, even with variable feed conditions. MBRs can produce water suitable for non-potable reuse or even feed to an RO system, without the need for additional filtration. Due to the older sludge age and higher mixed liquor suspended solids, the MBR process generally produces less sludge than conventional processes. MBRs can treat a higher capacity of wastewater in the same footprint as a conventional wastewater treatment plant. Due to plummeting costs and dramatically improving performance, water-treatment applications based on membranes are blossoming. In particular, Membrane Bioreactors (MBRs) are today robust, simple to operate, and even more affordable. They take up little space, need modest technical support, and can remove many contaminants in one step. Many case studies shown that the sewage water which is treated to be just disposed into the sea can be given a three stage treatment process to be converted into potable water. When such treated effluent with just disposable standard can be treated to produce potable water, sewage treated using MBR technology with reusable standards can definitely be converted into potable water.

- **N.N. Asha, K.S. Chandan (2016)** They discussed about the effectiveness of physical and chemical method in treating the wash water collected from the two automobile service station in the city of Banglore. COD and Oil & Grease were taken as the crucial parameter in the automobile service effluent for the study. Sugarcane bagasse and saw dust were used for a chemical and physical treatment for automobile waste water and was explored for different column heights. It was further concluded by them that being a low cost absorbent, sugarcane, saw dust and alum could be fruitfully used for the removal of COD and Oil & Grease over a wide range of concentrations. It was seen that higher the concentration pf alum, percentage removal of oil and grease and COD is higher.

- **Ocanas and Mays** presented a waste water reuse planning model to minimize the overall cost of supplying water in hypothetical community for a single period and in the San Antonio river basin.

- Limited work has been completed mathematically representing and optimizing water supply systems. **Huang and Loucks** posed an inexact two-stage stochastic programming model and applied it to a hypothetical water supply system. More recently, **Cohen et al.** (2004) considered a water supply system in southern Israel and developed an optimization model to minimize the total cost of transporting, treating, and purchasing water.

- A few tailored object-oriented system dynamics water supply system models have been developed. For example, **Palmer et al** developed a water supply and transmission model for Portland, WA, USA.

CHAPTER-3

DECENTRALZED WASTEWATER TREATMENT SYSTEM

3.1. INTRODUCTION

3.1.1. DECENTRALIZED WASTEWATER TREATMENT SYSTEM

Decentralized wastewater management (DWWM) may be defined as “the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation”. In case of decentralized systems, both solid and liquid fractions of the wastewater are utilized near their point of origin, except in some cases when a portion of liquid and residual solids may be transported to a centralized point for further treatment and reuse.

A decentralized system employs a combination of onsite and/or cluster systems and is used to treat and dispose of wastewater from dwellings and businesses close to the source. Decentralized wastewater systems allow for flexibility in wastewater management, and different parts of the system may be combined into “treatment trains,” or a series of processes to meet treatment goals, overcome site conditions, and to address environmental protection requirements. Managed decentralized wastewater systems are viable, long-term alternatives to centralized wastewater treatment facilities, particularly in small and rural communities where they are often most cost-effective. These systems already serve a quarter of the population nationwide1and half the population in some states. They should be considered in any evaluation of wastewater management options for small and mid-sized communities.

It is very important for the community to decide which management approach is right for its wastewater treatment. Community leaders first1need to ask some questions and then create a management plan. What circumstances are causing a reevaluation of present wastewater treatment? Are local septic systems failing? Is residential development stifled because of a lack of adequate wastewater treatment facilities? An organized plan will help managers clearly define the problems, review the possibilities, and assess the costs associated with each potential solution. Many options now exist for wastewater treatment and disposal in rural areas and small communities. Each technology has advantages, as well as limitations, so a treatment technology must be selected specifically to meet local conditions and treatment objectives. Similarly, every community's own financial, physical, and regulatory factors must be evaluated to find the best technology for their circumstances. Onsite systems now1include a number of alternatives that surpass conventional septic tank and drain field systems in their ability to treat wastewater. Alternative onsite processes, such as sand filters, peat filters, aerobic treatment units, pressure distribution systems, drip irrigation, and disinfection systems, can be employed in a wide range of soil and site conditions. Alternative systems require more monitoring and maintenance, making a strong case for these systems to be managed. Small satellite treatment plants or soil absorption systems that have low-cost collection sewers are called cluster systems. Cluste systems treat wastewater from a group of dwellings and/or businesses and are most appropriate in moderately populated areas. These systems serve two or more dwellings (but not usually an entire community) and are located near the buildings they serve. The wastewater from each dwelling or business flows into its own interceptor (septic) tank to settle out and allow solids to break down. From the tank, the effluent is able to travel through smaller diameter, therefore less expensive, collection pipes. These pipes are buried at a shallower depth than full sewers and run relatively short distances to smaller, less maintenance-intensive treatment and disposal units. These units often use soil absorption fields or effluent recycling rather than discharging the treated wastewater into surface waters.

Decentralized treatment plants can be used for wastewater treatment generated from an individual isolated house to a cluster of houses or to a subdivision. Decentralized systems may also be used for the treatment of wastewater generated at universities campuses, or by isolated commercial, industrial and agricultural facilities. In all the above cases, reclaimed water is utilized typically at the vicinity of wastewater generation. Decentralized wastewater treatment systems usually are not linked to a central sewer wastewater collection system network and to a centralized treatment plant, however, in some occasions they may be connected with a centralized plant. Solids accumulated in cluster and decentralized systems are discharged on a periodic basis to a centralized collection system**.**

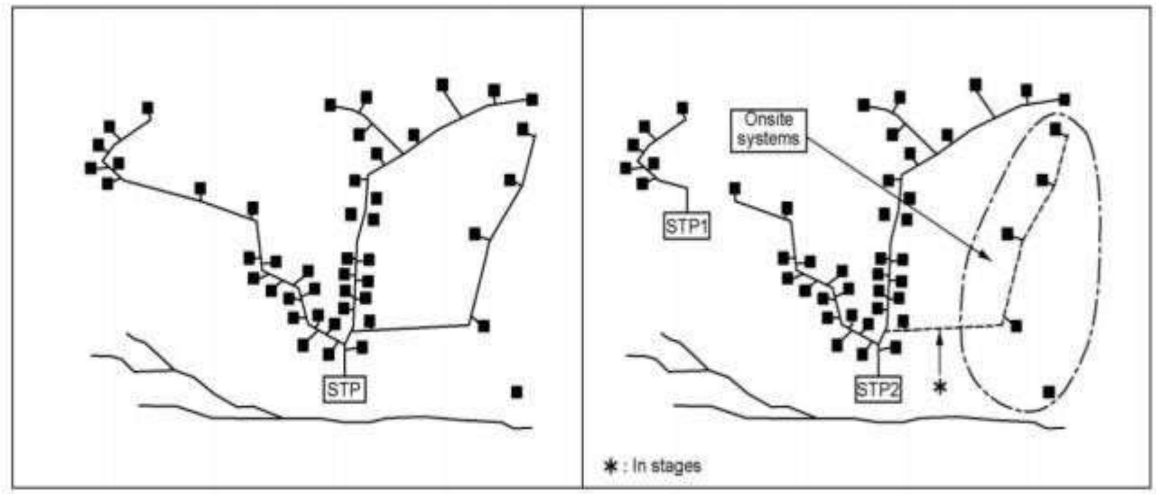

Figure 3.1 Centralized and Decentralized Treatment approaches (Rocky Mountain Institute, 2004**)**

A key advantage of the decentralized cluster approach to wastewater treatment is the ability to design1a 'fit for purpose' treatment option. Depending on the end use, a number of treatment process options can be utilized to produce effluent ranging from Class C through to Class A+. The increasing acceptance of decentralized wastewater treatment and reuse has led to the development of several wastewater treatment options including the traditional activated sludge treatment, MBR treatment and textile filter options. A number of different treatment and disinfection technologies are also available for use within decentralized plants. These include the use of multimedia filtration, chlorination, hydrogen peroxide oxidation ultra-violet radiation, ultrafiltration, high velocity-sonic-cell-disintegrators, ozonation and reverse osmosis. Traditionally a combination of these1approaches is required to ensure the effluent is a Class A+ standard. The only consistent treatment is that the water is dosed with chlorine to ensure a residual effect during its storage and reticulation.

3.1.2. CLASSIFICATION OF DEWATS

For structuring the review, the following classification of (decentralized) wastewater treatment systems has been used:

i. Natural treatment systems

ii. Aerobic systems

- Suspended growth
- Attached growth
- Combined suspended and attached growth

iii. Anaerobic systems

- Suspended growth
- Attached growth

iv. Combined (aerobic/anaerobic/ natural) systems

- Anaerobic –aerobic
- Anaerobic– natural
- Anaerobic– aerobic– natural

3.1.3. ADVANTAGES AND DISADVANTAGES OF DECENTRALIZED WASTEWATER TREATMENT SYSTEMS

3.1.3.1. ADVANTAGES OF DWWMs

i. The environmental damages and mishaps will be less comparatively as the flow rate at any point in the system will remain sufficiently low.

ii. System production outcomes in much less environmental disturbances as smaller pipes could be hooked up at shallow depths and might be extra flexibly routed.

iii. The future expansion of the plant will be safer and easier as new treatment centers may be added without routing ever more flows to present facilities.

iv. Monitoring of various industrial discharges can be done easily.

v. Sector wise treatment permits sewage transmission over shorter distan ces.

vi. The problem associated with the odor and insect nuisance can be easily avoided due to their closely placed treatment units.

vii. Construction of the sewer pipelines requires less capital cost.

viii. Decentralized wastewater treatment units requires active participation of the local community which makes them to participate in the supervision and monitoring of the system which in turn develops confidence among the people.

ix. Quality of remedy is greater efficient than conventional gadget because of accurate estimation of wastewater technology and lower quantity of wastewater.

x. Effluent sewage that is being discharged from the treatment units can be effectively used for recreational applications like toilet flushing, gardening. Landscape irrigation and make ups of cooling tower.

xi. Decentralized wastewater treatment units are easy to maintain.

xii. Ecology of rivers, streams ponds can be efficaciously managed via letting better treated waters incrementally alongside their duration.

xiii. Groundwater recharge options may be related to appropriate websites the carrying all sewage from side to side before and after remedy.

3.1.3.2. DISADVANTAGSE OF DWWMs

i. Policies regarding installation, operation and maintenance are not yet well established in many of the developing countries.

ii. Standardization of the systems is difficult as significant variation exists with regard to technical design to suit the local geography and climatic conditions.

iii. Local people will have to bear all by themselves the O&M of the treat ment plant.

iv. Getting a site for the STP may be difficult amidst built up sections and eventually, only the graveyards or cemeteries have to be the site.

3.1.4. SITUATIONS SUITABLE FOR DWWM

Following situations are suitable for implementation of DWWM:

i. Where clusters of on-site systems are existing and there is no control on the fate of the pollutants.
ii. Improper maintenance of on-site treatment systems and exorbitant cost of conventional remediation by implementation of centralized systems.
iii. Community/ institutional facility is far away from the existing centralized system.
iv. Localities where there is scarcity of freshwater.
v. Localities where there is a possibility for localized reuse of treated wastewater.
vi. Localities where discharge of partially treated wastewater is prohibited due to various1environmental reasons.
vii. Localities where extension of existing centralized system is impossible.
viii. Newly developed or existing clusters of residences, industrial parks, public facilities, commercial establishments and institutional facilities.

3.2. PLANNING FOR DWWM

The initial phase in the getting ready for DWWMS is the site choice. The potential destinations are distinguished in light of

- Population density, land availability,
- Topography,
- Reuse potential,
- Existing streams for discharge of treated wastewater if required.

A reconnaissance survey should be conducted for possible locations for DWWM. These possible locations should confirm to the overall sanitation plan for1the city / town, and should not overlap with those areas where a centralized system already exists or in the offing. Ranking of sites from the preliminary list for implementing the DWWM, is based on as signing weightages to certain criteria. Following criteria, along with the corresponding ranks, can be used.

Selection of specific sites from the preliminary list, suitable for the implementation of DWWM, is based upon the overall ranking for the site. Environmental sensitivity should also be considered while selecting the sites. Stakeholders participation is very essential for selecting the sites. For the chosen sites, detailed investigations should be carried out with respect to

- Population,
- Topography,
- Wastewater quantity and quality,
- Details of existing on-site1treatment systems,
- Reuse potential,
- Presence of any drainage channel

3.3. ONSITE TREATMENT SYSTEMS

3.3.1. Septic tank

Septic tank is the most well known and common method for onsite treatment of sewage. They are most common for small scale and decentralized treatment plants in the worldwide. The purpose of a septic tank is to1provide a receiving vessel for all wastewater generated from domestic dwelling and to afford primary treatment that wastewater. A septic tank may be defined as a primary settling tank whose detention time comparitively longer than normal sedimentation tank. The detention time of the septic tank is usually considered as 12 to 36 hours. The septic tank is a single or multi-chambered watertight chamber. Septic tank provides the first and very important pretreatment in the typical small-scale on-site wastewater treatment system and accomplishes approximately 50% of the ultimate treatment within the tank (Sebloom et al., 2003). Digestion of the sludge inside the septic tank usually take place in an anaerobic conditions therefore the technique and working of septic tank unit is categorized under the process that worked upon the principle of anaerobic decomposition. The process that occurs inside of septic tank is same as anaerobic process are settling of solids, the anaerobic conversion of organic matters and accumulation or digestion of sludge. (Lier and Lettinga, 1999). In their general designs, septic tank is buried underground. But septic tank can be located on places based on their designs and availability of the space. In some region with spare space like rural area, septic tank is constructed outside of the house. The regions which have scarce and limited space like metro cities, septic is buried under bathroom. It can be explain in the figure below.

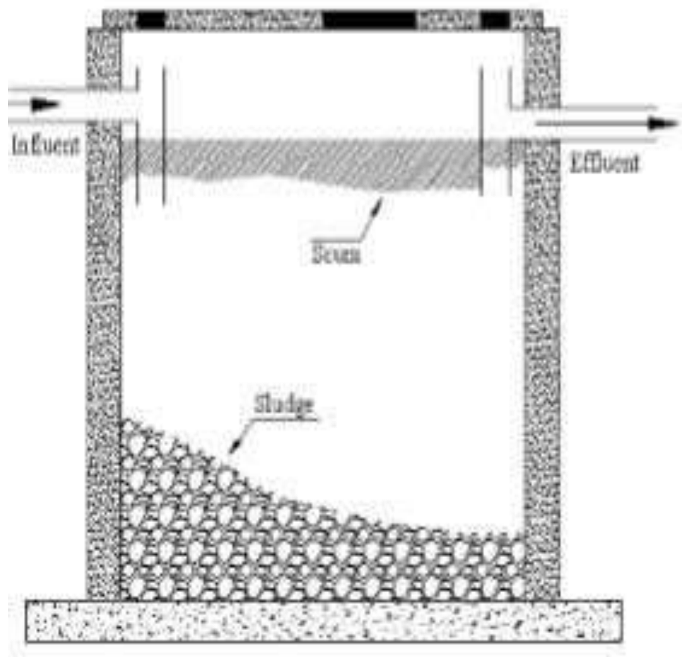

Figure 3.2. Schematic View of Single Chamber Septic Tank

Table 3.1 Advantages and Disadvantages of Septic Tank

Advantages	Disadvantages
▪ Simple operation ▪ Little space requirements (under ground) ▪ Low maintenance requirement ▪ Nutrients are returned to the soil ▪ Cost-efficiency regarding treatment ▪ Long-lasting	▪ Low treatment efficiency ▪ Enrichment of nutrients and disease caused microorganisms in effluent. ▪ Foul-smelling emissions created by anaerobic digestion

3.3.2. Baffled Septic tank

The baffled septic tank also known as "baffled reactor", prefers use for wastewater with a high percentage of non-settleable suspended solids and low COD/BOD ratio. According to the Sasse (1998), Baffled septic tank is large and shallow tank. It is an improvement of septic tank and using the advantages of the UASB for treatment of wastewaters. It consists of 2 to 5 serial chambers with eventually a filter in the last part. The first compartment always is a settling chamber and a series of up – flow chambers are followed. There is an intensive contact occurring between fresh influent and resident sludge. The process-taking place in the chambers is the anaerobic degradation of suspended and dissolved solids. This process leads to a COD removal of 65 – 90 %. The importance parameter for design is low in up-flow velocity. This value should not excess 2 m/h.

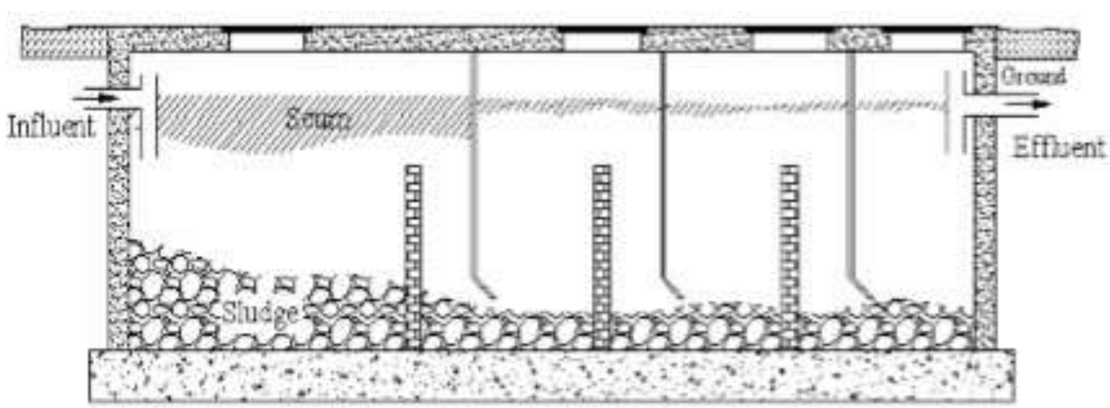

Figure 3.3. Schematic view of Baffled Septic Tank

Table 3.2. Advantages and Disadvantages of Baffled Septic Tank

Advantages	Disadvantages
▪ High treatment efficiency ▪ Simple to built and operate ▪ Hardly any blockage ▪ Durable system ▪ Relatively cheap ▪ Low affect due to shock load and shock hydraulic.	▪ Less efficient with weakly polluted wastewater ▪ Long start-up phase ▪ Large volume requirement

3.3.3. Anaerobic / Fixed1Bed1Filters

Anaerobic filters, also known as fixed bed or fixed film reactor, can be used for pre-settled domestic and industrial wastewater of narrow COD/BOD ratio and low SS concentrations. Therefore, they not only are used in combination with primary treatment (for example a septic tank or baffled septic tank), but also treat non –settleable and dissolved solids by bringing them in close contact with active bacteria mass on a filter media.

The filter should be rough. The rough surface of media is target for bacteria growth. Surface of filter material should be from 90 to 300 m^2/m^3 of reactor volume. The materials such as gravel, rocks, cinder or specially formed plastic pieces provide additional surface area for bacteria to settle, the larger the surface for bacterial growth, the quicker digestion. The requirement tank volume should be 0.5 to 1 m^3/capita. The COD removal efficiency can achieve up to 70 – 90%. Biogas utilization should be considered in the case of BOD concentration is higher than 1000 mg/L. The hydraulic retention time should be higher than 24 hours.

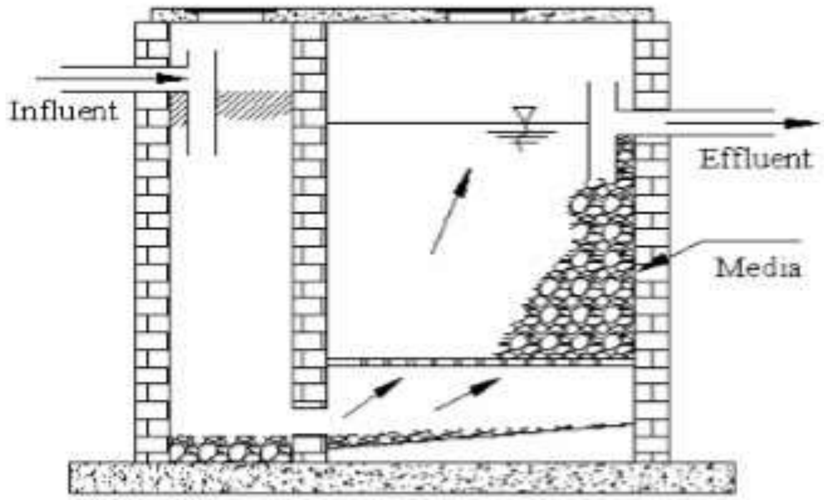

Figure 3.4. Schematic of Anaerobic/fixed bed filters (Sasse, 1998)

Table 3.3. Advantages and Disadvantages of Anaerobic Filters (Sasse, 1998)

Advantages	Disadvantages
▪ Simple and durable system	▪ High construction costs (filter media)
▪ High treatment efficiency	▪ Blockage of filter possible
▪ Little space requirements	▪ Effluent can smell

3.3.4. Imhoff Tank

Inhoff tank has some more advances than septic system, but its effluent fails to meet discharge criteria requirements, therefore, use is limited. Normally, Imhoff tanks are typically used for domestic or mixed wastewater flows above 3 m^3/d. The tank consists of a settling compartment above the digestion chamber. The sedimented solids flow from the upper chamber through a slot in the bottom into the lower one, where solids are accumulated and digested in anaerobic condition. The influent is separated firmly from the bottom sludge: funnel-like baffle walls prevent up-flowing foul sludge particles from being mixed1with the effluent and from causing turbulence.

The effluent is fresh and odourless due to the suspended and dissolved solids do not get into contact with the active sludge. Sludge removal should be done right from the bottom of reactor to ensure that only fully digested substrate is discharged. Only a part of the sludge is removed regularly in order to keep some active sludge in the reactor. The removed sludge should receive further treatment immediately by in drying beds or compost pits for pathogen control.

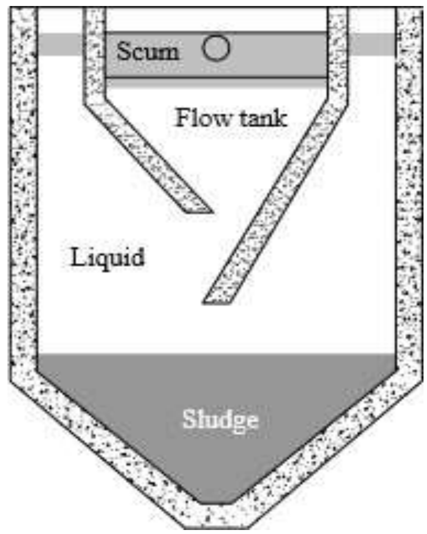

Figure 3.5. Cross Section of Imhoff Tank (Sasse, 1998)

Table 3.4. Advantages and Disadvantages of Imhoff Tank (Sasse, 1998)

Advantages	Disadvantages
▪ Durable ▪ Little space due to underground construction ▪ odourless effluent	▪ Less simple than septic tank ▪ Need very regular desludging

3.4. Advantages of On-Site Wastewater Treatment Systems

i. System construction would result in less environmental disturbances as almost no collection system is required.
ii. This can be used as a preliminary stage in the wastewater management system in an expanding urban area.
iii. Treatment units are closely packed systems, mostly free from aweful odors and insects.
iv. Almost no investment is required1for the sewer pipelines.
v. Planned, constructed and maintained by individual households / establishments.
vi. Power requirement is zero.
vii. Maintenance of the treatment system is very easy.

3.5. Disadvantage of On Site Wastewater Treatment Systems

i. Policies regarding installation, operation and maintenance are not well established in many of the developing countries.
ii. Standardization of the systems is difficult as significant variation exists with regard to technical design to suit the local geography and climatic conditions.
iii. Individual households / establishments will have to bear the operation and maintenance cost of the treatment systems.
iv. Improper maintenance of the treatment plant will have significant environmental consequences.
v. Commonly used onsite systems such as pit latrines, septic tanks and anaerobic baffle wall reactors will not be able to meet the discharge standards. Effluents from such systems will have high COD and pathogen content.

CHAPTER 4

MEMBRANE BIOREACTOR IN WASTEWATER TREATMENTS

4.1. HISTORY

The use of MBRs have been increased on a large scale from 1960's for the treatment of wastewater, mainly on a commercial1scale. However, only since the 1990's and the improvement of immersed membranes has their software come to be greater sizeable. Wastewater treatment with MBRs essentially is predicated on the activated sludge system, but the activated sludge is separated from the dealt with wastewater by using filtration as opposed to sedimentation. The benefits are a higher effluent exceptional due to whole particle retention (which include retention of microorganisms) and a maller spatial footprint. These advantages are spark off towards their higher energy consumption and operational expenses because of chemical cleansing and membrane lifespan.

Due to their advantages and optimization capacity, MBRs are an interesting choice for decentralized treatment plants. The short distances among wastewater production and the remedy facility allow easy reuse of the permeate. Several groups around the world have advanced technologies for decentralized wastewater treatment with MBRs. However, regardless of the extensive dissemination of this era, simplest little statistics about its performance at household degree is to be had, and performance evaluation is mostly primarily based on data supplied from suppliers and public government, or extrapolations from lab experiments. Data received from synthetic or degritted wastewater from centralized remedy plants may also1now not be comparable to that applicable to fresh wastewater form houses. Closing this information gap is crucial if MBRs are to be taken into consideration a real alternative.

4.2. MBR PROCESS DESCRIPTION

Membrane bioreactor is combination of membrane separation and biological treatment in order to remove organic matters, nutrients, pathogens, and potentially micro pollutants in water. It not only can be operated under aerobic and anaerobic conditions but it is also operated in low and high organic loading. That lead membrane bioreactor is widely used for water and wastewater treatments.

The MBR process is a suspended growth activated sludge system that utilizes microporous membranes for solid/liquid separation in lieu of secondary clarifiers. The typical arrangement shown in Figure below that includes submerged membranes in the aerated portion of the bioreactor, an anoxic zone and internal mixed liquor recycle. Incorporation of anaerobic zones for biological phosphorus removal has been the focus of recent research, and there is at least one full1scale facility of this type being designed presently in North America. As a further alternative to this submerged membrane some plants have used pressure membranes (rather than submerged membranes) external to the bioreactor.

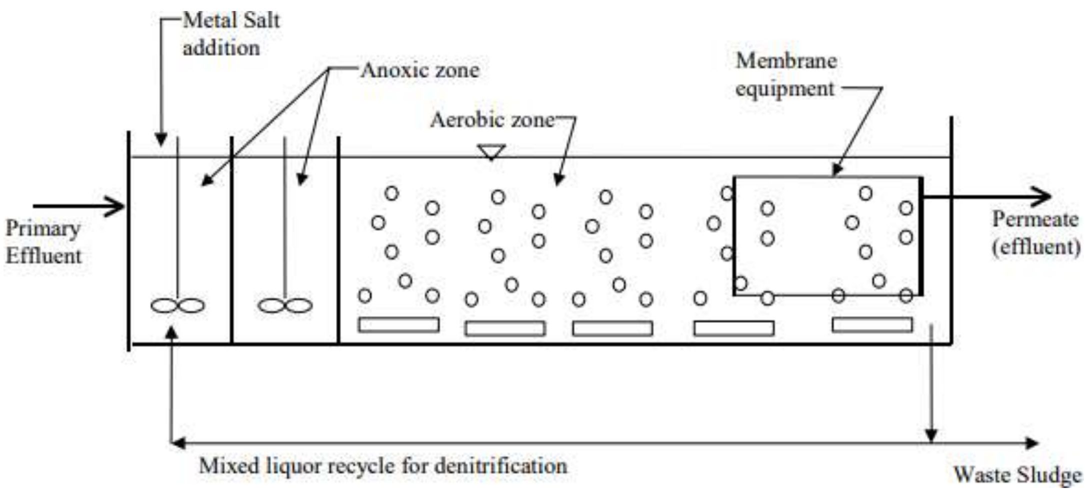

Figure 4.1 Schematic View of Membrane Bioreactor

4.3. ADVANTAGES OF MBR SYSTEMS

The advantages of MBR include:

- Secondary clarifiers and tertiary filtration processes are eliminated, thereby reducing plant footprint. In certain instances, footprint can1be further reduced because other process units such as digesters or UV disinfection can also be eliminated/minimized (dependent upon governing regulations).
- Unlike secondary clarifiers, the quality of solids separation is not dependent on the mixed liquor suspended solids concentration or characteristics. Since elevated mixed liquor

concentrations are possible, the aeration basin volume can be reduced, further reducing the plant footprint.

- No reliance upon achieving good sludge settleability, hence quite amenable to remote operation.
- Can be designed with long sludge age, hence low sludge production.
- Produces a MF/UF quality effluent suitable for reuse applications or as a high quality feed water source for Reverse Osmosis treatment. Indicative output quality of MF/UF systems include SS < 1mg/L,turbidity.

4.4. MEMBRANE BIOREACTOR PROPERTIES

Micro- filtration (MF) and Ultra -filtration (UF) membrane are process that filter material based on particle size. Membranes are made of polyethylene or ceramic. MF has pore size from 0.1 to 0.4 µm UF has pore size from 2 to 50 nm. Both types of membrane are applied in bioreactor. A membrane must achieve some properties as much as possible such as mechanical strength, high degree of selectivity, high throughput of desired permeate. Membrane bioreactor (MBR) is devices that combine of activated sludge process with membrane separation. Both membranes are very popular in term of membrane bioreactor. MBR have two configuration based on the location of membrane in the module, that are submerged membrane bioreactor system and external cross flow membrane bioreactor system.

According to the Roest et al. (2002), some basic concepts that use in the membrane process are flux, trans-membrane pressure and permeability. The flow of liquid through a specific membrane surface area is called flux. Flux can be express as:

$$\textbf{Flux} = \frac{\textbf{Permeate flow}}{\textbf{membrane surface used}}$$

In this equation **Flux** in L/m2 .h

Permeate flow in L/h

Membrane surface used in m^2

A flow through the membrane has associated with driving force and pressure drop. From these pressures, trans -membrane pressure (TMP) can be determined as:

Tran – membrane pressure = Static pressure – Dynamic pressure

- Static pressure: pressure at zero permeate flow (bar)
- Dynamic pressure: pressure at permeate flow (bar)
- Tran-membrane pressure or (bar)

The permeability of membrane is determined by equation below:

$$\textbf{Permeability} = \frac{\textbf{Flux}}{\textbf{TMP}} \ \textbf{(at temperature } \mathbf{T^0}\textbf{ C)}$$

The unit express as: **Permeability** in L/m2 .h.

bar Flux in L/m2 .h

TMP in bar

4.5. HOLLOW FIBER MEMBRANE FILTER

A hollow-fiber membrane filter are bundles connected by manifolds in units that are designed for easy changing and servicing. Packed in extreme high density, hollow fibers can range from smaller than a strand of human hair to bristles several hundred microns in diameter. Hollow fibers devices are used in both ultrafiltration and reverse osmosis applications. Fibers are produced by extrusion through annular dies. Thousands of strands are tightly bundled and bonded at the end into potting. The bundles are usually housed in PVC or stainless steel. When1applied in a suitable1application, hollow fiber membranes are more economical and cost effective than conventional separation method

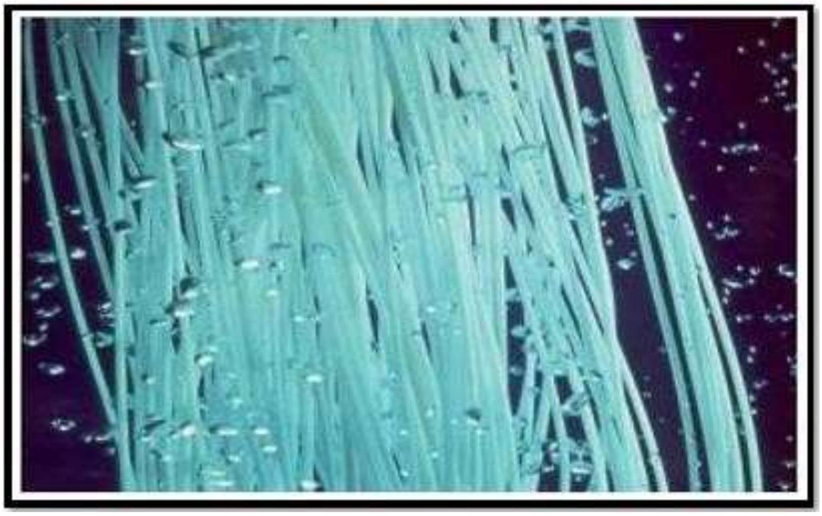

Figure 4.2. Hollow Fiber Membrane

4.6. VARIOUS MEMBRANE BIOREACTOR PROCESS

4.6.1. Cross flow Membrane Bioreactor System

In this process the membrane is installed outside of the active sludge tank. The principle of cross flow is high flow velocity in order to prevent the building up of solid cake on the membrane surface. This method requires maintain the sludge velocity across the membrane surface for membrane cleaning and required pressure drop for permeation. This method is easy for operation and maintenance but require large amount of energy that lead to high operation cost. Because high velocity and excess shear break micro floc and system operate in unstable (Roest et al., 2002).

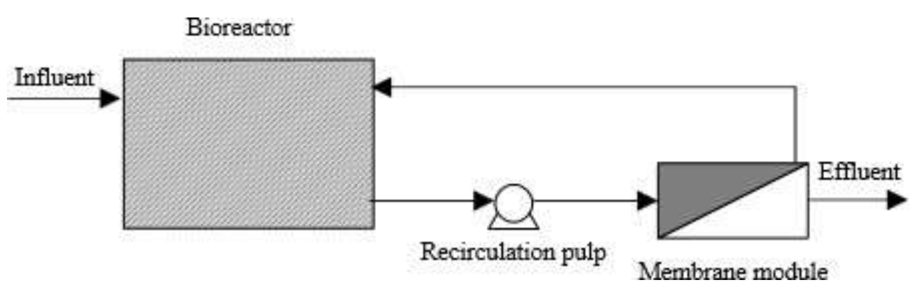

Figure 4.3. Cross Flow Membrane Bioreactor

4.6.2. Submerged Membrane Bioreactor System

Submerged membrane bioreactor system (SMBR) is a membrane module that is immersed in a bioreactor. The permeation is extracted by suction or pressure on bioreactor. The pressure applied in permeate extraction is lower than that required for cross-flow permeation. In SMBR is absent of recirculation pump which is requirement in cross flow. The mechanical used to create the cross flow stream on the surface of membrane is low pressure air diffusion and it can be considered part of activated sludge process. The air diffusion facilitates two processes that are cleaning of membrane surface and supply oxygen to the biomass.

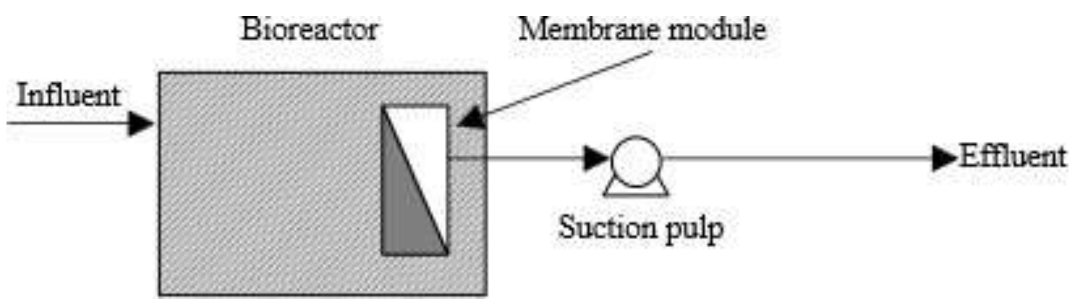

Figure 4.4. Submerged Membrane Bioreactor

CHAPTER 5

DECENTRALIZED WASTEWATER TREATMENT SYSTEM FOR DEHI TECHNOLOGICAL UNIVERSITY

5.1. ENVIRONMENTAL EXAMINATION REPORT

5.1.1. PROJECT DESCRIPTION

Delhi being a metropolitan city is situated on the bank of Yamuna river and is considered as the major contributor towards its pollution followed by Agra and Mathura. The main source of pollution of Yamuna in National Capital Territory is due direct discharge of wastewater from the industries and various other sources. About 85% of the total pollution in the river is contributed by domestic sources. The condition of river deteriorate further due to abstraction of significant amount of river water, leaving almost no fresh water in the river, which is essential to maintain the assimilation capacity of the river. In the critically, polluted stretch of Yamuna river from Delhi to Chambal confluence, there was significant fluctuations in dissolved oxygen level from Nil to well above saturation level. This reflects presence of organic pollution load and persistence of eutrophic conditions in the river.

As per estimation, the Total BOD load generation at NCT – Delhi during the year 2003 was 443 tonnes/day (TPD). The sewage treatment facility was available for 355 TPD of BOD load, however, treatment facility of 265 TPD of BOD load was1utilized. Because of which, there was reduction of about 43% in the total BOD load generated during the year 2003 by NCT – Delhi.

The main aim of the project is to study the existing wastewater treatment facility of Delhi Technological University and to find the application of Decentralized Wastewater Treatment solution in order to reduce the discharge of wastewater in the river and to reduce the burden on existing sewer pipelines. For this study various treatment units along with the design of MBR facility for the wastewater treatment is designed and proposed. The use of MBR, specifically and External MBR with Hollow Fiber Membrane, will meet the effluent standards with less sludge production. A Hollow Fiber Membrane will be used to separate volatile and semivolatile organic compounds. Sludge will be collected and dried to make soil conditioner which will be used for agricultural purposes. The necessary data for the design will be attained by grab sampling method, measuring the parameters needed for the design of said treatment facility. Design parameters are – Food to Microorganisms Ratio, Settable Volume Index, pH, COD, BOD, Total Suspended Solids, Total Dissolved Solids, Surfactants, and oil and fats. Through this study, this design project shall be built for better innovation.

5.1.2. PROJECT LOCATION

Delhi Technological University is geographically located at 28.7501˚ N and 77.1177. Delhi Technological University is an educational institution located in Capital city of India, New Delhi. The total land area of the university is 163.78 acres which have the total intake of the students as approximately 8000.

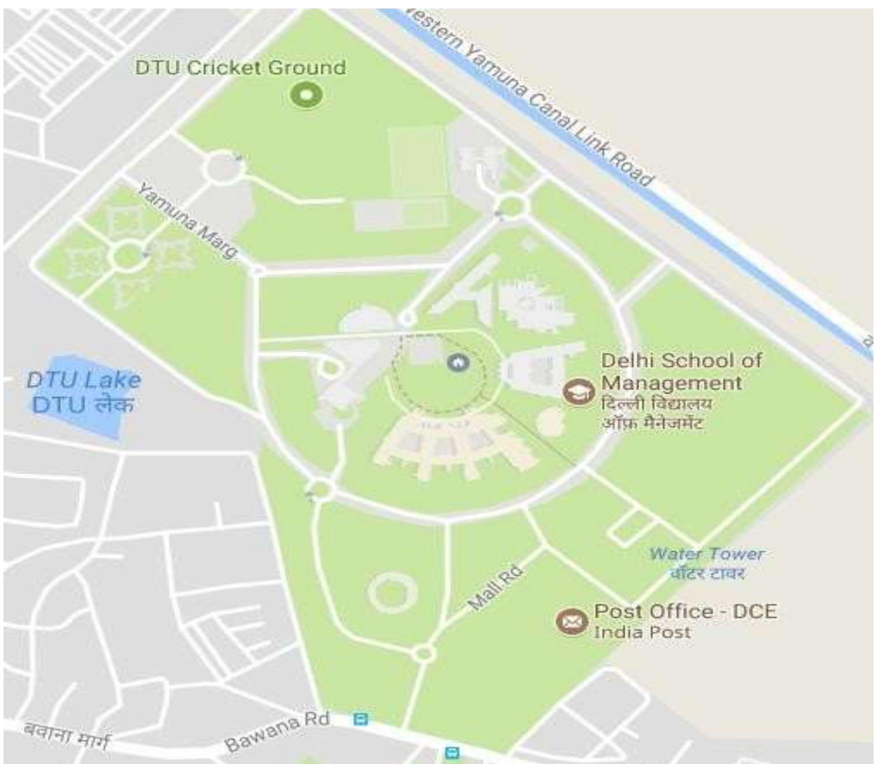

Figure 5.1 Location of Delhi Technological University

5.1.3. PROJECT INFORMATION

In the design of decentralized wastewater treatment plant, a case study of Delhi Technological University was examined. In the process of designing treatment facility for the campus comprising domestic waste from the residents, hostels, canteen and municipal waste from college, a provision of MBR facility is provided after the process of activated sludge tank. This process is a tool basically applied to reduce biological and chemical waste products from the water in order to promote the treated water to be used for other purposes in the campus which will lead to the reduced burden on main sewer pipeline or public sewers and reduces the chances of wastewater to be discharged on existing river streams. The proposed project is designed to be placed in DTU Campus. Hollow Fiber Membrane just allows treated water to go through the channel. The MBR system is a treatment procedure comprising of the accompanying:

Screening, to expel the extensive inorganic and natural particles to counteract stopping up of pipe lines and pumps. Since the wastewater contains high nitrogen content, Anoxic Tank to denitrify wastewater can be applied where the electron donor is carbon from domestic sewage and electron acceptor is nitrate. By denitrifying bacteria, nitrate will be converted to nitrogen gas which able to escape from the tank. Sludge will conveys to Activated Sludge Tank involves mixing air with the wastewater to provide the suitable condition for microorganisms to digest organic matter and nutrients to sustain their life process. To sustain the food to microorganism ratio, the study will also be include the treatment of domestic wastewater in their treatment facility. During this phase, flocculation will take place by the slime layer of the bacteria, glycocalyx, and cause to bind them together with the wastewater. Biomass then conveys to the external MBR to separate and remove pathogens particularly fecal coliform and E. coli without applying disinfectant.

5.2. DETAILED ENGINEERING DESIGN

5.2.1. DESIGN RATIONALE

The various elements of the detailed engineering design of the project mainly focusses on the efficiency and working of the Membrane Bioreactor and its phenomena. For the study of the project the various other factors were also important. The following computations and constants are taken from Manual on Sewage and Sewage Treatment (CPHEOO). The study is also guided by the standards implemented by the Delhi Pollution Control Committee (DPCC), the Effluent Standards for Treated Wastewater and the Recommended Standards for Wastewater Facilities set by the Central Pollution Control Board- Pollution Control Agency in Delhi, India. The proper dimensions of the tanks, the time of aeration and hydraulic retention time (HRT) are very well stated so as to get expected efficient results. The characteristics of the wastewater are taken through tests and the specifications of pumps, air blower, air diffusers and the hollow fiber membrane were obtained from various other sources. For the cost study of the project various bills related to the project were unobtainable from the institute office therefore the study is carried out assuming further data and figures looking for an alternative. Several other data of wastewater influents from different places in the institute were obtained from the Civil engineering Department. Data on number of residential houses and hostels including girls and boy hostel, hostel mess, canteen were obtained to nearly accurate figures and the volumes of wastewater generated from these sources were calculated manually. The population of the Delhi Technological University is calculated approximately as 9305 with the wastewater flow as 836 m^3/day. The complete calculation for the demand of water per capita and the discharge rate of wastewater is computed below in detail.

Step 1: Calculation for the flow rate of wastewater discharge

The first part of the study was survey and monitoring work done for the estimation of total population of the Delhi Technological University.

The total number of boy hostel in DTU is 8. Each of these hostels have a different capacity to accommodate students. The total number students in boys hostel is calculated to an approximate figure as 2400. Total girls hostel in the campus vicinity is 6 which has the capacity to accommodate 600 girl students.

Total students in DTU = 8000

Students Residing in Hostels (both girls and boys hostel) = 2400 + 600

= 3000 students

Day Scholars = 8000 – 3000

= 5000 students

Total number of Residential flats in the Campus = 326

Total residential flats reserved for students = 65

Flats available for the faculty and staff = 326-65= 261

Assuming that the families residing in the flats have 5 family members.

Population living in residential flat = 261 × 5 = 1305 say **1350 residents**

As per IS 1172-1993 Minimum domestic water consumption (Annual Average) for Indian towns and cities with full flushing systems is **200 l/h/day** and water requirement for an educational institution ranges from **45-90 l/head/day** for day scholars. On the other hand this figures increased to **135-225 l/head/day** for the hostlers.

In this project study for the calculation of water demand for an educational institute following assumptions are made for the per capita demand. These are as follows:

- Per capita water demand for hostlers – **200 lpcd**
- Per capita water demand for residents living in the campus – **200 lpcd**
- Per capita water demand for day scholars – **45 lpcd**

On the basis of above assumptions, total water demand for campus is calculated as:

Water demand = (3000 × 200) (5000 × 45) (1350 × 200)

Hostlers day scholars Domestic

Total water consumption = 1095×10^3 litres/day

= $1095\ m^3$/day

The per capita sewage which is produced in a community can be estimated by assuming it as 75 to 80% of the per capita water supplied to the public.

Therefore the waste water flow can be calculated as:

Waste water flow = (1095 m^3/day × 80%)

= 876 m^3/day

5.2.2. WASTEWATER CHARACTERISTICS

Wastewater discharged from the various sources from the college include wastewater coming from the residential houses situated in the premises, various other sources include all the boyhostels and girls hostels, college canteen, hostel mess, college departments and their laboratories. The waste coming from these sources is highly rich in organic matter. These characteristics identify market wastewater from domestic wastewater. Desirable treatment must be conducted in order to decrease the organic content of the water before discharge or reuse. The following data on the characteristics of the institute wastewater are obtained through tests conducted manually for the BOD5, COD, and TSS. The Average Design Flow is taken through estimation based on existing data of different wastewater flow from several institutions in Delhi. The temperature is set to a standard of 20^0 C.

Table 5.1- Raw Wastewater Characteristics

RAW WASTEWATER CHARACTERISTICS	
CHARACTERISTICS	**RANGE**
Wastewater Temperature	20^0C
Average Design Flow	876 m^3/day
BOD_5	500 mg/l
COD	900 mg/l
Total Suspended Solids	400mg/l

5.2.3. OPERATIONAL PARAMETRS & BIOLOGICAL KINETIC COEFFICIENT

Characteristic of the wastewater during and after treatment should always be considered in the design and operation as a guide in the design calculation and specifications of the treatment facility and equipment. According to CPCB- Schedule IV which is given by "General Standards for Discharge of Environmental Pollution PART A" water must not be greater than 30 mg/L and 100 mg/L of BOD and Total Suspended Solids (TSS) for inland surface water and 100 mg/l as BOD and 200 mg/l Total Suspended Solids (TSS) on land for irrigation purposes. These standards also make the water suitable for and cleaning and gardening purposes. The mean cell residence time, commonly known as the "sludge age", is the most essential part in the biological part of treatment. The net growth rate of a sludge is subjected to the retention time of the sludge. A five-day retention time is considered to result to good sludge settling characteristic.

Table 5.2- Operational Parameters for the Design

Operational Parameters to be followed for the Design based on Water and Wastewater manual	
Characteristics	**Range**
Effluent BOD	30 mg/l
Effluent TS	50 mg/l
Design Mean Cell Residence Time (θ_C)	10-15 days
MLVSS	3000-5000 mg/l
Yield Coefficient	0.5
$\frac{BOD_5}{BOD_u}$	0.67
Decay Constant	0.06 per day
$\frac{MLVSS}{MLSS}$	0.8
F/M ratio	0.1-0.18
HRT	12-24 hr

Assume:

(1) Removal of BOD and TSS in screening is assumed to be 15% and 25%, respectively.

(2) BOD and TSS removal in Equalization Tank are 40% and 55%, respectively.

(3) Air weights 1.202 kg/m3 and contain 23.2% oxygen by weight

(4) Oxygen transfer efficiency for air diffuser is 8% and safety factor of 2 is used to determine the actual volume for sizing the blowers.

(5) S.G. of raw market wastewater is less than 2.65 and 4.5% of solid content

(6) Oxygen consumption is 1.45 mg per mg of cell oxidized

5.3. DESIGN CALCULATIONS

5.3.1. SCREENING

Screening is first operation that the wastewater will be undergoing for treatment. It is a physical unit operation that removes large particles, such as paper, plastics, rags, that contributes to the clogging of pipes. It also helps in preventing damage to the equipment, piping, and other appurtenances downstream. Due to a limited space for the treatment facility, a flow channel with bar screens would not be efficient and conventional for the design. The researchers decided to design a stainless steel wire mesh basket to be place at the inflow pipe of the equalization tank where the wastewater coming directly from the market would be screened and undergoing its first physical treatment. The calculation of BOD and TSS entering the equalization tank is taken from the removal rate of the screen basket. With the aid of screens, about 15% and 25% of BOD and TSS is removed, respectively. (Lin 2007)

Step 1. <u>Calculate the removal rate of BOD and TSS in screening</u>

<u>BOD Loading</u>:

BOD loading = (BOD_5) (Q_{avg})

BOD loading = $(500\text{ mg/l} \times 10^{-6}\text{ kg})$ $(876\text{ m}^3\text{/day} \times 10^3\text{ l})$

BOD Loading = 438 kg/day

<u>TSS Loading</u>:

TSS loading = (TSS) (Q_{avg})

TSS loading = (400 mg/l $\times 10^{-6}$ kg) (876 m^3/day $\times 10^3$)

TSS Loading = 350.4 kg/day

<u>BOD Removal</u>:

BOD removed = (BOD loading) (15% removed)

= 436 kg/day × 0.15

BOD Removed = 65.7 kg/day

This is the amount of BOD removed in the process of screening

<u>TSS Removal</u>:

TSS removed = (TSS loading) (25% removed)

= 350.4 kg/day × 0.25

TSS Removed = 87.6 kg/day

This is the amount of TSS removed in the process of screening

Following are the assumptions made in the design of screen bars:

- Slope of the manually cleaned screen is kept to be 80˚ with horizontal.
- Clear spacing between the bars is assumed to be 20mm for manually cleaned bars.
- Shape of the bar- M.S. flats
- Size- 10mm × 50mm (10mm facing flats)
- Velocity normal to the screen = 0.8m/sec

Design of screens

Waste water flow = 876 m^3/day

= 876 ×10^3 l ×10^{-6} = 0.876 MLD

Average wastewater flow = 0.876 MLD = 0.010 m^3/sec

Max wastewater flow = 2× Avg flow

= 2× 0.010 m^3/day = 0.0202 m^3/sec

Min wastewater flow = 2/3 (avg flow rate)

= 2/3 (0.010 m^3/sec) = 0.006 m^3/sec

At peak flow, net inclined area required

$$= \frac{0.0202\ m^3/sec}{0.8\ m/sec} = 0.025\ m^2$$

Gross inclined area = 0.025 × 1.5 = 0.0375 m^2

Gross vertical area required = 0.0375 × Sin80^0 = 0.0369 m^2

Provide submerged depth = 0.3m

Width of channel = $\frac{0.0369\ m^2}{0.3}$ = 0.123 m. **Provide width as 0.1 m**

Check velocity in duct = $\frac{0.0202\ m^3/sec}{0.3 \times 0.1}$ = 0.67 m/sec

Therefore approach velocity U/s of screens > 0.4 m/sec **Okay**

Providing 20 bars of 10mm × 50mm at 20mm clear spacing

5.3.2. EQUALISATION TANK

After passing through the screens, the wastewater enters an equalization tank. The equalization tank, from the term itself, equalizes the volume of wastewater entering the activated sludge tank and as well as the proceeding treatment processes. It prevents the passage of wastewater in the activated sludge tank in order not to disrupt the wastewater being aerated and also not to agitate the settling particles during the sedimentation process.

An effective size of the tank must be strategically computed. Having a daily flow of 876 m^3 per day and very small area for the tank, the researchers must be able to contain the volume of wastewater per treatment cycle. The average hourly flow rate is computed for 24 hours. The treatment facility can accommodate two (2) cycles of treatment per date having a Hydraulic Retention Time (HRT) of 12 hours. HRT is the number of hours the wastewater is being retained or held in the equalization tank.

Step 2: Calculate for the remaining BOD and TSS from screening entering the equalization tank.

BOD Remaining:

BOD remaining=438 kg/day – 65.7 kg/day (**BOD removed in screening process**)

BOD remaining = 372.3 kg/day

TSS Remaining:

TSS remaining = 350.4 kg/day – 87.6 kg/day

TSS remaining = 262.8 kg/day

According to the Water and Wastewater Calculations Manual, 40% of BOD and 55% of the COD entering the equalization tank is retained. The other percentage of these values passes through and enters the activated sludge tank. The sludge flow rate (SFR) is also subtracted since it will also be retained in the equalization tank. The SFR is the amount of sludge that has settled on the bottom of the equalization tank. The sludge that settled below the tank is pumped out with the use of a sludge pump.

BOD Removal:

BOD Removed = (372.3 kg/day) (40%)

BOD removed = 148.92 kg/day

BOD Remaining = 372.3 kg/day – 148.92 kg/day

BOD Remaining = 223.38 kg/day

TSS Removal:

TSS Removed = (262.8 kg/day) (55%)

TSS Removed = 144.54 kg/day

TSS Remaining = 262.8 kg/day – 144.54 kg/day

TSS Remaining = 118.26 kg/day

Sludge Flow Rate

$$SFR = \frac{\text{TSS Removed}}{\text{S.G} \times D_{water} \times \%\ \text{Solid content}}$$

$$= \frac{144.54\ \text{kg/day}}{2.65 \times 1000 \frac{\text{kg}}{\text{m}^3} \times 0.045}$$

SFR = 1.21 m^3/day

5.3.3. ACTIVATED SLUDGE TANK WITH HOLLOW FIBER MEMBRANE

The activated sludge tank, containing the hollow fiber membrane, is considered the heart of the system. It is where the wastewater is converted into its reusable form and decanted into a water tank for storage and reuse. The entire process of aeration, settling, and membrane filtration takes place in this tank.

5.3.3.1. Dimensions of the Tank

The computations below must be followed in order to come up with the volume and dimensions of the tank.

Step 1. Calculation for the flow of BOD and TSS entering in Activated Sludge Tank

$Q_{in} = Q_{avg}$ - SFR

Q_{in} = 876 m^3/day – 1.21 m^3/day

Q_{in} = 874.79 m^3/day (50% will only proceed)

Q_{in}=437.39 m^3/day

$$BOD_{in} = 50\% \left[\frac{\text{BOD Loading} - \text{BOD Remaining}}{Q_{in}}\right]$$

$$BOD_{in} = 50\% \left[\frac{372.3\,\frac{kg}{day} - 148.92\ kg/day}{437.39\ m3/day}\right]$$

BOD_{in} = 0.25 kg/m^3

BOD_{in} = 250 mg/l

S_O = 250 mg/l

Amount of BOD coming to STP (S_O) = 250 mg/l

BOD to be left in effluent discharge (S_e) = 30 mg/l

$$TSS_{in} = 50\% \left[\frac{\text{TSS Loading} - \text{TSS Removed}}{Q_{in}}\right]$$

$$TSS_{in} = 50\% \left[\frac{262.8\frac{kg}{day} - 144.53\ kg/day}{437.39\ m^3/day}\right]$$

TSS_{in} = 0.27039 kg/m^3

TSS_{in} = 270.39 mg/l

Step 2. Estimation of soluble BOD_5 will enter to hollow fiber membrane.

To estimate, determine the BOD5 of the effluent suspended solids assuming 85% biodegradable solids and 1.45 mg of oxygen is consumed per mg of cell oxidized.

Biodegradable Effluent Solids = (Effluent BOD5)(% biodegradable)

= (30 mg/L)(85%)

= 25.5 mg/l

BODu of Biodegradable Effluent Solids = (25.5mg/L) (1.45 mg O2/ mg cell)

= 36.98 mg/l

BOD_5 = 0.67 (BOD_u)

BOD5 = 0.67 (36.98 mg/l)

BOD_5 = 24.8 mg/l

COD = 2(BOD_5) {approx. twice of BOD_5}

COD = 2(24.8 mg/l)

COD = 49.6 mg/l

Effluent BOD = influent soluble BOD + BOD of effluent suspended solids

30 mg/L = S + 24.8 mg/L

= 5.22 mg/l

Step 3. Check the biological treatment Efficiency based on soluble BOD

$$E = \left[\frac{S_0 - S}{S_0}\right]$$

$$E = \left[\frac{250\frac{mg}{l} - 5.22\ mg/l}{250\ mg/l}\right]$$

E = 97.91%

Therefore Extended aeration process of Activated Sludge Process is adopted that has the BOD removal efficiency ranging between 95% - 98%.

Step 4. Calculate the Dimensions of the Aeration Tank

Volume of the tank can be designed by assuming a suitable values of MLSS and θ_c.

(or $F/_M$ ratio)

For Extended Aeration System

MLSS = 3000- 5000 mg/l (assume 3800 mg/l)

$$\frac{MLVSS}{MLSS} = 0.8$$

$F/$ ratio = 0.1 – 0.18 (assume 0.12)

Volume of the tank is calculated by the equation

$$VX = \frac{Y\,Q_0\,(S_0 - S)\theta_c}{1 + K_d\,\theta_c}$$

OR

$$F/M = \frac{Q_0 \; S_0}{VX}$$

$$V = \frac{876\frac{m^3}{day} \times 250 \text{ mg/l}}{3800\frac{mg}{l} \times 0.12}$$

Volume = 480.26 m^3

Let us adopt Aeration Tank dimensions as

Depth = 3- 4.5 m (**adopt d= 3.5 m**)

Width = 5-10 m

$\frac{\mathbf{B}}{\mathbf{D}}$ ratio = 1.2 to 2.2 (adopt it as 2)

Width = 7 m

Than

$$L = \frac{V}{BD} = \frac{480 \text{ m}^3}{7 \times 3.5} = 19.59$$ (**say L = 20**)

Therefore Volume provided = 20× 7× 3.5

= 490 m^3

i. Check for aeration period or HRT

$$t = \frac{V}{Q} .24 \text{ hrs}$$

$$= \frac{490 \text{ m}^3}{\mathbf{876\ m^3/day}} . 24 \text{ hrs}$$ = 13.42 ~ say 14 hr

It should lie between 10 hour-15 hours **OKAY**

5.3.3.2. Oxygen Requirement

Oxygen requirements estimation provide the extent of air required to be provided per day of aeration. The theoretical requirements of the oxygen have to be calculated from the BOD_5 and the concentration of microorganisms that should be present in the wastewater per day. Typical period of aeration is about 4 to less than 24 hours per cycle. For the system, aeration time shall be 8 hours per cycle of treatment after 1 hour feeding time for the tank.

Step 1. Theoretical Oxygen Requirement

$$BOD_u \text{ used} = \frac{Q_{in}(S_o - S)}{0.67}$$

$$= \frac{437.39\frac{m^3}{day}\left(250\frac{mg}{l} - 5.22\frac{mg}{l}\right)10^{-6}kg}{0.67 \times 10^{-3} m^3}$$

= 159.79 kg/day

Step 2. Solve first the observed yield in the system

$$Y_{obs} = \frac{y}{1 + 0.06\,\theta_c}$$

$$= \frac{0.5}{1 + \frac{0.06}{day}(5\text{ days})} = \mathbf{0.3846}$$

Step 3. Than solve increase in the mass of MLVSS

$$P_x = 0.3846\,(437.39\,m^3/day)\frac{\left(250\frac{mg}{l} - 5.22\frac{mg}{l}\right)10^{-6}}{10^{-3}}$$

= 41.17 kg/day

Step 4. Calculate for the amount of oxygen required

O_2 required = BOD_u used – 1.42 (mass of organism wasted, P_x)

(1.42 is the oxygen demand of biomass in gm per gm of sludge wasting)

= 159.79 kg/day -1.42 (41.17 kg /day)

O_2 required = 101.32 kg/day

Step 5. Solve for theoretical oxygen requirement

$$\text{Theoretical } O_2 \text{ air required} = \frac{O_{2\ \text{required}}}{(\text{weight of air})(\%\ O_2 \text{ by weight})}$$

$$= \frac{101.32\ \text{kg/day}}{(1.202\frac{\text{kg}}{\text{m}^3})(1.218\ O_2\ /g_{\text{air}}}$$

(At 20^0C and 101.325 kPa, dry air has a density of 1.202 kg/m^3)

Theoretical O_2 required = 69.20 m^3/day

Step 6. Actual air requirement

The oxygen transfer efficiency for an air diffuser is 8% as for the actual air required

With a safety factor of 2.

$$\text{Actual air requirements} = \frac{\text{Theorectical air required}}{8\%\ \text{of } O_2\ \text{transfer efficiency}}$$

$$= \frac{69.20\ \text{m}^3/\text{day}}{8\%}$$

= 865 m^3/day

Actual air requirement= 0.60 m^3/min

Actual air requirement

= 21.19 ft^3/day

Design air required = (Actual air requirement) (Safety factor)

= (0.60 m^3/min) (2)

= 1.20 m^3/min

Design air requirement = 1.20 m^3/min × 35.31

= 42.372 ft^3/min

= 0.70 cfs

5.3.3.3. Sludge Wasting

In Activated Sludge Treatment process, Sludge wasting is a important procedure as it is defined as the quantity of sludge that is removed from the tank per day. The tank must contain a sufficient amount of sludge to support the growth of microorganisms. The following steps are to be followed in calculating for the sludge wasted.

Step 1. Calculate for the sludge wasting flow rate

$$\theta_c = \frac{(V)(MLVSS)}{(Q_{sw})\ (MLVSS) + (Q_0)(X_e)}$$

$$5 \text{ days} = \frac{490 \text{ m}^3 \times 3000 \text{ mg/l}}{(Q_{sw} \times 3000 \text{ mg/l})\ (437.39 \text{ m}^3)(50 \text{ mg/l})(0.8)}$$

Q_{sw} = 92.168 m^3/day

Step 2. Calculating increase in MLSS (P_y) by using increase in MLVSS (P_x) = 41.17 kg/day

$$P_y = \frac{P_x}{0.8} = \frac{41.17}{0.8}$$

P_y= 51.46 kg/day

Step 3. TSS lost in effluent is calculated than

P_L = (Q_{in}- Q_{sw}) (effluent TSS)

= (437.39 m^3/day- 92.168 m^3/day) (50 mg/l)

P_L = 17.26 kg/day

Step 4. Quantity of sludge to be wasted daily

Wastewater Sludge = P_y - P_L

= (51.46 kg/day – 17.26 kg/day)

Wastewater sludge= 34.2 kg/day

5.3.4. HOLLOW MEMBRANE FIBER

The following specifications are the specifications of Membrane Bioreactor suitable for the treatment of waste water of the Institute depending upon the Indian scenario.

Figure 5.2. Components of an MBR facility

Table 5.3. Hollow Fiber Membrane Specifications

Model	MBR-25F (MBR-25FR)
Design flow	10-20 L/hr-m²
Recommended flow	5.0-9.0 m³/day
Standard Filter Area (m²)	25m²
Length × Width (mm)	2100×800
Membrane Material	PVDF (Polyvinylidene fluoride or Reinforced PVDF)
Diameter of Hollow Fibre	1.0/1.66mm (normal) or 2.0/2.5mm (Reinforced)
Pore size	0.1 μm
Porosity	>80%
Temperature	5-45⁰C
pH	2-12
BOD	< 2 mg/l
TSS	< 1 mg/l
Lifespan (after installation)	3-5 years

Computing for daily permeate flow per cycle:

$$Q_p = (20\ l/hr/m^2)\left(\frac{1\ m^3}{1000\ l}\right)\left(\frac{12\ hr}{1\ cycle}\right) \times 25\ m^2 \times 5\ cassettes$$

$$\mathbf{Q_p = 30\ m^3/cycle}$$

Computing for daily permeate flow

$$Q_{p\ avg} = 30\left(\frac{m^3}{cycle}\right)\left(\frac{1\ cycle}{0.5\ day}\right)$$

$$\mathbf{Q_{p\ avg} = 60\ m^3/day}$$

Since the membrane has a very small pore size, there will be lesser chance for impurities in the wastewater to pass through, resulting to a BOD and TSS of less than 2 mg/L and 1 mg/L, respectively.

5.3.5. SUMMARY OF TREATMENT PROCESS

The following shows the summary of the detailed design of the entire MBR Facility, from screening, to design of activated sludge process.

Table 5.4.Summary of Membrane Bioreactor

Screening	
BOD Loading	438 kg/day
BOD removed	65.7 kg/day
TSS Loading	350.4 kg/day
TSS removed	87.6 kg/day
Screen Mesh Specifications	
• Spacing	20 mm
• Basket Dimensions Length Width Height	 50 cm 10 cm 10 cm
Equalization Tank	
BOD Loading	372.3 kg/day
BOD removed	148.92 kg/day
TSS Loading	262.8 kg/day
TSS removed	144.54 kg/day
Sludge Flow Rate	1.21 m^3/day
Activated Sludge Process	
BOD Loading	223.38 kg/day
TSS Loading	118.26 kg/day
Influent flow rate (Q_{in})	437.39 m^3/day
Influent BOD (S_o)	250 mg/l

Biodegradable Effluent solids	25.5 mg/l
BOD of Biodegradable effluent solids	36.98 mg/l
BOD_5	24.8 mg/l
COD	49.6 mg/l
Effluent BOD (S)	5.22 mg/l
Efficiency	
Tank Dimensions • Length • Width • Height	 20m 7m 3.5m
Volume	490 m^3
Feeding Time	1 hour
Aeration Time	8 hour
Settle time	2 hour
Decant Time	45 min
Idle Time (Sludge wasting & membrane backwashing)	15 min
HRT	12 hours
Sludge Wasting flow rate (Q_{sw})	34.2 kg/day
Hollow Fiber Membrane	
Average Daily Design Flow	60 m^3/day
BOD	< 2 mg/l
TSS	< 1 mg/l

CHAPTER -6

CONCLUSION AND SUMMARY

Following are the conclusions that can be drawn from the study entitled "Decentralized Wastewater Treatment for an Educational Institute" covering the campus of Delhi Technological University:

- Decentralized Wastewater Treatment plants plays an important role at Global level in the management of water quality of river, lakes, estuaries and aquifers by treatment the wastewater at the source1thus limiting the pollution of nearby water bodies and are generally upgraded with facilities enhancing nutrient removal, disinfection or solid removal and by means of membranes for greater efficiency.
- Small wastewater treatment plants assure a greater level of environmental sustainability by supporting the potential reuse of treated wastewater as well nutrient recovery.
- The case study covers the treatment of campus domestic waste and waste coming from campus departments consisting of high content of organic matter that can be effectively treated using advanced Membrane Bioreactor Technology using Hollow Fiber Ultrafiltration Membrane that is capable enough for the design of treatment unit that helps in meeting the objective of discharging an effluent complying with standards set up by Central Pollution Control Board (CPCB)- Schedule IV which is given by "General Standards for Discharge of Environmental Pollution PART A. The entire MBR Facility covered a land area of 60 m^2 that is proposed to be located inside the campus. Different biological and physical treatments applied to the wastewater resulted to an effluent passing the standards for bathing and other primary contact recreation.
- Membrane Bioreactors gives a high level of wastewater treatment making it adequate for reuse. From the study and design it can be seen that the effluent coming from the treatment plant meet the standards stated by Government of India that notified the standards of polluted effluents for discharge on land for irrigation or various other purposes like gardening, car washing under Environment (Protection) Rules 1986. As to this, people in society can in this way, utilize the treated water as a water supply for human diversion.
- Sludge wasted from the system can be converted into sludge cake through filter press and then, as a soil conditioner when dried. Therefore, the system has been also able to meet the

requirements of not having any discharge from the facility wasted or discarded by converting it into a renewable resource.

- The construction of the facility comprising decentralized wastewater treatment system using membrane technology can be of great benefit for the public institutions with small population and cluster of domestic households in the promotion of sustainable development, proper sanitation, and a healthy and pollution free water bodies and environment for everybody to live in.

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