Development of Membrane Based Septic Tank in Treating Domestic Wastewater

BY

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Certified that the contents and forms of the thesis entitled "Development of membrane base septic tank in treating domestic wastewater" submitted by Mr Saadat Ali have been found satisfactory for the requirement of the degree.

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Saadat Ali

TABLE OF CONTENTS

List of Abbreviations

MBST	Membrane base septic tank
R_T	Total resistance
R_C	Cake resistance
R_M	Intrinsic membrane resistance
R_F	Resistance due to pore blocking
EPA	Environment Protection Agency
IESE	Institute of Environmental Science and Engineering
NEQS	National Environmental Quality Standards
WHO	World Health Organization
NTU	Naphthalometric turbidity unit
TMP	Trans-membrane pressure
P	Phosphorous
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
SS	Suspended Solids
MGD	Million Gallon Per Day
TC	Transition Countries
DC	Developing Countries

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Centralized treatment systems are complex and expensive in terms of construction, operation, and maintenance. Whereas decentralized systems are simpler and low cost in operations at or near the point of wastewater generation. Therefore, the most suitable approach for sanitation in developing countries is decentralized on-site treatment of wastewater. Several options are available for on-site wastewater treatment. Among them, on-site anaerobic treatment such as septic tank systems is considered the best suited. The septic tank is a conventional on-site wastewater disposal system providing only primary treatment (settlement of solids) offering little biological degradation. To further improve the quality of treated water, conventional septic tank can be modified by the introduction of membrane module capable of effective rejection of suspended solids as well as associated particulate organic matter. The study reveals that a pilot-scale membrane based septic tank using flat-sheet woven fiber microfiltration membrane (WFMF) module is able to remove SS 65%, Turbidity 99%, COD 60%, coliform (99%) and even N 50%, P 45% from institutional wastewater. Effluent of the membrane septic tank can be used for horticulture, landscaping and any other non-potable purposes.

CHAPTER # 1

INTRODUCTION

BACKGROUND

More than a billion people globally do not have approach to fresh/potable water. Alone 38 million people of Pakistan don't have access drinkable water (Riaz, 2009). Pakistan is already one of the most water-scared countries in the world, a circumstance which is going to degrade into complete water scarcity (World Bank, 2005). One of the solutions to meet up rising water demand is water reclamation and reuse for non-potable purposes (Anderson, 2003). There are two main concepts to wastewater treatment, centralized and decentralized wastewater treatment (Wilderer and Schreff, 2000; Lens et al, 2001).

The centralized system, sewer pipes run from each house to a main collection point where the wastewater is treated and then typically discharged into surface water like a river or lake. These systems are expensive to build and require trained operators to run them.

In Pakistan 1% of the domestic wastewater receives treatment (GOP, 2002). A wastewater treatment plant (WWTP) in Islamabad has three phases, but out of three, one is functional. For big city like Karachi, it has only two trickling filters and the effluents usually receive primary treatment. In Lahore there are some screening and grit removal small units, but they are barely functional. Faisalabad has a WWTP in which wastewater receives primary treatment. Rural areas of Pakistan WWT systems are nonexistent, which promotes pollution of surface and groundwater (PWG, 2008).

The present deteriorated situation due to mismanagement of WW collection system e.g. 1.6 million peoples of Rawalpindi city generates 70MGD of wastewater. Currently only 30 % of the total WW is collected by WASA and the residual 70% of the WW is being disposed of into open drains of Nalluh Lai (Islamulhaq, 2008).

Residential areas without WWT depend only on on-site treatment of wastewater, e.g. latrines and septic tanks for preliminary treatment (Chaggu et al, 2002).

Septic tank works over principle of flotation and sedimentation and clear water overflows to pubic sewer or leachfield if sewer system is not available. As per Model Building/Zoning Regulations, in Punjab, it is compulsory to have a septic tank in each building (GoPb, 2006).

Septic systems mostly used in those areas when centralized STP is not available, they carefully treat wastewater which produced from domestic applications such as wastewater comes from toilets, kitchen, and laundry. This wastewater can have some disease-causing germs that should get treatment to guard human health (Michael, 2004).

The septic tank is the mainly functional system for on-site treatment of wastewater. But the treated water quality of the septic tanks is quite poor despite of operated at long HRT (Mgana, 2003; Mohammad et al, 2007).

Septic systems, consisting of a septic tank followed by a soil absorption system, are the preferred on-site WWTS for most homeowners because they are inexpensive to install and require a minimum maintenance. When accurately installed in appropriate soils they can offer a sufficient level of WWT for long period of time. However, the septic tank in a conventional on-site WWT system provides only primary treatment, but little biological degradation. (Moore, 2010)

In 2009 Institute of Environmental Sciences and Engineering (IESE), National University of Sciences and Technology (NUST), Islamabad have been successfully setup and operated two bench-scale Membrane Bioreactor (MBR) systems for WWT. The performances of present laboratory-scale MBR units at IESE-(SCEE) laboratory have proven that MBR systems is a consistent and efficient process which can be effectively used to reclaim water. However, the main weakness of MBR systems is there high operation cost. Although membrane costs have decreased significantly over the last years resulting in a decrease in investment costs, but membrane fouling control brings to elevated energy demands and has become the main part to operation cost (Anja, 2010).

Now IESE with the collaboration of Asian Institute of Technology (AIT), Thailand has planned to conduct research on membrane based septic tank (MBST). Twenty flat sheet Woven Fiber Microfiltration (WFMF) modules for this study were provided by the partners AIT. In this study, a membrane module was submerged in the septic tank to reclaim WW for non-portable uses.

Membrane Septic Tank system was able to eliminate Suspended Solids (SS), Chemical Oxygen Demand (COD) and even Nutrients in form of (N) and Phosphorus (P) from domestic WW (Hitachi, 2002). Effluent of the membrane based septic tank can be used for horticulture, landscaping and any other non-potable purposes.

1.1 OBJECTIVE OF STUDY:

The research has following objectives:

A. Design and install Membrane Based Septic Tank (MBST) at IESE Building, NUST Campus, Sector H-12, Islamabad.
B. Investigate treatment performance and operational parameters of the membrane based septic tank in terms organic matter, solids, nutrients removal, TMP rate etc;

C. Prepare an operating manual for institutional (IESE building) WW.
D. Evaluate the maintenance requirements, economic viability and potential of treated WW in septic tank for various reuse/non-potable applications.

1.2 SCOPE OF STUDY:

Following points are explaining the scope of the project:

A. Construction of septic tank at the premises of IESE Building.
B. Setup and install Membrane modules into the Septic Tank.
C. Monitoring of TMP at constant Flux and maintenance in term of physical and chemical cleaning of membranes.
D. Analyze MBST performance in terms of physical, chemical and biological parameters.

LITERATURE REVIEW

Water is precious for all aspects of life and the main feature of our earth. 97 per cent of all water is found as saline in oceans and from the remaining fresh-water, only 1 per cent is accessible (UN-HABITAT, 2010). Almost 40% of the world population lives under water scarcity and expected to increase to 60% by 2025(Hoffmann, 2009). Nearly 900 million people still do not have access to clean and safe water (UNDESA, 2009) and some 2.6 billion do not have access to satisfactory sanitation (WHO/UNICEF, 2010). Water scarcity occurs even in areas where there is sufficient rainfall or freshwater (WHO, 2010).

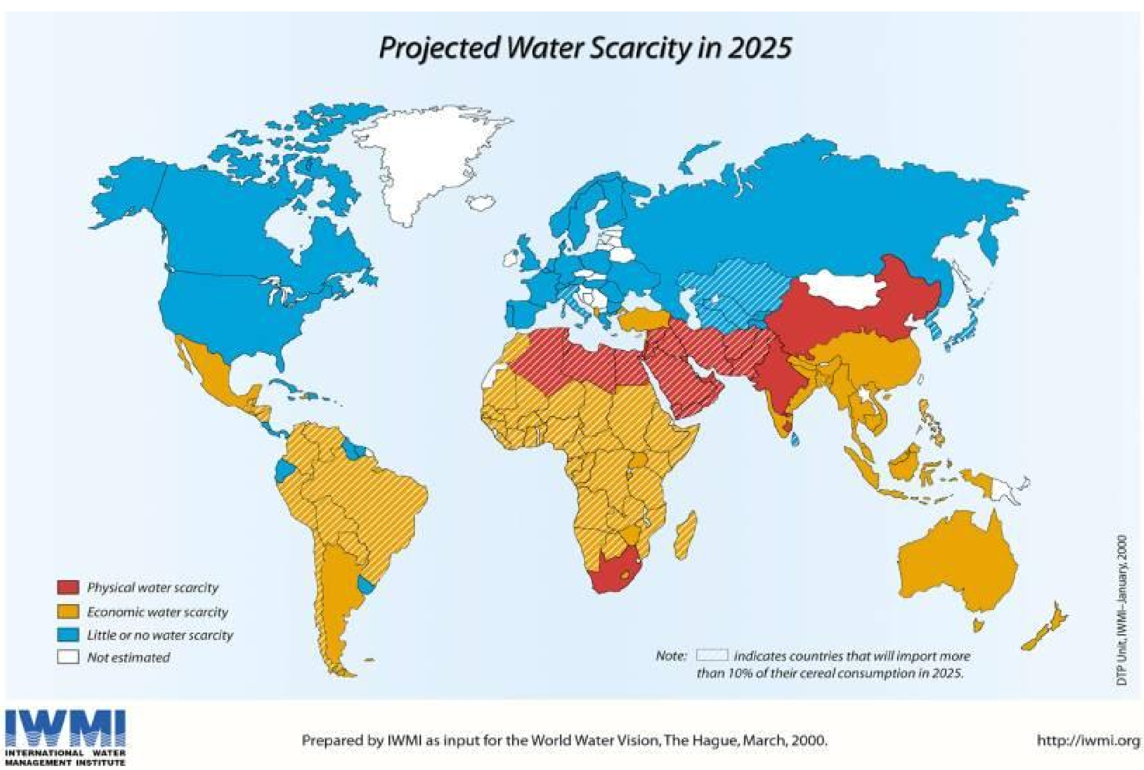


Figure 2.1: Water scarcity trend of world (www.waternunc.com/.../waterscarity2025.jpg)

Water scarcity affects one in three people on every continent. The situation is getting worse as needs for fresh water rises with increase in population growth, urbanization and household and industrial use (WHO, 2009). For climatic reasons, differences in average annual precipitation divide the world into water-scarce and water-sufficient regions. Similar divides exist within countries themselves. (Gregor, 2004)

2.1 WASTEWATER TREATMENT

Wastewater is used water and that must be treated before it is discharged into another water resource, so that it does not cause further pollution of fresh water reservoirs. Wastewater generated by a variety of sources. Everything that flushes from toilet or wash down to drain is wastewater. Runoff, along with a variety of pollutants, goes down to the main sewer line end up at a WWTP. Wastewater is also generates from agricultural and industrial sources. (SDWF, 2008)

Domestic wastewater can also be segregated into different types according to their source. Usually two types are renowned, black water generated from toilets and grey water from bath, washing and kitchen (Henze, 2001). The majority of the organic matter, nutrients and harmful bacteria's in domestic wastewater are in present black water (Terpstra, 1999) makes its management of the great significance (Lettinga et al, 2001).Characteristics of domestic wastewater, black water and grey water are presented in Table 2.1

Table2.1: Average characteristics of domestic wastewater, black water and grey water from conventional toilets (Henze and Ledin, 2001)

factor (mg/1)	Domestic wastewater	Black Water	Grey Water
BOD	110–410	310–610	110–410
COD	200–750	910–1500	210–710
N	21–81	120–320	9–31
P	5–22	45–95	3–8

2.2 WASTEWATER TREATMENT CONCEPTS

Wastewater treatment approaches ranges from the conventional centralized systems to cluster systems up to onsite decentralized systems. The centralized treatment systems typically collect and treat large quantity of wastewater, which require larger pipes, big infrastructure (USEPA, 2004).Alternatively, decentralized treatment systems treat wastewater of individual dwellings (Tchobanoglous et al, 2004). Although decentralized treatment systems treat and recycle wastewater on or near the point of generation, on the other hand centralized treatment systems recycle/dispose far-off from generation point. Cluster systems can be centralized or decentralized which can provide treatment to more than a home and more (Jones et al, 2001).

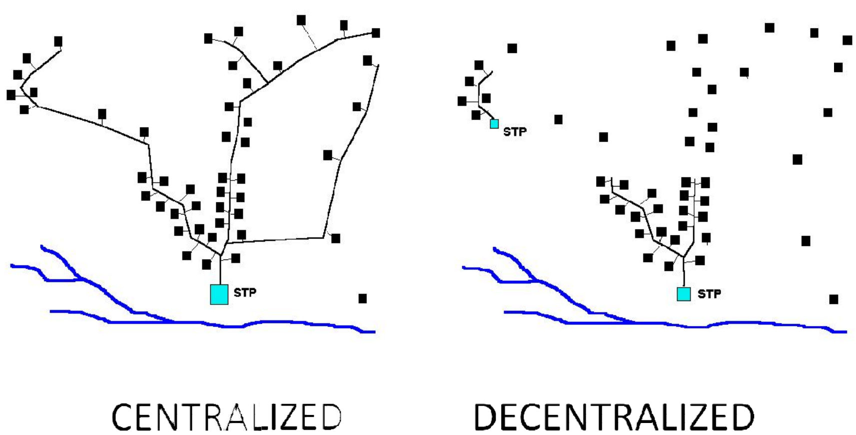


Figure2.2: Centralized and decentralized approaches (Rocky Mountain Institute, 2004)

2.2.1 CENTRALIZED TREATMENT

Centralized systems involve collection and treatment of large quantities of wastewater (West, 2001). Thus, construction of centralized treatment facility for small communities of low income countries results in burden for the public (Parkinson, 2003).

Centralized wastewater treatment has great value in the managing the water resources of new communities. The basic concept for the use of centralized treatment is to sever individual sources, collect and transport wastewater to a centralized place for treatment and dispersion of effluent to the environment and/or reclamation. While centralized systems served society sound, but new technologies are required as a outcome of population growth, and the need to grow more sustainable approaches to save water resources (Petros et al, 2009).

Still several treatment systems are not successful in DC and unsustainable because they were just copied from Western regions without considering the suitability of the equipment for the society, land, and environment. Numerous implemented installations were discarded because, high cost of operation and maintenance (Leir, 1998). Merits and demerits of centralized systems are listed in table 2.2.

Table 1.2: Advantages and disadvantages of centralized systems

Aspects	Advantages	Disadvantages
Technology	Well-known and developed technology	poor treatment ability: underutilization (dry weather), restrictions (heavy rain)
	High performance according to modern standards	Leaking sewer structure
		Little flexibility
		Financing expensive for construction (hard ware)
Economic	Predictable investment and O&M costs	Investments not ensured in a continuing perception

		Low efficiency (WB, 2001)
environmental	shelter of water resources	High utilization of water as collection, thus system not suitable for areas with water shortage
	Control and protection sanitary security	Reliance on centralized systems can lead to large exposure
	security of infrastructure because of decrease of flooding	Strength of nutrients
	community acceptance	Risks of pollution (Leaking sewerage)
	Control over a single centralized system	
	ease in operation	
	Easy to O&M for community	

Source: (Zaidi, 2005, adapted)

2.2.2 DECENTRALIZED TREATMENT

Decentralized wastewater management is a system for disposal/recycling of wastewater from individual homes, remote communities, industries or institutions, on or near the generation point. (Tchobanoglous, 1995)

Decentralized systems are suitable for low-density communities and are economical than centralized systems. The basic components of decentralized systems are conventional septic systems, superior designs of on-site and cluster systems. Up till now, the efficiency of the decentralized systems relies upon the standard check up and maintenance. Collection, treatment and disposal are basic mechanisms of any wastewater treatment system but collection has the least important for treatment of wastewater. However, collection expenses contain more than 65 percent of the total funds for wastewater management in a centralized system, mainly in those areas with low population densities (Hoover, 1999). On the other hand decentralized system keeps the collection component as minimal as possible. Decentralized wastewater systems are getting popular because they are less resource demanding and more ecologically sustainable form of sanitation (Tchobanoglous and Crites, 2003). Other merits and demerits of decentralized wastewater systems are listed in table 2.3.

Table 2.3: Merits and demerits of decentralized systems

Aspects	Advantages	Disadvantages
Technical	Short /straightforward collection systems	Unfamiliar technology
	appropriate at any scale	performance of prototype applications not yet High enough
	Flexibility	
	Resource efficient treatment capacity	
	Low costs for sewer system	
Economic	healthy and consistent/ low cost technologies	Operation & maintenance expenses repeatedly underestimated
	Balanced investment peaks	Expenditure for training
	Take little time to install infrastructure	Control over multiple facilities
	Source manage	
	little water use for transport	
Social / environmental	Little Sludge production	O & M know how required (joint information)
	Treated water as bonus resource to scarce area	Public approval
	greatest reckaimation and reuse of water	Hygienic hazards if O&M failures
	Small hazard of contamination	
	Small dilution of nutrients	
	fewer land use	
	Individual liability amplified	

Source: (Zaidi, 2005, adapted)

2.3 CENTRALIZED VS DECENTRALIZED TREATMENT

The centralized wastewater treatment concept has shown its limits in some developing countries, particularly in rapid-growing cities with inadequate water resources. Decentralized systems with their modular makeup are leading to be a successful method in facing fast urban growth and with its prospective to nearby reuse. The examination of new trends in wastewater treatment and the main merits and demerits of both centralized, decentralized treatment systems are listed in table 2.4.

Table 2.4: Assessment of centralized vs. decentralized systems

Treatment systems	Literature
Centralized wastewater treatment	The treatment price per unit volume is still viable then decentralized treatment(collection system previously present) (Bakir, 2001; Ho and Anda, 2004; Ho, 2005; Maurer et al., 2006);
	as regards 75-85% of the total expenses are connected to the collection system (Maurer et al., 2006)
	The collection system needs renewal after 50-60 years (Maurer et al., 2006)
	Rainwater is frequently interred from residential areas by infiltration and diluted wastewater requires more expensive treatment approaches(Ho, 2005; Libralato et al., 2008)
	Dependency on electrical energy supply (Maurer et al., 2006);
Decentralized wastewater treatment	It supports recovery and reuse of treated effluent(Weber et al., 2007; Borsuk et al., 2008; Brown et al., 2010)
	It decreases the issue related to discharge and collection, (Ho, 2005)
	It has potential to decrease eutrophication events (Libralato et al., 2008; Brown et al., 2010)
	Small WWT permit the division of domestic WW and rainwater, avoid dilution factor (Ho and Anda, 2004; Ho, 2005)
	It has potential to diminish the health risk by preventing disastrous events(Libralato et al., 2008)
	Small WWTPs are usually compact, (Brown et al., 2010)

Source: (Giovanni, 2011 adopted)

2.4 THE CHALLENGES TO WASTEWATER MANAGEMENT

Water is our basic need and it's hard to survive without it, and there are no alternatives. Some researchers have likened the matter of water shortage to our present economic fight over petroleum. With no petroleum, we can't use our vehicles, but we can walk to school/work. But in the case of water doesn't relate with inconveniences we are facing the issue of sustaining life itself.

The importance of freshwater supply and safely treated wastewater return cannot be overemphasized. No matter how hard we try, we are still a long way from the most efficient, economic and reliable ways to ensure our cities are properly equipped and ready for the challenge (Nelik, 2012). Although significant resources, water stress is rising, both in terms of scarcity and quality. Globally, considerable growth has been made in WWT for developed areas as compared to rural areas which holdup far behind. WWTP stand for one of the main investments because of its high assets cost with addition to operation and maintenance (Paraskevas et al., 2002).

The amount of wastewater generated by household and commercial sources has amplified with population, urbanization, enhanced living condition, and financial growth. While urban residents in DC increase and seeks better living standards, requires superior amounts of clean water (Qadir et al., 2008). Issues related to water sanitation starts from the increase in urban resettlement and the practice of disposing polluted wastewater. The uncontrolled increase in urbanization has made development and extension of water and sewage systems very hard and expensive to accomplish.

The countries wastewater volume is growing, but is still not enough to treat all the generated waste. The elevated cost also suggests a requirement for alternatives to centralized STP which are inexpensive, only if they are environmentally sustainable. (USEPA, 2002).

2.5 SOLUTIONS FOR WATER SCARCITY

In order to make any improvements related the issue of water shortage, more than one solution is needed. Good technological solutions don't have to be complicated solutions will be different in different regions of the world. Few times, new centralized systems possibly suitable. While onsite systems might work in a different place. Table 2.5 lists many common wastewater problems encountered in world, and the suggested solutions.

Table 2.5: Wastewater problems and solutions

Problems	Solutions
Common wastewater issues	
Wastewater issues are not recognized	Arrange wide review to determine watershed's present wastewater volume • Execute biological stream monitoring • Discover needs of residents
Untreated Wastewater discharged	In isolated properties, build an onsite system Otherwise think about combined solutions: • Cluster systems • conventional treatment systems
Wastewater treatment needs new improvement	Contribute in permitting new plants to classify requirements for new systems.
Problems with traditional systems	
Traditional plants generated untreated wastewater	protract and raise funds • Upgrade capacity • Fix inflow issues • Remove combined collection system overflows
Treating more wastewater than capacity	Help to manage and reduces infiltration
Problems with onsite systems	
Onsite system failure	Maintain the onsite system For community problem, Cluster systems conventional STP
Maintenance requirement	Educate the professionals to work

Source: (WVWO, 2005 adopted)

Although water shortage is not a critical issue to all countries but several are experiencing the effect of water shortage but if this issue is not been solved quickly, it will grow to be a problem for many others in the coming few years. There are many procedures that can be useful in preserving water for future**.** One of those is to build up more efficient on-site wastewater treatment that can produce water of high quality which can be reused for non potable purposes (Schwikert et al., 2003).

The growing trend in wastewater reclamation and reuse is to consider wastewater reuse practices as an essential component of sustainable and integrated water resources management. The development of wastewater reclamation and reuse in many countries is related to water scarcity, water pollution control measures and protection of the aquatic environment, and to obtaining alternative water resources for the growing population (Takashi et al., 2011).

2.6 ON-SITE WASTEWATER RECLAIMNATION/RESUSE

Mostly on-site treatment systems are of the conventional kind and usually contain a septic tank along with the soil absorption system that allows treated water to penetrate into the soil. These systems are efficient at removing pollutants before they enter to the surroundings (Christopher et al., 2005). New strict performance requirements have directed to major improvements in the design of treatment systems. An anaerobic sewage treatment system are considered sustainable (Lettinga, 1996; Hammes et al., 2000) and appropriate for on-site systems (Zeeman and Lettinga, 1999) since they are low energy intensive, and also requires small foot print and simple design.

2.6.1 SEPTIC TANK

Septic tank is the system that allows the onsite treatment for wastewater at residence or small commercial units. The quiescent condition inside tank allows the portions of suspended solid to settle, floatable to rise up and provides storage space for biological activity (Clearinghouse, 2000).

The 1st reported application of domestic use of septic tank was in France in 1860 that was a 'box' located among the house and the cesspool trapped excrement, which reduced the solids and generate clean water which entered to the soil more quickly. In the America, household septic tank was 1st used in 1883 which have two-section tank design. After that the septic tank use increases rapidly and now it is implemented in many parts of the world (BUTLER et al., 1995).

Conventional septic systems, consisting of a septic tank followed by a soil absorption system, are the preferred on-site wastewater disposal system because they are inexpensive to install and require a minimum of maintenance. When properly installed in suitable soils they can provide an adequate level of wastewater treatment for many years. However, the septic tank in a conventional on-site wastewater disposal system provides only primary treatment (settlement of solids), but little biological degradation. This means that the soil absorption field receives a significant load of suspended solids. Not only are these suspended solids potentially high in harmful bacteria and pathogens, they also clog up the pores of the native receiving soil, eventually causing the system to fail. To minimize potential contamination of wells and surface water by conventional septic systems, regulations require large (100-foot) minimum separation distances between them. This has the effect of severely limiting the places on a lot where a conventional septic system can be installed. Until now, whenever a site for a conventional on-site wastewater disposal system could not found on a lot, due to poor soils, shallow groundwater or insufficient separation distances.

2.6.2 PROBLEMS AND PRACTICE

Table 2.6 lists the problem and their instant effects. The ordinary causes are related to the soil absorption system, which may be blocked and the tank being full of sludge, which also can block of the absorption zone.

Table2.6: Symptoms and immediate causes of septic tank problems

Symptom	Instant cause
Odor	Inadequate ventilation of drains Blockage of absorption zone Insufficient area of drainage field
Backflow of manure	Blockage of inlet of the drains Insufficient area of drainage field Tank is over sludge
Flooding of absorption feild	Blockage of inlet of the drains Blockage of absorption zone
Solids flow out from tank	Insufficient area of drainage field
	Tank is over sludge
Water channel pollution	Tank is over sludge ineffective or small tank
Pollution of Groundwater	Blockage of absorption zone Insufficient area of drainage field Tank is over sludge
Groundwater entered the tank /tank lifts	Absorption zone working properly but system location is incompatible
	High level of water table

Source: (Butler, 1995)

2.7 MEMBRANE-BASED ONSITE TREATMENT SYSTEMS

An on-site treatment system poses a tough issue for engineers. It needs a balance of appropriate levels of technology and the operational difficulty essential to attain good quality water collectively with sufficient consistency and ease to contain rare maintenance (Gaulke, 2005). Several technologies might be considered for on-site treatment but to reply the water shortage and the sludge problem right now membrane technology is seen as a promising technology. Membrane technology with its modularity is appropriate for space-saving on-site use.

2.7.1 MEMBRANE TECHNOLOGY

Membrane can b defined as a selective barrier which only permit a particular species to pass through whereas retaining the course of others. In water and wastewater treatment systems membrane filtration have four groups Microfiltration (MF), ultra filtration (UF), and Nano filtration (NF), Reverse osmosis (RO)

Use of membrane based systems has considerably improved, for water/ wastewater management (Anon, 2006). Mainly big-scale use of membrane technology is obviously set up in the developed countries, but a great enhancement is predicted in developing countries e.g. China (Anon, 2006). Membrane technology is attractive for the TC and DC as it gives complete barriers for controlling sanitation hazards and its new modifications allows good performance at all scales. Even though this technology has become more competent and also the costs of membranes have reduced radically (Churchhouse, 2000), but it remains too expensive for the population living in 3rd world countries.

2.7.2 WFMF MEMBRANES

In most real applications, a membrane will eventually become fouled. Operational strategies such as scouring, sub-critical flux operation, back flushing etc reduce the rate of fouling, but will not prevent the eventual fouling of the membrane. The ability to be cleaned and recover permeability after being fouled is a critical aspect of the technical viability of any membrane technology. It is usually possible to find a mixture of chemicals that will remove any given fouling layer. However, if chemical cleaning can be avoided the applicability, economics and environmental impact of the technology will improve greatly. It will also make the technology more sustainable in developing economies, where regular access to chemical cleaners may not be guaranteed. In previous investigations into WFMF, a major advantage was that the system never required a chemical clean. Mechanical agitation (e.g. pulsing) or drying was sufficient to remove the fouling layer. This is probably because the WFMF system does not have "pores" that can be penetrated by foulants as in a conventional rigid membrane. Accordingly, mechanical agitation and drying were tested as cleaning strategies in this project.

2.8 MEMBRANE BASE SEPTIC TANK

Conventional wastewater treatment techniques take more space and are less efficient, therefore it is important to evaluate advanced wastewater treatment technologies which produce reusable water in comparatively less time and space. But there is need of extensive research in the field of advance wastewater treatment to make them economically viable.

CHAPTER # 3

MATERIALS AND METHODS

WAPDA reported in 2002 that only 1% of the domestic and industrial wastewater receives treatment (GOP, 2002). According to the Water Situational Analysis of Pakistan, A wastewater treatment plant (WWTP) in Islamabad has three phases, but out of three, one is functional. For big city like Karachi, it has only two trickling filters and the effluents usually receive primary treatment. In Lahore there are some screening and grit removal small units, but they are barely functional. Faisalabad has a WWTP in which wastewater receives primary treatment. Rural areas of Pakistan WWT systems are nonexistent, which promotes pollution of surface and groundwater (PWG, 2008).

Demand management is reducing the quantity and/or strength of wastewater from the Wastewater generation point. If the quantity of wastewater generated can be reduced, then the size of facilities, such as sewers and WWTP can be reduced the related costs .For this purpose this study is conducted to develop a Sustainable water reclaim/reuse plan for IESE NUST.

3.1.2 DESCRIPTION OF STUDY AREA:

The plan encompasses following components:

- Construction of an on-site system modified with membrane filtration.
- Reducing wastewater flow to sewer through reclamation and reuse of wastewater from membrane based septic tank (MBST).
- Producing highly-treated effluent suitable for landscaping, agriculture and non potable reuse.

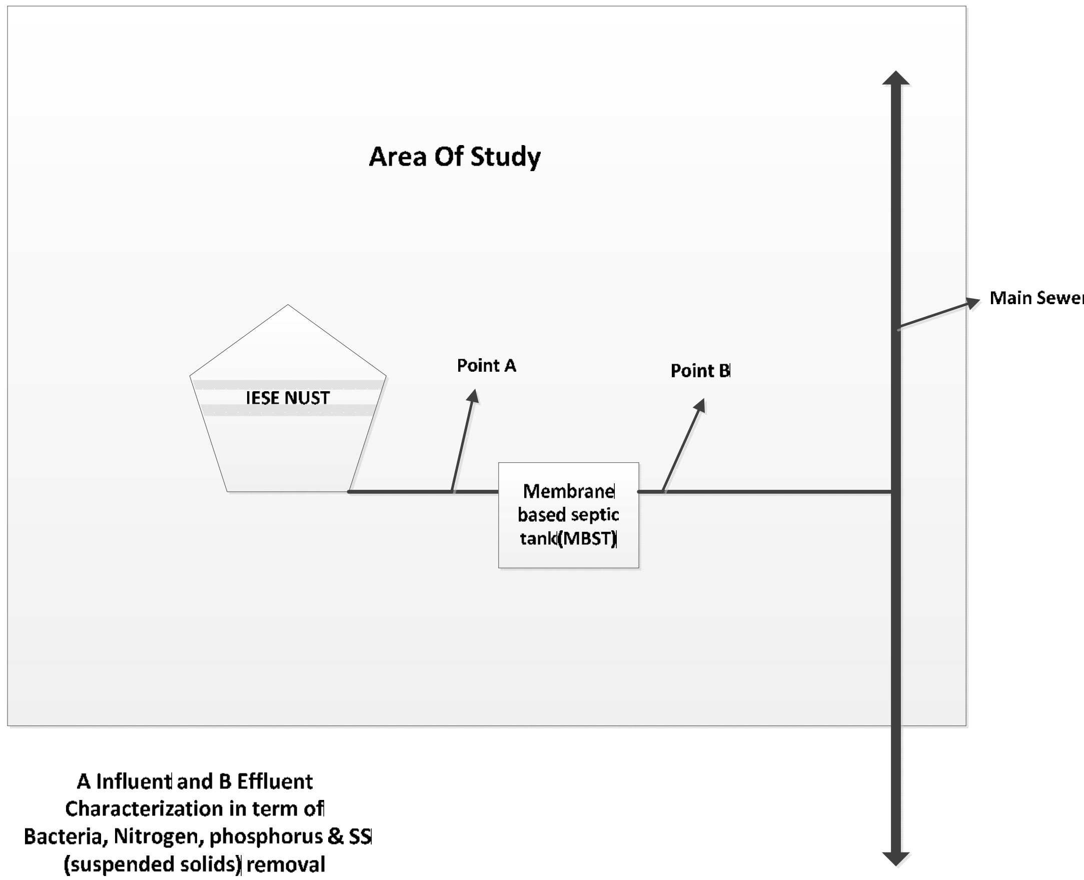


Figure 3.1: Study Area limits

3.2 CONSTRUCTION OF SEPTIC TANK

In this study, a septic tank was constructed near IESE Building at NUST campus, H-12 Islamabad detailed pictures of construction phase and operational phase are shown in annex B. Design of septic tank is shown in **Figure 3.2 & 3.3**, and a pilot-scale membrane module was proposed to be used in the septic tank to reclaim wastewater for non-potable purposes Septic tank of one thousand gallon volume was constructed on the basis of wastewater generation that is shown in the Table3.1.

Table3.1 sewage generation rate at IESE

Designations	numbers	Production of wastewater Per	Total volume of water per

of persons		capita per day(liters)	day in liters
Teachers	15	20	300
Students	150	20	3000
Staff	30	20	600
Total			3900liters/day

Wastewater flows from IESE to the septic tank. The tank is designed to retain waste water and allow solids to settle to the bottom. These solids are partially decomposed by bacteria to form sludge. Grease and light particles float, forming a scum layer on top of the waste water. Baffles installed at the inlet and outlet of the tank to help prevent scum and solids from escaping. Septic tanks have a partial concrete dividing wall in the center, thus making two compartments. This helps ensure the sludge does not get forced out of the baffle in sever line, and also have two manhole covers, one above each baffle as shown in Figure 3.2.

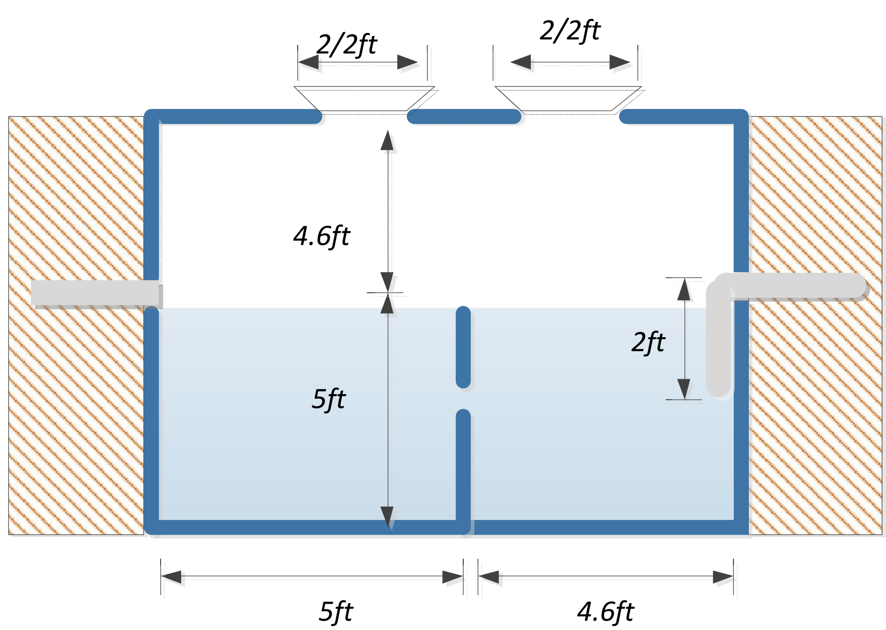


Figure3.2: (a) Cross-Section view.

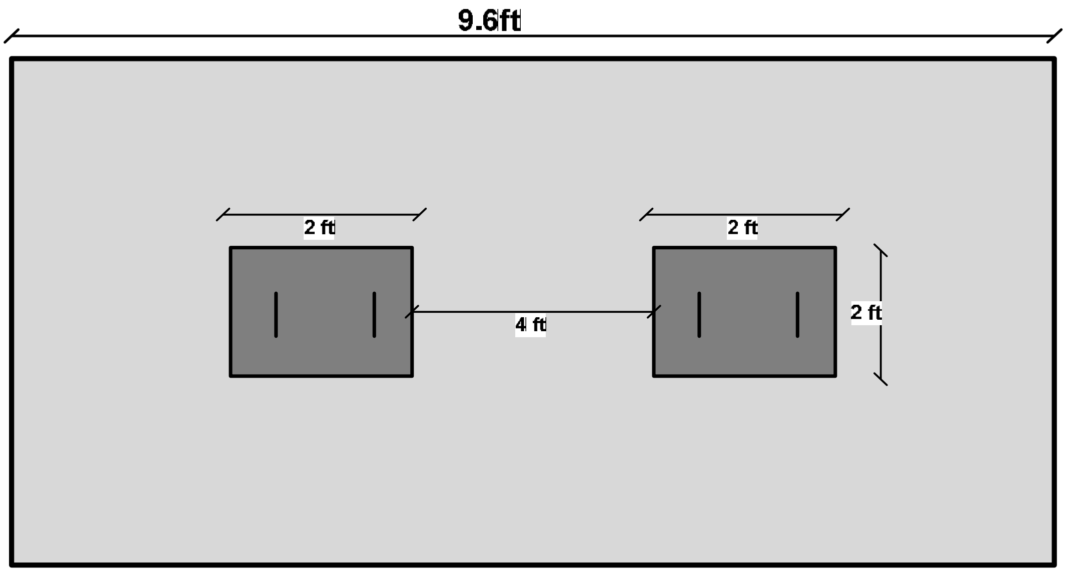


Figure3.2: (b) Plan view of Septic Tank

3.3 MEMBRANE SPECIFICATIONS

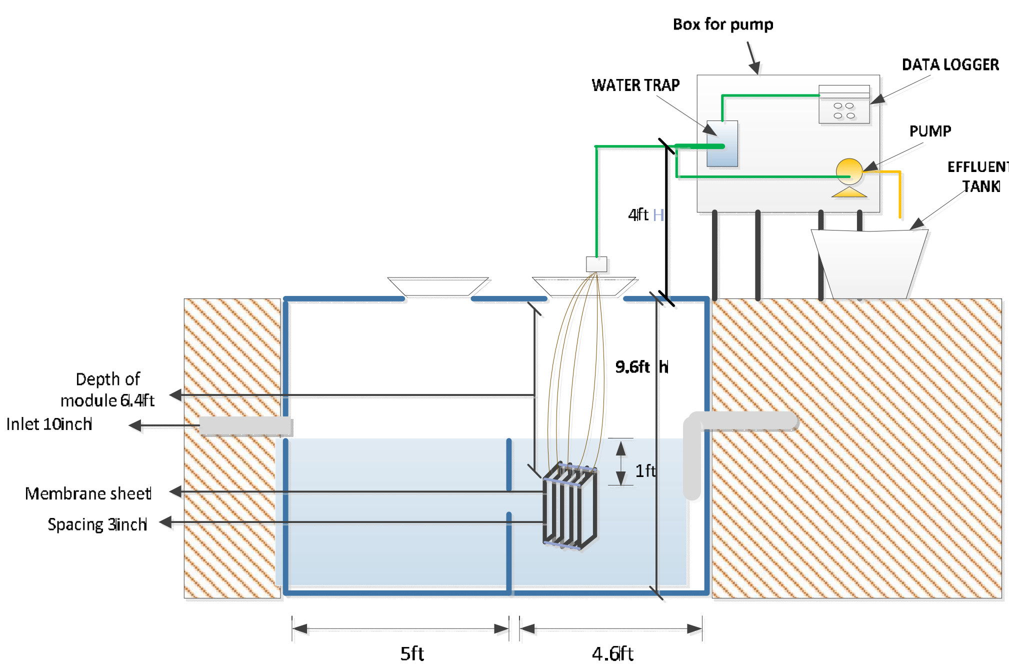
Specifications of the woven fiber microfiltration membranes (WFMF) are given in the following Table3.2

Table3.2 WFMF Membrane specifications

Item		Specification
Membrane type	-	Dead-end mode, outside-in, flat sheet
Number of membrane modules	-	5
Filter	-	2 sheets (fixed) + 1 spacer between the t\2 flat sheets
Material	-	Polyester
Pore size	μm	1-3
Effective size: L x W	cm x cm	38 x 28= 1024 cm^2
Total membrane area	m^2	$\frac{5 \times 2 \times 1024}{10000} \approx 1.00$

3.3.1 DESIGN OF MEMBRANE MODULE

Five WFMF Modules are tied together with four steel rods having equal spacing of three inches. These modules are hanged with steel rods two feet below into septic tank and these rods are screwed with manhole (cover). The top of module must be fully submerged into the sewage in the septic tank. Each WFMF membrane module is connected with a pipe and these five pipes are connected to a single pipe using connector and place outside the septic tank to conveniently avoid accidental leakage of the connectors. Pressure gauge is placed in the control panel and connected with the pipe before the peristaltic pump. Schematic description is presented as Figure.3.3



H = Height of surface to three way socket (pressure gauge connects)
h = Distance between ground level and water surface

Figure 3.3: Full scale diagram of MBST operation and design

3.4 SAMPLING METHODOLOGY:

In order to find the characteristics of wastewater grab sample was collected from the influent and effluent points as shown in figure 3.6

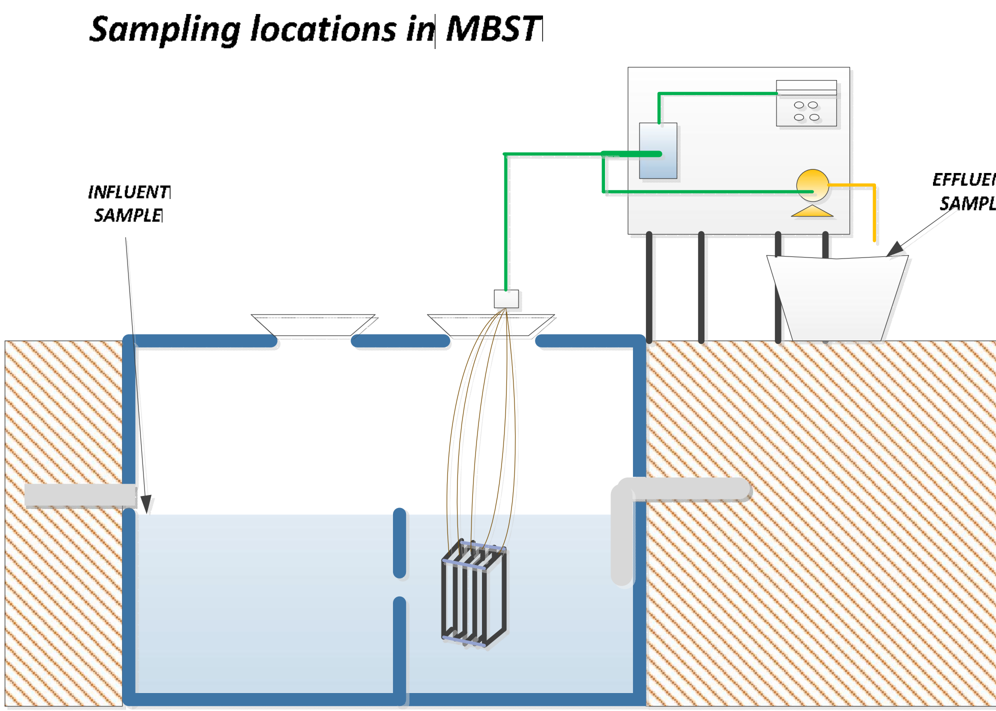


Figure 3.4: The sampling points in septic tank

3.5 ANALYTICAL METHODS

The parameters that were investigated, the technique adopted to determine each parameter and the equipment/material used are reported in Table 3.4. The detailed protocols for the measurement of the analytical parameters are discussed in the following sections

Parameter analyzed	Technique	Equipment/Material	References
SS	Filtration-Evaporation	1.2 µm (GF/C, Whatman); 105^{o}C oven (MLSS	APHA.,2005
COD	Closed reflux	COD tube; 150^{o}C oven	APHA.,2005
NH_4^+-N, NO_2^- -N, NO_3^-N	Hach Reagents	Spectrophotometer (DR 2010, Hach)	APHA.,2005
Total coliform /feacal coliform Analysis	MF filtration	Filtration assembly , media EMB agar	APHA.,2005
Turbidity	NTU	HACH Turbidiometer 2100N	Nephelometric Method

Table 3.3: Analytical parameters, methods and equipment

3.6 OPERATION OF MEMBRANE

I. OPTIMUM CONDITION DESIRED:

- One week uninterrupted operation at optimized flux(LMH)

3.7 MAINTENANCE OF MEMBRANE

During the maintenance of membrane modules the operation is stopped and modules are disconnected from the pump and pressure gauge. Manhole of septic tank along with modules is lifted using the steel rods. Membrane modules are washed by spraying water to remove the deposited solids. After physical cleaning, membrane modules are sun dried for 36 hrs.

3.7.1 CLEANING OF THE MEMBRANE:

To cleaning the membrane following protocols were followed.

- Operation was stopped when TMP reaches -80 kPa. At this point, disconnect the module from the pump and pressure gauge.
- Manhole of septic tank along with modules was lifted using the steel rods.

Figure 3.5: Membrane module along with steel rods

- Removed the membrane support after lifting the lid to avoid risk that module fall down into the septic tank.
- Before physical cleaning, the total hydraulic resistance (Rt) was measured using DI water by using this formulla $R_t = \Delta P/\mu.J$, $R_t = R_m + R_c + R_p$
- Membrane modules were washed by spraying tap water and using brush to remove the deposited solids.

Figure 3.6: Physical cleaning of membrane module with brush

- After physical cleaning with tap water, the resistances (Rm + Rp) was measured using DI water

Figure 3.7: Chemical cleaning of membrane module

- Finally Rc can be determined using formula: Rc = Rt – (Rm + Rp).
- After cleaning procedure is complete, the membrane module was kept in a clean dry condition for next filtration run.
- Membrane module was chemically cleaned twice after 1^{st} phase by using NaOCl (0.03%w/v).

3.8 MEMBRANE RESISTANCE ANALYSIS

MF membranes act as physical barrier to the suspended particles ensuring the retention of particles which are greater in size than that of pore size of the membrane. Membrane fouling is considered to be the sole reason for the decline of permeates flux with time in an MF membrane process. Tow fouling mechanisms are distinguished in microfiltration process, namely, cake layer formation & internal pore blocking. Fouling is a complex phenomenon which is characterized by a decline of permeates flux through the membrane as a result of increase in flow resistance due to one or more fouling mechanisms. The intensity of fouling caused by aforesaid fouling mechanisms is dependent upon various factors like pore size of the membrane, size of the particle, shape of the particle, particle concentration in the suspension, size distribution of particles, membrane material, temperature and the operating conditions of the MF process. The most desired quality in membrane processes is that the membrane should run at a sustainable high flux for a longer period of time. This can be achieved if the membrane fouling is kept to the minimum.

3.8.1 Experimental Setup:

Five new WFMF Modules were joined together with four steel rods having equal spacing of three inches. The top of the module was fully submerged in clean water tank of 100 liters capacity. Each WFMF membrane was connected with pipe and these five pipes from each membrane were connected to a single pipe using connectors which were placed outside the water tank to avoid leaks. Pressure gauge was connected with the pipe before the peristaltic pump as shown in Figure 3.10

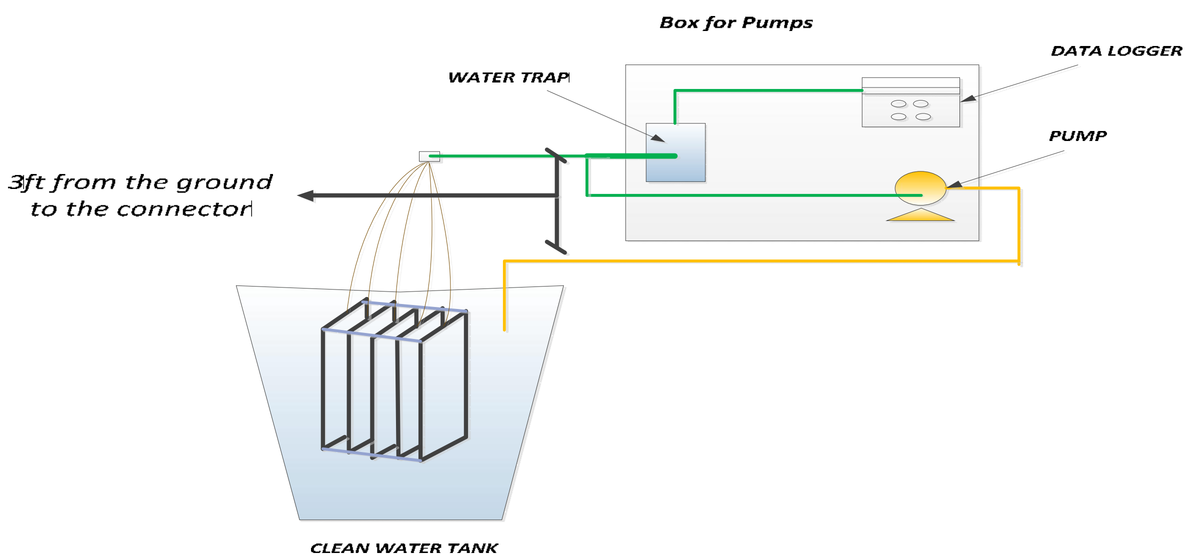


Figure 3.8: Experimental setup for membrane resistivity test.

The resistance-in-series model was applied to estimate the filtration characteristics using following equations (S.jamal, 2008):

$$J = \frac{\Delta P}{(\mu.ft.Rt)} \quad \text{Eq 3.1}$$

$$Rt = Rm + Rc + Rp \quad \text{Eq 3.2}$$

Where;

J = Operational flux ($L/m^2.s$),

ΔP = TMP (kPa),

μ = viscosity of permeate (Pa.s),

f_t = temperature correction to 20°C, $f_t = e^{-0.0239(T-20)}$

R_t= total hydraulic resistance (m^{-1}),

R_m= intrinsic membrane resistance (m^{-1}),

R_c= reversible cake resistance created by the cake layer (m^{-1}) and

R_p= irreversible fouling caused by adsorption of dissolved / colloidal onto the surface of membrane and also into the pores (m^{-1}).

R_t and R_m+R_p was calculated by filtering tap water during the membrane before and after removing the cake layer, respectively. R_m was calculated by filtering de-ionized (DI) water through a chemically cleaned membrane. Each of the R_t, R_m, R_c and R_p values were obtained by using the following equations:

$$Rt = \frac{\Delta Pw}{(\mu.J)} \quad \text{Eq 3.3}$$

$$Rm + Rp = \frac{\Delta P'w}{(\mu.J)} \quad \text{Eq 3.4}$$

$$Rm = \frac{\Delta P''w}{(\mu.J)} \quad \text{E 3.5}$$

$$Rp = (Rm + Rp) - Rm \qquad \text{Eq 3.6}$$

$$Rc = Rt - (Rm + Rp) \qquad \text{Eq 3.7}$$

Where J is the constant flux, ΔP_w and $\Delta P'_w$is the TMP at filtering tap water through the membrane before and after removing the cake layer, respectively and $\Delta P''_w$ is the TMP at filtering DI water through the chemically cleaned membrane.

CHAPTER; 4

RESULTS AND DISCISSION

4.1 ANALYSIS OF MEMBRANE FOULING

Membrane fouling was evaluated with the help of TMP profile obtained during membrane filtration. In this study TMP was monitored under four different fluxes of 2, 5,8,11 L/m^2.h and the filtration operation was stopped when the TMP reached 80kPa. At this stage the membranes were taken out of operation for physical membrane cleaning meanwhile performing the membrane resistance analysis to determine total resistance (R_t), cake resistance (R_c), pore blocking resistance (R_p), and intrinsic membrane resistance (R_m). TMP profiles of three phases of MBST are shown Figure. 4.1

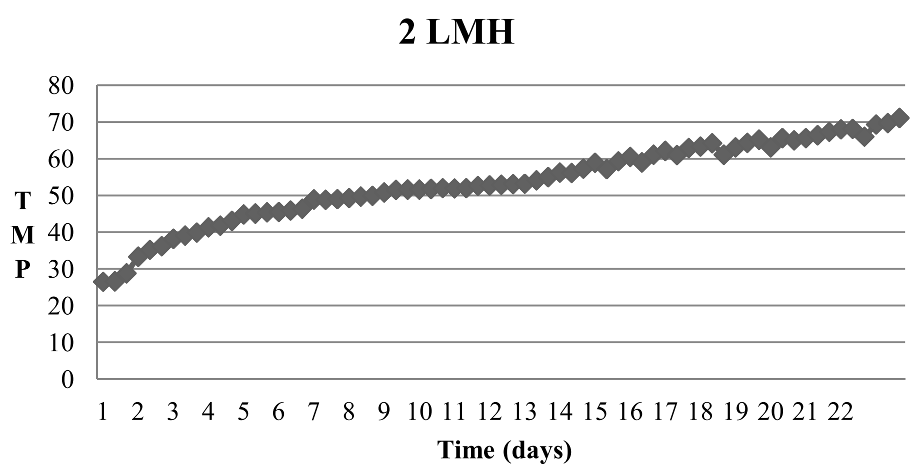


Figure4.2: TMP profiles of MBST at 2LMH

At **2LMH** systems worked for almost a month and after 20days of continues operation shown TMP reached a pressure range value of 69.9 – 70.1 kPa and remained in this range for week, but flux is very low that's why 1st phase of 2LMH is not considered as an optimize flux.

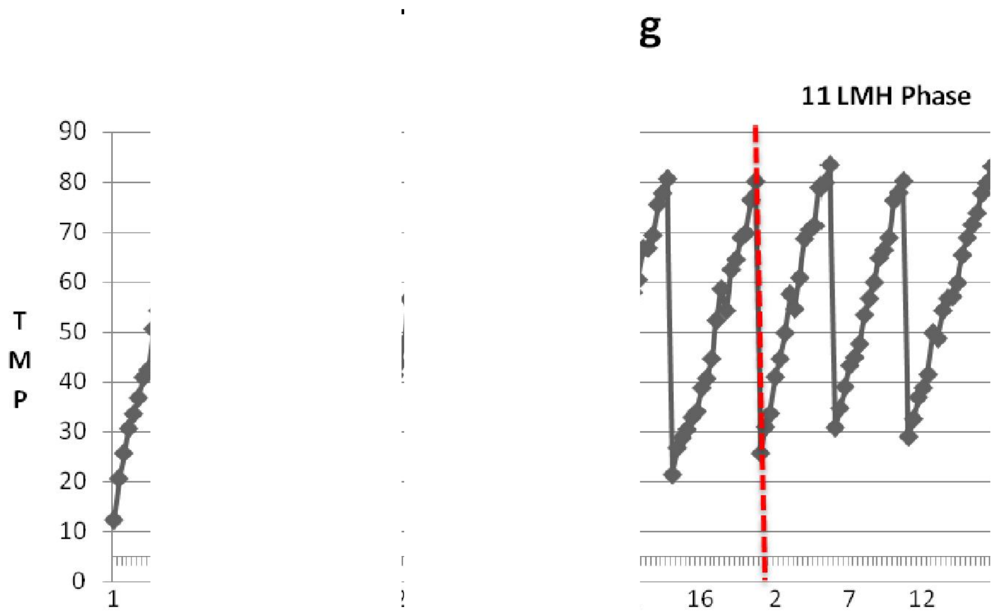


Figure4.2: TMP profiles of MBST

At the end of each filtration run, significant increase in hydraulic resistance was observed as TMP reached 80 kPa under suction pressure. However, the average filtration durations at 5, 8, and 11 LMH were found to be 8 , 6.5, 4.5 days respectably , which shows that flux of 8 LMH is optimum keeping in view considerable time for module disinfection (sun drying) for 36 hours followed by brushing and washing.

4.2 RESISTANCE ANALYSIS

The resistance-in-series model was applied to estimate the filtration characteristics. The resistance analysis results are summarized in Table 2 which represents the averaged resistance values after replicate experimental measurements. .

Table4.1: Resistance analysis of both modules at different fluxes

RESISTANCES		PHASE 1 (5LMH)	PHASE2 (8LMH)	PHASE 3 (11LMH)
Rm(x1012m-1)		0.80	0.80	0.80
Rp(x1012m-1)	RUN1	1.65	2.38	3.59
	RUN2	2.4e	3.4	3.91
	RUN3	3.61	4.13	4.5
Rc(x1012m-1)	RUN1	2.42	2.864	3.65
	RUN2	2.68	3.86	4.386
	RUN3	3.7	4.6	4.84
Rt(x1012m-1) AVG		7.80	8.414	9.06
Rc/Rt(%)		53.3	56.6	47.3
Rp/Rt (%)		36.9	43.1	43.9

It was found that the ratio of Rp/ Rt % was mostly within the range of 35-45 % Depicting that the physical cleaning protocol was effective in removing cake as well as pore blocking resistance without requiring chemical cleaning. On the other hand after each cycle the resistivity analysis shows that irreversible fouling of membrane also increases resulting in increase in R_p and R_c values, and same trend was oberved in increament of flow.

4.3 CHEMICAL CLEANING RESULTS:

The following issues after chemical cleaning of WFMF membranes were observed.

- Membrane sheet slightly detached from the membrane module frame.
- The binding material between frame and membrane sheet removed due to chemical cleaning and deform the module as shown in Figure 4.2.
- Deformation of membrane module due to chemical cleaning protocls used in this study suggests that chemical cleaning of these membrane modules by NaOCl (0.03% w/v) is not suitable.

Figure 4.3:.membrane separator detachment from sides

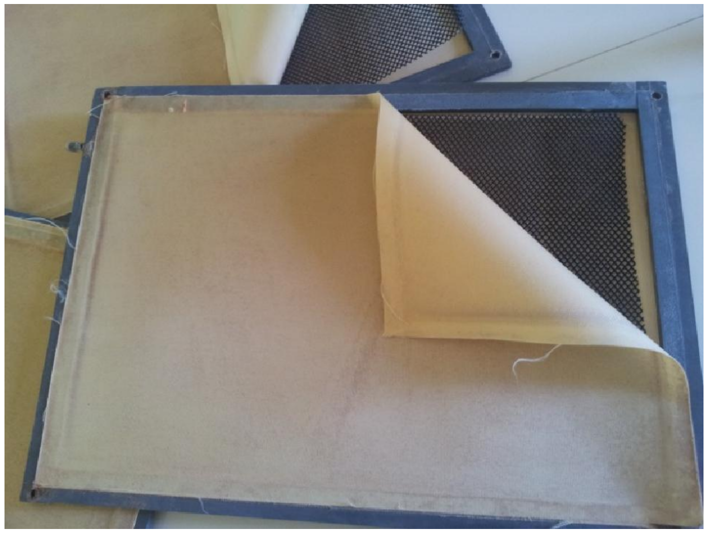


Figure4.4:.membrane sheet detachment from bottom

4.4. MBST PERFORMANCE PARAMETERS

4.4.1 TURBIDITY REMOVAL

Figure shows the relationship between the turbidity of influent to septic tank, permeate that is effluent from the membrane modules and time of operation and the removal efficiency of the MBST when system was operated in IESE (complete details; Annex. B-1).On average, the turbidity removal performance of MBST was almost 96% and the effluent turbidity was about 7 NTU.

Overall the turbidity in treated water produced from MBST is far lower as compared to allowable turbidity for non-potable water standards.

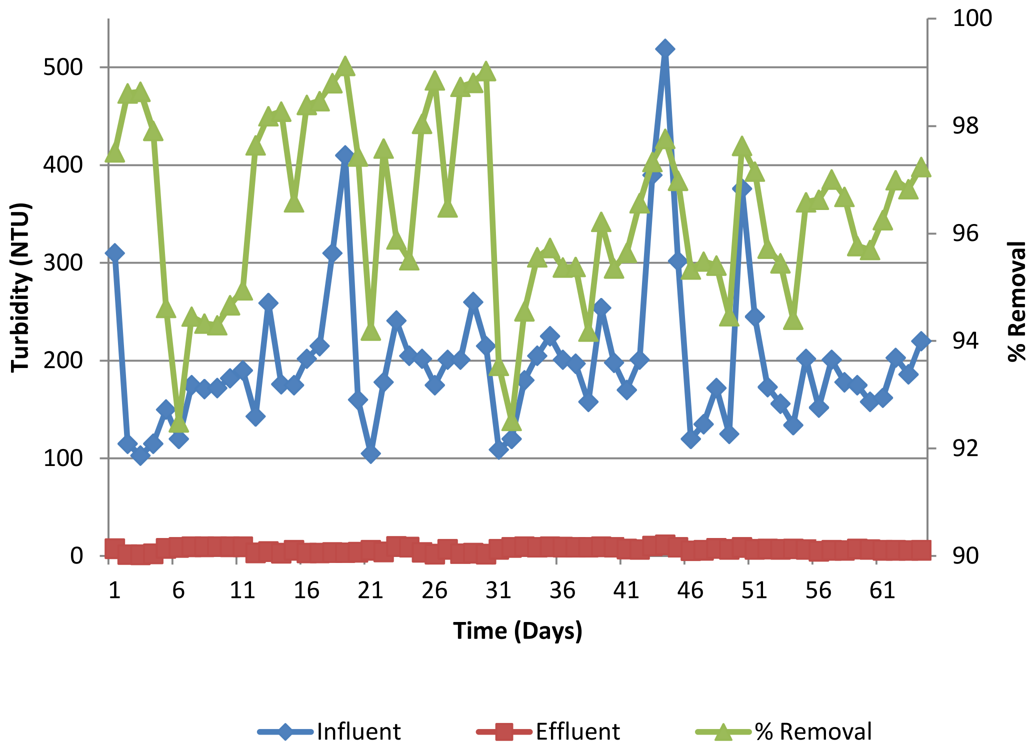


Figure4.5: Turbidity in influent, effluent and removal efficiency of MBST

4.4.2 SUSPENDED SOLIDS REMOVAL

Figure 4.5 presents the performance of MBST system in term of SS removal of WW. Permeate was found with free of SS in all phases on which MBST operated. On the other hand with increase in operation time the removal efficiency also increase and rise up to 72% because a thin layer of SS developed on the membrane surface which favor of the separation process by reducing the pore size of the membrane.

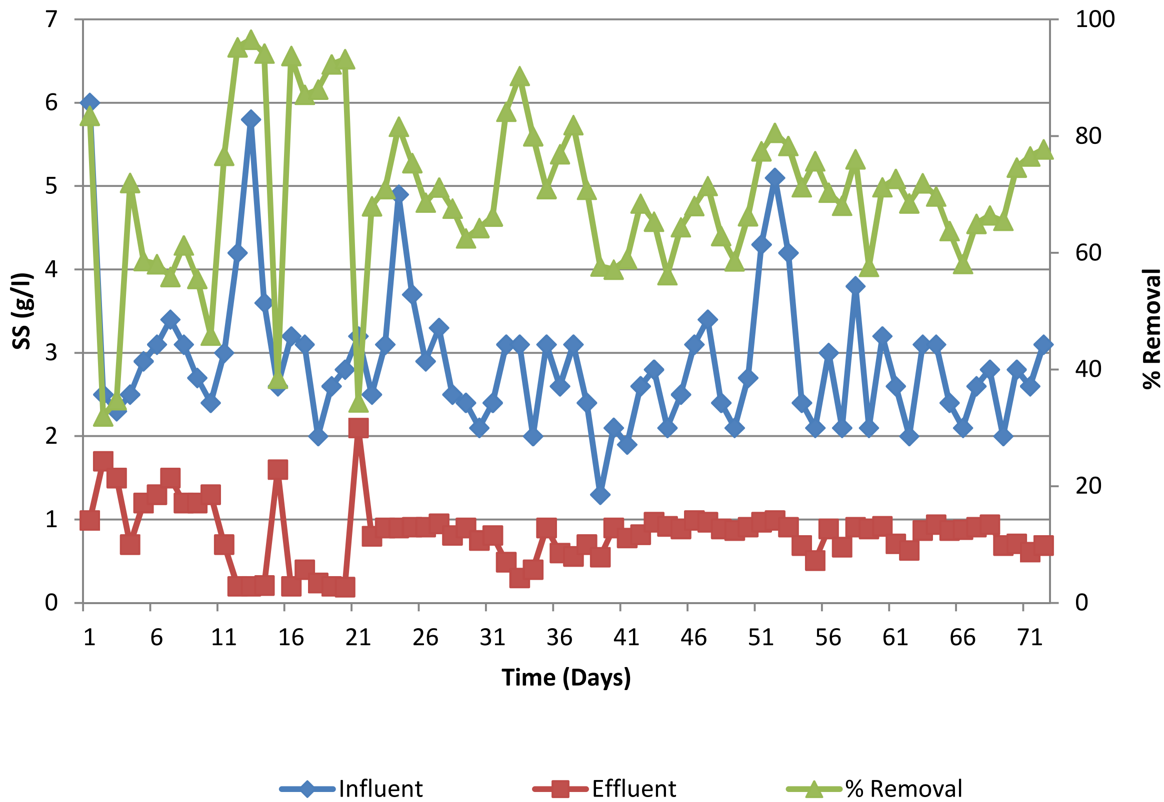


Figure4.6: SS presents in influent, effluent and removal efficiency of MBST

4.4.3 COD REMOVAL

Organic matter removal is one of the key parameter in WWT. The removal is generally measured in terms of COD and TOC. In MBST the removal of COD is due to filtration of solid retained by the membrane in the septic tank, some anaerobic biodegradation takes place. Moreover, the settleable solids settle at the bottom of septic tank which also removes a part of COD. Figure 4.7 shows the detail the performance of system in term of COD removal of WW.

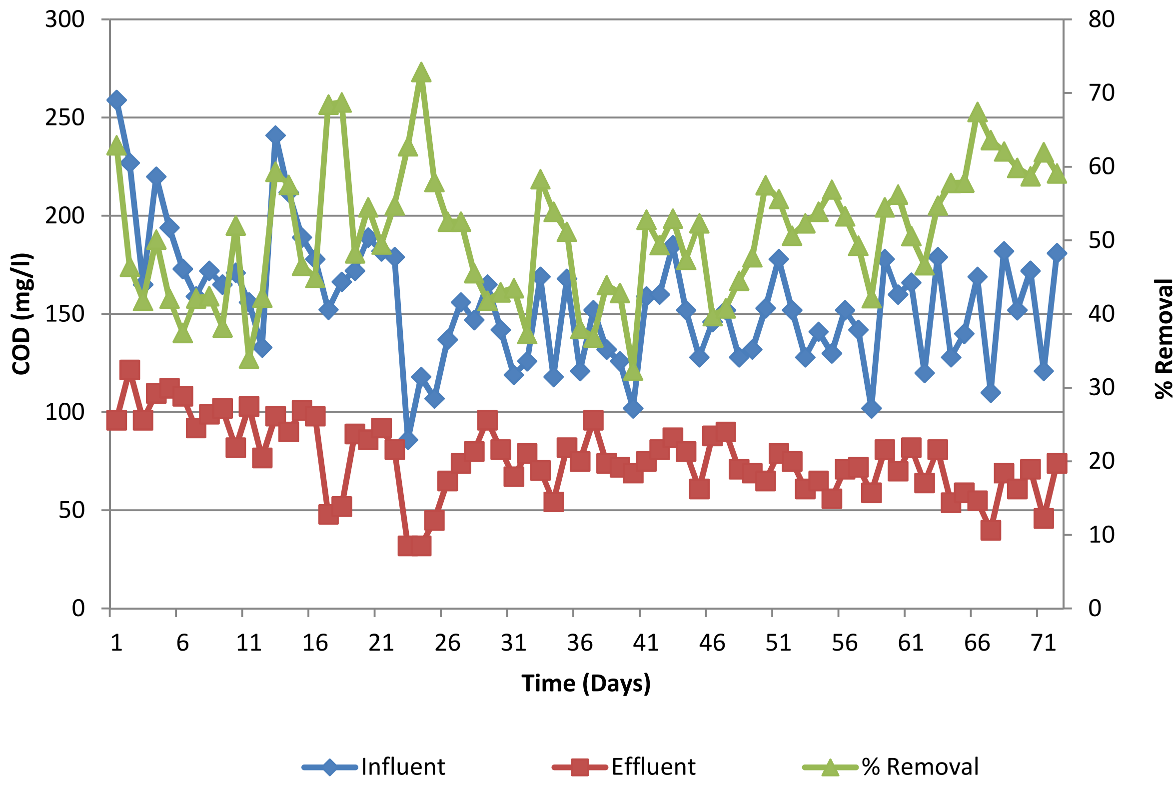


Figure4.7: COD in influent, effluent and removal efficiency of MBST

4.4.4 NUTRIENTS REMOVAL

In advanced WWT the treatment efficiency of certain nutrients likes ammonia-nitrogen and phosphorous is also monitored in the treated effluent along with conventional COD removal. In this study MBST was installed in an academic institution where the influent WW contained more nutrients then other organic matter because WW contains more urinal part then manure. Figures show influent, effluent and removal efficiency of ammonia and phosphorous. From Figure it is clear that the nutrient removal is low. The reason behind low removal efficiency is that almost all the nutrients in WW were found in soluble form which cannot be retained by MF membranes, but on the other hand nutrient presence in effluent water is a positive point for the use of effluent for horticulture and landscaping.

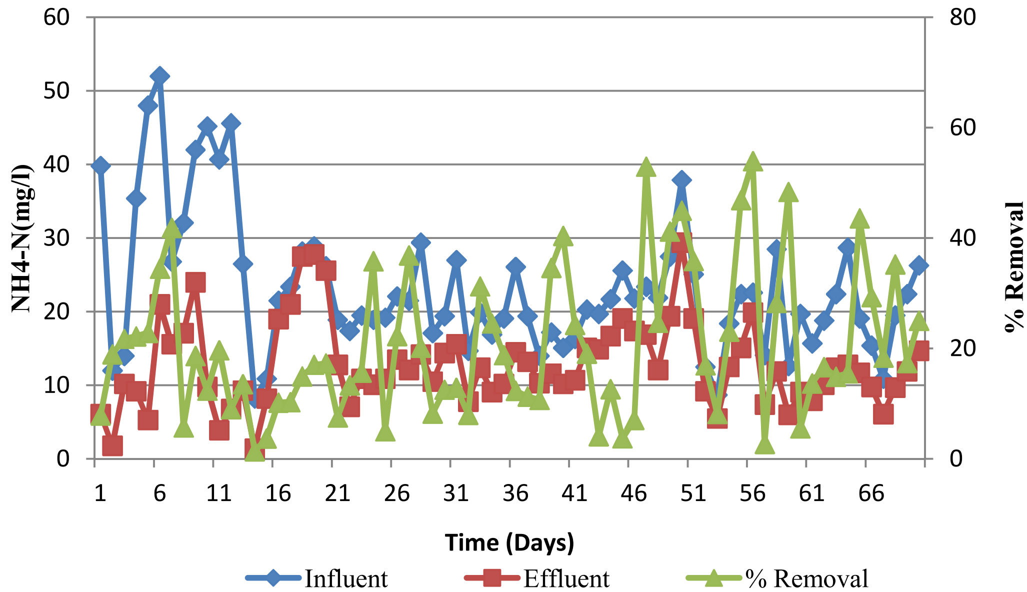


Figure4.8: NH_4-N presents in influent, effluent and removal efficiency of MBST

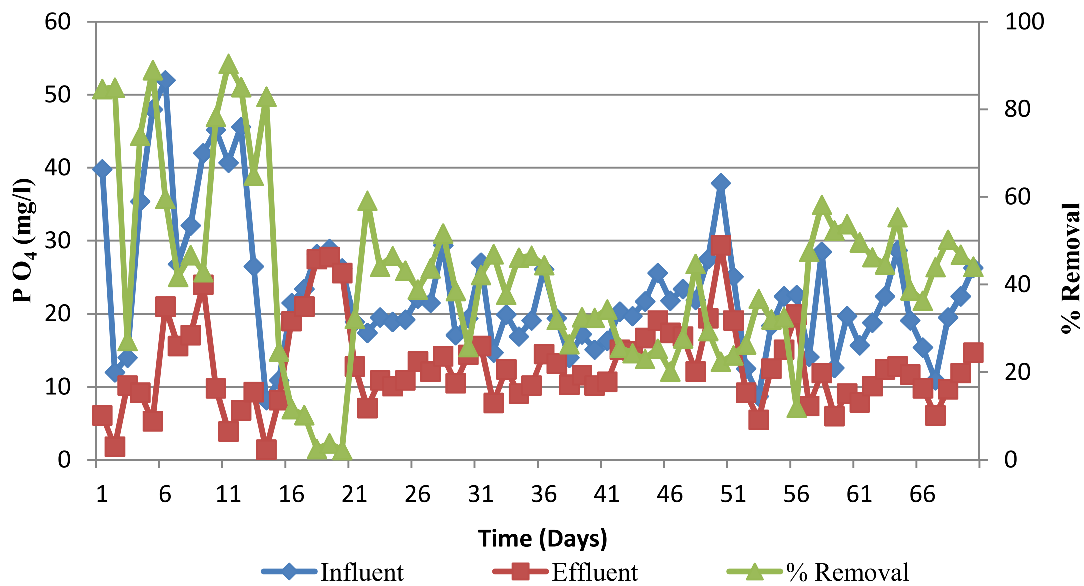


Figure4.9: Phosphorus presents in influent, effluent and removal efficiency of MBST

Presence of phosphorus in water has a great significance. Phosphate in small quantity used in water supplies to decrease scale formation, to increase transport capacity of collection system, to avoid corrosion in pipe, to reduce iron and manganese in small quantities and in \coagulation particularly in acid conditions. The presence of phosphate in bulk amount in waters shows pollution through domestic and industrial wastes. It promotes growth of Eutrophication (ASA, 2012). Its presence is essential for biological degradation of WW. Phosphorus is a vital nutrient for the growth of micro-organisms in biological WWT.

4.4.5 TOTAL COLIFORM (CFU/100ML)

Water borne pathogens can penetrate the human body through undamaged or compromised skin, aspiration, ingestion, or by direct contact with mucosa of the eye, ear, nose, and mouth and cause illness. Failure of water systems generally contributes to the greatest number of outbreaks of waterborne diseases (US-EPA, 2002). A risk analysis approach is needed for reducing the issues with waterborne diseases.

In this study microbial analysis is conducted in term of total coliform and feacal coliform test. The following table shows the detailed data about the analysis. The table clearly shows that the MBST is able to remove 99% of the harmful bacteria, but still there was some bacteria present in the effluent water which needs little disinfection before use. Results of the bacterial analysis are shown in figure 4.9

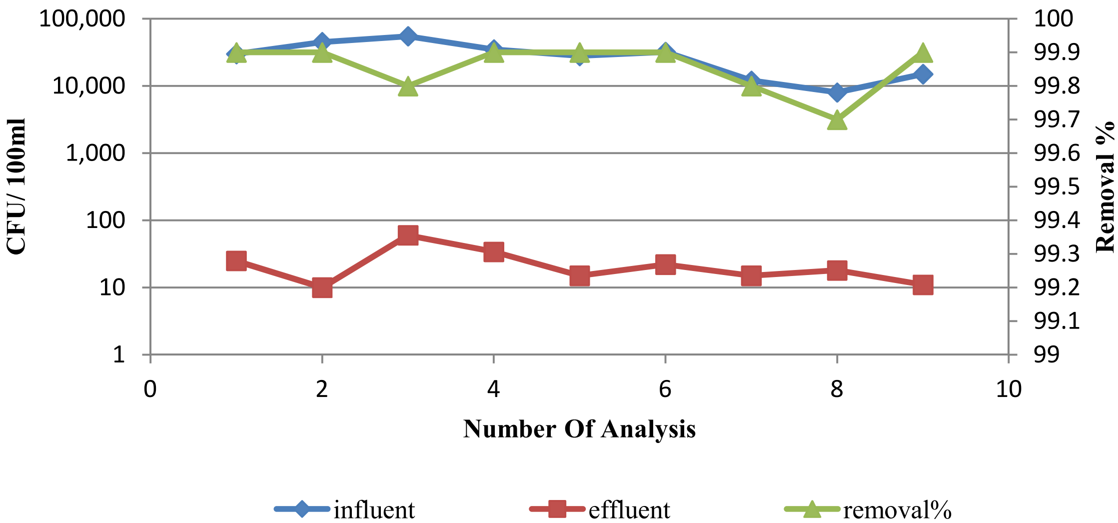


Figure 4.10: coliform present in influent, effluent and removal efficiency.

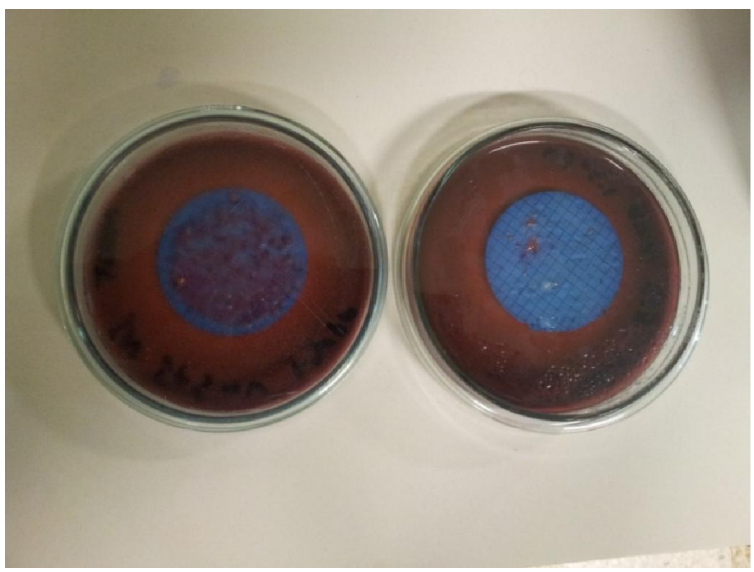


Figure 4.11: Too numerous to count (TNT) count of colonies in influent**.**

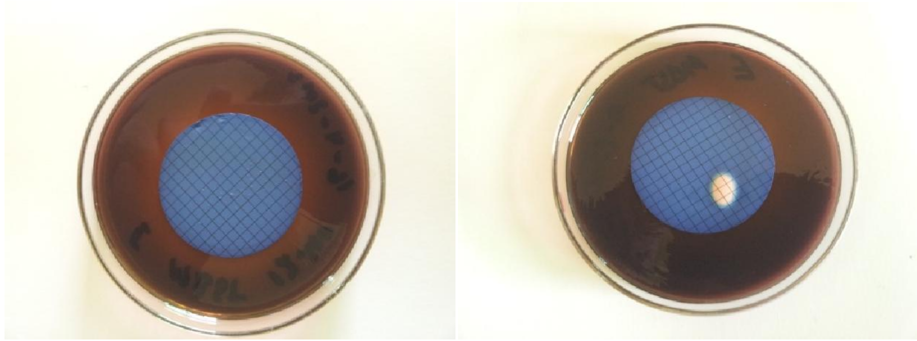


Figure4.12: The colony count in effluent**.**

Chapter # 5

CONCLUSIONS AND RECOMMENDATIONS

This study focused on development of feasible decentralized onsite wastewater treatment system for an individual home or building and adopted an approach which combines the old treatment technology that is septic tank with new and reliable membrane technology. The important conclusions are stated as follows.

5.1 CONCLUSIONS

Following conclusions were drawn from this study

The membrane based septic tank was able to satisfactorily treat wastewater at source and no further wastewater treatment was required to satisfy NEQS standards. Effluent of the membrane septic tank can be used for horticulture, landscaping and any other non-potable purposes. Moreover, the high quality effluent from membrane based septic tank easily meet the municipal effluent requirements as per National Environmental Quality Standards (2000) and will not require any further treatment thus eliminating the need of a centralized full-scale wastewater treatment facility which can save the distribution system cost and made wastewater treatment economical feasible.

At the end of each filtration run, significant increase in hydraulic resistance was observed as TMP reached 80 kPa under suction pressure. However, the average filtration durations at 5, 8, and 11 LMH were found to be 8 , 6.5, 4.5 days , which shows that flux of 8 LMH is optimum keeping in view considerable time for module disinfection (sun drying) for 36 hours followed by brushing and washing.

As operation time increases the irreversible fouling of the membrane increases and after each successive operation cycle TMP profile trend starts from the higher value of pressure then the last one due to irreversible fouling.

The use of wastewater for irrigation may serve as an additional source of water with fertilizing properties because the effluent of MBST has high nutrient concentration in terms of ammonia, nitrite and nitrate as nitrogen

It was found that the MBST Ws able to remove coliform up to 99% but little disinfection is still suggested in case the treated water can be used for laundry, floor washing etc.

5.2 RECOMMENDATIONS

Following recommendations are noteworthy for further study.

1. Effluent of the MBST should be analyzed for use on Horticulture ,Landscaping and any Non-potable purposes
2. Energy Consumption should be analyzed and renewable energy sources should be explored.
3. Aeration near the membrane surface should b introduced to reduce the fouling of membrane by scouring effect of the air with the membrane surface.
4. Effective but sustainable chemical cleaning procedure should be investigated to remove permanent fouling of membranes.

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APPENDIX A

FIGURES OF CONSTRUCTION PHASE /OPERATIONAL PHASE

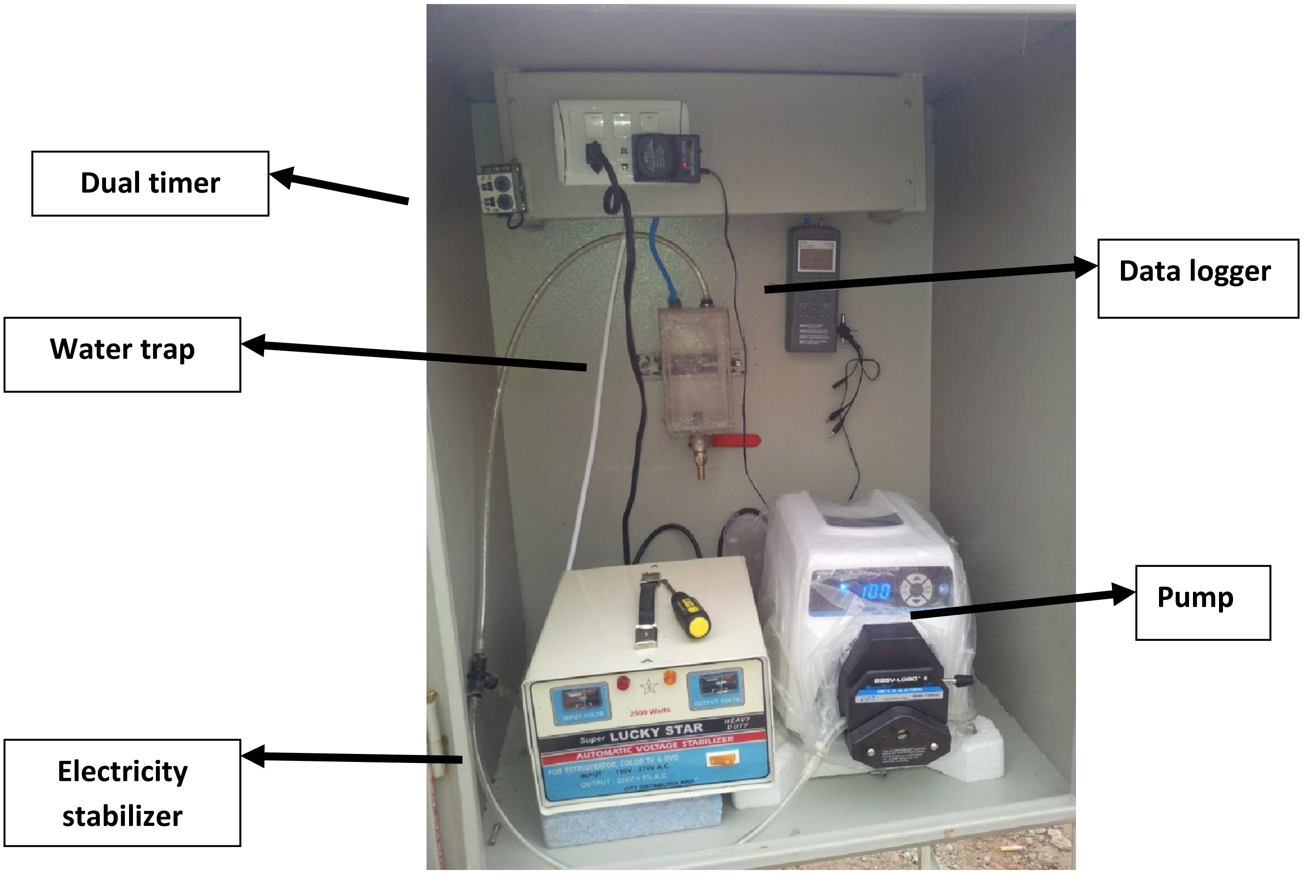

Figure A1:Experimental setup on septic tank:

Figure A2: Peristaltic Pump

Figure A3: Equipments panel installed on MBST

Figure A4: Desing of WFMF module

Figure A5: Construction phase pictures of septic tank

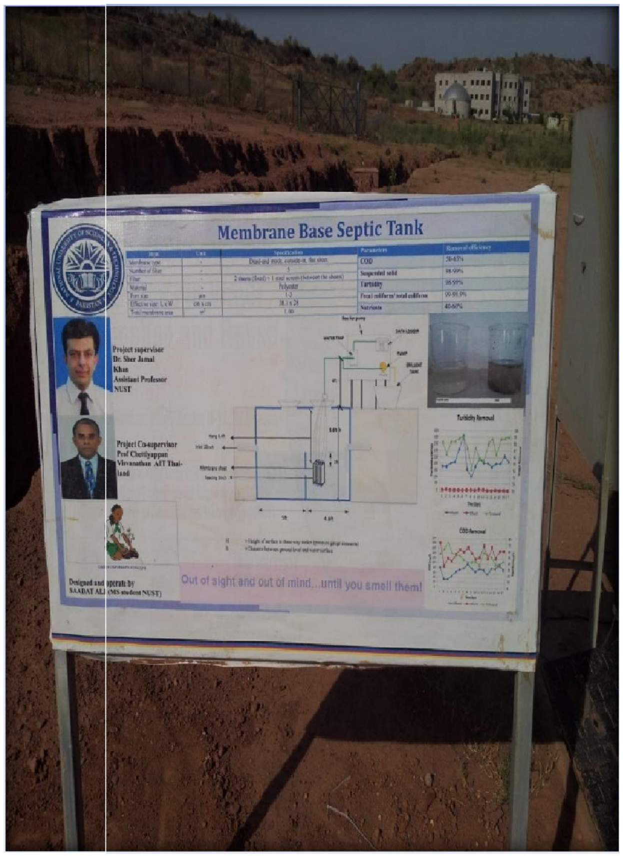

Figure A6: Poster installed on MBST

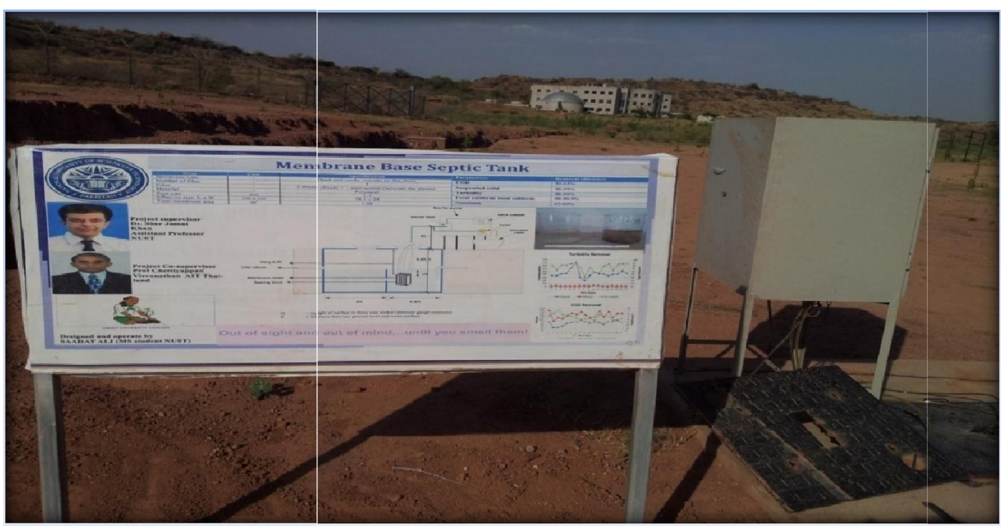

Figure A7: Overview of MBST

APPENDIX B

MBST PERFORMANCE PARAMETERS

Table B- 1: Influent, SS, COD, and turbidity effluent SS, COD and turbidity concentrations and corresponding removal efficiencies in MBST

Date	Suspended Solids (g/l) InfEff		COD (mg/l) InfEff		Removal % COD	Turbidity (NTU) InfEff		Removal %
15-2-2012	**6**	**0.99**	**259**	**96**	**63**	**310**	**7.7**	**97.5**
18-2-2012	**2.5**	**1.7**	**227**	**121.6**	**47**	**115**	**1.60**	**98.6**
19-2-2012	**2.3**	**1.5**	**165**	**96**	**42**	**103**	**1.4**	**98.6**
20-2-2012	**2.5**	**0.7**	**220**	**109.7**	**50**	**115**	**2.4**	**97.9**
24-2-2012	**2.9**	**1.2**	**194**	**112.3**	**42**	**150**	**8.07**	**94.6**
25-2-2012	**3.1**	**1.3**	**173**	**108.2**	**38**	**120**	**9.01**	**92.4**
27-2-2012	**3.4**	**1.5**	**159**	**92**	**42**	**175**	**9.7**	**94.4**
28-2-2012	**3.1**	**1.2**	**172**	**99**	**42**	**171**	**9.7**	**94.3**
29-2-2012	**2.7**	**1.2**	**165**	**102**	**38**	**172**	**9.81**	**94.2**
1-3-2012	**2.4**	**1.3**	**171**	**82**	**52**	**182**	**9.7**	**94.6**
2-3-2012	**3**	**0.7**	**156**	**103**	**32**	**190**	**9.6**	**94.9**
5-3-2012	**4.2**	**0.2**	**133**	**76.8**	**42**	**143**	**3.37**	**97.6**
6-3-2012	**5.8**	**0.2**	**241**	**98**	**59**	**259**	**4.7**	**98.1**
8-3-2012	**3.6**	**0.21**	**212**	**90**	**57.5**	**179**	**6.9**	**96.1**
9-3-2012	**2.6**	**1.6**	**189**	**101**	**47**	**185**	**3.45**	**98**
11-3-2012	**3.2**	**0.2**	**178**	**98**	**45**	**169**	**1.69**	**99**
13-3-2012	**3.1**	**0.4**	**152.2**	**48**	**62**	**158**	**2.8**	**98.2**
14-3-2012	**2**	**0.24**	**166.4**	**52**	**68.7**	**157**	**1.03**	**99.3**
15-3-2012	**2.6**	**0.2**	**172**	**89**	**48**	**165**	**1.6**	**99**
16-3-2012	**2.8**	**0.19**	**189**	**86**	**54.5**	**172**	**3.03**	**98.2**
22-3-2012	**3.2**	**2.1**	**182**	**92**	**49.4**	**189**	**3.1**	**98**
23-3-2012	**2.5**	**0.8**	**179**	**81**	**54.7**	**176**	**3.04**	**98.2**
25-3-2012	**3.1**	**0.9**	**86**	**32**	**62.7**	**175**	**5.98**	**96.5**
27-3-2012	**4.9**	**0.9**	**118**	**32**	**73**	**202**	**3.24**	**98.3**
29-3-2012	**3.7**	**0.91**	**107**	**45**	**57.9**	**215**	**3.30**	**98.4**
30-3-2012	**2.9**	**.91**	**137**	**65**	**52.5**	**310**	**3.72**	**98.8**
1-4-2012	**3.3**	**.95**	**156**	**74**	**52.5**	**410**	**3.6**	**99**
3-4-2012	**2.5**	**0.81**	**147**	**80**	**45.5**	**160**	**4.1**	**97.4**
5-4-2012	**2.4**	**0.9**	**165**	**96**	**41.8**	**105**	**6.09**	**94.2**
7-4-2012	**2.1**	**0.75**	**142**	**81**	**42.9**	**178**	**4.3**	**97.5**
9-4-2012	**2.4**	**0.81**	**119**	**67.2**	**43.5**	**241**	**9.9**	**95.8**
11-4-2012	**3.1**	**0.49**	**126**	**79**	**37.3**	**205**	**9.21**	**95.5**
12-4-2012	**3.1**	**0.3**	**169**	**70.4**	**58.4**	**202**	**3.95**	**98**
14-4-2012	**2.0**	**0.4**	**118**	**54.4**	**54.05**	**175**	**2.01**	**98.8**

16-4-2012	**3.1**	**0.9**	**168**	**82**	**51.2**	**201**	**7.06**	**96.5**
18-4-2012	**2.6**	**0.6**	**121**	**75**	**38**	**201**	**2.55**	**98.7**
19-4-2012	**3.1**	**0.56**	**152**	**96**	**36.8**	**260**	**3.1**	**98.8**
21-4-2012	**2.4**	**0.7**	**132**	**74**	**43.9**	**215**	**2.09**	**99**
23-4-2012	**1.3**	**0.55**	**126**	**72**	**42.9**	**109**	**7.04**	**93.5**
24-4-2012	**2.1**	**0.9**	**102**	**69**	**32.4**	**120**	**8.98**	**92.5**
26-4-2012	**1.9**	**0.78**	**159**	**75**	**52.8**	**180**	**9.8**	**94.6**
1-5-2012	**2.6**	**0.82**	**160**	**81**	**49.4**	**205**	**9.1**	**95.6**
3-5-2012	**2.8**	**0.97**	**185**	**87**	**53**	**225**	**9.6**	**95.7**
5-5-2012	**2.1**	**0.92**	**152**	**80**	**47.4**	**201**	**9.3**	**95.4**
7-5-2012	**2.5**	**0.89**	**128**	**61**	**52.3**	**197**	**9.1**	**95.4**
9-5-2012	**3.1**	**0.99**	**146**	**88**	**39.7**	**158**	**9.2**	**94.2**
10-5-2012	**3.4**	**0.97**	**152**	**90**	**40.8**	**254**	**9.6**	**96.2**
12-5-2012	**2.4**	**0.89**	**128**	**71**	**44.5**	**198**	**9.2**	**95.4**
14-5-2012	**2.1**	**0.87**	**132**	**69**	**47.7**	**170**	**7.4**	**95.6**
16-5-2012	**2.7**	**0.91**	**153**	**65**	**57.5**	**201**	**6.9**	**96.6**
18-5-2012	**4.3**	**0.97**	**178**	**79**	**55.6**	**390**	**10.4**	**97.3**
19-5-2012	**5.1**	**0.99**	**152**	**75**	**50.7**	**519**	**11.6**	**97.8**
21-5-2012	**4.2**	**0.91**	**128**	**61**	**52.3**	**302**	**9.1**	**97**
23-5-2012	**2.4**	**0.69**	**141**	**65**	**53.9**	**120**	**5.6**	**95.3**
24-5-2012	**2.1**	**0.51**	**130**	**56**	**56.9**	**135**	**6.1**	**95.5**
29-5-2012	**3**	**0.89**	**152**	**71**	**53.3**	**172**	**7.9**	**95.4**
31-5-2012	**2.1**	**0.67**	**142**	**72**	**49.3**	**125**	**6.92**	**94.5**
2-6-2012	**3.8**	**0.71**	**102**	**59**	**42.1**	**376**	**9.8**	**97.3**
4-6-2012	**2.1**	**0.61**	**178**	**81**	**54.5**	**245**	**6.92**	**97.1**
6-6-2012	**3.2**	**0.82**	**160**	**70**	**56.3**	**173**	**7.4**	**95.7**
11-6-2012	**2.6**	**0.65**	**166**	**82**	**50.6**	**156**	**7.1**	**95.4**
13-6-2012	**2**	**0.62**	**120**	**64**	**46.7**	**134**	**7.5**	**94.4**
15-6-2012	**3.1**	**0.89**	**179**	**81**	**54.7**	**202**	**6.9**	**96.5**
17-6-2012	**3.1**	**0.99**	**128**	**54**	**57.8**	**152**	**5.1**	**96.6**
19-6-2012	**2.4**	**0.87**	**140**	**59**	**57.5**	**201**	**6.01**	**97**
21-6-2012	**2.1**	**0.88**	**169**	**55**	**67.4**	**178**	**5.9**	**96.6**
22-6-2012	**2.6**	**0.91**	**110**	**40**	**63.6**	**175**	**7.4**	**95.7**
24-6-2012	**2.8**	**0.99**	**182**	**69**	**62**	**158**	**6.8**	**95.6**
26-6-2012	**2**	**0.69**	**152**	**61**	**59.8**	**162**	**6.07**	**96.2**
28-6-2012	**2.8**	**0.71**	**172**	**71**	**58.7**	**203**	**6.01**	**97**
30-6-2012	**2.6**	**0.61**	**121**	**46**	**61.9**	**186**	**5.9**	**96.8**
5-7-2012	**3.1**	**0.69**	**181**	**74**	**59.1**	**220**	**6.07**	**97.2**

Table B- 2: Nutrient nitrogen and phosphorus Influent, effluent concentrations and corresponding removal efficiencies in MBST

Date	AmmonuiaNH_4-N mg/l		Nitrate($NO3^{1-}$) mg/l		Nitrite($NO2^{1-}$) mg/l		Phosphorus($PO4^{3-}$) mg/l	
	In	Eff	In	Eff	In	Eff	In	Eff
15-02-2012	76	70	1.6	3.2	0.5	0.039	39.8	6.1
18-02-2012	66.4	53.8	5.2	6.8	7	1	12	1.8
19-02-2012	63.4	49.6	4.8	7.1	5	0.8	14	10.2
20-02-2012	39.6	30.8	0.78	1.6	0.7	0.4	35.4	9.2
24-02-2012	57.3	44.2	2.3	2.9	1.4	0.6	-	-
25-02-2012	60.9	39.9	1.9	3.4	2	0.7	-	-
27-02-2012	58.3	33.9	4.3	8.2	4.5	1.4	48	5.3
28-02-2012	52.4	49.4	3.7	6.2	5	2.5	52	21
29-02-2012	49.3	40.1	5	3.1	0.9	0.1	26.8	15.6
1-03-2012	45.2	39.6	3.1	5.4	0.7	0.1	32.1	17.1
2-03-2012	52.8	42.4	2.4	7.3	1.3	0.9	42	24
5-03-2012	56.5	51.4	1.9	6.2	2.1	0.99	45.2	9.8
6-03-2012	48.7	42.1	1.4	5.5	1	0.6	40.7	3.9
8-3-2012	49.8	49.1	2.1	4.8	1.9	0.91	45.6	6.8
9-3-2012	32.1	30.9	3.4	3.9	12	3	26.5	9.3
11-3-2012	39.2	35.2	1.3	4.8	5	18	8.2	1.4
13-3-2012	45.6	40.9	4.6	4.1	4	10	10.9	8.2
14-3-2012	49.4	42	2	5	0.2	1	21.5	25
15-3-2012	48.6	40.3	1.9	4.6	2.4	1.7	23.4	26
16-3-2012	46.2	38.2	2.1	5	3.6	2.4	28.2	28.9
22-3-2012	42.6	39.4	3.6	4.9	4.2	3.1	28.9	27.8
23-3-2012	29.2	25.3	2.2	3.8	2.8	2.1	26.2	25.6
25-3-2012	36.4	30.7	2.6	1.2	2	7	18.9	12.8
27-3-2012	40.2	25.8	8.9	4.9	2	1	17.4	7.1
29-3-2012	37.8	35.9	6.2	3.1	3	1.1	19.5	10.9
30-3-2012	51.6	40.1	8.5	7.4	5	3.9	18.9	10.1
1-4-2012	59.4	37.5	8.2	14.5	7.1	4.2	19.2	10.9
3-4-2012	62.4	49.8	4.6	5.4	6	5	22.1	13.5
5-4-2012	48.6	44.6	8.4	6.8	10	6	21.5	12.1
7-4-2012	46.2	40.4	7.9	6.8	12	7	29.4	14.2
9-4-2012	54.2	47.2	7.6	2.8	7	2	17.1	10.5
11-4-2012	48.6	44.7	7.1	3	8	2	19.4	14.4
12-4-2012	45.4	31.2	3.3	2.9	8	4	27	15.6

14-4-2012	56.2	42.4	4.8	1.8	5	1	14.7	7.8
16-4-2012	49.4	40.1	3	1.6	6	2	19.9	12.4
18-4-2012	46.1	40.4	2.8	2.6	6	5	16.9	9.1
19-4-2012	36.2	32.1	3.1	2.4	5.9	4.8	19.1	10.2
21-4-2012	32.7	29.2	4.1	3.2	6.4	4.9	26.1	14.5
23-4-2012	46.2	30.2	3.1	2.9	5.2	4.8	19.4	13.2
24-4-2012	49.5	29.5	3	1.3	1.6	0.9	14	10.3
26-4-2012	56.4	42.7	2	1.1	2.1	1	17.2	11.6
1-5-2012	39.8	32.2	2.5	1.25	1.7	0.99	15.1	10.2
3-5-2012	41.2	39.5	4.2	1.75	1.2	0.84	16.3	10.7
5-5-2012	39.5	34.5	2.4	2	6	2	20.3	15.1
7-5-2012	34.7	33.4	2.1	1.9	5	2	19.7	14.9
9-5-2012	38.1	35.4	2.8	2.1	4.1	2.4	21.7	16.7
10-5-2012	42.1	19.8	2.4	1.9	6	4	25.6	19.1
12-5-2012	39.7	29.9	2.1	1.8	4.2	3.4	21.8	17.4
14-5-2012	51.2	30.1	2.3	1.79	3.4	2.9	23.4	16.9
16-5-2012	53.1	29.2	2.1	1.2	3.2	2.1	21.9	12.1
18-5-2012	46	29.5	3.5	1.5	8	4.1	27.5	19.4
19-5-2012	21.8	18.1	4.7	3.5	10	5.1	37.9	29.4
21-5-2012	20.8	19.1	3.5	2.1	4.1	2	25.1	19.1
23-5-2012	22.1	17	3.2	2.9	4.7	4	12.5	9.2
24-5-2012	32.4	17.2	3.5	3.2	5	4.1	8.7	5.5
29-5-2012	38	17.5	3.9	3.5	4.2	3.1	18.4	12.5
31-5-2012	22	21.4	4.1	3.2	6.1	4.6	22.4	15.1
2-6-2012	46	33	5.4	5.2	9	2	22.6	19.9
4-6-2012	37	19.1	4.8	4.7	4.7	2.1	14.1	7.4
6-6-2012	45	42.5	5.1	4.6	10.1	3.7	28.5	11.9
11-6-2012	30.7	26.5	3.7	3.3	3.2	1.1	12.6	6
13-6-2012	48.1	40.1	3.2	2.9	5.9	1.4	19.7	9.1
15-6-2012	32.9	28	4.7	3	4.1	2.1	15.7	7.9
17-6-2012	46.4	39.2	8.1	4.7	5.7	3.1	18.8	10.1
19-6-2012	51.6	29.1	4.2	3.9	5.1	2	22.4	12.4
21-6-2012	56.9	40.2	6.7	6	5.4	2.4	28.7	12.8
22-6-2012	50.1	40.9	5.4	4.6	4.7	1.1	19.1	11.7
24-6-2012	68.1	44.1	3.7	3.1	4.6	1.7	15.4	9.8
26-6-2012	51.7	42.7	3.2	2.2	4	1.4	10.9	6.1
28-6-2012	61.5	46.1	5.4	3.9	7.1	2.3	19.5	9.7
30-6-2012	-	-	4.8	3.4	6.3	1.9	22.4	11.9
5-7-2012	-	-	4.9	3.1	8.7	3.1	26.3	14.7

APPENDIX C

MBST BIOLOGICAL PERFORMANCE PARAMETERS

Table C-1: shows Coliform bacteria presence in influent, effluent of MBST along with removal efficiency

Date	Influent (cfu/100ml)	Effluent (cfu/100ml)	Removal %
2-3-2012	**30,000**	**25**	**99.9**
15-3-2012	**45,000**	**10**	**99.9**
29-3-2012	**TNT**	**100**	**N/A**
10-4-2012	**55,000**	**60**	**99.8**
15-4-2012	**35,000**	**34**	**99.9**
16-4-2012	**28,000**	**15**	**99.9**
18-4-2012	**32,000**	**22**	**99.9**
25-4-2012	**12,000**	**15**	**99.8**
14-5-2012	**8,000**	**18**	**99.7**
24-5-2012	**15,000**	**11**	**99.9**