STUDY OF SUSTAINABLE APPROACH TO SEPTAGE MANAGEMENT WITH APPLICATION OF PIT LIFE EXTENDER (PLE)

A thesis submitted towards partial fulfilment of the requirements for the degree of

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Abstract

In developing countries establishing an eco-friendly, cost effective sanitation system comes as biggest challenge. In addition to that its ever expanding population, lack of awareness for public hygiene, constraint of fund and scarcity of research work make this harder. Lot of places including India still heavily dependent on onsite sanitation system (OSS) which typically includes a septic tank and a soak pit. Sewage generated from household, commercial building stored in this system for a certain time and then disposed to connected drainage system. This system needs periodic removal of sludge stored in the tank and this sludge contains high amount of organic matter, bacteria etc. so heavy measures have to be taken before disposal it in environment. It is also to be mentioned that process of removing sludge by mechanical means incurred a significant amount of price which is not so feasible to the common people. In this study it is endeavoured to find out a sustainable solution to extend the period of sludge cleaning of septic tank which indirectly cuts down the cost of sludge removal. In this study various types of filter are arranged in decreasing order of their pore size and sewage water directly pumped out of the septic tank is passed through this system. Samples are collected after each filtration and after certain interval of time. These samples are tested for physiochemical parameters to find out the efficiency of the unit and characteristics of the effluent whether it meets the environmental disposal standards laid down by concerning authority.

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CHAPTER:

1. INTRODUCTION

Introduction

In the context of infrastructure services proper, well planned and well implemented sanitation is one of the basic requirements. Urban area generally poses a well planned sanitation system, but rural areas are still deprived of these services. So this is a challenge to provide this sanitation facility to all the people belonging from rural to urban areas. But we also have to keep in mind that ever rising population in developing countries makes this problem harder.

When designing a sanitation system various steps are to be taken in account, such as study of current population and growth of population of that region, topography of the region, detailed planning, meticulous implementation and procurement of documents from concerning government department. Management of output wastewater and solid sludge bear as much as importance as laying sanitation systems .This output wastes may be either reused or discharged without harming any surrounding individual. Septic tank is a feasible choice in small scale household system for discharging of wastewater generated from these households. Along with it septage management needs to be implemented and monitored time to time by the concerning authority. Septage management is managing both faecal sludge from septic tanks and pits existing in urban and rural area. As nearly 75 percent in India is dependent on onsite sanitation system, which emphasises the importance of septage management to achieve proper and hygienic sanitation system.

Rural areas and the outskirts of the urban areas may not have significant population and infrastructure to build well planned centralised treatment plant and sewer system. That's why onsite sanitation system (OSS) becomes mandatory to maintain hygienic living conditions. Septic tank and pour flash toilets are widely used as OSS. Sludge of septic tank needs to be cleaned periodically and should be treated before utilization as manure. Removal of faecal sludge must be done very cautiously as it may cause health hazards.

Now a days vacuum tankers are mainly used for removal of sludge from septic tank subjected to availability of space to install the machine. But dumping of sludge should not be done in an area without assessing its possible impact on environment and public health. Municipal town areas aren't mostly covered under septage management facilities. This results in uncontrolled open dumping of municipal wastes including sludge of septic tank.

The government of India has undertaken an ambitious social change endeavour to establish a clean and open defecation free (ODF) India which is already starts being implemented in urban and peri-urban centres. Continuous efforts in this direction may upgrade the sanitation scenario in India which in turn will help in attaining the United Nations' Sustainable development Goal 6(established by UN in 2015) of universal and equitable access to safe and affordable drinking water and adequate and equitable sanitation and hygiene for all.

1.1 Project background

Generally manual handling of faecal sludge in the process of removing from septic tank is prevalent in many developing countries. This process may cause severe health disease to the operator and usually considered illegal. After removing it is also often dumped in the open piece of land which is highly risky for public health.

The use of vacuum truck is very suitable method without risking any individual health but it comes with a high price range which makes this facility restricted to few customers. In addition to that lack of treatment plant results in indiscriminate dumping of removed waste from septic tank. So although this process eliminate manual handling, it couldn’t stop it’s environmental impact.

An international non profit organization named Water for people endeavours to solve of sanitation problem and makes sanitation system more economic, accessible to all and eco-friendly without risking any individual life. Now it appears that extending the pit life of septic tank might be an option for more eco-friendly approach within the limited budget. Membrane technology is a plausible solution for solid liquid separation which also produces effluent suitable to use in aqua culture, irrigation etc. This technology wasn’t that much popular due to its high cost. Now the scenario has changed, development of domestic membrane manufacturing in India reduce the cost of this technology which makes it feasible for commercial use.

Membranes are arranged in decreasing order of pore size to separate and treat the supernatant part of septic and pit latrine sludge. This Pit Life Extender (PLE) is developed by Water For People and further improvised as per field requirements by School of Water Resources Engineering, Jadavpur University. That unit treats the water from septic tank by the means of filtration and adsorption. The aim was to develop a low cost solution suitable for installing in households which filters out the water from the tank and decreases the water level inside it which in turn would increase the pit life of that particular septic tank.

1.2 Onsite Sanitation

Where either sewer pipe is on the process of construction or couldn't be laid due to unavoidable circumstances onsite sanitation system is viable choice. It is basically a treatment process which provides treatment of sewage at the where it is generated instead of a centralised treatment plant.

1.2.1 On-site Classification

This subsection summarizes the classification of toilets and on-site treatment methods as well as their features.

A) Pit Latrine/Toilet

In this process no separate tank is created to store human excreta, instead of that here human faeces and urine are collected on spot directly from a hole on the floor of latrine. This process can be done with either dry or pour-flush system. Properly built pit latrines can decrease the spread of diseases by reducing the amount of human feces in the environment from open defecation this decreases the transfer of pathogens between feces and food by files. These pathogens are main cause of infectious diarrhea and intestinal worm infection. Infectious diarrhea resulted in about 700,000 deaths in children under five years of age in 2011 and 250 million lost school days.

The toilets are categorized roughly into four types according to application: a toilet in a detached house, a common toilet in an office or community, a public toilet for unspecified users, and a mobile toilet for emergency such as a disaster.

B) Simple Treatment Method

A septic tank system, a typical on-site treatment facility that consists of a septic tank and a soak pit, employs two technologies. The first is anaerobic treatment and the second is adsorption. It shows stable performance, provided that the water temperature is kept suitable to digestion and the soil has good permeability to facilitate well adsorption. However, the septic tank has a BOD reducing rate of up to 50%, so if underground penetration is impossible due to high groundwater levels, rocky strata, non-availability of land for soak-pit, another method must be employed to hygienically treat sewage passing through the septic tank such as anaerobic filter and contact aeration. When this system is applied to an urban area with high population density, care must be taken not to have an effect on the surrounding environment. In this process two basic technologies is used one is anaerobic digestion and second is ground adsorption. It consists of two main structure one is septic tank another is soak pit. Here septic tank may be of two or three compartment depending on various parameters, but generally two compartments is used. Septic tank has BOD removal efficiency of 40% to60 %. After that sewage passes through soak pit for adsorption, but in some cases due to many reason it is not possible to allot a land to construct soak pit then another method must be employed to hygienically treat sewage passing through the septic tank such as anaerobic filter and contact aeration.

C) Advanced Treatment System

Well designed and well maintained conventional septic tank can effectively remove about 40-50% BOD and 50-70% TSS. So as it is a partial treatment process that's why effluents may cause health hazards which makes uses of soak pit mandatory. Due to recent groundwater pollution related incidents, scarcity of space for soak pits and under rocky strata, soak pits are avoided and the effluent is commonly discharged to open stormwater drains. Hence, it is causing another type of pollution menace such as eutrophication, odour, flies and water related diseases.

Modernised design of septic tanks such as uses of anaerobic baffled reactor or the post treatment of septic tank effluents by anaerobic filters can be an interim solution. Both configurations can minimize the pollution related problems by increasing the overall BOD removal to more than 70%. In these way burden of organic pollution can be reduced without any extra energy cost. Only capital cost of conventional septic tank may gets by 20-30%.

But despite of all these technologies anaerobic sewage treatment has its own limitation due to which BOD and TSS level can not be brought down to the national effluent discharge standards. So an aerobic treatment such as contact aeration becomes necessary. This system is capable of bringing down effluent BOD to less than 30 mg/l and TSS to less than 50 mg/l but at the cost of electrical energy operating for 24×7, air blower with standby equipment and standby power.

Example of such system is the Japanese type Johkasou system. This system is an integrated septic tank anaerobic filter-contact aeration-final settling tank with provision of effluent disinfection. However, due to higher cost considerations, these systems may be affordable only in very fragile environment or in developed countries where economy is least concerned. These systems have also been upgraded to remove nitrogen by using internal recirculation techniques.

1.3 Conventional Septic Tank

Conventional septic tank is a kind of onsite sanitation system facility where sedimentation and digestion occurs simultaneously. Here sewage is held for 24hrs to 48 hrs and suspended solids are settled down to the bottom. As there is no circulation of air anaerobic digestion of settled solid and liquid occurs, which results in reasonable reduction in the volume of sludge, reduction in biodegradable organic matter and release of gases like carbon dioxide, methane and hydrogen sulphide. Despite this treatment effluent will still contain noticeable amount of suspended putrescible organic solids and pathogens.

Therefore disposal of septic tank effluent needs to be taken very seriously. Due to its unsatisfactory quality of the effluent and also the difficulty in providing a proper effluent disposal system, septic tanks are recommended only for individual homes and small communities and institutions whose contributory population is less than 300. If it is to be used for larger communities then septic tanks should be supplemented with appropriate effluent treatment and disposal facilities. However, in both cases the effluent from the septic tank should be disposed into a lined channel constructed along with storm water drain if proper sewerage system is not laid.

1.4 Design

Several experiments and performance evaluation studies have shown that about 30% of the settled solids are completely digested in a septic tank and rest are remain un-digested or poorly digested. It has been found through periodic analysis of data that if a septic tank is not de-sludged for a time generally more than its design period, substantial portion of solids escape with the effluent. This doesn't serve the purpose of the septic tank. The purpose is that the sewage supposed to flow through outlet without dislocating either the scum which accumulates at the surface or the sludge which settles at the bottom. Normally sufficient capacity is provided to the extent that the accumulated sludge and scum occupy only half or maximum two-thirds the tank capacity, at the end of the design storage period.

From numerous analysis it has been stated that in order to provide sufficient sedimentation of suspended solids, minimum retention time for the liquid should be 24hrs. Therefore, considering the volume required for sludge and scum accumulation, the septic tank may be designed to retain sewage for 1 to 2 days.

The septic tanks are normally rectangular in shape and can either be a single tank or a double tank, in very few cases three tanks is used. In case of double tank, suspended solids get settled in the first compartment and remains there, liquid part enters the second compartment and then moves to outlet that's why solids concentration of the effluent is considerably lower than in the case of single compartment. Generally first compartment is made twice the size of the second as first compartment is used for sludge accumulation.

Septic tanks can be made of concrete, masonry or fibreglass. Septic tank made from concrete, masonry are of rectangular shape and generally circular shape is preferred if it is made of fibreglass. Baffle wall is used at both inlet and outlet of the septic tank so that floating matter and grease remain stored in the tank.

As the anaerobic digestion takes place biogases are produced which may slow down the sedimentation of the solids. To counter this problem septic tank should be provided with the ventilation pipe. The top of this pipe is covered with suitable mosquito proof wire mesh to mitigate mosquito problem. The top of the pipe should be extended to at least 2 m above the highest building height present in the vicinity of 20 m from the septic tank.

The liquid depth of the tank is 1 to 2 m and the length to the width ratio is in the range of 2:1 to 4:1. The cleaning frequency of the tank is generally 2 to 3 years.

Minimum of 300 mm of free board should be provided in the tank, it will help to accommodate scum and providing safety to the workers.

The effluent of the septic tank is highly dangerous. Hence, further treatment for septic tank effluent is necessary to maintain hygienic conditions of the surrounding environment. As septic tank doesn’t offer complete treatment, this facility is restricted to individual houses and apartments or institutes where total number of user is less than 300.

Typical design data of a septic tank:

Average flow per capita= 100 - 160 L/day

Peak flow per capita= 170 - 270 L/day

BOD per capita= 0.045 kg/day

Suspended solids per capita= 0.070 – 0.090 kg/day

Soluble solids per capita= 0.035 kg/day

Sludge accumulation per capita= 0.073m^3/year (*Ref: NPTEL)*

Post treatment can be achieved by aerobic treatment. Diffused aeration with solids recycling (extended aeration), sand filter or synthetic media filter (attached growth process) can be used for treatment of septic tank effluent. Filter bag equipment and hypochlorite addition will also be suitable for treatment. However, frequent replacement of filter bag and hypochlorite addition makes it costly.

Inlet and Outlet Pipes

An elbow or T pipe of 100mm diameter is submerged to a depth of 250-600mm below the liquid level. For outlet pipe an elbow or T type of 100mm diameter pipe is submerged to a depth of 200-500mm below the liquid level. Pipes may be of stone ware or asbestos.

Baffle Walls of Septic Tank

For small tanks, RCC hanging type scum baffle walls are provided in septic tanks. Baffle walls are provided near the inlet. It is optional near the outlet. The inlet baffle wall is placed at a distance of L/5 from the wall, where L is the length of the wall. The baffle wall is generally extended 150 mm above to scum level and 400-700mm below it. Scum being light, generally floats at the water level of the tank .Thickness of the wall varies from 50mm to 100mm. for large tanks lower portion are having holes for flow of sludge.

Roofing Slab of Septic Tank

The top of the septic tank is covered with a RCC slab of thickness of 75-100mm depending upon the size of the tank. Circular manholes of 500mm clear diameter are provided for inspection and sludge removal. In case of rectangular opening clear size is kept as 600X450mm.

1.5 Construction Details

The inlet and outlet should not be located at such levels where the sludge or scum is formed. Otherwise, the force of water entering or leaving the tank will unduly disturb the sludge or scum. Further, to avoid short circuiting, the inlet and outlet should be located as far away as possible from each other and at different levels. Baffles are generally provided at both inlet and outlet and should dip 25 to 30 cm into and project 15 cm above the liquid. The baffles should be placed at a distance of one-fifth of the tank length from the mouth of the straight inlet pipe. The invert of the outlet pipe should be placed at a level 5 to 7 cm below the invert level of inlet pipe. Baffled inlet will distribute the flow more evenly along the width of the tank and similarly a baffled outlet pipe will serve better than a tee-pipe.

For larger capacities, a two-compartment tank constructed with the partition wall at a distance of about two-thirds the length from the inlet gives a better performance than a single compartment tank. The two compartments should be interconnected about the sludge storage level by means of pipes or square openings of diameter or side length respectively of not less than 75 mm. Every septic tank should be provided with ventilation pipes, the top being covered with a suitable mosquito proof wire mesh. The height of the pipe should extend at least 2 m above the top of the highest building within a radius of 20 m.

Septic tanks may either be constructed in brick work, stone masonry or concrete cast in situ or pre-cast materials. Pre-cast household tank made of materials such as asbestos cement could also be used, provided they are watertight and possess adequate strength in handling and installing and bear the static earth and superimposed loads.

All septic tanks shall be provided with watertight covers of adequate strength. Access manholes of adequate size shall also be provided for purposes of inspection and de-sludging of tanks. The floor of the tank should be of cement concrete and sloped towards the sludge outlet. Both the floor and side wall shall be plastered with cement mortar to render the surfaces smooth and to make them water tight. A typical two compartment septic tank is shown in Fig. 1.

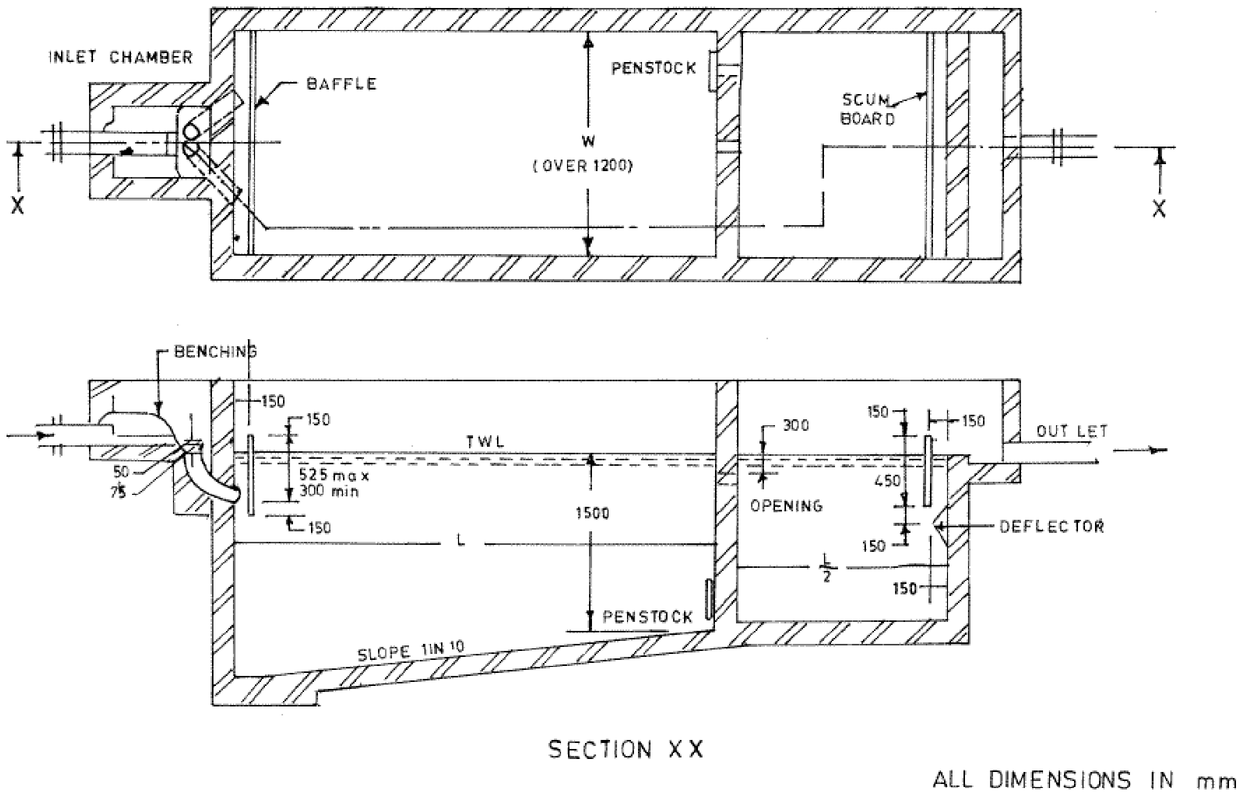

Fig. 1: Diagram of a Typical Septic Tank (*Ref. CPHEEO manual)*

1.6 Soak Pits

The water in the septic tank is not pure, it is called grey water because it still contains organic materials that need to be filtered out. A Soak Pit is a covered, porous-walled chamber that allows water to slowly soak into the ground. Pre-settled effluent from septic tank is discharged to the underground chamber from where it infiltrates into the surrounding soil. Water table must be sufficiently below ground level to construct a soak pit. Soak pits should be preferred only when land is limited or when a porous layer underlies an impervious layer at the top, which permits easier vertical downward flow than horizontal spread out as in the case of dispersion trenches. Minimum horizontal dimension of soak pit should be 1 m, the depth below the invert level or inlet pipe being at 1 m. The pit should be covered and the top to be raised above the adjacent ground to prevent damage by flooding.

1.7 Membrane Technology

Membrane filtration refers to the use of a material as a barrier to distinguish one size of particle from another. Most commonly this is used in water treatment to separate everything from suspended particles to dissolved ions from water. However, it has been also applicable in gas separation and low temperature distillation. The summary that follows focuses on the technologies of cloth filtration, micro filtration, GAC, ultra-filtration, which are used in water treatment.

The membrane systems used in water treatment are dependent on the feed water quality, flows that are required and required product water quality. A Reverse Osmosis membrane will filter everything from a water source and produce drinking water quality, but without proper pre-treatment by screening, UF and bio fouling control, the system will block within minutes and become useless. Looser membranes also allow more flow rate than stiffer ones at any given pressure, which makes selection of membrane vital from the point of operating cost efficiency. Most membranes are made of organic polymers which are cased in such a way that water can be pushed onto the feed side of the membrane and the filtered water collected through a separate port. Some membranes are designed to operate with a steady cross flow that recirculates, as well as with backwashing in mind to prevent a build-up of solids on the surface and to maintain flow across the membrane surface. Reverse Osmosis and nano-filtration membranes are unable to be backwashed and must operate with a constant cross flow, as well as cleaned periodically to prevent foul ant building up. Membrane systems are arranged in the order of largest pore size to smallest. All membrane systems should have primary screening to prevent debris that could damage membrane material. Screens can be automatically backwashed or manually cleaned by operators.

Table 1: Various Type of Filter Classification *(Ref. Chakraborty (2018))*

Process	**Pore size**	**Process**	**Filtration Pressure Estimate**	**Filtration Removes**
Standard Filtration	> 10 µm			
Micro-filtration (MF)	0.1-10 µm	**Micro-filtration (MF)**	< 100 kPa	Larger bacteria, yeast, some suspended particles
Ultra-filtration (UF)	0.01 µm	**Ultra-filtration (UF)**	100 kPa – 1 MPa	Large organic molecules, bacteria, suspended solids
Nano-filtration (NF)	1-10 nm	**Nano-filtration (NF)**	300 kPa – 2 MPa	Viruses, divalent ions, some colour
Reverse Osmosis (RO)	< 1 nm	**Reverse Osmosis (RO)**	1 MPa – 8 MPa	Dissolved salts and small organics

CHAPTER:

2. DIFFERENT TYPES OF MEMBRANE TECHNOLOGY

2.1 In-pit Cloth Filter

In this project cloth filter is used for covering the perforated pipe. A perforated pipe placed inside the 2nd compartment of the septic tank and a cloth filter is wrapped around the perforated pipe. Pore size is an important consideration when selecting the proper filter cloth for a particular application. Pore size is determined by the number of fibres, fibre size, and the type of weave. Filter cloths come in many different materials including polypropylene, polyester, cotton, and various synthetic materials. The cloths are made from monofilament fibres, multifilament fibres, or spun fibres. It is used in this project to separate the suspended solids present in the raw sewage from the liquid and to reduce the organic load in the sewage.

2.2 Micro-filtration

Micro-filtration is the membrane technologies used in water treatment, with a nominal pore size range of 10 µm to 1 µm. Micro-filtration is used to remove suspended solids, macromolecules and some pathogens from water. A Micro-filtration system can operate in either cross-flow or dead end filtration mode, depending on the volume of liquid that is being treated and whether it is intended for the membranes to be continually operative or planned to be replaced when choked. Any large scale treatment plant generally operates in some sort of cross flow arrangement due to the cost effectiveness of this process.

Micro filters can be used in the form of hollow fibre membranes, flat membrane sheets or wound cartridge. In this project wound cartridge is used. Wound cartage provides low cost of replacement and wide distribution of the filters. These are to be operated via dead end node system. Due to the dead-end filtration, proper pre-screening is essential to prevent rapid fouling, that's why previously mentioned cloth filter is used. Pressure may be checked at upstream and downstream of the micro-filter, as well as flow rate to assess the performance of the filter.

2.3 Granulated Activated Carbon

The two principal mechanisms by which activated carbon removes contaminants from water are adsorption and catalytic reduction. Organics are removed by adsorption and residual disinfectants are removed by catalytic reduction.

Activated carbon's adsorptive properties are used to remove organics. Generally, adsorption takes place because all molecules exert forces to adhere to each other. Activated carbon adsorbs organic material because the attractive forces between the carbon surface (non-polar) and the contaminant (non-polar) are stronger than the forces keeping the contaminant dissolved in water (polar).

Iodine number is one of the most fundamental parameter used to classify activated carbon. Iodine number is defined as the milligrams of iodine adsorbed by one gram of activated carbon leaving the iodine concentration in the residual filtrate at of 0.02 normal (i.e. 0.02N). Basically, iodine number denotes the quantity of iodine adsorbed in the pores which indirectly indicate of the pore volume available in the activated carbon of interest. Generally, carbon used for waste water treatment has iodine numbers ranging from 600 to 1100. Frequently, this parameter is used to determine the degree of exhaustion of a carbon in use. However, this practice should be viewed with caution, as chemical interactions with the adsorbate may affect the iodine uptake, giving false results. Thus, the use of iodine number as a measure of the degree of exhaustion of a carbon bed can only be recommended if it has been shown to be free of chemical interactions with adsorbates and if an experimental correlation between iodine number and the degree of exhaustion has been determined for the particular application.

2.4 Ultra-filter

This is a type of membrane filtration which requires external pressure to filter out the effluent. With respect to micro-filtration, ultra-filtration having smaller pores is even able to reject not only bacteria and inorganic particles, but also smaller contaminants, such as viruses and macromolecular substances. Along with that pre treatment by activated carbon before ultrafiltration, substantially improves the removal efficiency of the system for humic substances and pesticides. As with Micro-filtration, ultra-filtration can operate in cross flow or dead-end filtration modes, with the same advantages and limitations existing for both systems.

Ultrafiltration membranes are typically formed as either hollow fibre or spiral wound modules, with an active membrane layer made of Polyvinyl Di-fluoride (PVDF). The ultra-filtration membranes operate in dead end mode, made of hollow fibre structure are used in this project.

Ceramic ultra filters are a more recent development that continues to become more cost competitive. Ceramic filters have advantages of superior abrasion resistance, chemical resistance and membrane flux, however they are not yet economic comparable with polymer based membrane systems.

CHAPTER:

3. OBJECTIVE AND SCOPE OF STUDY

3.1 Objective of This Study

In this study the main objective is to provide more feasible solution for septage management by increasing the pit life of the septic tank. In this process pit life extender (PLE) is used, which is basically an arrangements of filter on order of decreasing pore size. Sewage extracted from the septic tank is passed through different filters one by one and performance of the unit is monitored by checking the reduction in various physiochemical parameters of the sewage water.

3.2 Scope of This Study

- To study the nature of supernatant liquid in septic tank. .
- Study of performance of cloth-filter.
- Study of performance of micro-filter.
- Study of performance of Granular Activated Carbon.
- Study of performance of ultrafiltration technique.
- Study of modification of the unit required to achieve better quality of effluent.
- Study possibility of using the filtered effluent in different sectors.

CHAPTER:

4. LITERATURE REVIEW

4. Literature Review

Some literatures of national and international status are mentioned below which are in the context of this research work.

4.1 National Status

Ghosh, *et al* (2011) work on a comparative study was conducted to find out the potential of single channel ceramic micro-filtration membrane along with various physicochemical treatments, viz. bio-treatment and adsorption using kitchen-sink wastewater. Studies were carried out with tubular ceramic membrane with Cross-flow micro-filtration (CMF) in single channel and multi-channel configuration. Bio-treatment was studied using activated sludge process (suspended growth system) and adsorptive treatments were studied using a biological absorbent prepared from the dried roots of Eichhornia crassipes, an aquatic weed which is abundantly grown in polluted water. The study showed better performance of 19 channel ceramic membrane compared to the single channel membrane in terms of the permeate quality, viz. BOD, COD, turbidity, TSS etc., as well as, permeate flux. Micro-filtration of the adsorbent treated feed appeared to be most promising in comparison with the other feeds wherein, about 98% reduction of BOD and 99% removal of COD were attained. The quality of the treated water was found to be fit for use in horticulture, irrigation, aquaculture etc.

Sarin (2013) studies involve the quality and the treatment processes of municipal wastewater, industrial effluent taken from Juice processing unit and examine the bio kinetics and fouling characteristics. Membrane bioreactor (MBR) combines membranes with biological processes for treatment of waste water which is used in this research work to treat waste water. MBR provides high quality of treated water with complete solid removal and disinfection capability, combined with high rate and efficiency of organic and nutrient reduction in one unit, small foot print low or near zero sludge production, high loading rate capability, rapid start up, modular and retrofit. It is free from sludge bulking problem thus, has high performance and low maintenance. The effluent has a 90% reduction of COD, phosphorus removal is low as 31%, TSS removal observed was always above 98.5%.

Vrushali and Chatterjee (2014) stated that Waste water, is any water that has been degraded in quality by external influence. The indiscriminate disposal of untreated sewage water from colonies as well effluent from industrial units has been identified as main cause of water pollution across developing countries. Sewage is a kind of waste water generated from people living in communities. It is the water which is produced as a waste after various activities like washing dishes, laundry, flushing of toilets etc. this water has to be treated to certain specified level before discharging in the environment so that it doesn't affect the surrounding environment.. This sewage is characterized by volume or rate of flow, physical condition, chemical condition and the bacteriological organisms that it contains. As the population increases the demand of the water increases in many folds, which compelled us to do research in the field of reusing the sewage water. During recent years, there has been an increasing awareness and concern about water conservation all over the world. Hence, new approaches towards achieving sustainable development of water resources have been developed internationally.

In this research paper a lab scale study was conducted to evaluate the treatment efficiency of biological treatment (Activated Sludge Process followed by Chlorination and Dual Media Filtration) in treating sewage. The BOD, COD ,TSS concentration of sewage used as raw sample are 190 mg/L , 320 mg/L & 200 mg/L respectively.. Treatment technologies adopted are activated sludge process, chlorination & filtration. The results were very encouraging. The treatment system achieved removal of 96.8% BOD, 92.5% COD and 95% TSS & 99% Total coliform removal respectively at outlet effluent. The treated sewage can be reused for various purpose like cooling water make up, gardening , landscape development , toilet flushing, road washing etc. thus leading towards sustainable water conservation process.

Vaidya (2015) stated that sewage treatment and proper eco-friendly disposal are major issue in many developing countries like India due to treatment facilities and lack of awareness among the common people. To find out a system of disposal of domestic wastewater which is eco-friendly as well as economic is one of the most relevant issues in today's civilization. Conventionally, septic tank is used for on-site treatment of domestic wastewater; but it sometime causes groundwater pollution and produce partially treated effluents. Recently other technologies have been developed such as bio-filtration, membrane bioreactors, bio-towers, sequential batch reactor, fluidized aerobic bioreactor, packed bed reactor, submerged fixed film technology, concentric chamber reactor and various combinations of aerobic and anaerobic processes which have given better performance than that of septic tank. This paper reviews the application of such technologies as alternatives for on-site treatment of domestic wastewater. The different types of reactors developed by researchers are also reviewed in order. This paper is focussed on the treatment options for domestic wastewater generated at municipal level.

Ravishankar *et al* (2018) studied reuse of waste water in individual houses situated in peri-urban areas of Banglalore where main source of water is groundwater. Access to groundwater is through water tankers, private bore wells, Bruhat Bengaluru Mahanagara Palike (Urban Local Body) bore wells, and public stand posts. All modes of water distribution except by tankers provide water to the community free of charge. Reclaimed water from sewage treatment plants (STPs) is in use by industries and some gated communities and multi-storied apartments for toilet flushing and landscaping. This paper concerns the possibility of reusing water in individual houses. Consequently, this research paper investigates the willingness of residents in peri-urban areas of Bengaluru to use reclaimed water for non-potable end uses.

To find out actual ground reality about willingness of the residents and key motivations for the use of treated water, a survey of residents in the peri-urban ward of Bellandur was conducted paper. In this region, the sewerage board had prepared a media advertisement to create awareness of water conservation, reuse and to sell reclaimed water to other users, including local residents. This advertisement was shown to respondents, asking if they were willing to accept and buy the reclaimed water at 15 Indian Rupees (INR) per kiloliter. Here in this study it has been shown that sixty-seven percent of residents who were household owners were willing to buy reclaimed water, 20% were sceptical about hygiene, and 33% of respondents lacked trust in the public agency with respect to water quality standards. The study concludes that public awareness from key stakeholders is essential for the reuse of reclaimed water. It also recommends stringent regulation by levying fees for groundwater extraction in addition to making reclaimed water readily available and supplied free of charge to the consumers. In addition, the quality of reclaimed water should meet international standards to gain the confidence of the people.

Sahasranaman & Ganguly (2018) stated the requirements of wastewater treatment for water security in India. This paper assesses the quality of water in surface water bodies which are important source of potable water across India. data on water The quality in rivers upstream and downstream of selected cities over a period of time was analysed along with the present and anticipated future water demand of the city . The ground reality of sewage treatment across Indian states was also found out, to understand the need of waste water treatment to meet the demand of the general public. The existing institutional and legal measures available for the control of water pollution were also analysed. The paper also debates on construction of new wastewater treatment infrastructure rather than improving the existing wastewater treatment systems, upgrading of wastewater treatment systems and renovation of the old sewer system, all incorporating aspects of economic viability and environmental sustainability.

4.2 International Status

Kennedy and Geel (2000) studied on the water holding capacity and adsorption capacity of peat make it a favourable filter medium over sand or gravel which are commonly used as the filter medium for the drainage field of septic systems. Peat is an alternative filter medium for the treatment of various waste streams including septic tank effluent This paper presents the results of a field study to evaluate the hydraulics of a peat filter used to treat the septic tank effluent from a public school west of Ottawa, Canada. An experimental box was placed within the filter during its construction to provide access to the vertical profile of the peat layer. The filter is periodically pulsed with septic tank effluent, which is distributed over the top of the filter and flows vertically through the peat. The filter was instrumented with sensitometers and transducers to monitor the pore water pressures in response to a pulse of septic tank effluent. An in-depth study of the hydraulics of the system was completed. The soil moisture retention curve and the hydraulic conductivity as a function of density were determined in laboratory experiments. A one-dimensional unsaturated flow model was used to predict the pressure response due to a pulse. A comparison of the field and model results illustrates the impact of the density variations, and the corresponding hydraulic conductivity variations, on the model predictions. The compaction of the peat is an important design consideration for the filter since it directly impacts the flow characteristics and the hydraulic retention time within the filter.

Ingallinella and Sanguinetti (2002) stated in urban centres of developing countries, on-site sanitation systems are installed in majority of houses such as septic tanks and pit latrine. The faecal sludges (FS) collected from these systems are usually discharged untreated or with minor treatment where effluent quality doesn’t meet the stipulated standard of that country, posing great risks to water resources and to public hygiene. Contrary to wastewater management, the development of strategies to cope with faecal sludges, adapted to the conditions prevailing in developing countries, has long been neglected. The authors describe the present scenario and discuss selected issues of faecal sludge management. A proposal is also suggested for treatment standards in economically emerging countries. The authors stipulate that regulatory measures should be taken into account by considering local economic, institutional and technical conditions. A separate section is devoted to the practice and to regulatory aspects of (faecal) sludge management in Argentina. An overview of treatment options, which may prove sustainable in less industrialized countries is provided. This paper also reviews the faecal sludge management practices in Thiland, which has been improved in recent four years.

Patterson (2003) studied to provide local guidelines on the typical quality of septic tank effluent, mostly taken as grab (spot) samples of many operating septic tanks of particular area and averaged over the set. There is often no qualification as to the operational status, loading rate, time of day, or water use under which individual systems were operated at the time of sample collection. As water use within the home and the chemicals associated with personal hygiene and household cleaning can add significant levels of particular elements, an understanding of their impact upon water quality is required.

Greya and Sadoff (2007) studied on attaining basic water security, utilizing the productive potential of water and limiting its destructive impact, should be a national priority. To apprehend this duality, water security is defined here as accessibility of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production of crop, along with an acceptable magnitude of water-related risks to people, environments and economies. This paper seeks to find out the dynamics of attaining water security in a hypothetical water and growth "S-curve", which elucidate how a small amount of investments in water institutions and infrastructure can derive a tipping point beyond which water makes an increasingly positive contribution to growth of the country and how that tipping point will vary in various countries in different circumstances.

Bhuyar (2013) stated some results in this paper are from studies on a laboratory-scale packed bed reactor treating domestic wastewater at different hydraulic retention time. The experiments were performed at hydraulic retention times of 1, 2 and 3 d based on empty reactor volume and the performance of the reactor was evaluated based on the removal of organic matter COD, SS, PH Changes and biogas production. The average COD and SS removal efficiencies for Domestic wastewater were 63.87, 70.85, 75.92 % and 75.24, 84.55, 94.25 % respectively. PH changes from 7.2 to 4.2. Biogas was produced 0.50 to 0.59 l/d.l on same HRT. The relationship between the organic removal rate and HRT was linear at flow rates of 0.58, 0.29 and 0.19 l/h. The study demonstrated the influence of hydraulic retention time (HRT) and suitability of up-flow anaerobic packed bed reactor (UAPB) for treatment of domestic wastewater.

Radcliffe *et al* (2013) studied on on-site wastewater treatment systems (OWTS) which work by first storing the wastewater in a septic tank before releasing it to soils for treatment that is generally effective and sustainable. However, it is not clear how the abundance of *E. coli* changes during its passage through the tank. In this study, which was conducted under the UGA young Scholar Program in summer of 2010, it is examined that the change in wastewater quality parameters during the passage of the wastewater through the tank and after its release into soil. Wastewater samples are collected at the inlet and outlet of an experimental septic tank in addition to obtaining water samples from lysimeters below trenches where the drainpipes were buried. It is reported that *E. coli* concentration was higher by 100-fold in the septic tank effluent than influent wastewater samples, indicating the growth of *E. coli* inside the tank under typical Georgian summer weather. This is contrary to the assumption that *E. coli* cells do not grow outside their host and suggests that the microbial load of the wastewater is potentially enhanced during its storage in the tank. Electrical conductivity, pH and nitrogen were similar between the influent and effluent wastewater samples. *E. coli* and total coliform concentrations were mainly below detection in lysimeter samples, indicating the effectiveness of the soil in treating the wastewater.

Peace and Hounkpe *et al* (2014) stated that poor wastewater management coupled with lack of awareness at the ground level has aggravated the sanitation problem in developing countries. This study was aimed at providing information on the present scenario of sanitation in Cotonou City (Benin, West Africa) through various surveys. The most common sanitation facilities in the city were septic tanks, latrines and soak pits. Mechanical sludge removal was mainly used (94%) for latrines and septic tanks with a frequency of less than once a year for 73% of the houses; manual sludge removal was most common for soak pits. 84% of sludge generated is disposed without treatment. The only existing stabilization pond plant, managed by a private company SIBEAU, is overloaded; the effluent is poor (up to 2250mg/l BOD5) and does not meet any quality standards. 96% of survey respondents recognise that the sanitation situation in the city is not good; it has to be improved by providing an appropriate and sustainable sanitation management system.

Chirisa *et al* 2017 studies shown until recently there has been little, if any, concern over revamping let alone improving wastewater management system in Zimbabwe’s urban areas given the dominance and institutionalised water-borne system. Yet, the current constraints in this system and the immensity of urbanisation in the country begs and compels planners, engineers and systems thinkers to rethink what best can work as a sustainable wastewater system. With particular reference to the ever-expanding Harare metropolitan region, this article provides an evaluative analysis on the potentiality, risks and strategies that can be adopted by Harare and its satellites in addressing the problems of the conventional wastewater management system. The suggested framework of operation is a decentralised domestic wastewater collection and treatment system which however has its own multifarious risks. Using systems dynamics conceptualisation of the potentiality, opportunities, risks and strategies, the paper seeks to model the path and outcomes of this decentralised domestic wastewater collection and treatment system and also suggests a number of policy measures and strategies that the city of Harare and its satellites can adopt.

CHAPTER:

5. MATERIALS

&

METHODOLOGY

5.1 Methodology

At first septic tank is located which is to be used for this study. It is to be notified PLE machine is supposed to be installed on 2nd compartment and tank must contain sufficient amount of liquid otherwise purpose of this machine couldn't be served. After successful installation electric connection is made and unit is started to operate. Sampling is started after a short interval as unit requires a certain time to acclimatize to the field condition and achieve its full fledged potential. Then sample of filtered water after individual filtration unit is collected while keeping suitable safety precaution of the people assigned to this process. After that those samples are transported from the location to the laboratory for analysis and along with that flow rate of filtered water, reading of pressure gauges are continuously monitored. It is intended to keep the unit operative for duration of 72 hrs, but if it is not achieved then intricate observation on duration of operation of individual filter and unit as a whole is to be noted down carefully which will help us to proceed with further modification. After analysing various physiochemical parameters of collected samples performance of the unit and individual filters are assessed and further development is suggested.

Water For People

It is an international non-profit organisation serving across 9 countries and 4 million people. Around the globe 2.1 billion people don't have access to safe water and 4.5 billion lack access to adequate sanitation. To counter this vehemently untoward situation this organisation is in the pursuit of making safe drinking water accessible to all the people and providing sustainable hygienic sanitation condition to all. This organisation partnered with School of Water Resources Engineering, Jadavpur University to conduct this study to ascertain a sustainable and eco-friendly approach to septage management in the context of sanitation problems in developing countries.

Flow Chart of Methodology:

Selection of Site

⇩

Installation of PLE machine

⇩

Collection of sample on specific time interval

⇩

Testing of the sample for certain parameters

5.2 Site Location

Site 1:-
Location- 12/12B, Bireswar Dhol Lane
No. of users: 5, Length= 3 m, Breadth= 0.75 m, Depth= 1.5m. Liquid depth= 1.2 m
Total volume= 3.375 m^3

Fig. 2: Septic Tank at Site 1.

Site 2:-

Location – At JU campus besides mechanical building.

No. of users: 4, Length= 6.1 m, Breadth= 1.82 m, Depth= 1.82 m. Liquid depth= 1.52 m Total volume= 20.20 m^3

Fig. 3: Septic tank at Site 2.

Site 3:-

Location- At JU staff quarter

No. of users: 70 (approx), Length= 6.1 m, Breadth= 1.82 m, Depth= 1.82m.
Liquid depth= 0.92 m, Total volume= 20.20 m^3

Fig. 4: Septic Tank at Site 3.

Site 4:-

No. of users: 5, Length= 3 m, Breadth= 1.35 m, Depth= 1.2m. Liquid depth= 0.91 m Total volume= 4.86 m^3

Fig 5: Septic Tank at Survey Site 4.

5.3 Pit Life Extender (PLE)

This machine is nothing but arrangements of filter in decreasing order of their pore size. Four type of devices are being used to treat the sewage water, which are perforated pipe covered with cloth-filter, micro-filter, granulated activated carbon membrane, ultra-filter. A perforated pipe wrapped with cloth filter is put into the 2nd compartment of the septic tank and a submersible pump is kept inside that perforated pipe. When sewage starts seeping through cloth-filter and enters perforated pipe, this pump starts pumping this sewage water to the PLE machine which is rested on the surface of the tank. Sewage water then starts to enter the filters arranged in certain order placed in the machine. After passing through each device (cloth filter, micro-filter, GAC, ultra-filter) sample of the treated water is collected at specified interval of time and from specific collection point. Then those samples are tested for certain parameters to find out efficiency of the unit.

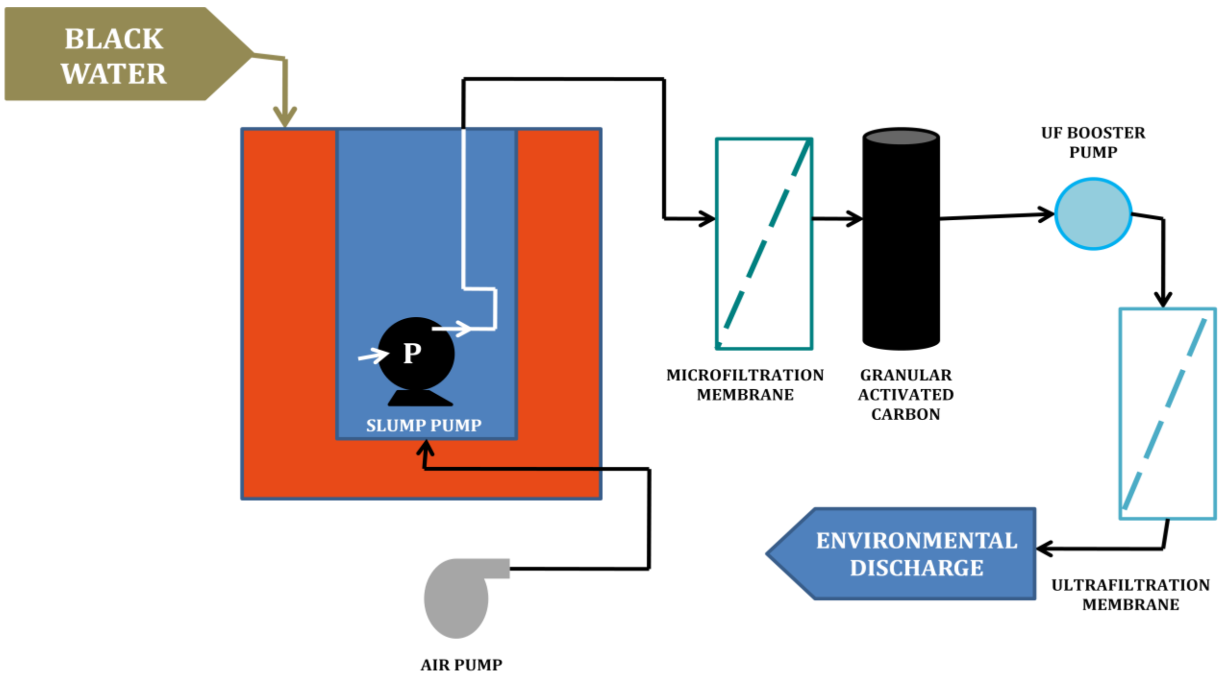

Fig. 6: Flow Diagram of PLE

5.4 Sampling Arrangements

In general sampling refers to collection of certain samples which is a part of the observation of present study for analysis. This forms an important portion of the study as the outcomes of sample analysis have great impact on the shape of research work. Analysis of different parameters of samples is very crucial step to decide further course action of the research work.

Depending of the type of sampling requirements of the process of sampling is changed. Below mentioned items are used for sampling.

- Measuring Cylinder.
- Stop Watch.
- Bucket.
- Mug
- Tool
- Rope
- Stick
- Gloves
- Hand wash
- Mask
- Autoclave Sampling Bottles (1liter).
- Ice.
- Sample Carriage Basket.

5.5 Standard Method For Determination Of Physicochemical Parameters:-

5.5.1 Determination of pH Value

Introduction:

The pH of a solution is measured as negative logarithm of hydrogen ion concentration. At a given temperature, the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen ion concentration. pH values from 0 to 7 are diminishing acidic, 7 to 14 increasingly alkaline and 7 is neutral.

Measurement of pH in one of the most important and frequently used tests, as every phase of water and wastewater treatment and waste quality management is pH dependent.

Principle:

The determination of pH may be made electrometrically using pH meter provide with pH electrode. pH vary with temperature.

Procedure:

a) Observe the sample temperature and set the pH meter to the appropriate temperature.

b) Calibrate the pH meter against standard buffer solution of pH 4.0, pH 7.0 and pH 10.01

c) For calibrating use standard buffer range that is close to sample pH. Now take the sample in a beaker and dip the electrode of pH meter into it and record pH.

5.5.2 Turbidity

Principle:

Turbidity in water is caused by the presence of suspended and colloidal substances, such as clay, silts and finely divided organic and inorganic matter, plankton and other microorganisms.

The method is applicable to drinking water, ground water and surface water in the range of turbidity 0 to 40 NTU. High values may be obtained by dilution of sample. The values are expressed in Nephelometric turbidity units (NTU). NTU are considered comparable to Jackson Turbidity Unit JTU.

Apparatus:

Nephelometric turbidity meter consisting of a light source and one photoelectric detector with a readout device to indicate intensity of light scattered at 90° to the path of incident light.

Calibration: Prepare a series of standards having turbidity of 5,10,20,30 and 40 NTU by diluting 1.25, 2.5, 5, 7.5 and 10 ml of stock primary formazin suspension to 100 ml. Follow HACH operation instruction.

Procedure:

Values less than 40 NTU:

Shake the sample thoroughly. Wait until air bubbles disappear and pour sample into the sample tube. Read the scale reading and determine turbidity from appropriate calibration curve.

Values above 40 NTU:

Dilute sample with turbidity free water until turbidity falls between 30 and 40 NTU. Complete turbidity of original sample from turbidity of diluted sample and the dilution factor

5.5.3 Determination of BOD Value:-

Principle:

BOD is the quantity of oxygen required by a definite volume of liquid effluent for oxidizing the organic matter contained in it in presence of micro organisms under the specified conditions of time and temperature. For its determination, the dissolves oxygen content of the sample with or without dilution is measured before and after incubation at 20° C for 5 days or 27° c for 3 days.

Apparatus:

a) Incubation bottle, 300 ml capacity BOD bottles.

b) Air incubator, thermostatically at 20 ± 1°C or at 27 ± 1°C

Reagents:

a) Phosphate Buffer solution: Dissolve 8.5 g of potassium di-hydrogen phosphate (KH_2PO_4), 21.75g of di-potassium hydrogen phosphate(K_2HPO_4), 33.4g of disodium hydrogen phosphate($Na_2HPO_4.7H_2O$) and 1.7g of ammonium chloride in 500ml of distilled water and dilute to 1.0 litre. The pH should be 7.2

b) Magnesium sulphate Solution: Dissolve 22.5g og $MgSO_4.7H_2O$ in distilled water and dilute to 1.0liter.

c) Calcium chloride: Dissolve 27.5g anhydrous $CaCl_2$ in about 7000mL of distilled water and dilute to 1 Litre.

d) Ferric chloride: Dissolve 0.25g $FeCl_3.6H_2O$ in about 700mL of distilled water and dilute to 1 L.

e) Sodium sulphate solution 0.025N: Dissolve 1.575g Na_2SO_3 in distilled water and dilute to 1000mL. Solution should be prepared daily.

f) Acid and Alkali solutions 1N: Prepare 1N H_2SO_4 and 1N NaOH or neutralization of caustic or acidic sample.

g) Nitrification inhibitor: 2-chloro-6-(trochloromethyl) pyridine [Nitrification inhibitor 2570-24 (2.2% TCMP), Hach Co. equivalent]

h) Glucose-glutamic acid solution: Dry reagent grade glucose and glutamic acid at 103ºC for 1h. Dissolve 150 mg glucose and 150mg glucose acid in distilled water and dilute to 1000mL. Prepare fresh immediately before use.

Procedure:

Preparation of dilution water:

a. The source of dilution water may be distilled water, tap or receiving-stream water free of biodegradable organics and bio inhibitory substances such as chlorine or heavy metals.

b. Aerate the required volume of dilution water in a suitable bottle by bubbling clean-filtered compressed air for sufficient time to attain DO saturation at room temperature or at 20ºC/27ºC. Before use stabilise the water at 20ºC/27ºC.

c. Add 1mL each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride solutions in that order for each Litre of dilution water. Mix well. Quality of dilution water may be checked by incubating a BOD bottle full of dilution water for 5 days at 20ºC for 3 days at 27ºC. DO uptake of dilution water should not be more than 0.2mg/L and preferable not more than 0.1mg/L.

d. Domestic waste water, un-chlorinated effluent from biological waste treatment plant and surface water receiving waste water discharges contain satisfactory microbial population. The preferred seed is waste from biological treatment system processing the waste. Where this is not available use supernatant from domestic waste water after settling at least 1hr but no longer than 36 hr.

e. Determine BOD of the seeding material. This is seed control. From the value of seed control determine seed DO uptake. The DO uptake of seeded dilution water should be between 0.6mg/L and 1mg/L.

Sample preparation:

a. Neutralise the sample to pH 6.6 to 7.5, if it is highly acidic or alkaline.

b. The sample should be free from residual chlorine. If it contains residual chlorine remove it by using $Na_2S_2O_3$ solution as described below.

c. Take 50mL of the sample and acidify with addition of 10mL 1 + 1 acetic acid. Add about 1g Kl. Titrate with 0.025N $Na_2S_2O_3$, using starch indicator. Calculate the volume of $Na_2S_2O_3$ required per Litre of the sample and accordingly add to the sample to be tested for BOD.

d. Certain industrial wastes contain toxic metals, e.g. planting wastes. Such samples often require special study and treatment.

e. Bring samples to 20 ± 1ºC before making dilutions.

f. If nitrification inhibition is desired, add 3mg 2-chloro-6-(trichloromethyl) pyridine (TCMP) to each 300mL bottle before capping or add sufficient amount to the dilution water to make a final concentration of 30mg/L. Note the use of nitrogen inhibition in reporting results.

Dilution of sample: Dilutions that result in a residual DO of at least 1mg/L and DO uptake of at least 2mg/L after 5-d incubation produce reliable results. Make several dilutions of the pre-treated sample so as to obtain about 50% depletion of DO or DO uptake of 2mg/L. Prepare dilutions as follows:

Siphon out half the required volume of seeded dilution water in a graduated cylinder or volumetric flask without entraining air. Add the desired quantity of mixed sample and dilute to the appropriate volume by siphoning dilution water. Mix well with plunger type mixing rod to avoid entraining air.

Determine the initial D.O. in one of the two bottles of each dilution using azide modification method. The other bottle should be water sealed and incubate it at 20°C for 3 days. After incubation for 3days, determine the final D.O. in samples and blanks in the same manner as in initial D.O.

Calculation:

a) When dilution water is not seeded

$$\text{BOD as } O_2 \text{ mg/L} = \frac{(D_1 - D_2) \times 100}{\% \text{ dilution}}$$

b) When dilution is seeded-

$$\text{BOD } O_2 \text{ mg/L} = \frac{(D_1 - D_2) - (B_1 - B_2) \times 100}{\% \text{ dilution}}$$

Where,

D1 = DO of sample immediately after preparation, mg/L

D2 = DO of sample after incubation period, mg/L

B1 = DO of blank (seeded dilution water) before incubation, mg/L

B2 = DO of blank (seeded dilution water) after incubation, mg/L

F = ratio of seed in diluted sample to seed in seed control (Vol. Of seed in diluted sample / Vol. of seed in seed control)

5.5.4 Determination of COD Value:-

Introduction:

Chemical Oxygen Demand is not only a measure of oxygen required to oxidize organic matter present in the sample but also inorganic substances which can be oxidized. As it encompasses both oxygen demands of organic and inorganic substances, it always must have higher value than BOD. The ratio BOD to COD may help to analyse the quality of waste present in the sample.

Principle:

The organic matter gets oxidised completely by potassium dichromate ($K_2Cr_2O_7$) with silver sulphate as catalyst in the presence of concentrated H_2SO_4 to produce CO_2 and H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with ferrous ammonium sulphate [Fe $(NH_4)_2(SO_4)_2$]. The quantity of FAS required is direct measure of quantity potassium dichromate ($K_2Cr_2O_7$) left after oxidizing organic matter present in the sample, more the presence of organic matter lesser will be the required FAS.

Apparatus and Equipment:

a) 250 or 500mL Erlenmeyer flask with standard (24/40) tapered glass joints

b) Friedrich's reflux condenser (12 inch) with standard (24/40) tapered glass joints

c) Electric hot plate or six-unit heating shelf

d) Volumetric pipettes (10, 25, and 50mL capacity)

e) Burette, 50mL with 0.1mL accuracy.

f) Burette stand and clamp

g) Analytical balance, accuracy 0.001g

h) Spatula

i) Volumetric flasks (1000mL capacity)

j) Boiling beads, glass

k) Magnetic stirrer and stirring bars.

Reagents and Standards:

a) Standard potassium dichromate solution, 0.25N (0.04167 M): Dissolve 12.259g $K_2Cr_2O_7$ dried at 103°C for 24h in distilled water and dilute to 1000mL. Add about 120 mg sulphamic acid to take care of 6 mg/L NO_2 – N.

b) Sulphuric acid reagent: Add 10g of Ag_2SO_4 to 1000mL concentrated H_2SO_4 and let stand for one to two days for complete dissolution.

c) Standard ferrous ammonium sulphate approx. 0.25N (0.25M): Dissolve 98g $Fe(NH_4)_2(SO_4)_2.6H_2O$ in about 400mL distilled water. Add 20mL concentrated H_2SO_4 and dilute to 1000mL.

d) Ferroin indicator: Dissolve 1.485g 1, 10-phenanthroline monohydrate and 695mg $FeSO_4.7H_2O$ in distilled water and dilute to 100mL.

e) Mercuric Sulphates: $HgSO_4$, crystals, analytical grade

f) Potassium hydrogen phthalate (KHP) Standard: Dissolve 425mg lightly crushed dried potassium hydrogen phthalate ($HOOC.C_6H_4.COOK$) in distilled water and dilute to 1000mL. This solution has a theoretical COD of 500μg O_2/mL.

Standardization of FAS:

Since the procedure involves chemical of organic matter by potassium dichromate as oxidizing agent, which is a primary standard, calibration is not applicable. For standardisation of ferrous ammonium sulphate, dilute 10mL standard $K_2Cr_2O_7$ to about 100mL. Add 10mL concentration of H_2SO_4 and allow it to cool. Titrate with ferrous ammonium sulphate (FAS) to be standardized using 2-3 drops of ferroin indicator. Calculate normally.

$$\text{Normality of FAS} = \frac{(\text{ml } K_2Cr_2O_7)\ (0.25)}{\text{ml FAS required}}$$

The deterioration of FAS can be decreased if it is stored in a dark bottle.

Procedure:

Treatment of samples with COD>50 mg/l: place 50ml (or an aliquot diluted to 50 ml with distilled water), in a 500 ml refluxing flux. Add 1g $HgSO_4$, several glass beads and very slowly add 5ml sulphuric acid reagent, with mixing to dissolve $HgSO_4$. Cool while mixing to avoid possible loss of volatile materials. Add 25ml 0.0417 M $K_2Cr_2O_7$ solution and mix. Attach the flask to the condenser and turn on cooling water. Add remaining 70 ml sulphuric acid reagent though open end condenser. Continue swirling and mixing while adding sulphuric acid reagent.

Cover open end of condenser with a small beaker to prevent foreign material from entering refluxing mixture and reflux for at least 2hr. cool and wash down condenser with distilled water. Disconnect reflux condenser and dilute mixture to about twice its volume with distilled water. Cool to room temperature titrate excess $K_2Cr_2O_7$ with standard FAS while using 2-3 drops of ferroine indicator.

Reflux blank in the same manner using distilled water instead of sample.

Calculations:

COD as mg/L = (a –b) x N x 8000 / ml sample

Where, a = mL FAS used for blank

b = mL FAS used for sample

N = normality of FAS

5.5.5 Total Suspended Solid:-

Principle:

Total suspended solids mean the portion of solids that retained by a filter. The estimation of suspended solids depends on the nature of filter paper and particle size of the suspended solids.

A well mixed sample is filtered through a weighed standard glass fibre paper, grade GF/C and the residue retained on the filter is dried to a constant weight at 103°C to 105°C. The increase in weight of the filter represents the total suspended solids.

Apparatus:

Filtration set containing filter holder suitable 47 mm GF/C filter paper, suction flask and suction pump.

Procedure:

Dry the glass-fibre filter paper in an oven at 103°C to 105°C for one hour, cool it in a dessicator for 30 min, and weigh.

Assemble filtering apparatus and filter a measured amount of well-mixed sample (usually 100 ml) through pre-weighed glass-fibre filter paper. Wash with three successive 10 ml volumes of distilled water, allowing complete drainage between washings and continue suction for about 3 min after filtration is complete. Carefully remove the filter paper and dry it in an oven at 1030c-1050c for one hour. Cool in a desiccator for 30 min and immediately weigh. Repeat the cycle of drying, cooling, desiccating and weighing until a constant weight is obtained.

Calculation:

$$\text{Total Suspended Solids, mg/l} = \frac{(A-B)\times 1000}{\text{Sample volume, ml}}$$

Where, A= Weight of filter plus dried residue, mg

B= Weight of filter, mg

5.5.6 Microbiological Analysis:-

Water receives its bacterial pollution from air, soil, sewage, organic wastes, dead plant and animal etc. These bacteria in water may be harmless or harmful to human consumers. Therefore bacterial examination of water is first and foremost necessary to disclose the presence of micro-organism. Specially, that might constitute a health hazards. It is universally recognized that the excreta of man, mammals and birds contain enormous number of coliform bacteria. The coliform group comprises all of the facultative, gram-negative, non spore forming rod shaped bacteria that ferment lactose with gas formation within 48hrs at 37^0C. Thus presence of those organisms in water undoubtedly indicates faecal contamination of water.

Apparatus

1) Pipette of 10ml, 1ml volumetric capacity.
2) beaker volumetric capacity 500ml.
3) Stirring rod.
4) MacConkey broth.
5) Brilliant Green Lactose Bile Broth.
6) 10 ml and 20 ml test tube
7) Test tube rack.
8) Inoculation apparatus.

Procedure

Total Coliform: 15nos. 20ml test tube, above mentioned (1), (2), (3) apparatus are autoclaved so that it doesn’t contain any bacteria before using for experiment. Now MacConkey broth is prepared in the quantity of 8mg with 100 ml distilled water for a 150ml solution. Then it is poured in all the 20nos test tubes as quantity of 10ml per tube. Then three sets of test tubes having five test tubes in each set are marked. Durhams tube is added carefully. In three different sets first set is added with 10 ml sample, second set is added with 1ml sample and rest 9ml is filled with distilled water, third set is added with 0.1 ml sample and rest 9.9ml is filled with distilled water. Then it is made air tight using cotton and is put into incubator at 37^0C for 24hrs. After that samples are taken out of the incubator and it is to be checked if colour is changed and presence of gasses is observed in Durhams tube and then by using MPN chart number of coliform bacteria is counted.

Faecal Coliform: brilliant green bile broth (BGLB) is prepared in the quantity of 4mg with 100ml distilled water. Each test tube contains 5ml of BGLB. After checking the number of test tube detected for total coliform, BGLB is prepared. The number tube having presence of total coliforms are tested by the process of inoculation for checking whether it contain faecal coliform or not. Durhams tubes are also used in this process. After inoculation samples are kept in water bath for 44 hrs. Then number of a faecal coliform is found by using MPN chart.

CHAPTER:

6. RESULT & DISCUSSION

6.1 1st Cycle of Operation at 12/12B Bireswar Dhol Lane

Site.1:- **Installation date:-28th august, 2018**

Fig. 7: Installation at Site 1. for 1st Cycle

6.1.2 Objective of All The Studies Carried Out at Various Places:

Total operation is done in six cycles at four locations. Four sites are already mentioned in chapter: 5. In all the installations below mentioned objectives are intended to be fulfilled.

- Performance of PLE will be monitored continuously for 72 hours by taking samples from different identified location at selected interval of time.
- Flow will be measured at specified interval of time. In addition pressure gauge at suitable location will be installed.
- Parameters such as pH, COD, BOD, Suspended Solids, Turbidity, Total Coliform and Faecal Coliform will be analysed for the samples to be collected during the study.
- All samples will be stored in the ice-box to maintain lower temperature.
- The samples will be transported within 12 and 18 hours to the laboratory for analysis.
- The operational life of each unit e.g. cloth filter, MF and UF will be assessed during the study in terms of quantity of liquid treated.

6.1.3 Arrangements of PLE at Bireswar Dhol Lane for 1st cycle

- A perforated pipe of 20.32cm (8 inch) diameter and 1.82m (6 ft) height is installed in the septic tank, it rests on the bottom of the septic tank. Submersible pump is placed inside the pipe rests on a plate previously attached to the pipe. 40.64cm (16 inch) from the bottom of the perforated pipe is not perforated because it would have caused accumulation of the sludge. Above this part has perforation of diameter of 4mm for a length of 76cm (2 ft 6inch), it is covered with a cloth filter of 10 µm.
- Septic tank has user of 4 to 5 persons.
- Water extracted from the pit enters to the micron filter of size 5 µm. Then it passes through activated carbon and finally through ultrafiltration.
- This pattern flow of water (MF to GAC to UF) continues for 2cycles in same location with minute improvisations.

6.1.4 Material specifications

Submersible pump

Voltage= 165-240V, Frequency= 50 Hz, Maximum head=2.5 M, Output=3500 L/hr

Booster pump

Voltage=48VDC, Nominal flow rate=1.8 LPM

Micro filter

Pore size = 5 µm.

Perforated pipe

A pipe of diameter20.32cm(8inch) is used having total length of 1.82m(6ft),perforated for a length for 76cm(2ft 6inch) and keep bottom 1ft 4inch is blocked.

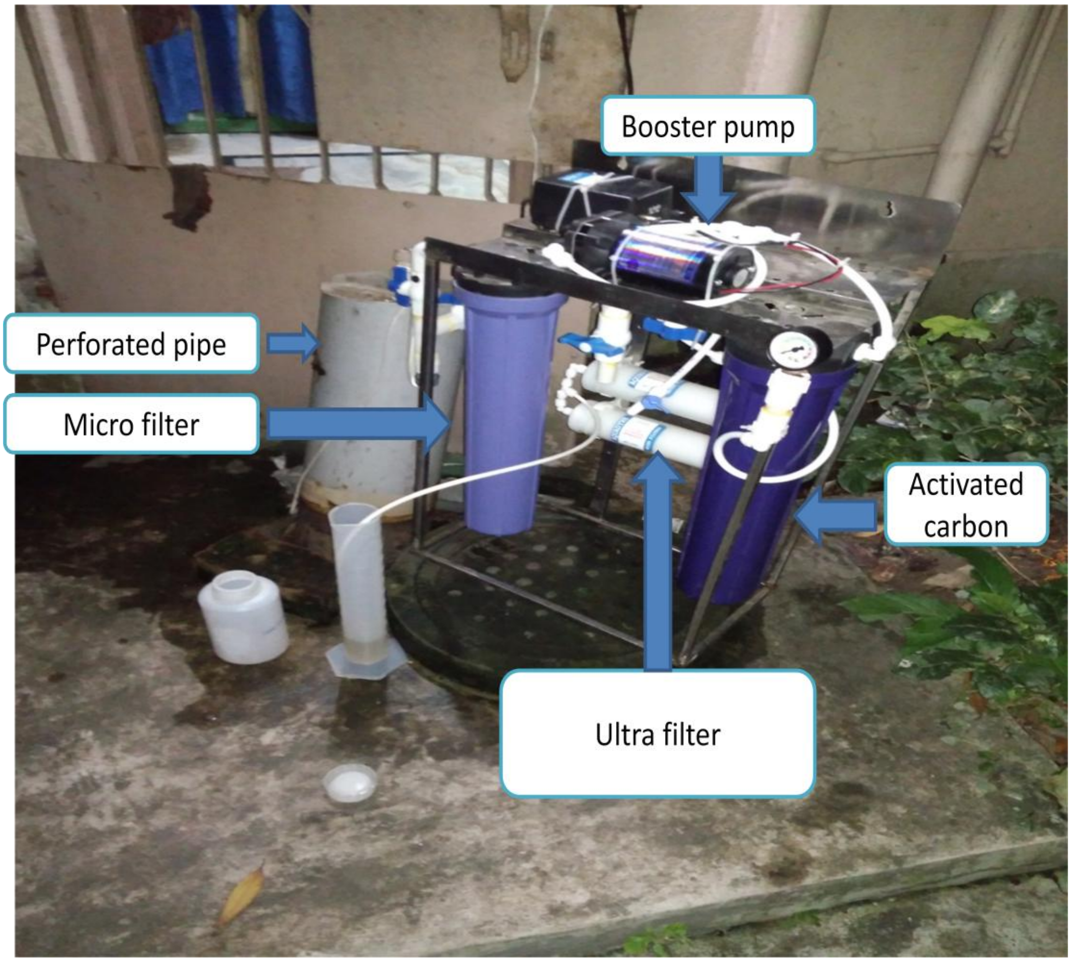

Fig. 8: Various Parts of PLE Unit

6.1.5 Parameters measured

A- Raw sample.

B- Sample after cloth filter.

C- Sample after micro filter.

D- Sample after activated carbon.

E- Sample after ultra filtration.

BOD, COD, pH, total suspended solids (TSS) measured in **mg/litre**.

Turbidity measured in **NTU**.

Number of Total Coliform (TC) & Faecal Coliform (FC) are in the order **of 1000 per 100 ml**.

Pressure Gauge reading is in **kg/cm^2**.

Flow measured in **litre per hour.**

Table 2: Sampling Chart for 1st Cycle at Site 1.

Location Bireswar dhol lane 1st cycle	BOD	COD	pH	TSS	TURBIDITY	TC*1000	FC*1000	PRESS.	FLOW (lph)
02:35pm (0hr) on 28.08.18									
1A	60	97	7.91	57	39	30	21		
1B	56	88	7.88	48	28.4	28	20.5		140.4
1C	43	77	7.8	39	14.1	25	19.5		
1E	34	62	8.19	13	4.0	22	17		116.6
04:35pm (2hr) on 28.08.18									
2B	50	85	7.88	37	13	25	22		121.5
2E	44	80	7.96	15	4.9	22	21		69.22
06:35pm (4hr)on 28.08.18									
3E	32	64	7.86	8	4.6	21	18		111.1
08:35pm (6hr) on 28.08.18									
4E	43	79	7.93	12	4.5	25	21		111
02:35am (12hr) on 29.0818									
5E	64	105	8.07	32	12.4	27	22		0.72

6.1.6 Few Observation of PLE at Bireswar Dhol Lane for 1st Cycle:-

- Pressure gauges were not working properly, too much fluctuation.
- Pressure at the ultra filtration at 06:35pm was between 0.3kg/sq.cm to 0.8kg/sq.cm.
- No flow comes out of GAC.
- Flow from micro filter at 0hr was not measured. After that no flow was came through micro filter.
- At 2am on 29.08.18 perforated pipe was moved upward from previous position, very little flow has coming from outlet in a very inconsistent manner such as, 500ml in 42min and 140ml in 1hr4min.
- At 07:30am on 29.08.18 flow was completely stopped.
- BOD and COD of raw water are found to be reduced to around 50% and 60%of its original value at 0hr after ultra-filtration.
- After ultra filtration pH is found to be almost uniform with tedious variations, TSS & Turbidity is found to be reduced to around 20% & 10% respectively of its original value at 0hr after ultra-filtration.
- TC & FC counts are found to be reduced to 73% & 80% respectively of its original value at 0hr after ultra-filtration.

Expected cause of the upward movement

It may have happened that flow of water in the perforated pipe get reduced significantly resulting in less water accumulation in the pipe. So downward weight of the pipe gets reduced and as per the law of buoyancy displaced water gives upward force to perforated pipe results in floatation of the pipe system.

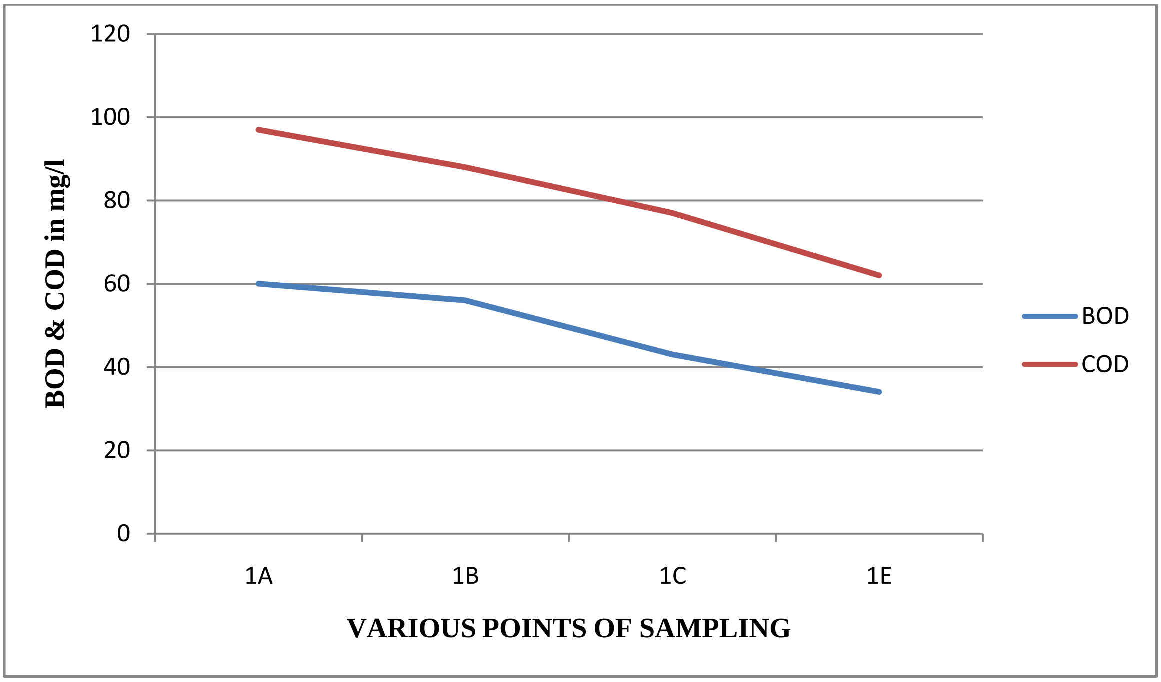

Fig. 9: Variation of BOD & COD of samples collected from different outlet at initial time (0 hr) at Site 1 for 1st cycle

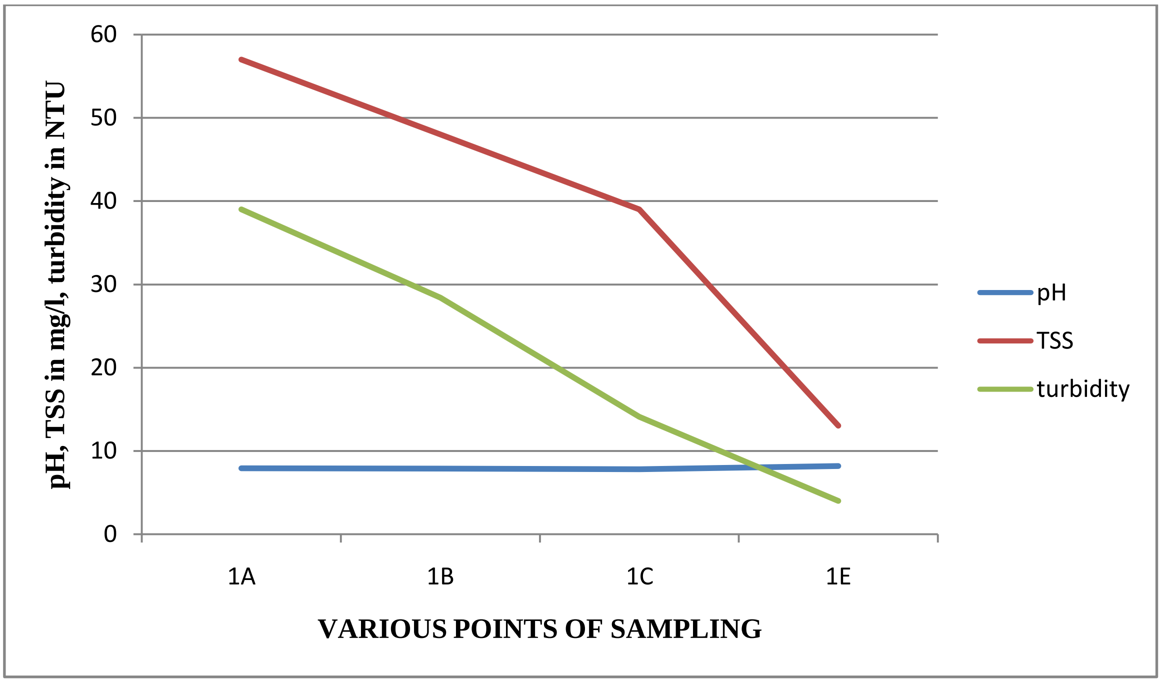

Fig. 10: Comparative analysis pH, TSS, turbidity of samples collected from different outlet at initial time (0 hr) at Site 1 for 1st cycle

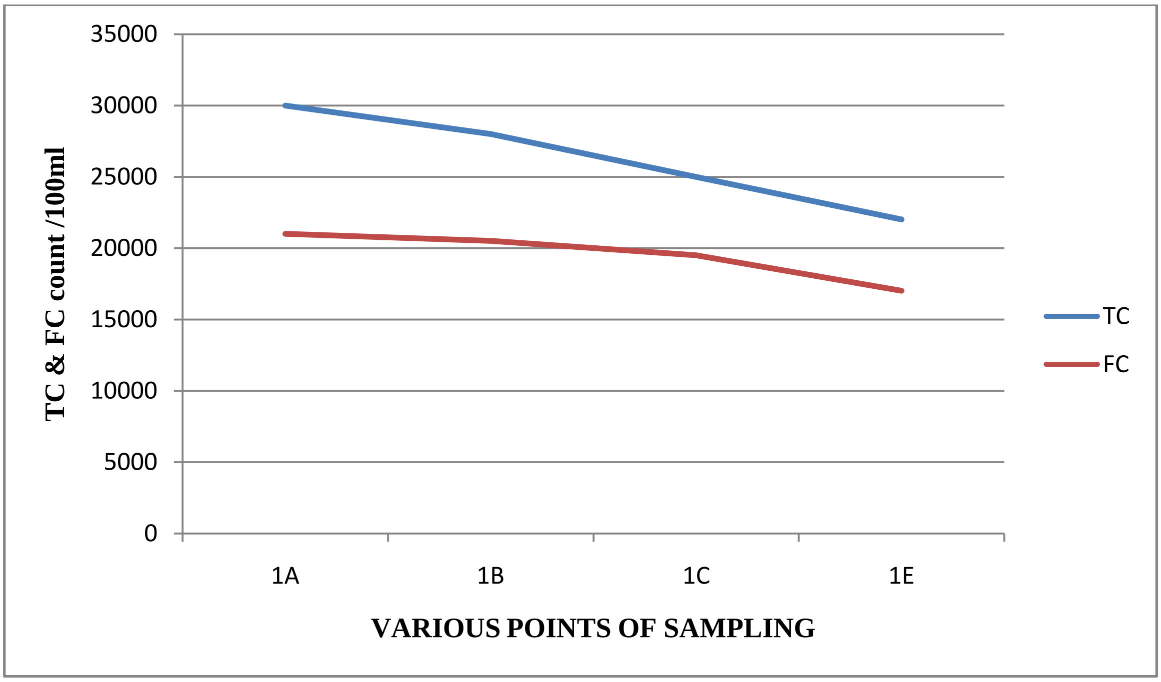

Fig. 11: Comparative analysis TC & FC of samples collected from different outlet at initial time (0 hr) at Site 1 for 1st cycle.

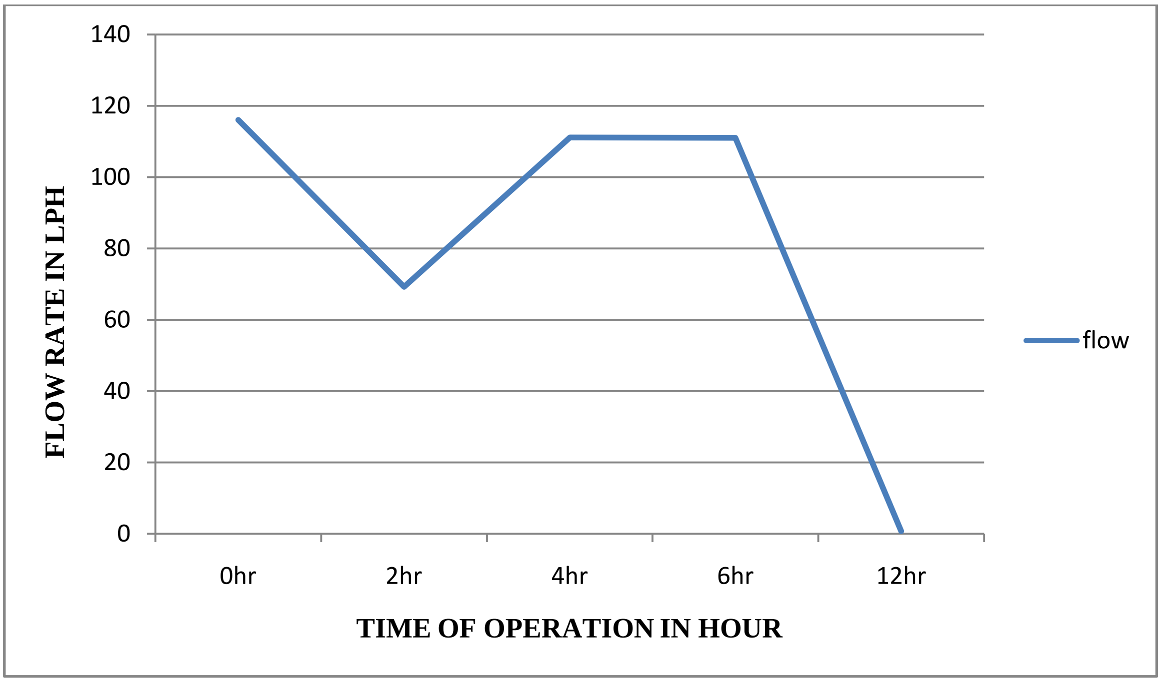

Fig. 12: Variation of flow rate at final outlet with respect to the time of operation at Site 1 for 1st cycle

Fig. 13: Micro filter after three days of running previously it was white

Fig. 14: Perforated pipe

Fig. 15: Brick is placed upon the pipe to resist its upward movement

Fig. 16: Flexible Pipe connecting perforated pipe and PLE machine is subjected to tension due to upward movement the perforated pipe

6.2 2nd cycle in 12/12 Bireswar dhol Lane

Site.1:- **Installation date:-10th September, 2018**

Fig. 17: Installation at Site 1. for 2nd Cycle

6.2.1 Few Improvisation of PLE at Bireswar Dhol Lane for 2nd Cycle:-

- Due to the incident of floatation of the perforated pipe some modifications have done to reduce the chances of clogging of the pipe.
- The cloth filter covering the perforated pipe is changed with a new double layer of 10 micron cloth filter.
- Drilling of diameter 13mm is done apart from previous 4mm and previous accumulation of solids surrounding the pipe is brushed off using steel rod.
- Apart from above mentioned modifications everything remains same as previous cycle on 28.08.18.

6.2.2 Material Specifications

Submersible pump

Voltage= 165-240V, Frequency= 50Hz, Maximum head=2.5M, Output=3500L/hr

Booster pump

Voltage= 48VDC, Nominal flow rate=1.8 LPM

Micro filter

Pore size = 5 micron.

Perforated pipe

A pipe of diameter 8inch is used having total length of 1.82m(6ft),perforated for a length for 76.2cm(2ft 6inch) and keep bottom 40.64cm(1ft 4inch) is blocked.

6.2.3 Parameters Measured

A- Raw sample.

B- Sample after cloth filter.

C- Sample after micro filter.

D- Sample after activated carbon.

E- Sample after ultra filtration.

BOD, COD, pH, total suspended solids (TSS) measured in **mg/litre**.

Turbidity measured in **NTU.**

Number of Total Coliform (TC) & Faecal Coliform (FC) are in the order **of 100**

Pressure Gauge reading is in **kg/cm^2**

Flow measured in **litre per hour**

Table 3: Sampling chart for 2nd cycle at site 1

LOCATION BIRESWAR DHOL LANE 2ND CYCLE	BOD	COD	pH	TSS	TURBIDITY	TC*1000	FC*1000	PRESS.	FLOW (LPH)
04:50pm (0hr) on 10.09.18									
1A	105	174	7.88	42	18	28	22		
1B	96	165	7.84	38	16	26	21	0	324
1C	90	120	7.89	20	12	24	19	0	216
1D	82	115	7.94	24	10	21	17	0	117
1E	68	103	7.97	17	7	18	16	0	95.25
06:50pm (2hr) on 10.09.18									
2B	91	135	7.9	27	15	28	22	0	312
2C	82	126	8.05	25	12	26	21	0	230
2D	79	110	7.94	18	8	22	18	0	114.4
2E	62	98	7.91	15	4.5	17	15.5	0.4-0.5	114.26
08:50pm (4hr) on 10.09.18									
3B	80	126	8.02	23	9	28	22	0	5.02
3C	61	108	8.01	14	8.2	24	20	0	2.91
3D									
3E	45	91	8.06	12	3.8	18	15	2	14.86

Table 3: Sampling chart for 2nd cycle at site 1(contd.)

LOCATION BIRESWAR DHOL LANE 2nd cycle	BOD	COD	pH	TSS	TURBIDITY	TC*1000	FC*1000	PRESS.	FLOW (LPH)
10:50pm (6hr) on 10.09.18									
4E	40	85	8.21	12	3.7	18	16	0.5	5.4
04:50am (12hr) on 11.09.18									
5E	37	73	8.34	10	3	15	13	0	4.18
04:50pm (24hr) on 11.09.18									
6E	34	70	7.9	9.2	2.8	14	12	0.5	8
04:50am (36hr) on 12.09.18									
7E	32	64	8.09	8	2.5	14	12	0	2.5
04:50pm (48hr) on 12.09.18									
8E	28	53	8.77	7.4	2.2	13	11	0	2.48
12:44pm (72hr) on 13.09.18									
9E	19	40	8.16	6	1.9	12	10	0.5	4.4

6.2.4 Few Observations of PLE at Bireswar Dhol Lane for 2nd Cycle:-

- The unit has operated for a duration of 68hrs**.**.
- This time no such problem like upward movement of pipe is occurred, which indicates that less number of perforation may have caused this problem in the 1^{st} cycle.
- Samples are collected in proper time and iced.
- Suddenly at 5:20am on 11.09.18 pressure at ultra-filtration rises to 5kg/sq.cm.
- BOD and COD of raw water are found to be reduced to 64% and 60% of its original value at 0hr after ultra-filtration.
- After 72hrs of operation BOD & COD are found to be reduced to 18% & 23% respectively of its original value after ultra-filtration.
- After ultra filtration pH is found to be almost uniform with tedious variations. TSS & turbidity are found to be reduced to around 40% & 38% respectively of its original value at 0hr after ultra-filtration.
- After 72hrs of operation TSS & turbidity are found to be reduced to 15% & 10% respectively of its original value after ultra-filtration.
- TC & FC counts are found to be reduced to 64% & 72% respectively of its original value at 0hr after ultra-filtration.
- After 72hrs of operation TC & FC are found to be reduced to 42% & 45% respectively of its original value after ultra-filtration.

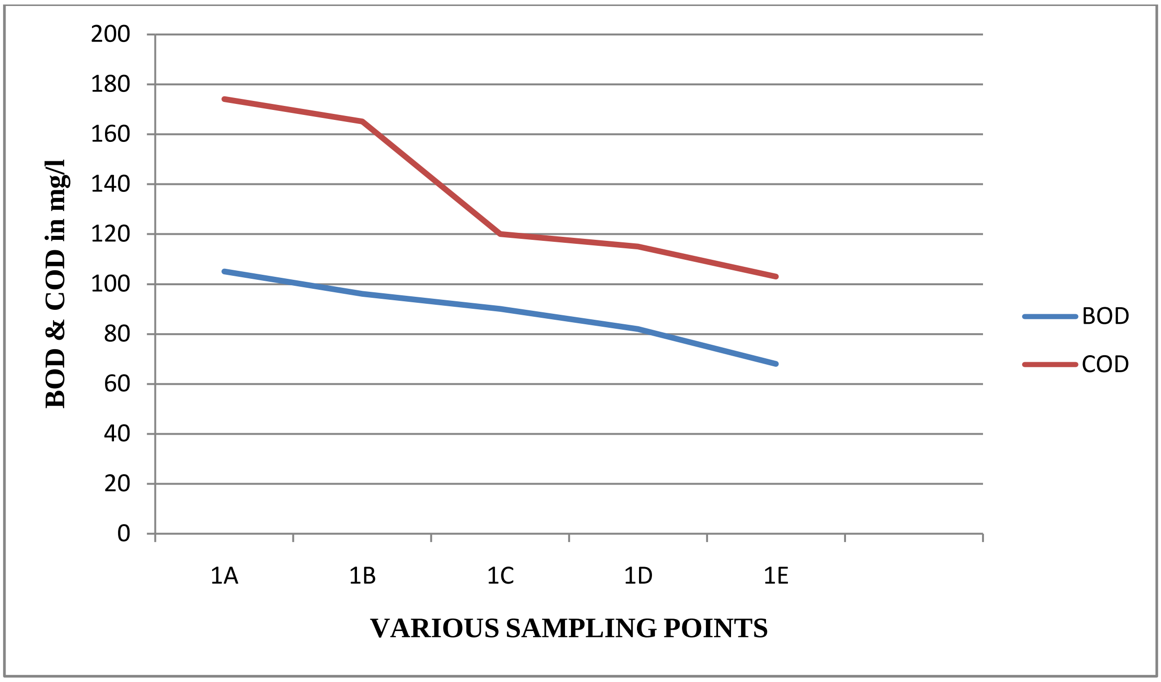

Fig. 18: Comparative analysis BOD & COD of samples collected from different outlet at initial time (0 hr) Site 1. for 2nd Cycle

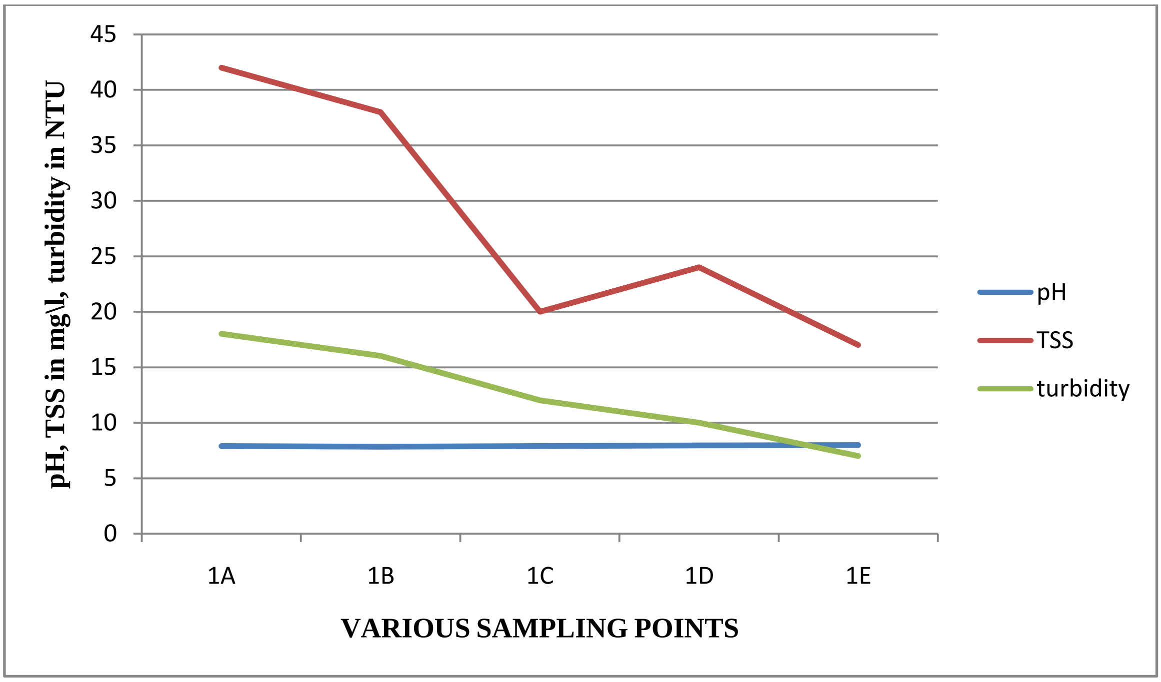

Fig. 19: Comparative analysis pH, TSS, turbidity of samples collected from different outlet at initial time (0 hr) Site 1. for 2nd Cycle

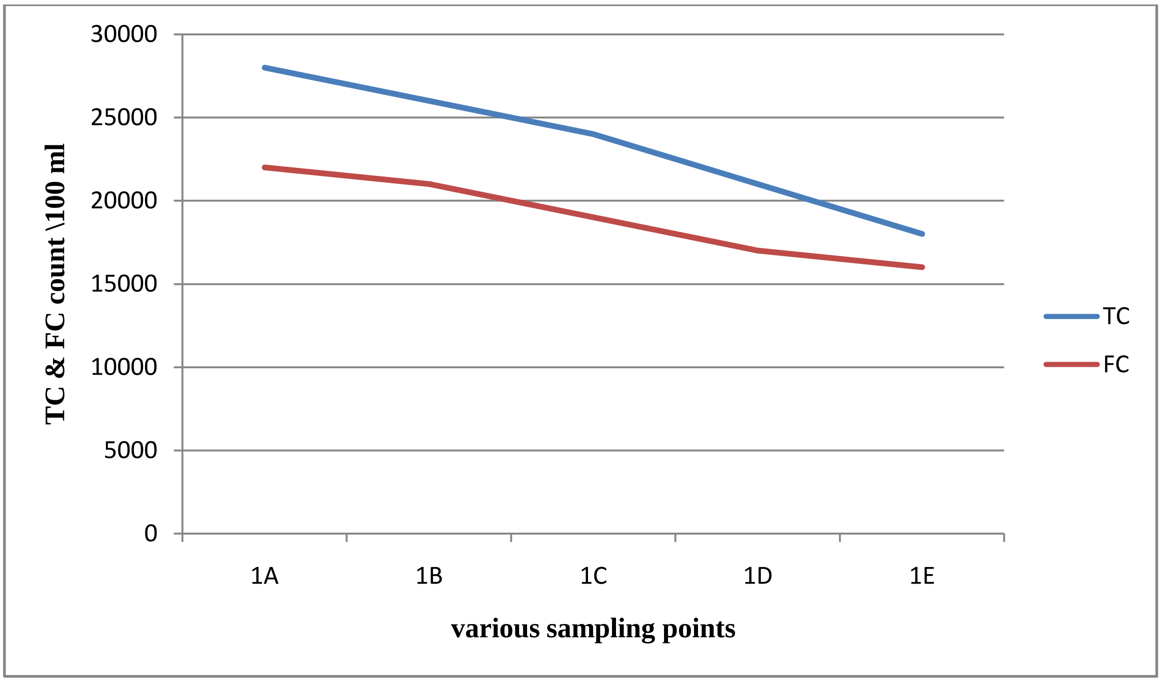

Fig. 20: Comparative analysis TC & FC of samples collected from different outlet at initial time (0 hr)

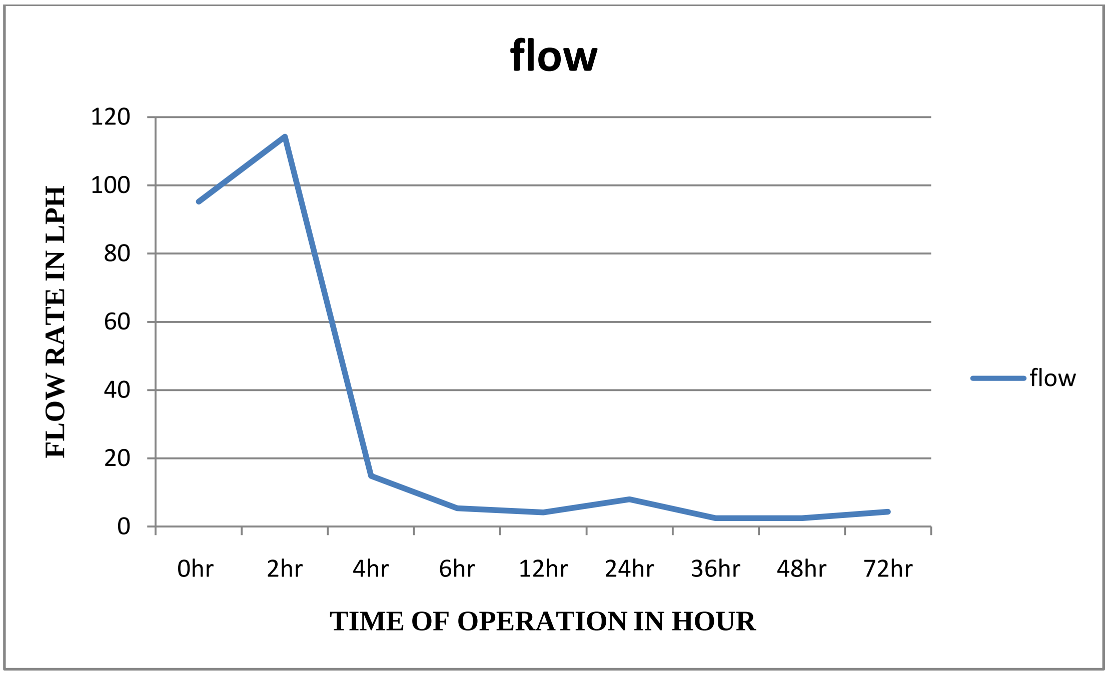

Fig. 21: Variation of flow rate at final outlet with respect to the time of operation Site 1. for 2nd Cycle

6.3 1st Cycle in JU Campus besides Mechanical Building

Site.2:- **Installation date:-11th December 2018**

Fig. 22: Installation at Site 2. for 1st Cycle

6.3.1Arrangements of PLE at JU campus for 1st cycle of Operation

- Perforated pipe is not used this time, sludge pumping pump is used as submersible pump. It is placed 30.48cm (1ft) above the bottom portion of the tank of depth 1.82m (6ft) which is filled up to 1.52m (5ft) with sewage.
- Septic is of dimension of length 6.1m(20ft) and breath1.82m(6ft) and depth 1.82(6ft).This tank has a volume of 20.20m^3 and has user of four person per day.
- Water extracted from the pit enters in to the activated carbon membrane. Then it passes through micro filter and finally through ultra-filtration. This is a difference between previous course of action where extracted water enters micro filter first then activated carbon membrane.
- This pattern flow of water (GAC to MF to UF) continues for 2cycles (72hr+72hr) at same location with small improvisations.

6.3.2Material Specifications

ITEM	SPEC
Micro filter spec	0.45 Micron
Ultra filter spec	0.01 Micron
GAC	600 IV
Booster pump spec	0.25 HP, 220 V
Submersible pump spec	1HP, 220 V

Submersible pump

Eterna SW											
Pump Model	Del. Pipe Size (mm)	Power Rating (kW/HP)	Discharge (LPM)							Solid Size	Min Sub. From
			3	4	5	6	7	8	9		
			Total Head in meters								
750SW	40	0.75/1.0	-	150	120	95	60	-	-	15	370

Booster pump

PERFORMANCE UNDER STANDARD TEST CONDITIONS											
PUMP MODEL	POWER RATING		PIPE SIZE (mm)		FULL LOAD CURRENT (in amps.)	RATED VOLTAGE (Volts)	TOTAL HEAD IN METRES				
	kW	HP	SUC.	DEL.			3	6	9	12	15
							DISCHARGE IN LITRES PER HOUR				
TINY	0.18	0.25	19	19	2	230	1600	1300	1100	800	600

MATERIAL OF CONSTRUCTION		
Pump Body	:	Stainless Steel for SW CI FG 200 for BW
Impeller	:	Noryl for SW CI for BW
Shaft	:	Stainless Steel
Cable Length	:	10 meters
Class Insulation	:	F
Ingress Protection	:	IP 68

Fig. 23: Submersible pump

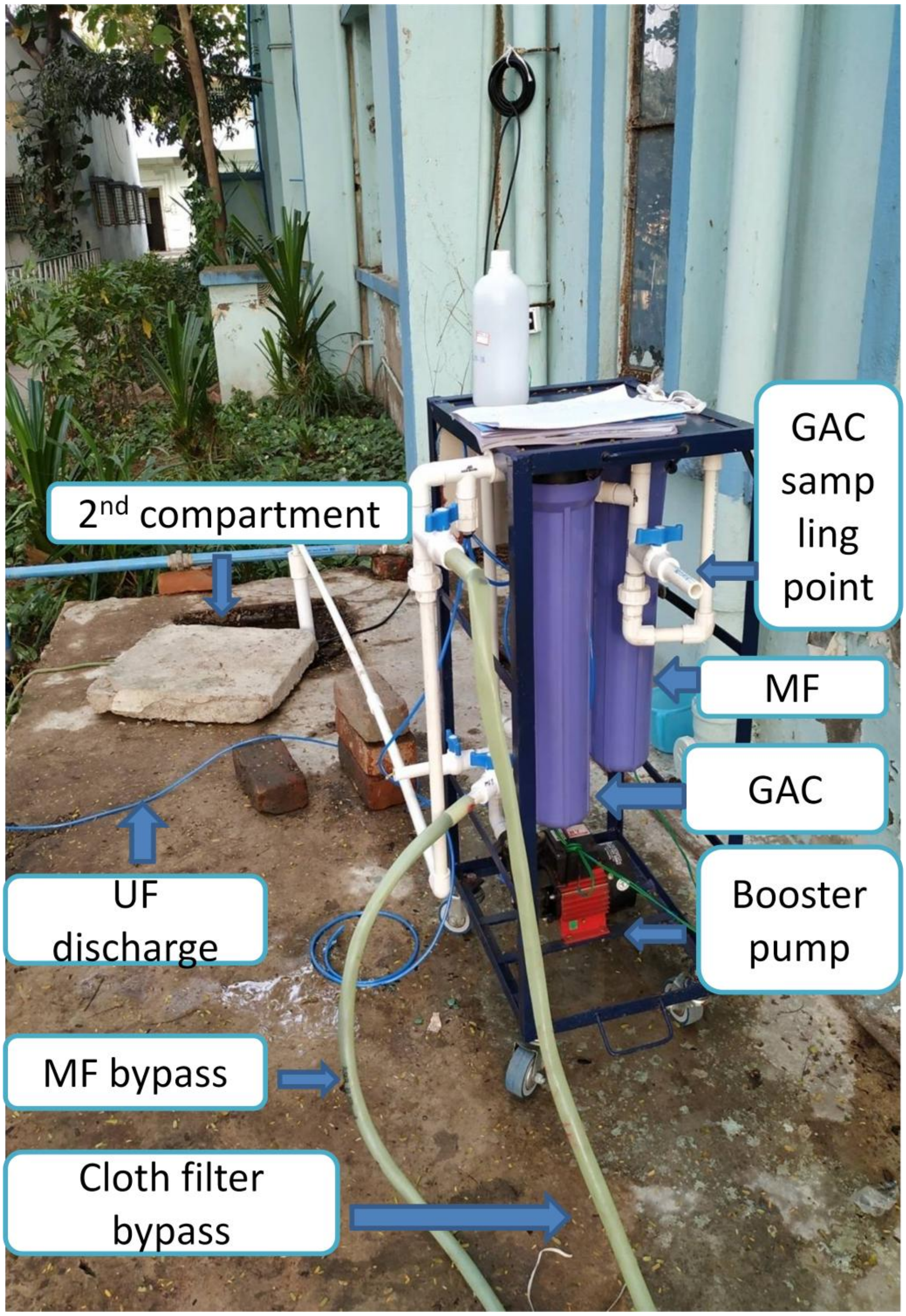

Fig. 24: PLE machine after complete installation

6.3.3 Parameters Measured

A- Raw sample.

B- Sample after activated carbon.

C- Sample after micro filter.

D- Sample after ultra filtration.

BOD, COD, pH, total suspended solids (TSS) measured in **mg/litre**.

Turbidity measured in **NTU**.

Number of Total Coliform (TC) &Feacal Coliform (FC) are in the order **of 100.**

Pressure Gauge reading is in **kg/cm^2**.

Flow measured in **litre per hour**

Table 4: Sampling chart for 1st cycle at site 2.

Location Beside mechanical building at JU campus 1st cycle	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
03:30pm (0hr) on 11.12.18									
1A	39	88	7.72	46	26	130	79	0.7	
1B	26	67	7.64	38	15	108	72	0.6	
1C	21	58	7.86	29	14	90	54	0.55	
1D	15	38	7.83	18	12	79	49	2.4	30.34
05:30pm (2hr) on 11.12.18									
2A	20	61	7.79	25	16.2	150	90	0.5	
2B	19	49	7.81	15	12.0	94	70	0.6	
2C	16	43	7.93	12	11.5	90	94	0	
2D	12	32	7.92	12	10.4	69	35	2.1	14.58
07:30pm (4hr) on 11.12.18									
3A	40	94	7.54	24	16	120	70	0.6	
3B	26	46	7.80	15	20	84	63	0.6	
3C	17	32	7.86	14	16.5	94	70	0	
3D	5	24	7.97	10	8.5	63	26	1.9	11.34

Table 4: Sampling chart for 1st cycle at site 2. (contd.)

Location Beside mechanical building at JU campus 1st cycle	BOD	COD	PH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
09:30pm (6hr) on 11.12.18									
4B	18	32	7.77	22	16.5	63	26	0.5	
4D	7	26	7.91	8	3.7	55	30	1.5	8.64
03:30am (12hr) on 12.12.18									
5B	19	40	7.93	27	19	94	32	0.5	
5D	11	27	7.93	6	3	74	43	1-1.5	5.25
03:30pm (24hr) on 12.12.18									
6A	11	44	7.74	18	9.4	120	70	0.5	
6B	17	32	7.93	16	9.3	63	26	0.5	
6D	12	29	8.01	9	2.8	41	27	1	4.57
03:30am (36hr) on 13.12.18									
7A	8	38	7.81	18	9.3	84	26	0.6	
7B	7	38	7.97	15	8	40	27	0.6	
7D	4.5	22	8.02	5	2.5	38	32	1.1	3.8

Table 4: Sampling chart for 1st cycle at site 2. (contd.)

Location Beside mechanical building at JU campus 1st cycle	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
03:30pm (48hr) on 13.12.18									
8A	7	38	7.76	12	9	94	49	0.6	
8B	8	39	7.95	9	4.6	49	22	0.6	
8D	5	27	7.97	4.2	2.2	31	23	1.1	1.87
03:30pm (72hr) on 14.12.18									
9A	7	34	7.83	19	10.8	84	42	0.55	
9B	8	37	7.75	26	14.6	38	20	0.6	
9D	3	12	7.95	3	1.9	24	19	1.5	3.6

6.3.4 Observations of PLE at JU Campus besides Mechanical Building for 1st cycle:-

- The unit has operated for a duration of 72hrs.
- Samples are collected and iced in proper time.
- BOD and COD of raw water are found to be reduced to 38% and 43% of its original value at 0hr after ultra-filtration.
- After 72hrs of operation BOD &COD are found to be reduced to 7% &13% respectively of its original value after ultra-filtration.
- After ultra filtration pH is found to be almost uniform with tedious variations. TSS & turbidity are found to be reduced to around 39% &41% respectively of its original value at 0hr after ultra-filtration.
- After 72hrs of operation TSS & turbidity are found to be reduced to 6% &7.30% respectively of its original value after ultra-filtration.
- TC & FC counts are found to be reduced to 60% &62% respectively of its at original value at 0hr after ultra-filtration.
- After 72hrs of operation TC & FC are found to be reduced to 18.4% &24% respectively of its original value after ultra-filtration.

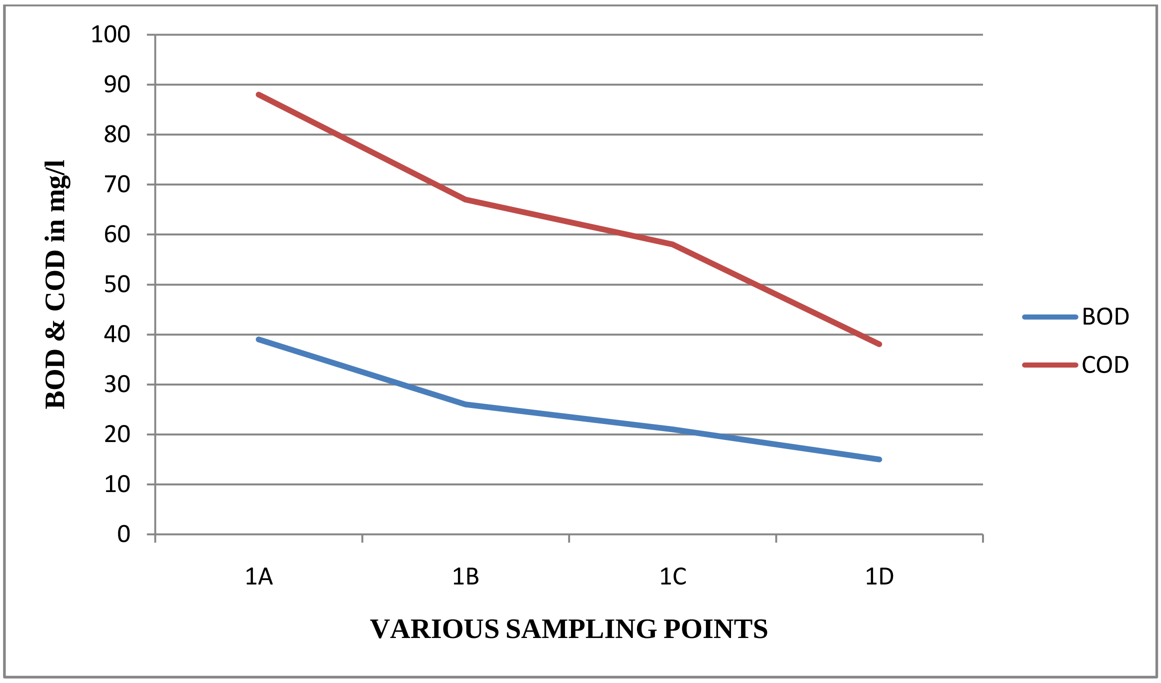

Fig. 25: Comparative analysis BOD & COD of samples collected from different outlet at initial time (0 hr) Site 2. for 1st Cycle

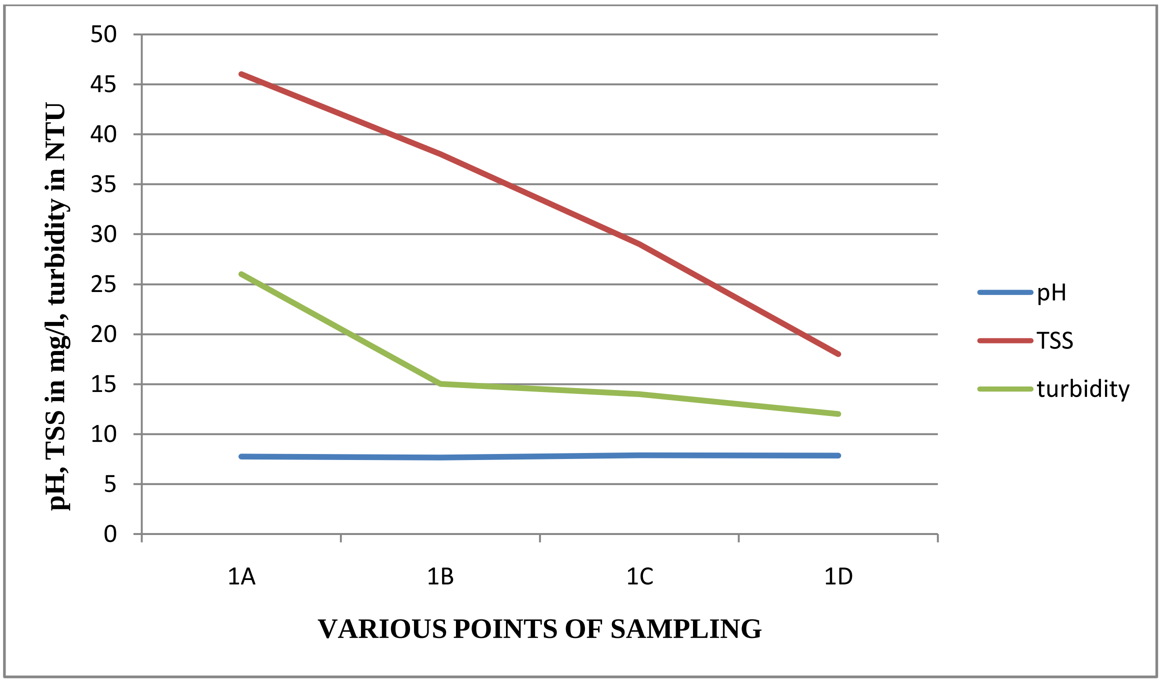

Fig. 26: Comparative analysis pH, TSS, turbidity of samples collected from different outlet at initial time (0 hr) Site 2. for 1st Cycle

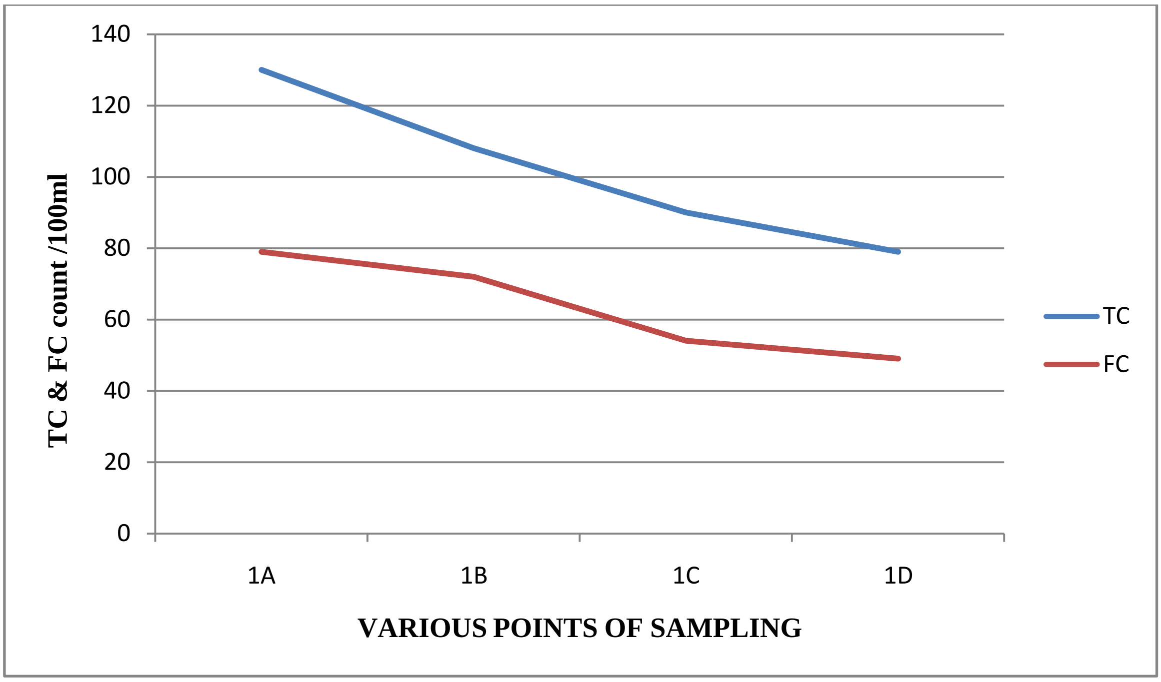

Fig. 27: Comparative analysis TC & FC of samples collected from different outlet at initial time (0 hr) Site 2. for 1st Cycle

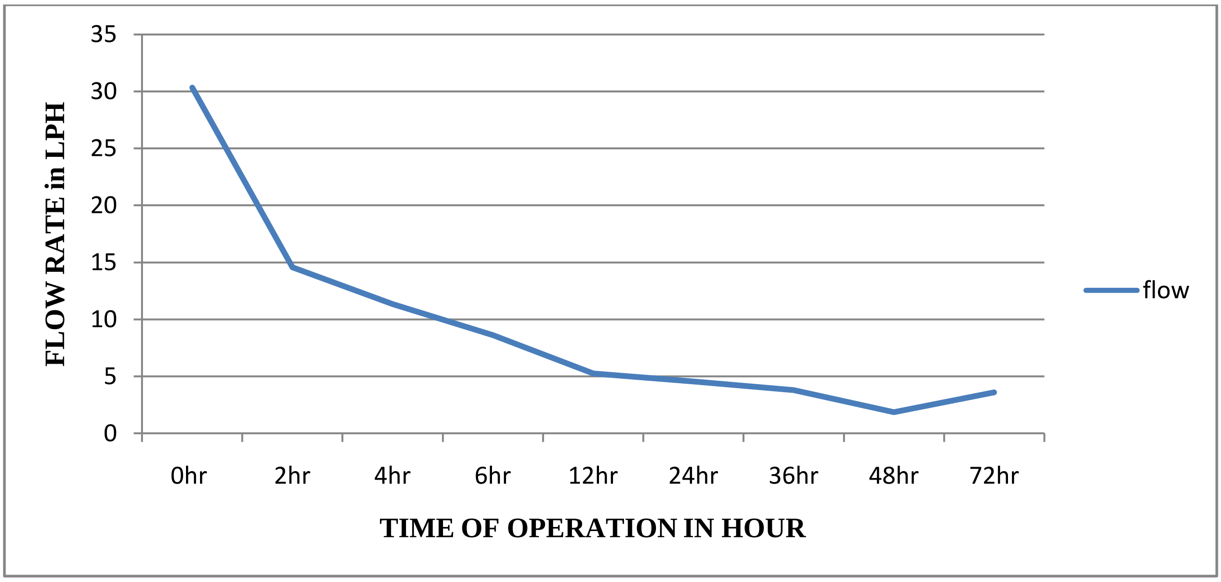

Fig. 28: Variation of flow rate at final outlet with respect to the time of operation Site 2. for 1st Cycle

Fig. 29:- installation of perforated pipe

Fig. 30: Condition of micro filter &ultra filter after 3days

Fig. 31: Granulated activated carbon

Fig. 32: Pressure gauge

6.4 2nd Cycle in JU Campus besides Mechanical Building

Site.2:- **Installation date:-18th December 2018**

Fig. 33: Installation at Site 2. For 2nd Cycle

6.4.1 Improvisation

This time we used perforated pipe of diameter 61cm (2ft) with perforation for a depth of 15.24cm (6 inch) at the bottom and we covered it with cloth filter. All the other conditions remain same as previous cycle on 11th December 2018.

All other conditions and instrument specifications remain same as per previous operation on 11th December 2018 to 14th December 2018.

6.4.2 Parameters Measured

A- Raw sample.

B- Sample after cloth filter.

C- Sample after activated carbon.

D- Sample after micro-filter.

E- Sample after ultra-filtration.

BOD, COD, pH, total suspended solids (TSS) measured in **mg/litre**.

Turbidity measured in **NTU**.

Number of Total Coliform (TC) &Feacal Coliform (FC) are in the order **of 100.**

Pressure Gauge reading is in **kg/cm^2**.

Flow measured in **litre per hour**

Table 5: Sampling chart for 2nd cycle at site 2.

LOCATION Beside mechanical building JU 2nd cycle	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
01:45pm on 18.12.18									
1A	35	102	7.91	19	11	120	70		
1B	10	42	7.6	14	9	94	64	0.5	
1C	9	39	7.84	13	8.9	85	49	0.25	
1D	8.5	32	7.9	11	8.3	63	33	0	
1E	7	27	7.94	8	4.3	58	26	1.5	32.4
03:45pm on 18.12.18									
2B	11	44	7.84	15	13.5	84	62	0.5	
2C	10.5	38	7.83	12	9	72	51	0.25	
2D	9.4	32	7.83	9	4.1	64	34	0	
2E	7	15	7.98	7	3.5	52	25	1	15.84
05:45pm on 18.12.18									
3B	17	34	7.87	14	12.1	94	70	0.55	
3C	16	28	6.95	11	8.6	84	58	0.6	
3D	15	22	7.9	10	6.3	79	55	0	
3E	9	18	7.88	6		45	23	0.8	3.71

Table 5: Sampling chart for 2nd cycle at site 2. (contd.)

LOCATION Beside mechanical building JU 2nd cycle	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
07.45pm on 18.12.18									
4C	11	29	7.89	16	9.8	74	42	0.6	
4E	8.4	26	7.95	6	2.9	37	16	0	2.62
1:45am on 19.12.18									
5C	10	35	7.78	17	12	46	33	0.6	
5E	8.6	28	8.09	4.2	2.4	41	22	0	1
1:45pm on 19.12.18									
6A	12	52	7.85	14	8.8	63	34		
6C	9	44	7.85	12	4.9	60	32	0.6	
6E	7	32	7.9	4.2	2.3	37	23	0	1
01:45am on 20.12.18									
7A	9.5	42	7.21	13	8.6	64	43		
7C	10	46	7.18	12	4.9	49	38	0.7	
7E	5	22	7.81	4	2.1	33	19	0	0.94

LOCATION Beside mechanical building JU 2nd cycle	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
01:45pm on 20.12.18									
8A	10	25	7.23	14	5	59	38		
8C	7.6	22	7.27	10	4	48	32	0.6	
8E	5.4	20	7.75	3.5	1.9	30	16	0-0.5	1.1
01:45pm on 21.12.18									
9A	11	27	7.41	11	3.7	52	33		
9C	8	21	7.2	8	2.2	27	21	0.7	
9E	3	14	7.53	2	1.2	24	14	0.4-0.6	3.17

6.4.3 Observation of PLE at JU Campus besides Mechanical Building for 2nd Cycle:-

- The unit has operated for a duration of 72hrs**.**
- Samples are taken at proper time and iced.
- In the 1st cycle on 11th December 2018 perforated pipe covered with cloth filter wasn't used, instead we used a pump with sludge pumping feature.
- In the 2nd cycle on 18th December 2018 we change the process and included perforated pipe and cloth filter.
- BOD and COD of raw water are found to be reduced to 20% and 26% of its original value at 0hr after ultra-filtration.
- After 72hrs of operation BOD & COD are found to be reduced to 8.57% & 13.7% respectively of its original value after ultra-filtration.
- After ultra filtration pH is found to be almost uniform with tedious variations. TSS & turbidity are found to be reduced to around 42% & 39% respectively of its original value at 0hr after ultra-filtration.
- After 72hrs of operation TSS & turbidity are found to be reduced to 10.5% &11% respectively of its original value after ultra-filtration.
- TC & FC counts are found to be reduced to 49% &37% respectively of its at original value at 0hr after ultra-filtration.
- After 72hrs of operation TC & FC both are found to be reduced to 20% of its original value after ultra-filtration.
- As we used a pump of huge capacity nearly giving a discharge of 1400lph, we have to bypass large volume water all the time to protect the filters from high pressure. This is indeed uneconomical. So next time we decided to use pumps with such a power so that no flow is bypassed.

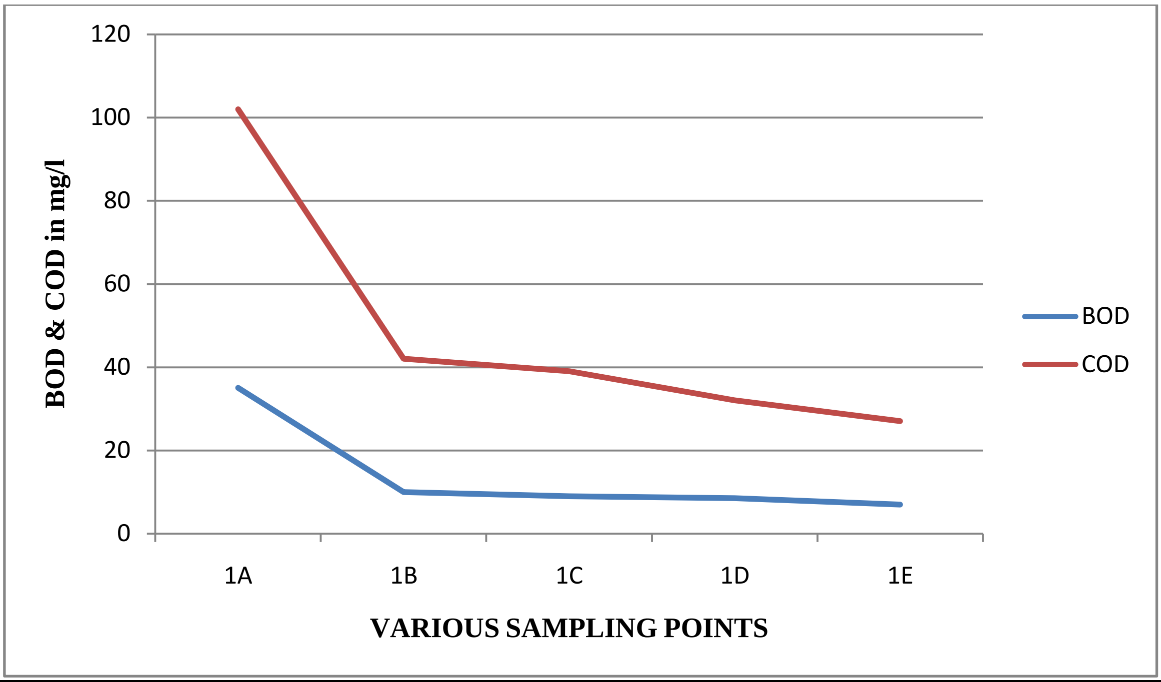

Fig. 34: Comparative analysis BOD & COD of samples collected from different outlet at initial time (0 hr) at Site 2. For 2nd Cycle

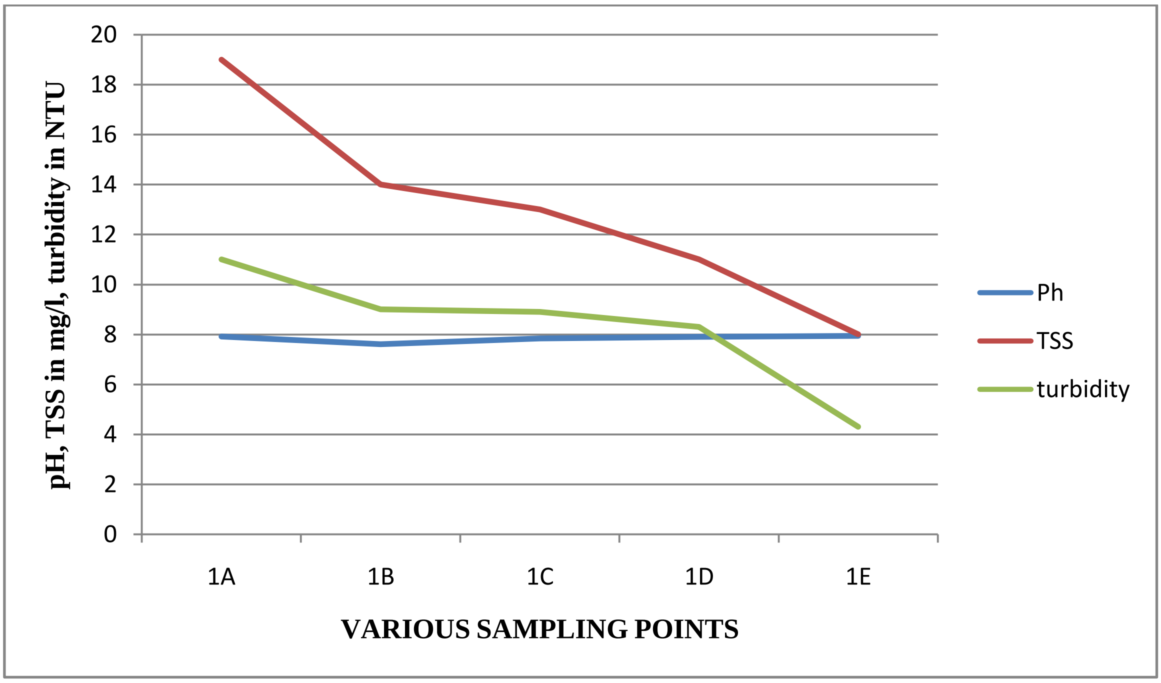

Fig. 35: Comparative analysis pH, TSS, turbidity of samples collected from different outlet at initial time (0 hr) at Site 2. For 2nd Cycle

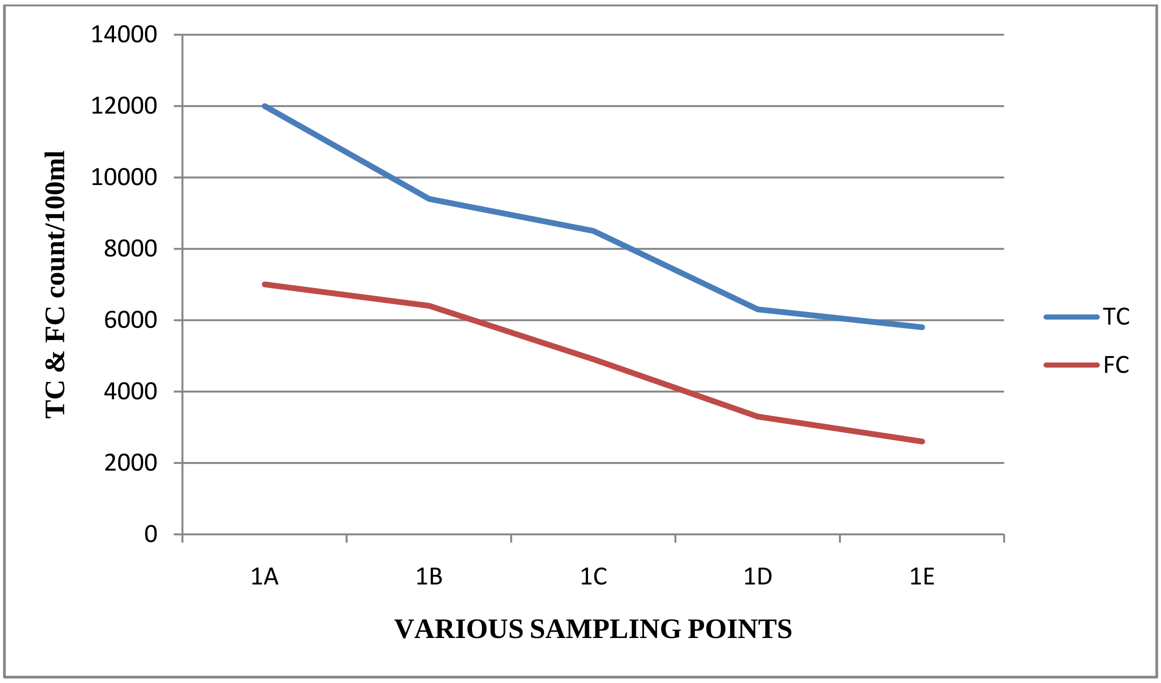

Fig. 36: Comparative analysis TC & FC of samples collected from different outlet at initial time (0 hr) at Site 2. For 2nd Cycle

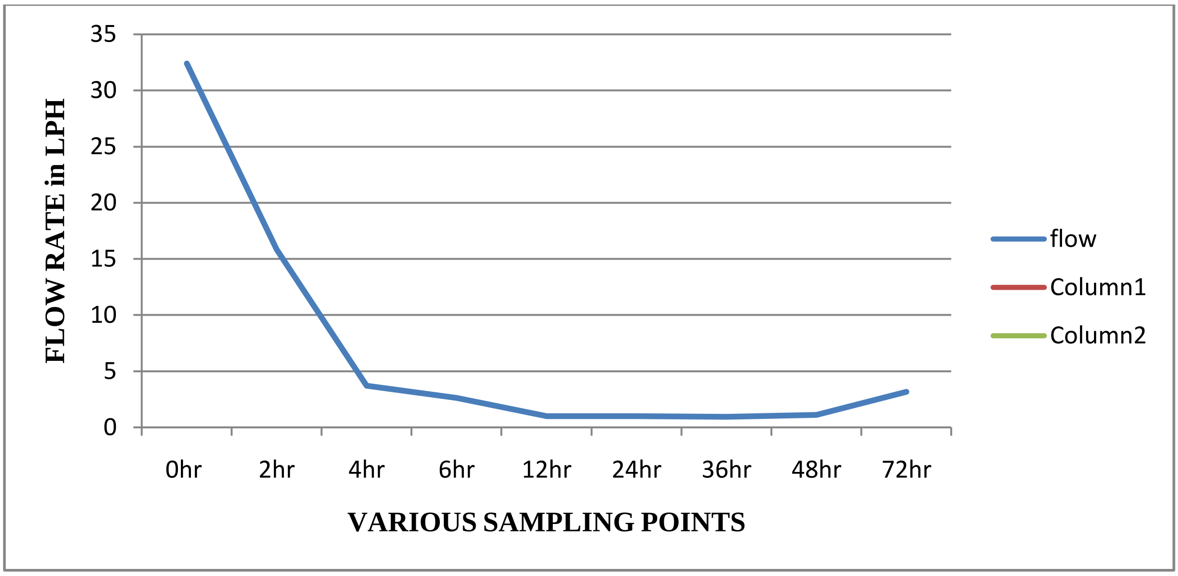

Fig. 37: Variation of flow rate after final outlet with respect to the time of operation at Site 2. For 2nd Cycle

Fig. 38: Perforated pipe covered with cloth filter

Fig. 39: Collecting of raw sample from 1st compartment

Fig. 40: Taking sample of cloth filter

Fig. 41: PLE machine

6.5 Installation at JU Staff Quarter

6.5.1 Arrangements of PLE at JU Staff Quarter

- Perforated pipe covered with cloth filter is used. Submersible pump is kept inside the perforated pipe. It is rested on 1ft (30.48cm) above the bottom portion of the tank of depth 1.82m (6ft) which is filled up to 0.92m (3ft) with sewage water.

- Septic tank is of dimension of length 6.1m (20ft), breath 1.82m(6ft) and depth 1.82m(6ft). It has a volume of 20.20 $m^3$and has user of 70persons (approx).
- Water extracted from the pit enters in to the micro filter. Then it passes through activated carbon and finally through ultra-filtration.

- This pattern flow of water (Micro filter to Activated Carbon to Ultra filter) continues.

6.5.2 Material Specification

Submersible pump:

220V, 40Watt, 3m head, flow-2000lph

Booster pump:

Flow-75 GPD, 220V

Micro filter:

0.45 micron pore size, length-50.8cm (20 inch)

GAC:

Iodine value- 600 IV, length-50.8cm (20inch)

Ultrafilter:

Flow-25lph, 0.01 micron pore size, length- 25.4cm (10inch)

Fig. 42: Submersible pump

Fig. 43: Booster pump

6.5.3 Parameters Measured

A- Raw sample**.**

B-Sample after cloth filter

C- Sample after micro filter**.**

D-Sample after GAC

E-Sample after ultrafiltration

BOD, COD, pH, total suspended solids (TSS) measured in **mg/litre.**

Turbidity measured in **NTU.**

Number of Total Coliform (TC) & Faecal Coliform (FC) are in the order of**100.**

Pressure Gauge reading is in **kg/cm^2**

Flow measured in **litre per hour**

Fig. 44: JU staff quarter

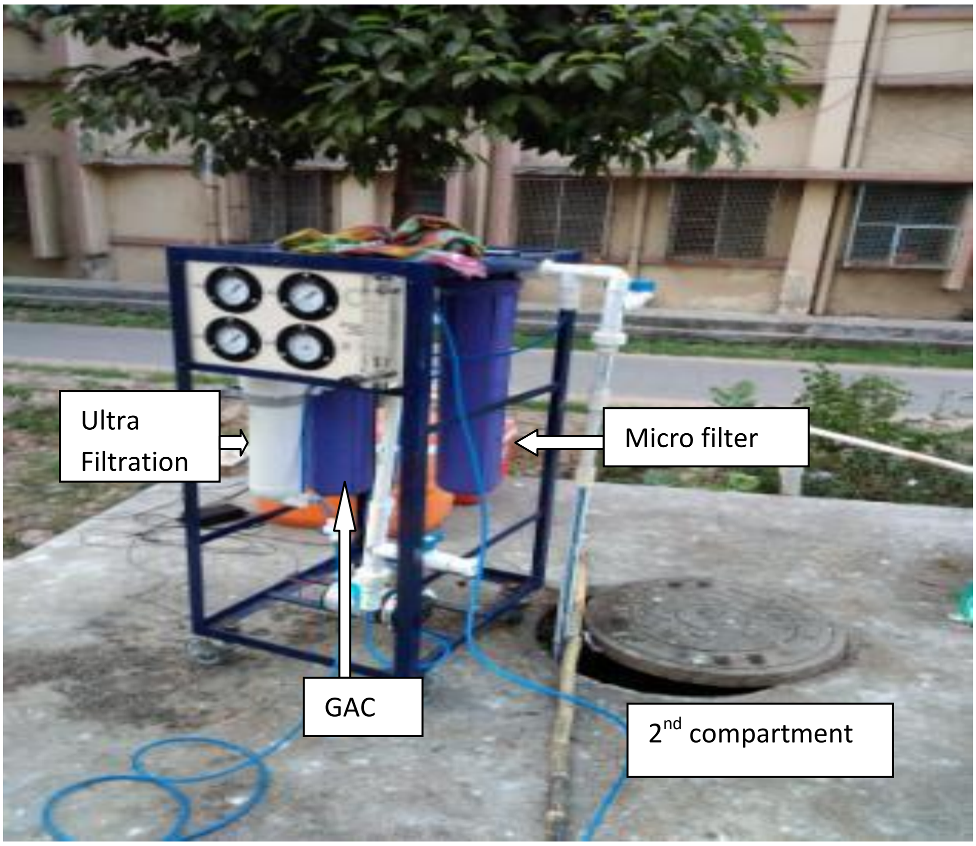

Fig. 45: Installation of PLE

Fig. 46: Perforated pipe

Fig. 47: Pressure gauge

Fig. 48: Perforated pipe after 3days of operation

Fig. 49: Sampling at night

Table 6: Sampling chart for installation at JU staff quarter

LOCATION JU staff quarter	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
02:00pm(0hr) on 14.02.19									
1A	132	281	7.31	137	146	940	700		
1B	125	266	7.41	67	118	630	330	0	108
1C								0	1.38
1E	48	98	7.75	19	30.9	79	27		12.8
04:00pm(2hr) on 14.02.19									
2B	130	276	7.55	135	142	700	260	0	105.5
2C	101	252	7.84	114	62	390	220	0	3.84
2E	39	88	7.55	15	12	34	22		12
06:00pm(4hr) on 14.02.19									
3B	143	205	7.51	117	123.2	400	240	0	104.34
3C	97	145	7.62	75	8.7	250	130	0	4.14
3E	28	77	7.43	12	6.4	17	11		10.2

Table 6: Sampling chart for installation at JU staff quarter (contd.)

LOCATION JU STAFF QUARTER	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
08:00pm(6hr) 14.02.19									
4E	35	87	7.57	21	16.1	20	17		9.25
02:00am(12hr) 15.02.19									
5E	20	55	7.45	12	12.5	34	27		8.82
02:00pm(24hr) on 15.02.19									
6A	122	230	7.48	152	44.3	940	700		
6E	20	58	7.56	12	10.5	21	13		4.37
02:00am(36hr) on 16.02.19									
7A	114	233	7.56	139	110	170	110		
7E	25	64	7.6	12	14	21	14		3.6
02:00pm(48hr) 16.02.19									
8A	94	150	7.54	116	88	330	270		
8E	33	87	7.52	22	9.2	54	36		2.82
02:00pm(72hr) 17.02.19									
9A	95	192	7.51	97	21.7	340	270		
9E	19	54	7.59	25	7.7	21	17		2.5

6.5.4 Observation of PLE at JU Staff Quarter Location:-

- The unit has operated for a duration of 72hrs**..**
- Micro filtration unit got choked after 8hrs of operation and hence could not function beyond that.
- There was no flow through GAC from the beginning.
- Pressure gauge fitted after booster pump was found to be fluctuating during the operation.
- BOD and COD of raw water are found to be reduced to 36% and 35% of its original value at 0hr after ultra-filtration.
- After 72hrs of operation BOD & COD are found to be reduced to 14.4% & 19.2% respectively of its original value after ultra-filtration.
- After ultra filtration pH is found to be almost uniform with tedious variations. TSS & turbidity are found to be reduced to around 13.8% & 21.1% respectively of its original value at 0hr after ultra-filtration.
- After 72hrs of operation TSS & turbidity are found to be reduced to 18.5% & 5.25% respectively of its original value after ultra-filtration.
- TC & FC counts are found to be reduced to 8.4% & 3.8% respectively of its at original value at 0hr after ultra-filtration.
- After 72hrs of operation TC & FC are found to be reduced to 2.20% and 2.4% respectively of its original value after ultra-filtration.

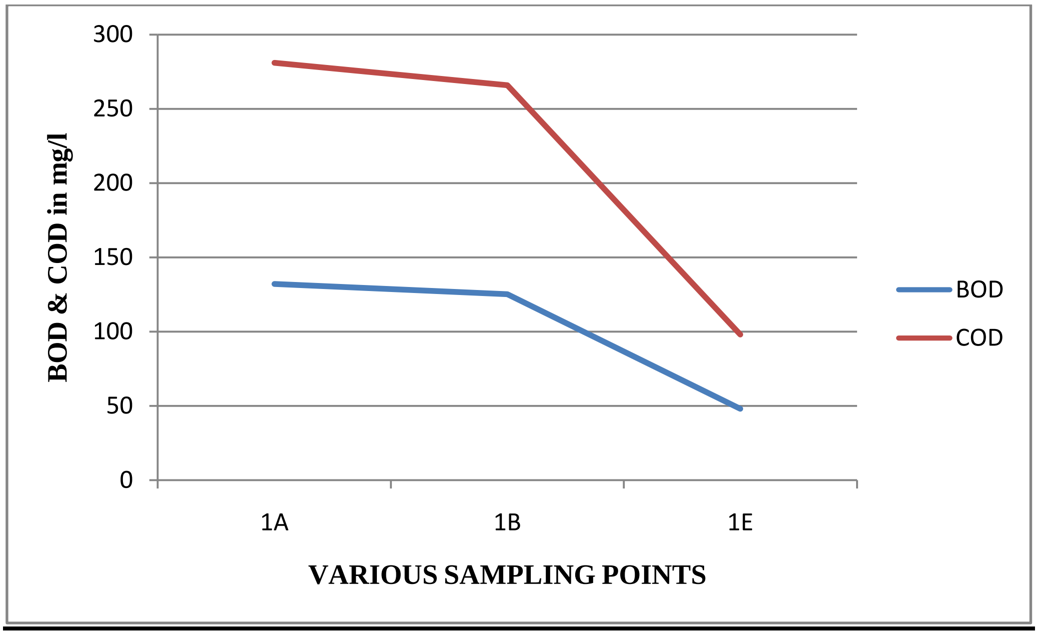

Fig. 50: Comparative analysis BOD & COD of samples collected from different outlet at initial time (0 hr) at Site 3

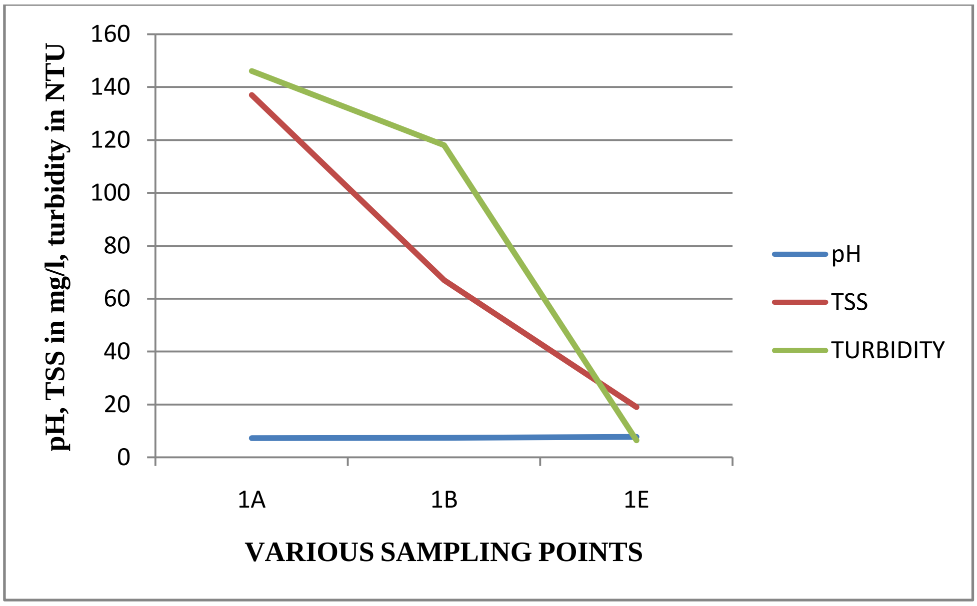

Fig. 51: Comparative analysis pH, TSS, turbidity of samples collected from different outlet at initial time (0 hr) at Site 3

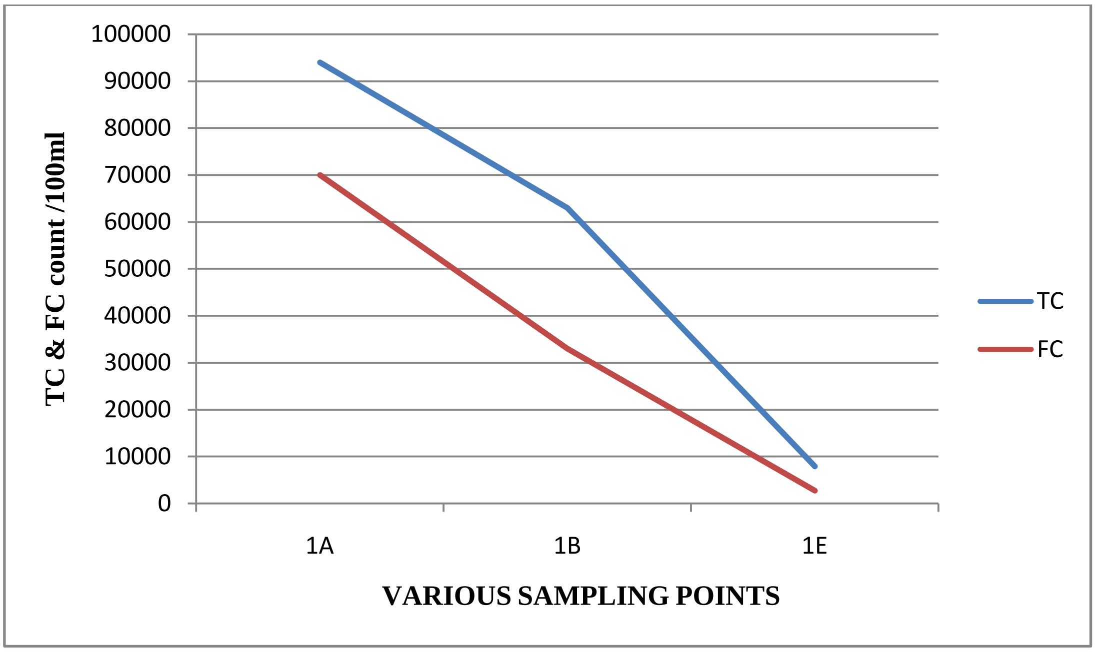

Fig. 52: Comparative analysis TC & FC of samples collected from different outlet at initial time (0 hr) at Site 3

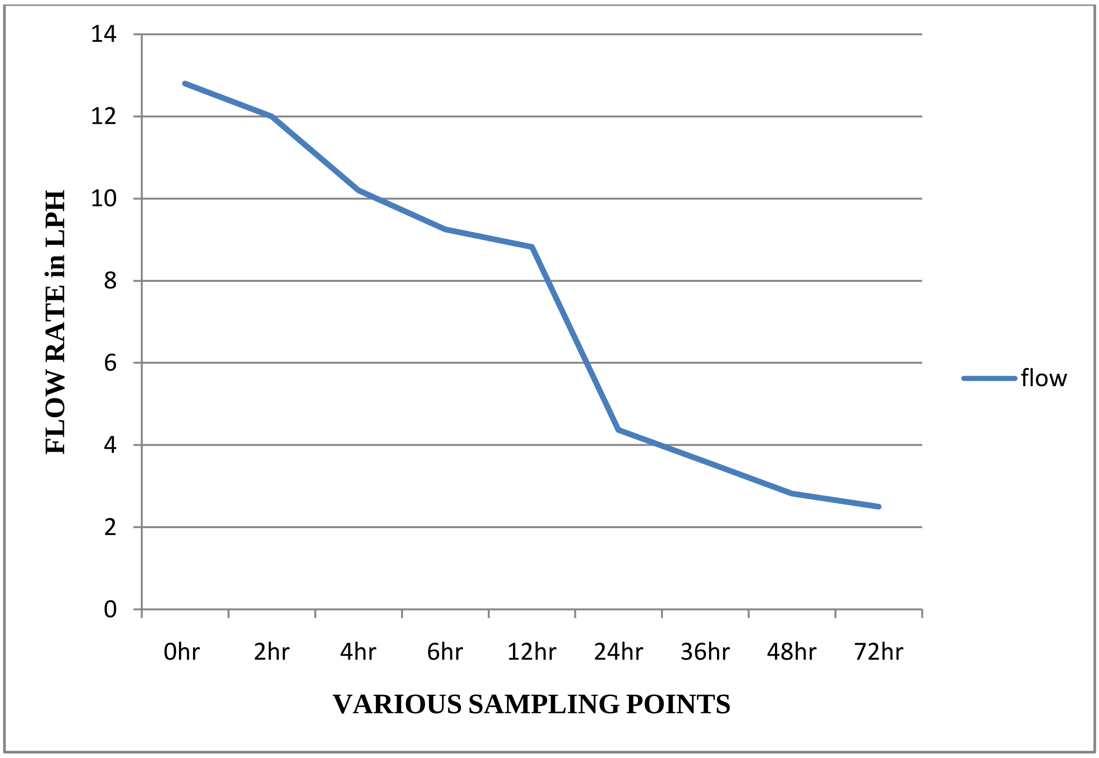

Fig. 53: Variation of flow rate with respect to the time of operation at Site 3

6.6 Installation at Survey Park

6.6.1 Arrangements of PLE at Survey Park

- Perforated pipe covered with cloth filter is used. Submersible pump is kept inside the perforated pipe. It is rested on 20cmabove the bottom portion of the tank of depth 1.2m (4ft) which is filled up to 0.91m (3ft) with sewage water.
- Septic tank is of dimension length 3m(10ft),breath 1.35m (4.5ft) and depth 1.2m(4ft).It has a volume of 4.86m^3 and has user of five.
- Water extracted from the pit enters into the micro filter .Then it passes through activated carbon and finally through ultra-filter.
- This pattern flow of water (Micro filter to Activated Carbon to Ultra-filter) continues.

6.6.2 Material Specification

Submersible pump:

220V, 40Watt, 3m head, flow-2000lph

Booster pump:

Flow-75 GPD, 220V

Micro filter:

0.45 micron pore size, length- 50.8cm (20 inches)

GAC:

Iodine value- 600 IV, length-50.8cm (20inch)

Ultrafilter:

Flow-25lph, 0.01 micron pore size, length- 25.4cm (10inch)

Fig. 54: Submersible pump

Fig. 55: Booster pump

6.6.3 Parameters Measured

A- Raw sample.

B-Sample after cloth filter

C- Sample after micro filter.

D-Sample after GAC

E-Sample after ultrafiltration

BOD, COD, pH, total suspended solids (TSS) measured in **mg/litre**.

Turbidity measured in **NTU.**

Number of Total Coliform (TC) & Faecal Coliform (FC) are in the order of **100.**

Pressure Gauge reading is in **kg/cm^2**

Flow measured **litre per hour.**

Table 7: Sampling chart for installation at Survey Park

LOCATION SURVEY PARK	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW (LPH)
08:00am(0hr) on 25.02.19									
1A	96	208	7.42	112	128	420	330		
1B	82	187	7.77	80	82	380	310	0	540
1C	70	146	7.62	57	67	210	180	0	495
1D	44	97	7.53	49	54	36	21	0	8.18
1E	34	72	7.84	23	25	31	19	1.6	13.71
10:00am(2hr) on 25.02.19									
2B	78	167	7.34	63	98	390	240	0	350
2C	62	146	7.68	51	74	320	180	0	310
2D	58	125	7.72	43	63	52	41	0	2.32
2E	36	47	7.45	20	28	32	25	1.6	11.3
12:00pm(4hr) on 25.02.19									
3B	82	174	7.66	58	97	390	230	0	326
3C	69	143	7.43	48	69	310	190	0	272
3D	60	138	7.49	40	52	51	42	0	1.46
3E	40	82	7.82	33	25	40	31	2.5	8.6

LOCATION SURVEY PARK	BOD	COD	pH	TSS	TURBIDITY	TC*100	FC*100	PRESS.	FLOW LPH
02:00pm(6hr) on 25.02.19									
4D	56	119	7.19	33	50	32	20	0	0.6
4E	36	80	7.36	14	25	27	18		7.81
08:00pm(12hr) on 25.02.19									
5D	NO FLOW THROUGH GAC								
5E	35	61	7.34	21	22	26	15		3.4
08:00am(24hr) on 26.02.19									
6E	32	70	7.68	19	26	27	19		3.13
08:00pm(36hr) on 26.02.19									
7E	32	62	7.58	14	22	27	18		2.73
08:00am(48hr) on 27.02.19									
8E	30	72	7.82	19	22	24	19		2.68
08:00am(72hr) on 28.02.19									
9E	28	64	7.41	17	20	18	11		2.4

6.6.4 Observation of PLE at Survey Park Location

- The unit has operated for a duration of 72hrs**.**
- Micro filtration unit got choked after 48hrsof operation and hence could not function beyond that.
- GAC unit got choked after 7hrs of operation and hence could not function beyond that.
- Pressure gauge fitted after booster pump was found to be fluctuating during the operation.
- BOD and COD of raw water are found to be reduced to 35% and 34% of its original value at 0hr after ultra-filtration.
- After 72hrs of operation BOD & COD are found to be reduced to 29.1% & 30.7% respectively of its original value after ultra-filtration.
- After ultra filtration pH is found to be almost uniform with tedious variations. TSS & turbidity are found to be reduced to around 20.5% & 19.5% respectively of its original value at 0hr after ultra-filtration.
- After 72hrs of operation TSS & turbidity are found to be reduced to 15% & 15.6% respectively of its original value after ultra-filtration.
- TC & FC counts are found to be reduced to 7.3% & 5.75% respectively of its at original value at 0hr after ultra-filtration.
- After 72hrs of operation TC & FC are found to be reduced to 4.30% and 3.3% respectively of its original value after ultra-filtration.

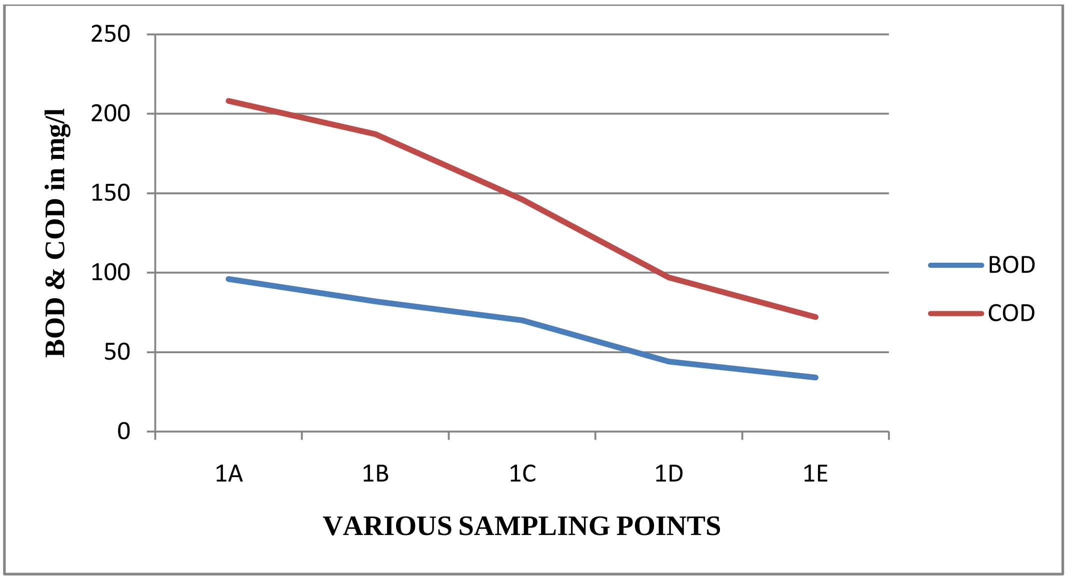

Fig. 56: Comparative analysis BOD & COD of samples collected from different outlet at initial time (0 hr) at Site 4.

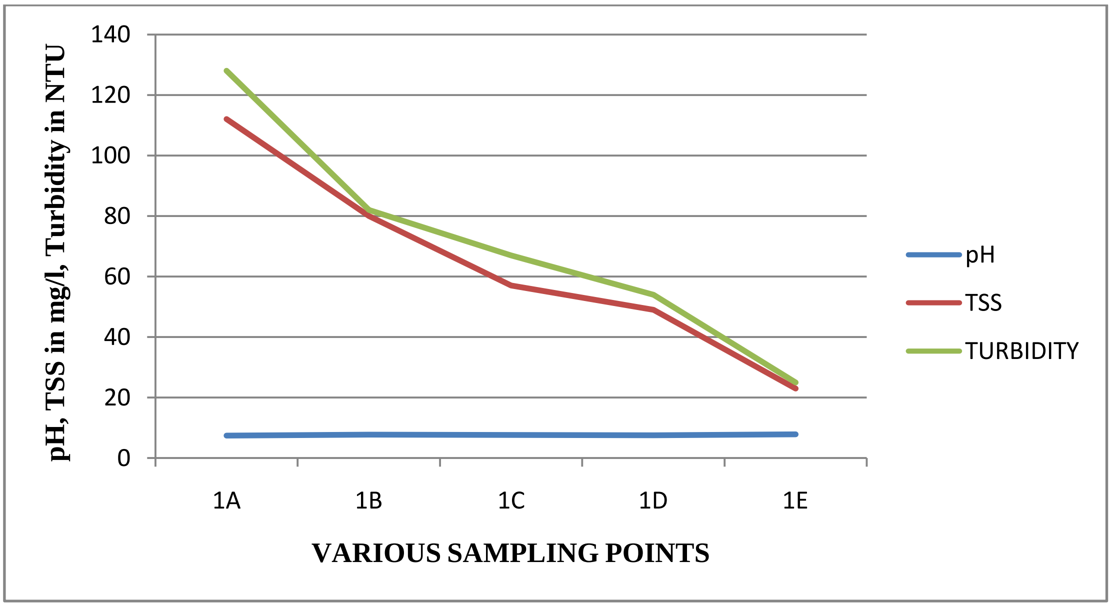

Fig. 57: Comparative analysis pH, TSS, turbidity of samples collected from different outlet at initial time (0 hr) Site 4.

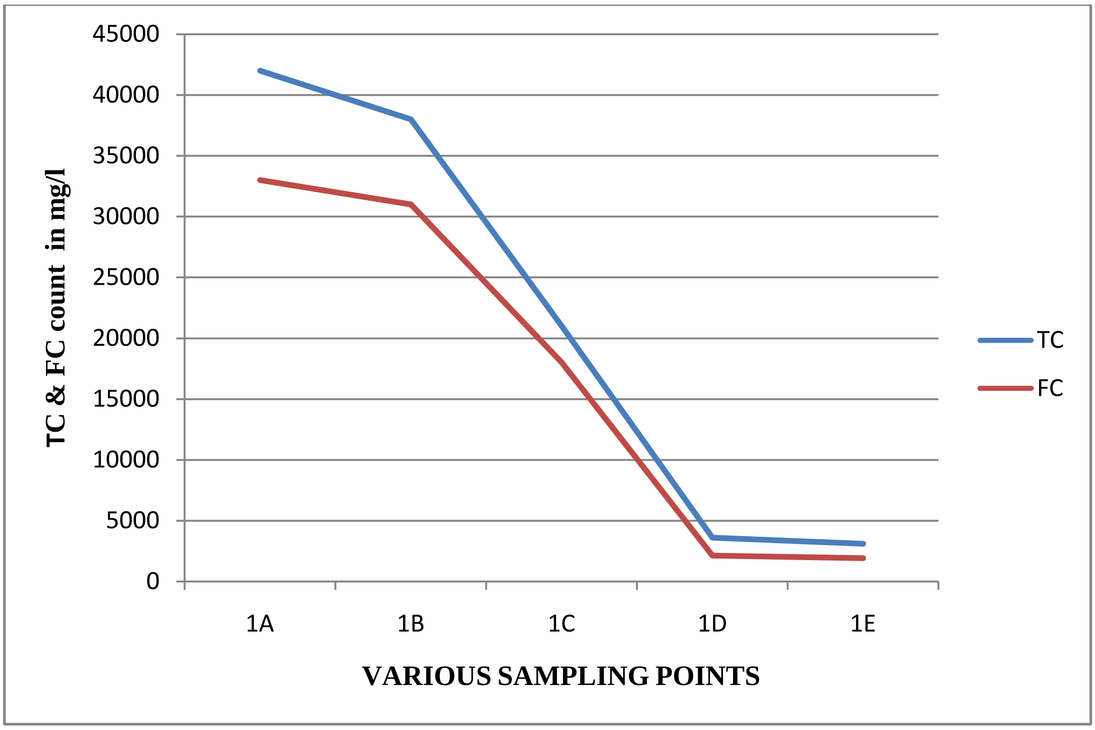

Fig. 58: Comparative analysis TC & FC of samples collected from different outlet at initial time (0 hr) Site 4.

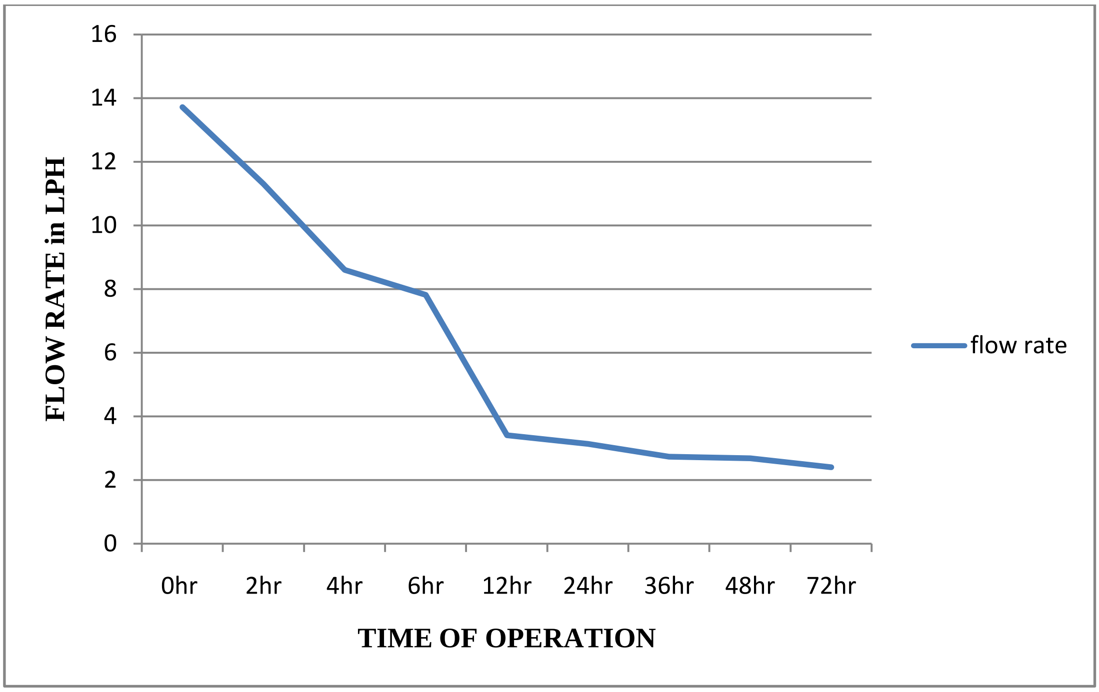

Fig. 59: Variation of flow rate with respect to the time of operation Site 4.

Fig. 60: Ultra filter

Fig. 61: Perforated pipe & cloth filter after three days of operation

Fig. 62: Removing old GAC after three days of operation

Fig. 63: Installing new GAC

Fig. 64: Micro filter

Fig. 65: Old ultra filter after three days of operation

Fig. 66: covering new cloth filter on perforated pipe

Fig. 67: Perforated pipe covered with cloth filter

Fig. 68: Installing machine at Survey park

Fig. 69: Machine was covered due to heavy rain

Fig. 70: Sampling at night

Fig. 71: Perforated pipe after three days of operation

Table 8: Characteristics of raw samples of septic tanks

Raw Sample	BOD (mg/l)	COD (mg/l)	pH	TSS (mg/l)	Turbidity (NTU)	TC (MPN per 100 ml)	FC (MPN per 100 ml)
1st cycle at 12/12 bireswar dhol lane baranagar	60	97	7.91	57	39	30000	210000
2nd cycle at 12/12 bireswar dhol lane baranagar	105	174	7.88	42	18	28000	22000
1st cycle at JU campus beside mechanical building	39	88	7.72	46	26	13000	7900
2nd cycle at JU campus beside mechanical building	35	102	7.91	19	11	12000	7000
Operation at JU staff quarter	132	281	7.31	137	146	94000	70000
Operation at survey park	96	208	7.42	112	128	42000	33000

Table 9: Characteristics of effluents after filtration

Treated effluent	BOD (mg/l)	COD (mg/l)	pH	TSS (mg/l)	Turbidity (NTU)	TC (MPN per 100 ml)	FC (MPN per 100 ml)
1^{st} cycle at 12/12 bireswar dhol lane baranagar	64	105	8.07	32	12.4	27000	22000
2^{nd} cycle at 12/12 bireswar dhol lane baranagar	19	40	8.16	6	1.9	12000	10000
1^{st} cycle at JU campus beside mechanical building	3	12	7.95	3	1.9	2400	1900
2^{nd} cycle at JU campus beside mechanical building	3	14	7.53	2	1.2	2400	1400
Operation at JU staff quarter	19	54	7.59	25	7.7	2100	1700
Operation at Survey park	28	64	7.41	17	20	1800	1100

CHAPTER:
7. CONCLUSION

7.1 Conclusion

In this study performance of Pit Life Extender (PLE) machine at various location at different condition is monitored. Here the quality of effluent sampled at different time from different outlet may be considered as an indicative measure of performance of this machine.

In the case of installation at Site 1 (12/12B Bireswar Dhol Lane) it is intended to operate this in two cycles. But on the first cycle of operation (28th August, 2018) due to choking of perforated pipe operation got stopped after 12 hour and couldn't continue further. To mitigated this problem next time (10th September, 2018) pipe with more perforation is used which solved the choking problem and unit operated for a duration of 72 hours. Now, if the quality of the effluent is considered then it is found that BOD is not as per the Indian standard of safe disposal which is 30 mg/liter and also percentage removal TC & FC is not satisfactory.

In the case of installation at Site 2 (besides mechanical building, JU campus) unit operated for complete two cycles. BOD & COD both are reduced to below 20% after final outlet. But the BOD of the raw was very less that is below 40 mg/liter which is just above the permissible value of effluent disposal standard. This septic tank is installed in an educational building where it is may not be regularly used that's why initial BOD remains low and performance of this machine couldn't be judged properly. In this case arrangement of MF and GAC is interchanged, which means after cloth filter sewage entered in GAC first then MF followed by UF. But that didn't add any better result than previous. Also by using a pump of huge capacity a large volume of water had to be bypassed to protect the filters, which turned out to be less economically viable.

In this case of installation at Site 3 (JU staff quarter, 14th February, 2019), three things were improvised based on previous operation one being the arrangement of filters are changed to original pattern (CF to MF to GAC to UF) another was using pump of suitable capacity so that no flow is bypassed and the last one is selecting of septic tank which receives sewage daily from large number of people (approx 70 persons reside at staff quarter). In this operation it is found that BOD was brought down 36% of its initial value at initial time. Using pump of suitable capacity ensured unit to be operative for 72hrs without requirement of bypassing. TC & FC is reduced to less than 10 times of its original value and sometimes effluent BOD from the final outlet touched the mark of less than 30 mg/ liter.

At the last installation at Site 4 (Survey Park, 25th February, 2019), nothing is altered from the previous set up at JU staff quarter. As it is installed in a small house BOD and other parameters is came up little less than previous site. Though in the previous case it had been noted that sometime BOD value came less than 30 mg/liter, But here even having better quality of influent BOD value couldn't be brought down to less than 30 mg/liter. These findings justify that may in the previous case some experimental error occurred. Here also TC & FC are brought down to less than 10 times of the original value.

It is to be concluded that in no case the necessity of further treatment before disposal is wiped out, it is immensely important to meet the effluent disposal standards stated by concerning authority. The effluent disposal standard is not achieved in all the cases. But it is also to be noted that maximum TC count for effluent discharge in water body or reuse for aquaculture, irrigation is 10,000MPN/100 ml as per Indian standard and effluent standard of BOD used for irrigation is 100 mg/liter. So this water can be used in the purpose of irrigation and aquaculture. Also the time of exhaustion of individual unit (CF, MF, GAC, UF) is noted which will further help to design a better model for future study.

7.2 Recommendation

- As the time of exhaustion of individual unit is already known then if it is feasible after the failure of particular unit, it is changed and operation continued. Otherwise different category of MF and GAC may be used as these two units tend to fail first.
- Use of advanced pressure gauges at ultra-filtration is recommended because in all the experiment it kept fluctuating.
- Differential pressure of each unit (MF, GAC, UF) also is to be measured.
- GAC consumption rates are to be found.
- Provision of backwashing may be introduced for better performance.
- Measures to be taken to bring down TC count to less than 1000 MPN/100ml as this is the desirable limit.

7.3 Future Scope

In developing countries due to huge population, limitation of fund and lack of technological development, a cost effective and environment friendly method of septage management will always be in demand. In this case a detail study of individual unit may be useful for designing a better model. Reduction of organic loads on each unit has to be calculated to understand exact size of various filters to be used.

Apart from improving the machine the provision of reusing this effluent in various sectors like irrigation, aquaculture etc. also be taken care of. East Kolkata Wetland (EKW) already set up an example of sustainable eco-friendly reusing of municipal waste through aquaculture.

In this study in many instances it is found that effluent does satisfy the condition for both aquaculture and irrigation.

CHAPTER:
8. REFERENCES

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8.1 Appendix I

NF: Nano filtration

RO: Reverse Osmosis

MF: Microfiltration

CF: Cloth Filtration

PLE: Pit Life Extender

FSM: Faecal Sludge Management

TSS: Total Suspended Solids

UF: Ultrafiltration

GAC: Granular Activated Carbon

SWRE: School of Water Resources Engineering

MLD: Mega litres per Day

COD: Chemical Oxygen Demand

BOD: Biochemical Oxygen Demand

TC: Total Coliform.

FC: Faecal Coliform

CPHEEO: Central Public Health and Environmental Engineering Organisation

8.2 Appendix II

Appendix III