TEMPORAL AND SEASONAL VARIATION OF NUST WASTEWATER

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Abstract

Water is the basic resource for survival of living organism. With such a quick development globally, the supply and demand gap is getting bigger and bigger with each passing day. So development has become a problem for many countries and regions worldwide. Countries that have fresh water below 1000 m^3 per person per year are classified as water scarce. Pakistan has annual rain fall of less than 250 mm.

These problems have become worse since ground water reservoirs are also exhausted. MBR technology allows building up decentralized wastewater treatment plants in areas where large treatment plants are difficult to construct and operate. It provides improved health conditions due to almost bacteria-free effluent and the possibility of re-using the treated water. In this study, samples were collected from different locations within NUST H-12 campus. Dissolved oxygen, temperature and pH were investigated on site and for further analysis transported to laboratory for analysis. The chemical and biological characteristics of wastewater were analyzed and variations in concentrations of wastewater constituents in different seasons were investigated. On the basis of data collected, GPS-X software was used for modeling and simulation of pilot scale wastewater treatment plant to be installed in h-12 campus at NUST Islamabad. Different scenarios were run in GPS-X and establish the most suitable conditions for pilot scale MBR plant.

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List of abbreviations

Abbreviations	Description
EPA	Environment protection agency
IESE	Institute of environmental sciences and engineering
NEQS	National environmental quality standards
WHO	World health organization
NTU	Nephelometric turbidity unit
TMP	Trans-membrane pressure
P	phosphorous
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
sCOD	Soluble chemical oxygen demand
SS	Suspended solids
SRT	Solid retention time
HRT	Hydraulic retention time
TN	Total nitrogen
TC	Total carbon
MLVSS	Mixed liquor volatile suspended solids
MLSS	Mixed liquor suspended solids
DO	Dissolved oxygen
F/M	Food to microorganism ratio
MBR	Membrane bioreactor
TOC	Total organic carbon
MGD	Million gallon per day

INTRODUCTION

1.1. Background

Water is the basic resource for survival of living organism. It is the essential natural resource for human society's development. The whole ecosystem is dependent upon water. With such a quick development globally, the supply and demand gap is getting bigger and bigger with each passing day (Zeng *et al*., 2013). So development has become a problem for many countries and regions worldwide. Countries that have fresh water below 1000 m^3 per person per year are classified as water scarce. There are 18 countries which are classified as water scarce currently. Most of these water scarce countries are in Middle East and North Africa (Syed *et al*., 2012).

The water scarcity problem is getting worse day by day. It is estimated that by the year 2025, the number of water scare countries are going to go up to 30 in the world. This is mainly, because current water shortages and with time the increase in population. The rapid increase in population and significant urbanization will make this problem worse, which will result in fresh water withdrawal for municipal and agricultural use. This problem may be partially solved by water recycling.

In the coming years it is expected that there is going to be a large scale population shift from the rural to urban areas. By the year 2025 it is expected that 1.7 billion new residents are going to shift to urban areas. So these new residents need to be housed in newly developed housing schemes, which will require more water. So the urban areas having water shortage are going to have some serious competition for allocating water for municipal use. Globally it is estimated that 70% of water is used for agriculture purpose (Zeng *et al.*, 2013), whereas some countries use 90% of water for agriculture. Water for agriculture will have the largest share even in future but new alternatives are required. New sources of water are required that may contribute to water supplies and prevent the worsening of water shortage.

Water demands already exceed the water supplied in many parts of the world. This imbalance is going to be experienced in other parts of the world in the coming years. Due to the increase in population, the water demand for household, agriculture and industrial sectors. Is also going to be increased. This would be even worse in the developing parts of the world.

Dating back to the first settlements, all the early settlements were near or beside water bodies. These water bodies served as water and food source plus transport medium to inhabitants. As these populations grew they started polluting water. Since the increase in industrialization the pollutants got more harmful and toxic and they just became common in runoff as a result adding misery to urban water sources. In the developing world, sewage treatment facilities are next to none. Serious help risks are connected to it. Untreated sewage is the main constituents of waterways in urban areas. With the development of new treatment and disposal techniques, there is a solution to it now by reclaiming water for non-potable applications.

Pakistan has annual rain fall of less than 250 mm. and its climate is mostly arid and semi-arid. Like any other developing and populous country Pakistan is also facing shortage of water. Pakistan is now classified as water scare country in the world (World Bank, 2006). The water resources are continuously being exhausted and polluted. Water from lakes and rivers is diminishing at a very fast rate and this problem is increased by the help of long droughts and poor water management. At the moment there is need of new water reservoirs to store water and use it at the time of no precipitation or dry season. Not only surface water but also the ground water is also diminishing at fast rate. The water per capita availability of from 5600 m^3 in 1951 dropped to 1100 m^3 in the year 2006; currently it has dropped further. Now it is assumed to be below 1000 m^3 per year. Now Pakistan is classified as water stressed country. With increase in population and no further development of water resources this problem will get worse with time. The areas which lie outside the Indus basin are experiencing worst water shortage. Areas which suffer from drought like Sindh have no access to fresh water and people have no other option but to use brackish water. Same is the case in the other provinces, groundwater table in dropping at the rate of 3.5 meter per year (Khair *et al.*, 2012). At this rate the ground water is going to be exhaust in a couple of decades. Water pollution has worsened the existing water scarcity situation. The water quality of rivers and lakes is no longer safe for human consumption. Even the ground water quality is affected and aquifers in the country are polluted *(*Azizullah *et al., 2011)*.According to national figures, about half of the population doesn't have access to safe potable water. According to national drinking water standards only quarter of the population have access to clean drinking water. WWF in 2007 reported that water being supplied by local municipalities is mostly infected with pathogens, toxic metals and pesticides. Drinking water is contaminated by hazardous chemicals or infectious microbes.

Surface and ground water in all large cities is polluted by the human activities and are not recommended for consumption. Pakistan Council of Research in Water Resources (PCRWR) conducted a study in all provinces from 2002 to 2006, concluded that around 90% of the water sources cannot be recommended for human consumption. The public is forced to go for the expensive alternative of drinking water which is commercially available in packed bottles in form of mineral water. Even this option of commercially available mineral water is not completely safe because there is no proper monitoring of the water processing. As a result, majority of the population of the country is exposed to unsafe drinking water, which may cause several diseases and other water related health problems. This growing pollution of drinking water is of great concern that needs to be solved and controlled, because this is not only a problem for the human health but also to the environment (Khair *et al.*, 2012).

Untreated disposal of wastewater that include industrial and domestic wastewater is the reason why water sources of water in Pakistan are unsafe and polluted. They are polluted because this is no check over what kind of effluents are directly discharged into receiving water bodies directly or indirectly.

Membrane bioreactor (MBR) is an advanced treatment technology to treat wastewater and reuse it non-potable applications. It is a process that combine membrane filtration and biological processes to treat wastewater. It is a very promising technology for treatment of wastewater as it produces good quality effluent MBR technology has COD removal of more than 90 % (Chen *et al.,* 2009).

1.2. Objectives of The Study

The objectives of the study are

1. Study the Physico-Chemical and biological characteristics of NUST Campus wastewater
2. Design of membrane bioreactor (MBR) plant using GPS-X software
3. Optimize conditions of membrane bioreactor (MBR) plant by controlling Dissolved Oxygen (DO) and Solid retention time (SRT)

1.3. Scope Of The Study

1. NUST H-12 Campus Wastewater characterization in terms of Physical, Chemical and biological parameters
2. Simulation of full scale wastewater treatment plant based upon GPS-X modeling and simulation.
3. Optimization of MBR plant.

Chapter No. 2

LITERATURE REVIEW

2.1.Water scarcity – A global perspective

Water resources globally are depleting at a very fast rate. Water scarcity of the resources has got the focus to this direction. Now the focus is on need to manage water resources efficiently. It is a known fact that water is the main factor for development in this world with population expanding rapidly. United Nations also has focused on water importance and water related activities to help in development and eliminating poverty at the global level (UN, 2003). One of the targets of Millennium development Goals signed in 2000 was to half the population without safe Drinking water and sanitation (United Nations, 2006).

The migration from rural area to urban centers has resulted in imbalance of population. Population gets stuffed resulting in high demand for water more than available. Cities with population over a million in 1950 were only 78. This number increased to 290 in 40 years. Whereas it is expected that in the year 2025 the number of cities with population over a millions would be more than 600 (Rosegrant *et al.*, 2002).A water supply in urban areas is failing to keep up with the demand that is caused by increasing urbanization. So there is a need for an innovative management strategy to be developed and this perception has to be changed that water conservation is only a drought relief mechanism which results in reduced service level (UN-HABITAT, 1999).

2.2.Water Availability In Developing Countries

Wars in future are going to be fought on water this is what the experts say. Water scarcity has already led to many problems in northern Africa and western Asia. This has resulted in loss of livelihood due to drought, water-borne diseases and even conflicts and migration *(*Zeng *et al.*, *2013).* If this problem is not addressed seriously then this region will very soon be facing problems managing fresh water, availability in sufficient quantity and of drinking water quality or water suitability for any other use. This problem is already severe in many countries in the region. This is a hurdle in social and economic development of the region (Vairavamoorthy *et al.,* 2008). Worrying thing for developing nations is water crisis is going to get worse. It has been estimated that one third of the developing world is going to be affected by water shortage by 2025 (Rosegrant *et al.,* 2002).

On the other hand global warming will add to the current situation. Water shortage in this region is of growing concern and reaching the limit. The demand for human population and agriculture is rising day by day. There is a serious need for water management to control this crisis and find a solution to this. The water stressed countries of Western Asia and North Africa can be divided into three types which are discussed as follows on the basis of Agro-ecologies.

First the area those are fed and dependent on low rainfall and very uneven rainfall, cause of which yields are minimal. The crisis worsened by frequent droughts. The soil is unable to absorb the rain because rain in form of unpredictable storms and intense. The moisture is unable to go deep in the earth. The moisture after rain is lost due to runoff and evaporation. Secondly there are regions those are watered by river and groundwater sources. These sources are over used and are depleting with time. Third are the water stressed areas those are totally manmade. They are totally because of increasing population and increasing water demand. This is mainly because of imbalance population and water resources (El Kharraz *et al.*, 2012).

Water scarcity has direct impact on the income, job opportunities, and agricultural industry. Economically, because of water shortage there is huge loss in production of goods which is mostly the agricultural goods. Loss of working hours that is faced due to shortage of water. Thus there is need of some serious steps to be taken by the governing body and the community and every party that is involved. There is a need of policy making to address water crisis which is getting worse (Vairavamoorthy *et al.*, 2008).

2.3.Challenges To Wastewater Management

Now there is change in interest and thinking of the people, in many parts of the world reuse of wastewater is of great interest including both industrial and developing nations. The reason for water is large demand of fresh water for the growing population for example Japan or like Australia, where rainfall is very low and in addition to that high evaporation, whereas some countries like Singapore reuse wastewater for environmental or economic concerns. This would result in lesser load on the wastewater treatment plants and minimize the wastewater handling and treatment cost (Zeng *et al.*, 2013).

As discussed earlier by the year 2025, at least 19 countries including Pakistan will be declared a water stressed countries. This will influence life of the people directly. According to a report 43% of the population in these areas live in rural areas and about 70% of this rural population lives below the poverty line with almost no proper water and sanitation set-up (El Kharraz *et al*., 2012).

There is need of assessing the present situation of water scarcity and drought by collecting data and information starting from the very low level. Point out the hurdles and measures to be taken to manage this issue as soon as possible. This would give an idea, scope and impacts of water scarcity and droughts in the region.

The main challenge in the region is depleting of fresh water sources. The world average for freshwater annual per capita is 7000 cubic meters whereas in this region it is below 1500 cubic meters, whereas in Pakistan, it has dropped below 1000 cubic meters (Khair *et al.,* 2012). It is expected to fall even further. Currently Jordan has per capita availability less than 230 which is alarming level for the whole region.

2.4. Sampling of Wastewater

Sampling of wastewater should be performed at an interval of 2 hours ideally in a day. It would determine the nature, amount and constituents of wastewater. This will also determine the changes in the chemical, biological and physical parameters of wastewater. The highest nutrient loading detected is sampling between 11:30am to 12:30pm because this is the peak working hour of the day. Wastewater samples should be collected in clean bottles and stored at 4°C and analyzed (Renuka *et al.,* 2014). The higher the number of samples more the accurate results it would give.

According to the guidelines by EPA for sampling water and wastewater, samples should be representative of the place where it is taken from. So the sample should be of good quality, reliable and exact copy of the body it is taken from. If not, the information gained from the analysis will never be correct. The main processes those can affect are described below. These processes are linked with each other which may influence several changes in the sample.

2.4.1. Contamination

Special care should be taken not to contaminate the sample from anything from outside. While sampling one should be careful that his hands, sampler and every other instrument is free from material that may contaminate sample. This may result in disturbing the biological or chemical condition in the sample.

2.4.2. Physical changes

Any step that could result is changing the physical nature of the sample hence resulting in reliability of that sample. Physical changes may be because of the following:

- Temperature
- Volatilization
- Sorption
- Degassing

2.4.3. Chemical changes

2.4.3.1. Precipitation

It is a process in which solids are formed from the dissolved material. Precipitation is caused by changed conditions of the sample like pH, temperature and chemical concentrations.

2.4.3.2. Oxidation

The entrance of oxygen from the air to the sample changes the DO of the sample, which increases DO, pH and redox. These changes results in a chain reaction disturbing other nutrients in the sample.

2.4.4. Biological Processes

Biological activity effects characteristics of a sample, both chemical and physical. Biological. Factors which influence biological activity are oxygen, pH, light and temperature in a sample. These factors may result in the change of its parameters like nitrite, nitrate, DO, or redox. Standard sampling methods are used to minimize the influence of factors stated above.

To minimize and to quantify the impact of these processes on sample integrity, quality control protocols and procedures must be developed and implemented at all stages of monitoring. Preserving protocols are important to stop any changes in the sample after sampling. If these protocols are followed properly the sample will not represent the real characteristics where it is taken from.

Some of the sampling preserving techniques are defined below. (EPA Guidelines: Water and wastewater sampling)

2.4.4.1. Refrigeration:

This method is used to preserve the sample characteristics for a short term (less than 24hrs). The samples are kept at a temperature between 1°C to 4°C which preserves biological, physical and chemical properties. Ice can be used to rapidly cool samples to 4°C before transport. It is recommended that microbiological samples be kept between 2°C and 10°C.

2.4.4.2. Chemical addition:

Chemical is added as a preservative depending upon conditions and preservative. With consultation of analytical technique used, these preservatives may include basic and acidic solutions, and biocides.

2.5. Seasonal Variations In Wastewater Characteristics

Micro-algal diversity shows a positive correlation with nutrients whereas with heavy metals and COD concentrations, it shows negative relation. Physicochemical characteristics show variation in composition and concentration. The pH of wastewater also varies with time ranging from 6.5 to 8.5. EC, TDS, salinity, alkalinity, chloride, hardness and calcium content were highest in February and lowest around September (Renuka *et al.,* 2014). COD samples show a wide variation and high in the winter season in the months of October to December, whereas for BOD, the trend was the opposite of COD. Dissolved oxygen didn't show a distinct change. PO_4–P level also didn't show much seasonal variation, but the highest levels were recorded in the month of April. NO_2–N was almost zero but during summer season it was comparatively more.NH_4–N and NO_3–N levels in wastewater showed highest variation, NH_4–N was highest in March. Wastewater ingredients vary with time and season.

2.6. Membrane Bio-Reactor (MBR)

Membrane bioreactor is a treatment is a process that combines two processes that is, biological and filtration. Bacteria are responsible for the biological process and the membrane does the filtration. MBR can treat wastewater with high biomass up to 20g/L (Holler *et al.,* 2001). MBR was used for the very first time to separate the activated sludge from biological wastewater in the year 1969. MBR has been evolved and the research in this field and grown especially since last decade. MBR has two main types of modules.

a) External membrane unit,

b) Internal membrane Unit

Pressure drives the separation in the first type and suction force is applied in the second type to extract water. The concentrated sludge is recycled in type 1 whereas sludge is retained at the surface of the membrane.

In internal membrane, Air is diffused at the base of the reactor to maintain a constant dissolved oxygen level for providing aerobic conditions. These bubbles also help in cleaning the surface of membrane by scouring the surface. The submerged membrane is more commonly used than the other one as it is energy efficient comparatively and membrane fouling is reduced because if the cleaning mechanism (Kraume *et al*., 2010).

MBR has a removal efficiency of 95% for chemical oxygen demand, 98% for biological oxygen demand and more than 99% of suspended solids from municipal wastewater. This is the cause why it is better than other conventional treatment. MBR has better control of over hydraulic retention time and solid retention time because of the use of membrane filtration (Holler *et al.*, 2001). Whereas for the other processes, gravitational force is the factor for separation of solids from the liquid. This is the motive that SRT in MBR processes is greater. With higher loading rates MBR sludge production is less, as a result the HRT shortens. The membrane used for separation of biomass in the ends eliminates the need for large clarifiers. So the space required for MBR is comparatively less and the whole setup is very compact.

Models play a vital role in designing, controlling and prediction of MBR plants. These models are so designed that they precisely portray the working of the processes and give clear idea of the working methodology. These models are complex to understand but still they assist in MBR technology (Fenu *et al*., 2010). MBRs have several advantages over the other water treatment technologies. It has high quality water, easy to function, small footprint and less sludge production. Therefore Membrane Bioreactors are leading in wastewater treatment industry.

2.7.Factors Affecting Membrane Performance

Membrane performance is affected by several factors which are described as follows

2.7.1. Dissolved Oxygen (DO)

In literature, there are several strategies that are proposed for controlling the treatment process and optimization of WWTP but they are difficult to be carried out. Strategies like external carbon dosing rate, dissolved oxygen concentration, sludge recycle flow rate and internal recycle flow rate (Holanda *et al*., 2008). DO Control is the most used method. It is difficult to control the treatment processes in activated sludge treatment of wastewater, because of their complex and nonlinear behavior, the control over the DO level of the plant plays a key role.

Dissolved oxygen control in wastewater treatment now is one of the very common methods used all over the globe. The control over DO level in the reactors greatly influences the behavior of the microorganisms whether heterotrophic or autotrophic those are present in the activated sludge (Yuan and Keller, 2002). The DO level in aerobic tanks or reactors in activated sludge processes should be high so that there is sufficient amount of oxygen available for the microbes to degrade the organic compounds. The DO should be maintained at required level. If oxygen is present in excessive amount then it affects the sludge quality and results in high energy consumptions.

As mentioned earlier several control strategies have been suggested in the literature. One of the simple approach is linear PI controller. Microbes are supplied with sufficient oxygen so that for their metabolism, enough final electron acceptors are available. Surface mechanical aeration or diffused aeration are used to supply oxygen to the system.

The energy consumption may be minimized greatly by the efficient use of the aeration system in activated sludge processes. Aeration is costly method the Dissolved oxygen level in the process will yield better result. Since the introduction of new and more reliable dissolve oxygen measuring devices, the control of DO has changed from the older methods to new advanced accurate and reliable methods. Which have more control and easy to operate accurately. As this fact is known that excess aeration should be avoided as this contributes to lesser oxygen transfer and efficiency (Holanda *et al*., 2008).

SCADA (Supervisory Control and Data Acquisition) systems and improved online sensors have helped the idea of full scale control at wastewater treatment plants. On the other hand, ASM and IWA models have helped to optimize and apply different strategies by simulation (Amand & Carlsson, 2012).

2.7.2. Solid Retention Time (SRT)

Filtration and biological treatment work together as a single process. The performance of MBR is totally dependent on characteristics of activated sludge, material from which membrane is made, how the membrane module is operated and biological conditions. Membrane operating conditions include flux, trans-membrane pressure backwash etc. whereas activated sludge consists of microorganism and inert material in form of suspended particles colloids and solutes (Defrance & Jaffrin, 1999). Literature review suggests that solid fraction mainly contributes to membrane fouling whereas some authors found non-settle able organic fraction present is of great importance (Rosenberger *et al* 2003).

A study carried out at Anjou Recherche Research Centre in Maisons-Laffitte, France worked on the results of immersed MBR, how SRT plays its role. Three MBRs were set up with 3 different SRTs. The objective was to find out an optimum SRT at which the plant yields the best results (Patricia *et al*., 2006). The project was divided into two different operating phases: the first phase, the hydraulic retention time (HRT) remained unchanged in the three MBR and in the second phase, the mixed liquor suspended solids (MLSS) was identical. The performance of the membrane is less dependent on the concentration of the sludge retention time of the sludge laboratory module.

Accordingly, 40 days sludge retention time showed the best operating performance. The concentration of the polysaccharide and therefore the fouling factors were the lowest biological degradation and get the most effective results. However, the high retention of the sludge is less applicable for plants with large time scale urban in practice because the volume of the reactor must be very wide and reduce economic efficiency. The sludge retention time of d 15 is more suitable for large scale applications. However, the performance of less efficient operation due to the slightly higher membrane fouling membrane operations requires superior cleaning and low designed. A retention time of sludge 8 showed poor operational performance and to higher fouling rate, which prevents a continuous and efficient operation. Since the filtration performance is a key economic factors MBR operation, the optimum time of sludge retention must be balanced between 15 and 40 d, according to the results of this study (Patricia *et al*., 2006).

2.7.3. Membrane Fouling

One of the problems that are linked with MBR is that membrane gets clogged. Membrane fouling is of two types, physically reversible fouling and physically irreversible fouling. The first can be dealt with by back washing or cleaning its surface. Whereas as the second fouling that is irreversible fouling cannot be done physically. For this chemical membrane cleaning is required. At first the reversible cleaning is applied and it is helpful until and unless it is no more effective to clean. And with time the physically irreversible fouling develops even if the membrane is cleaned well. So physically irreversible fouling should be avoided as it contributes in the cost of the membrane replacement. To control this fouling it is very crucial to understand the mechanisms of fouling which includes the characteristics of the components that cause fouling (Meng *et al*., 2007).

The major fouling causing agents in MBR are the soluble microbial products (SMPs) (Kimura *et al.*, 2009). Biomass concentration, solid retention and organic loading rate (OLR) are the factors that the characteristics of the SMP's depend upon in activated sludge processes. SMP's are also affected by the temperature; therefore temperature is also a factor that contributes to the fouling of the membrane in MBR (Rosenberger *et al.,* 2006) and (Drews *et al.,* 2007) reported that higher concentrations of polysaccharides in the process at low temperature results in fouling at a higher rate. But they didn't look into the physically irreversible fouling in their respective study. Fouling was high at low temperatures in both cases reversible and irreversible and proposed that slow biodegradation, sludge de-flocculation and reduction in mass transfer rate are just some of the features that may be linked to irreversible fouling (Jiang *et al.*, 2005). But they were unable to provide any data that could back what they proposed. The objective of the study was to find out the change in seasonal variation in membrane fouling using MBR as a treatment technology for domestic wastewater. The membrane fouling was examined in study that includes reversible and irreversible fouling, and how it is affected by the seasonal variation. MBRs were divided into two types of operating systems with different SRTs operationed in parallel. The changes in characteristics of organic matter and its effect in the development of physically irreversible fouling were investigated by analysis of dissolved organic matter in the MLSS of MBR.

Case Study

A study in Japan was carried out on two separate MBR with different solid retention times (SRTs) was different. MBR1 was operated with short SRT whereas MBR 2 was operated with long SRT. Both of the plants were operated in parallel, and fed with same wastewater. They were operated for a year. For roughly 200 days, that included the hot and cold season. This time period was divided into three, on the basis of temperature of the MLSS. The reason for membrane fouling and the characteristics of the foulant were examined that caused the physical irreversible fouling. These characteristics for each period were examined that caused this fouling (Miyoshi *et al*., 2009).

The operating conditions were controlled and the sludge was first acclimated to the conditions before beginning of the first period. Sludge was acclimated to 3 times of the SRT. The membranes used during the acclimatization were monitored carefully after chemical cleaning. After chemical cleaning of the membranes, the membranes were almost as effective as new ones, restoring membranes permeability and filtration resistances. At the end of each period, foulants were extracted from the membrane. And new membranes were installed for the next period.

Day 1 to day 57 was the first period. During this period the temperature was high as this was the summer season. Day 58 to day 143 was the second period in which the temperature was lowered with time as this period was the end of summer and start of autumn. The third period was from day 144 to the end of the operation, which was totally in winter and the temperature was low. The mean temperature in the 1st period was 22.6 ^{o}C and 10.1 ^{o}C in 3rd period. But the temperature in the 2nd period started with 21 ^{o}C and gradually decreased to 12 ^{o}C.

Filtration is done by using a suction pump at a known rate. Flow membrane 0.8m^3/m^2/day (33L/m^2/ h) was used as the membrane module 175, and a reactor having a volume of MBR1 with L. The volume of the reactor MBR2 350 and L of the membrane module were installed in MBR2. These two membrane modules were operated in different flow membrane. 0.8 m3 / data is obtained for the membrane of the membrane module operating flux m2 / day will be discussed herein. As a result, the MBR, the two HRT has other operations. However, the two HRT MBR difference is much lower than the SRT. Therefore, we have to be due mainly to the difference between two MBR SRT. Intermittent Filtration (filtration 12 minutes, 3 minutes break) it was also conducted. In each reactor, a continuous aeration of 4.5m3 / h was applied. If the film is a serious contamination, the membrane module was washed by spraying water under pressure on the cleaning surface with a membrane, and the sponge is removed from the reactor and physically. Based on visual inspection, all the accumulated cake can be effectively removed from the membrane surface in each of the physical membrane washing. Physical layer repeating housekeeping showed a large reduction of the number of times the irradiation intensity.

The results show a total resistance of a particular upper case change for each MBR filtration. Plot of the data showed the development of physical contamination irreversible each MBR. Seasonal changes of membrane fouling is evident in MBR1 (short SRT). MBR1 membrane contamination, therefore, was what happened in the second period (90 days), the second half of the period 3. Period was significant and frequent cleaning in the physical layer. The membrane was clearly significant obstacle MBR1 temperature was decreased. This result is generally consistent with the previous report (Drews *et al*., 2007). As for the physical irreversible contamination, however, a different pattern was observed. In MBR1, irreversible contamination rate periods 1 and 3 were lower than the period of rapid development of low-temperature membrane contamination period a result of two physical phenomena MBR1 show that the reversible physical fouling mainly due. Thus, the rapid development of a low temperature membrane fouling may assume that the film can be relaxed by applying effective physical cleaning by the operating system.

MBR2 in (long SRT), the development period of three irreversible physical MBR2 of membrane contamination was lower than MBR1 long continuous operation is similar, except schedule at the beginning of the speed of development of the pollution was not significant. Based on this result, two types of membrane contamination is reversible or irreversible physical contamination can be concluded that the relaxation can be significantly long SRT using the MBR. (Meng *et al*., 2006). If the MBR operation longer SRT as well as two types of seasonal changes in membrane fouling was less important.

2.8. Activated Sludge Models (ASM's)

International Water Association (IWA) formerly known as Water Pollution and Control formed a group with a task to come up with a model for operation of biological wastewater treatment plants in the year 1983 (Henze *et al*., 1987). As a result the group came up with its first model in 1987 known as Activated sludge Model 1. Then in the later years Activated sludge model 2, which is same as activated sludge model 1 but with the addition of phosphorus removal. There are several models that are developed with time like ASM1, ASM2, ASM2d, ASM3 and ASM3P.

A number of studies carried out suggest that the international water association (IWA) is concentrating on the minimizing the operational and capital cost of the activated sludge processes in wastewater treatment using ASMs. Studies are carried out on the new wastewater treatment plants using different activated sludge processes using several of the ASMs for simulation so that it would help in making of plants that are economical considering its cost including capital cost and operational cost (Wintgens *et al.*, 2003).

These models simulate both static and dynamic performance of biological treatment processes. Calibrations of these models play an important role. Well calibrated models would easily achieve the targets that are mentioned. This may only be achieved by accurate and number of field and lab measurements. Here is a summary of four Activated sludge models. IWA publications should be referred for complete details about the models (Aleen & Albert, 2007)

2.8.1. Activated Sludge Model No. 1 (ASM1)

Activated sludge model no. 1 (ASM1) was first developed in 1987. This model was developed to treat carbon and nitrogen present in wastewater (Henze *et al* 1987). This model has couple of concepts. First is, total chemical oxygen demand (COD) is in three main categories Bio-gradable COD, non-biodegradable COD and the third active biomass. Secondly death generation, the biomass or the microorganism they decay, when the biomass decays a portion of it is non-biodegradable and remains inert. The rest biomass is biodegradable and is consumed by the active mass for their growth.

The main processes in ASM1 include breaking down of biodegradable substances into simpler Compounds that maybe consumed by the organisms. And the growth and decay of the microorganism .autotrophs and heterotrophs are the two groups of microorganisms which are considered in this model. Autotrophs are responsible for nitrifying where as they grow by the oxidation of ammonia to nitrate under aerobic atmosphere. This is modeled on the basis of Monod kinetics (Aleen & Albert, 2007).

Heterotrophs are responsible for carbon removal and de-nitrification. They consume the soluble substrate which is present in form of decayed cell, and consume ammonia both in aerobic and anoxic surroundings. Oxygen is utilized in aerobic conditions and nitrate used as final electron acceptor in the absence of oxygen.

Autotrophs and heterotrophs are described by death regeneration concept of 1st order kinetics. But heterotrophs can reuse the biodegradable decay material whereas autotrophs decay slower as compared to heterotrophs.

ASM1 can be described by a simple mass balance equation which is as follows

$$\text{Accumulation} = \text{Input} - \text{Output} + \text{Reaction}$$

This model’s application enforces limitations as there are few assumptions in this model. One simple assumption is that this model operates at a constant temperature and a constant pH. The constant pH is near neutral. As we know that pH is a factor that can influence model parameters. Model parameters are constant. There are no changes in wastewater characteristics. Cell growth and organic substrate removal is not considered if the nutrient concentration is low. The microbes growth inside the system is balanced and nutrients required are sufficient. The kinetic parameters are kept fixed with no changes what so ever.

2.8.2. Activated Sludge Model No. 2 (ASM2)

ASM2 was introduced in the year 1995. This is same as ASM1 but this process developed to removal phosphorus also. This model adds a new type microorganism. Before which only autotrophs and heterotrophs existed. This new group of microorganism is called as phosphorus accumulating organisms PAO's, these organism have the ability of storing phosphorus in the form of polyphosphates and polyhydroxylkano stored (Aleen & Albert, 2007).

They store it in the form of internal storage material. This process occurs in anaerobic conditions but it has been observed that it occurs in anoxic and aerobic conditions also. The energy for this process comes from polyphosphates which results in production of soluble phosphates.

2.8.3. Activated Sludge Model No. 2d (ASM2d)

Activated sludge model no.2d is another model that states that phosphate accumulating organisms PAO's are able to use their internal products for de-nitrification and as a result they are able grow in anoxic conditions. This is the reason for addition of two processes that are the storage of polyphosphates and growth of phosphate accumulating organisms under anoxic conditions. The rest all processes in ASM2D are the same as in the ASM2 (Henze *et al.*, 1999).

2.8.4. Activated Sludge Model No.3 (ASM3)

Activated sludge model 3 is another form of activated sludge model 1 with some changes. It was revised in the year 1999, to give an accurate model. The major difference in ASM3 is that internal storage compounds in heterotrophs is taken into account, and focusing on storage of organic compounds other than hydrolysis (Henze *et al*., 1999). Biodegradable matter is consumed by heterotrophs and before growth it is stored in as cell component.

The heterotrophic organisms consume all the easily biodegradable substrate and store it as cell component before its growth. This is why the heterotrophic organisms are not dependent on external food for its growth.

For All forms of biomass loss and energy required endogenous respiration is used which is not linked to growth in ASM3. The growth and decay of microbes is clearly known. The particulates from biomass decay and particulate biodegradable organic nitrogen are ASM1's components that are not included in ASM3. The additional components that are added in ASM3 are dinitrogen, suspended solids and cell storage products of heterotrophs (Aleen & Albert, 2007).

There are 12 processes and 13 components in ASM3. ASM3 is specifically developed for domestic wastewater so it cannot be used for treatment of industrial wastewater. It can be applied only keeping these conditions well in the limits described. Temperature in the range of 8 to 23ºC, pH of 6.5 to 8.5, plus excluding anaerobic conditions and low concentrations of nitrate with low loads and high SRT.

2.9. GPS-X

GPS-X is a very simple computer program that helps you in modeling and simulation of wastewater treatments plants that may be industrial or municipal. It is simple software that is user friendly and easy to operate and at the same time gives you good control over the processes in wastewater treatment. It is one of the most advanced technology which is equipped with the recent modeling, simulation and graphic technology. With tool that helps in construction of most complex models with ease, simulate and produce accurate results (Nasr *et al.,* 2011).

From literature, it is found that GPS-X results are found to be similar to actuals treatment plants results. GPS-X is used to run in several modes to find the optimized results, which grades in having the best effluent depending upon the conditions. Resulting in better understanding and saving time and cost (Kim *et al*., 2010).

2.9.1. Case Study

A pilot scale WWTP is located in Guri, South Korea with treatment capacity of 85 m3/day. The plant consists of one pre-anoxic tank, followed by two switch tanks and then MBR tank. Switch tanks have the ability to be changed to anaerobic/anoxic conditions (Kim *et al*. 2010). These tanks can be operated according to the influent wastewater. The influent wastewater was led to pre- anoxic and then to switch tanks. Then the wastewater mixed well by the help of propellers installed in each of the compartment. MBR tank was aerated by the help of a blower installed at the bottom which also helped in mixing the sludge well. Denitrification was carried out in pre-anoxic tank in anoxic conditions. Phosphorus released in first switch tank under anaerobic conditions and denitrification carried out in second switch tank using organic matters from the influent. Phosphorus uptake and nitrification occur in MBR tank (Song *et al*., 2009).

In this study, GPS-X (4.1.2) version software was used. Both dynamic and static simulations were run. Library of models that almost represents all the processes were used (Olsson *et al*., 1999). GPS-X even help the user to adjust internal recycle ratio and its position. The conditions were set as were observed at the pilot scale plant.

GPS-X is specially designed for modeling and simulation of wastewater treatment plants. It can simulates using different conditions and several modes. Pilot scale WWTP in South Korea effluent had more than 99% removal of bio-chemical oxygen demand and suspended solids. Chemical oxygen demand, total nitrogen and total phosphorus removal efficiency of 90, 76 and 81% respectively.

First, GPS-X was used for analyzing the conditions of each reactor and its removal efficiency and over all plant performance. Then the results from the pilot scale plant were compared to GPS-X, it was observed that the results were similar (Kim *et al*. 2010).

Methodology

3.1. Sample Collection

Samples were collected in two phases in this study. Phase 1, samples were collected from 3 sites (A, B, C) for a period of 6 months and in phase 2, samples were collected from 5 sites for a period of 2 months. The second phase includes two additional sites D and E. (A, B, C, D and E) shown in figure 3.1. DO, temperature and pH were investigated on site and for further analysis transported to laboratory as per recommendation of APHA, 2012. Samples were collected in 1500 ml bottles. All the samples were tightly closed and labeled before transferring them to Laboratory and keeping them at a temperature of 4^{o}C before analysis. Bottles were rinsed with the sample first and then sample was taken.

Figure 3. 1 Sampling Sites at NUST Campus

The sampling was done for 10 months from March 2013 to December 2013. This covers almost three seasons including monsoon. Samples were collected thrice in a day at 9:30 AM, 12:30 PM and 3:30 pm. From October to December the number of sites was increased from 3 to 5.

Analyses were computed out of composite samples. A composite sample is mix sample. It is the mixture of several grab samples that are mixed together. Grab samples collected at different time and with regular interval. This sample analysis of wastewater will represent much better result of the whole day.

3.2. Sample analysis

Samples were initially collected from three different locations and later five different locations in the campus, samples were collected three times a day (morning, noon and evening) and twice in a week. The following tests were performed to analyze the following parameters of wastewater.

TSS, TVSS and COD were measured in accordance with Standard Methods (APHA, 2012). pH was measured by using Hach pH meter (Sension 1) whereas; temperature and BOD by Hach meter (Sension 5).

The protocols followed are APHA 2012, in most of the analysis of NUST wastewater.

Table 3.1 Protocols

Parameter	Method	Equipment	Reference
Temperature		DO/pH meter	Oakton PD 300, USA
DissolvedOxygen		DO/pH meter	Oakton PD 300, USA
pH		DO/pH meter	Oakton PD 300, USA
COD	Close reflux	COD Digester tubes	APHA 2012
sCOD	Close reflux	COD Digester tubes	APHA 2012
PO_4^-P	Molybdovandate Method	Spectrophotometer (DR/2400,HACH,USA)	APHA 2012
TN		TOC/TN analyzer multi C/N Analytikjena, Germany.	
TOC	TOC differential method	TOC/TN analyzer multi C/N Analytikjena, Germany.	
NO_2^-N	HACH Method	Spectrophotometer (DR/2400,HACH,USA)	APHA 2012
NO_3^-N	HACH Method	Spectrophotometer (DR/2400,HACH,USA)	APHA 2012
TSS	Filtration and Evaporation	1.2µm(GF/C,Whatman) filter 105 ^oC	
VSS	Filtration and Evaporation	1.2µm(GF/C,Whatman) filter 550 ^oC	

3.3. Modeling & Simulation Using GPS-X

GPS-X is one of the most advanced technology which is equipped with the recent modeling, simulation and graphic technology. GPS-X helps in construction of most complex models with ease, simulate and produce accurate results. It is a very simple computer program that helps you in modeling and simulation of wastewater treatments plants that may be industrial or municipal. It is simple software that is user friendly and easy to operate and at the same time gives you good control over the processes in wastewater treatment.

GPS-X based upon the mathematical models that are developed over the years. The model used for this plant was activated sludge model 1 (ASM1).

GPS-X uses several libraries for its modeling and simulation, for this study carbon/nitrogen library is used. This computer software can be divided into two parts. In the first part it is the modeling of the plant and in second using the data available simulating the plant to obtain results. The modeling and simulation is discussed below.

3.3.1. Modeling

First you have to build a plant model in computer program. All the plants components are available in the program. By using this first the layout was made of the plant same as on the ground. The model is then labeled and all the parameters are entered as obtained in analysis. The physical data that is entered includes physical dimensions of the plant, SRT, HRT, piping and etc. During the modeling phase the chemical characteristics and flow data in also given. The data provided should not disturb the pre-entered values in the program if it does so then several changes are made in the table to eliminate the error that has emerged.

3.3.1.1. Building Model layout

Layout of a plant model explains the physical and operational structure of it. A new layout is selected from the toolbar. A new layout is basically a drawing board for dragging and pasting processes and item from software library. From the main toolbar as shown below, select library from the model library. Carbon Nitrogen Library (cnlib) was selected modeling and simulation of NUST H-12 WWTP.

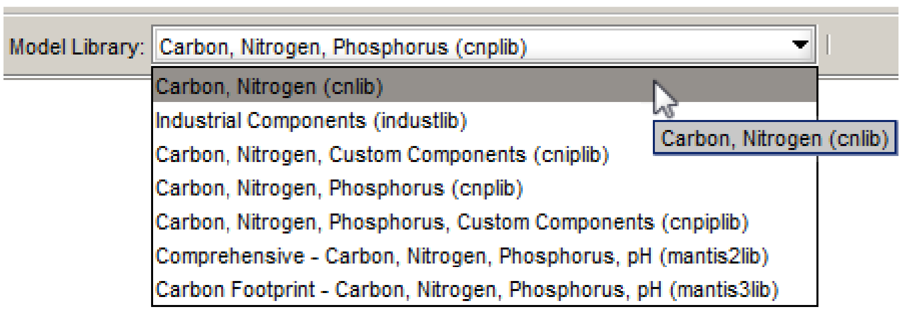


Figure 3.2 Model Library

From the process table which is located on the left hand side of the drawing board, icons groups of the same objects are made. Different icons from these groups were selected to build layout same as the plant in the field. These icons symbolize Unit processes and control points in the plant model. Below is the screen shot of process table.

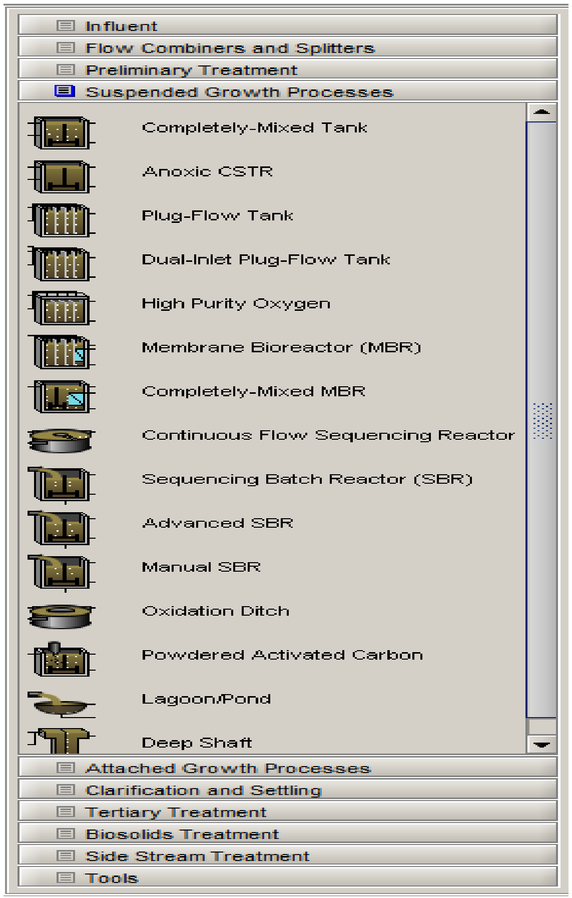


Figure 3.3 Process Table

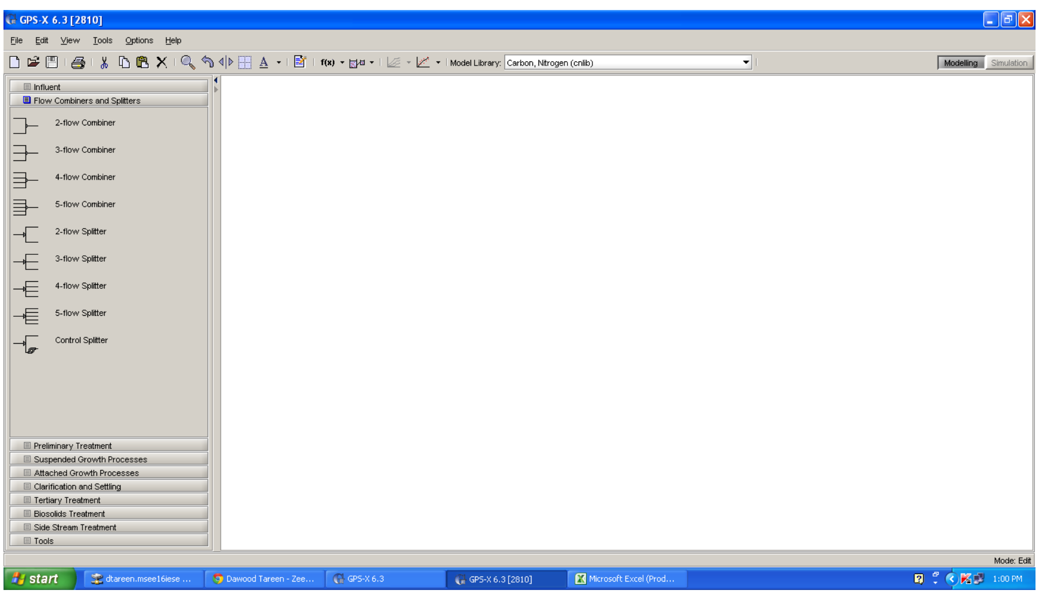
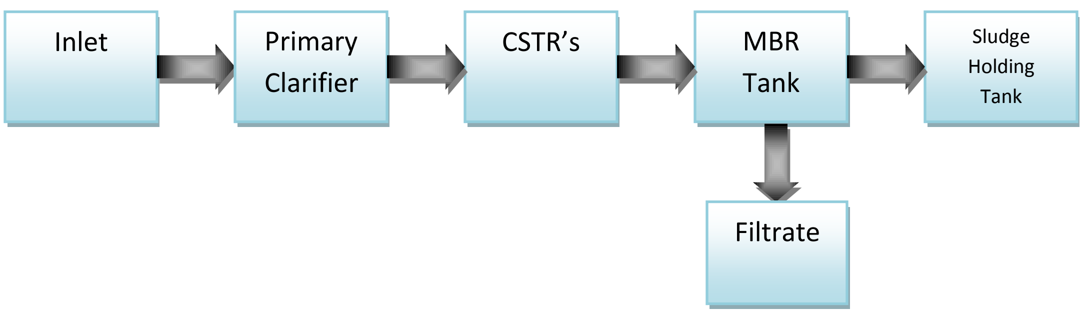


Figure 3.4: Creating new layout.

After creating a new layout, select icons from the process table according to the plant model to be constructed. NUST wastewater treatment plant consists of the following compartments/processes. NUST wastewater treatment plant consists

- Primary clarifier
- Equalization tank
- completely mix stir tank reactors
- MBR tank
- Sludge holding tank

Following flow diagram shows simple plant layout.



From the icons first select the source of wastewater which is shown in the figure below. Select the icon and drop it on the drawing board.

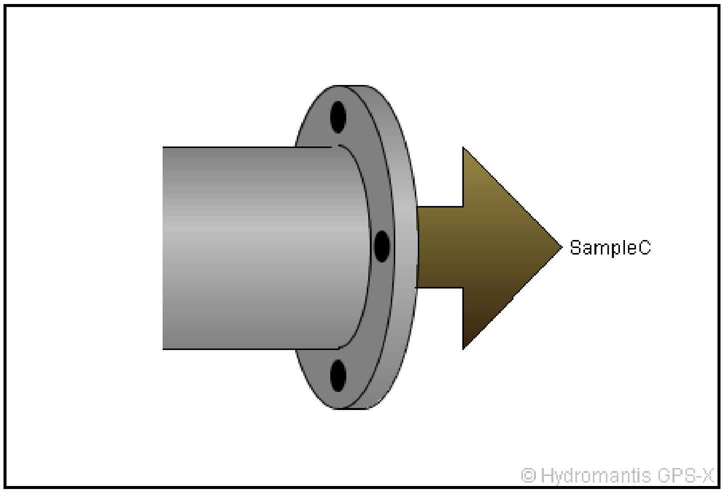


Figure 3.5 Influent

The influent composition was changed according to the wastewater sample analysis. This is done by right clicking on the icon on the drawing board. From the menu, select influent characterization. Change the values according to the parameters analyzed as shown in fig 3.6. The values are highlighted blue which indicate that the values are different from default GPS-X. The values manually inserted according to the wastewater of NUST H-12 are as shown in table 3.2 below. Once the values are inserted click accept option to save the changes.

Table 3.2 Influent Characteristics

Parameters	Unit	Sample C
Flow	m3/d	50
TSS	mg/L	238.89
VSS	mg/L	179.17
cBOD5	mg/L	232.72
COD	mg/L	430
Soluble COD	mg/L	107.5
Ammonia N	mg/L	25
TN	mg/L	40
Alkalinity	mgCaCO$_3$/L	350

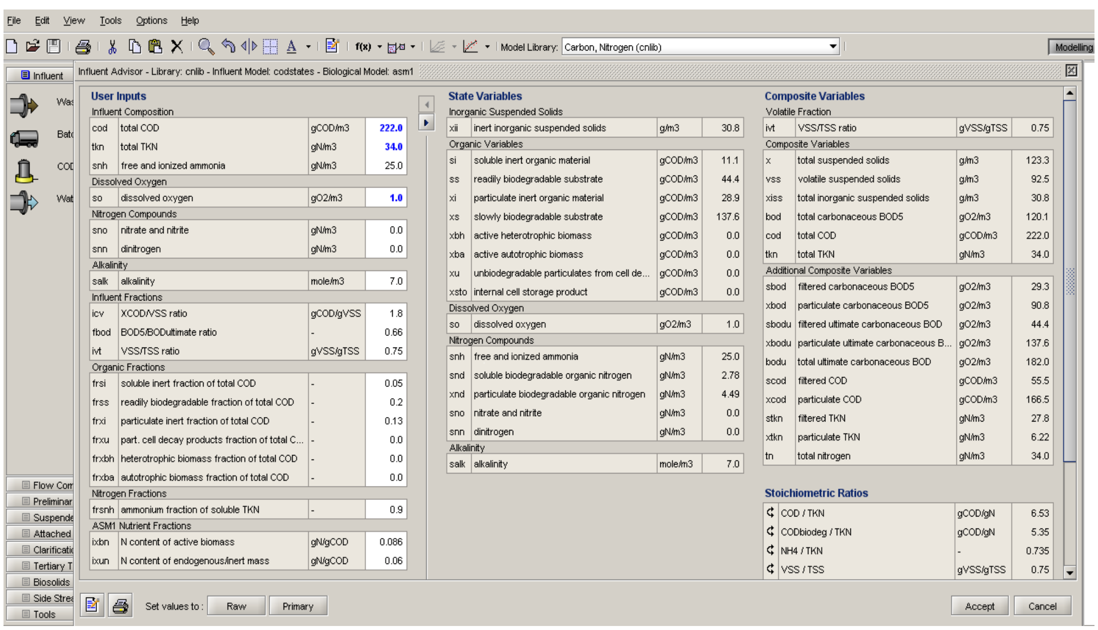


Figure 3.6 Influent Advisor tool

The Influent advisor tool is for characterization of wastewater as simple as possible. The Influent Advisor tool shows all input and output in an interactive way, allowing users to determine which inputs affect each output, and to trace all dependencies. The sheet contains three columns:

- Inputs
- State variables
- Composite variables

Make changes to influent parameters according to the values observed in the lab. After entering the values it could be noticed some output variable highlighted red. This is the result of poor characterization data. These red values indicate negative concentrations. By changing the concentration ratios this issue could be solved if faced.

After characterization of the input data in the influent advisor, the next step is to drag the other processes and drop it on the drawing board. Wastewater first enters to primary clarifier, where primary sludge is separated from it and water moves to the next tank.

To connect different objects on the drawing board, simply move the mouse pointer to the connection start point. When the mouse pointer changes the arrow this means that the pointer is over the correct connection point. Drag the arrow to the point where the connection is going to be joined. When the same arrow reappears then only releases the mouse button. In this manner the connection pipes are drawn between the objects. If the connection is incorrect, then the program itself will not create connection between the processes.

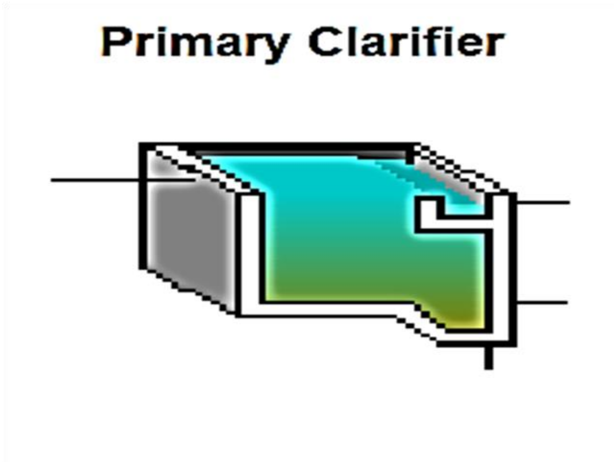


Figure 3.7 Primary Clarifier

Sample C is first connected to primary clarifier (PC), connect pipes following the steps explained above.

Right click primary clarifier select input parmeter and change the default values according to the plant. The changes to be made are physical and operational. In physical, volume and dimentions were set as in NUST WWTP. Pumped Flow, underflow, wasteage rate, and etc are set in operational menu.

The effluent from PC moves into Equalization Tank. Its connected to PC and using the same method change operational and physical properties as required.

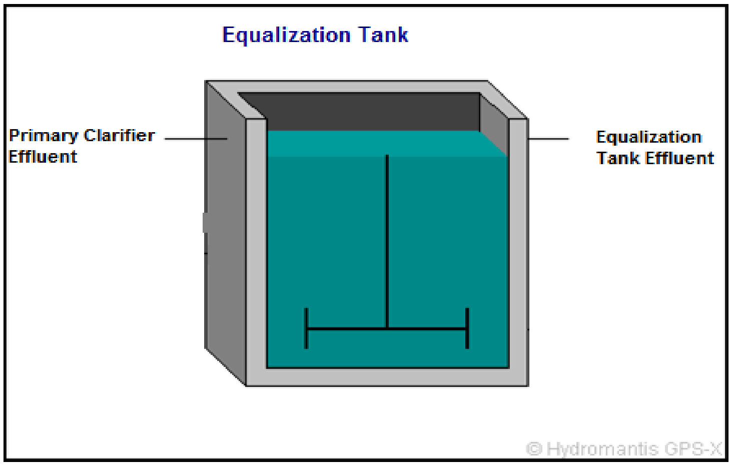


Figure 3.8 Equalization Tank

Wastewater from Equalization tank moves to the first of the Five Completely Mixed Stir Tank Reactors (CSTR). Wastewater enters CSTR 1 from two lines. One from equalization tank and the other from MBR tank as Recycled Activated Sludge (RAS). Before wastewater reaches MBR tank, it passes through CSTR's. CSTR's could be used according to need of the hour. The number of tanks to be used depends upon their requirement.

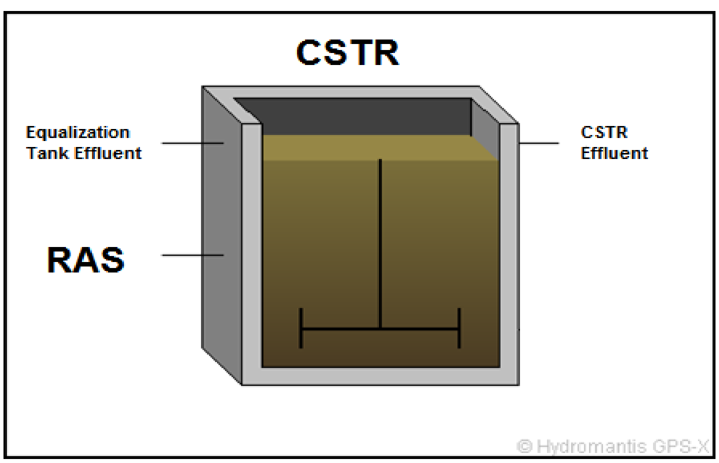


Figure 3.9 CSTR

From CSTR's wastewater then moves to MBR tank. Physical and operational properties of MBR tank were same as the plant. The table below gives you the specifications of MBR.

Table 3.3 MBR Tank

Sr.No	MBR Tank	
1	Tank Volume	2.34 m^3
2	Membrane Surface Area	96 m^2
3	Membrane Pore size	.03 µm
4	Backwash Interval	14.5 min
5	Backwash Duration	30 sec
6	Model	ASM1
7	MLSS	6000-9000 mg/L

Activated sludge is recycled, and connected back to CSTR 1. This again becomes the part of the system.

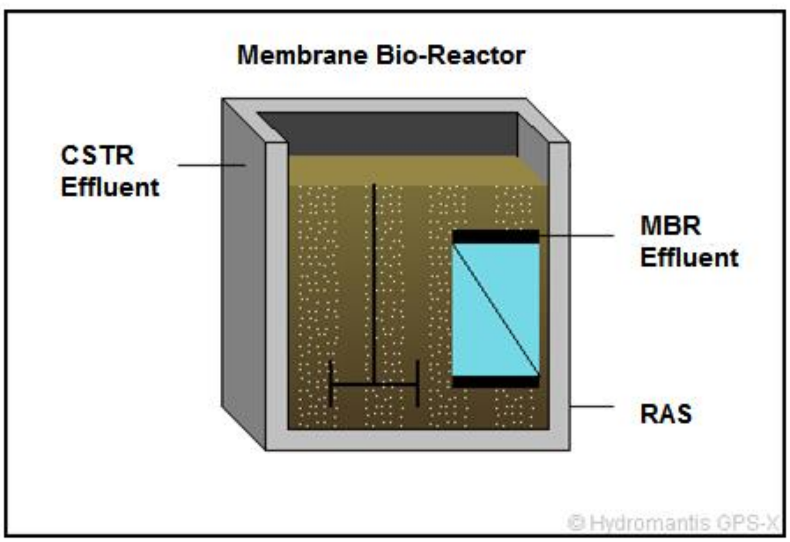


Figure 3.10 Membrane Bio-Reactor

The figure below shows complete model of NUST H-12 Campus WWTP. Which represent all components/processes of NUST WWTP. The Next step is simulation after completing each and every minor and major detail of the models and its components.

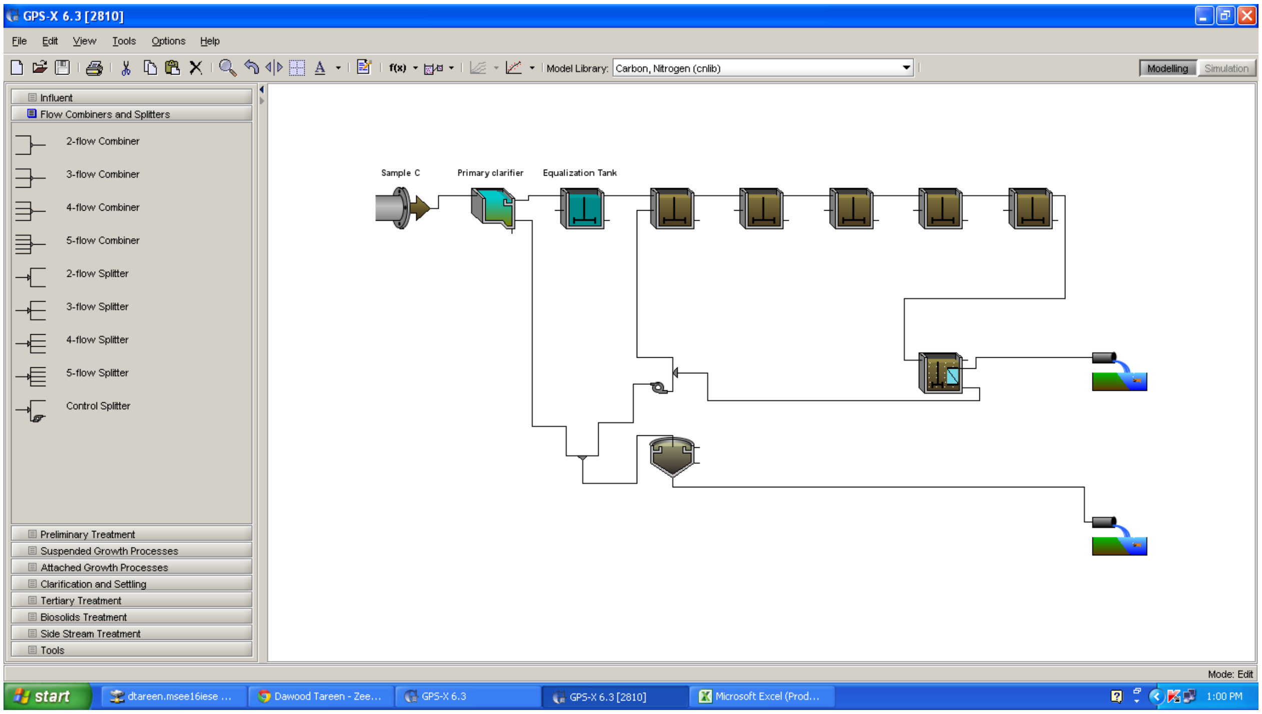


Figure 3.11 Plant Model Layout

Solid retention Time was controlled manually by use of a control splitter, which was installed after MBR. Control splitter was installed on RAS line, where it wasted activated sludge according to the set SRT for the system.

Activated sludge Model 1 (ASM1) was used for this plant. So all the items and processes were set to work on the basis of ASM1. This can be selected by right clicking the process item and select AMS1 from the model menu.

3.3.2. Simulation

When the modeling was completed then the second part of the program was simulation. The plant model in this computer program was the exact copy of real plant. During simulation GPS-X gives you the results in from of graphical display of each and every component in detail. The main purpose was to find out the optimized conditions for the operation of WWTP. Simulation was done applying different scenarios and examining its outcomes.

Once the Model layout is completed same as the plant the next step is to simulate. Click the simulation button to generate binary code. This initiates the process linking and compilation which results in creating model. This process takes a minute or two before completion. If there is any error in the plant model in this step it is going to be pointed out. This would give an error note and layout will not convert into a binary code. The image below shows the conversion of the model to a code for simulation mode.

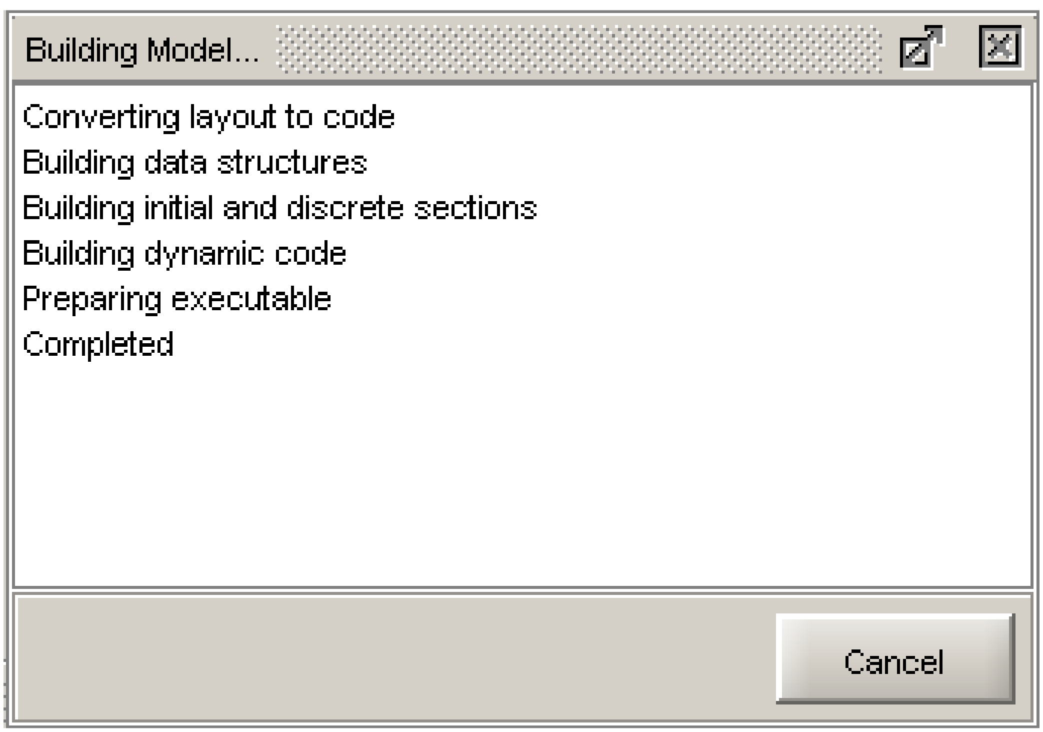


Figure 3.12 Conversion to Simulation Mode

Once the model is completed, simulation blank window will show up as shown in the figure. Plant layout is visible on the lower left hand side of simulation window.

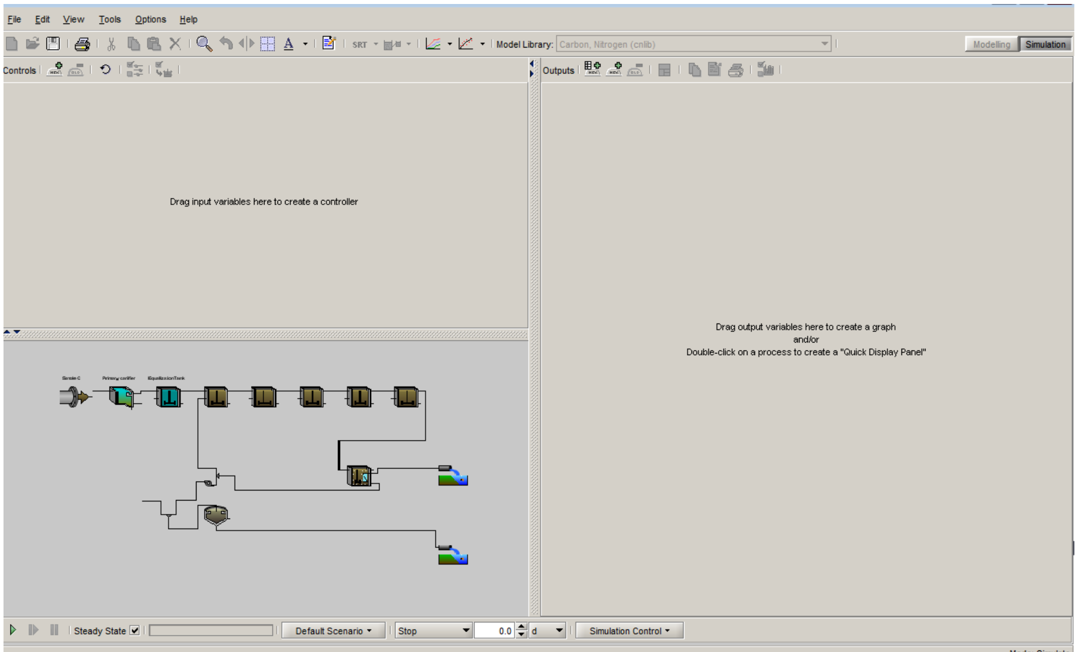


Figure 3.13 Simulation Mode

Now model is ready to run. Simulation control toolbar contains all the controls which are required for the run at the bottom of the screen. Specified the duration of the runs and there results were shown simultaneous on the right hand side of the simulation window.

Results and Discussion

4.1 Wastewater characteristics of NUST

During the study period (March 2013 to December 2013), characteristic of wastewater of NUST were measured. The parameters measures were COD, sCOD, $BOD_{5,}$ pH, Temperature, Dissolved oxygen (DO), Phosphate, nitrate, nitrite, TOC and TN. During analysis, the temperature increased followed by a decrease because of annual climate conditions, and remain in the range of 30 °C to 15 °C. The influent consisted of wastewater receiving from residential, commercial and institutional facilities inside NUST sector H-12.

4.2 Seasonal variation of wastewater at NUST

The change in domestic wastewater characteristics and flow depends upon size of the population that generates wastewater and seasonal activities (Metcalf and Eddy 2003). Several factor add to the variation of wastewater in the campus like monsoon season and rainy days, climate and vocations in between the educational activities. The table 4.1 below shows the seasonal and temporal variation of NUST wastewater.

Table 4.1 Summary Wastewater NUST H-12

Para-meters	Min					Max					Average				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Temp.	18.9	18.6	18.3	21.6	21.9	29.2	29.3	29.6	24.6	26.1	23.8	24.1	23.9	23.0	23.6
DO	0.6	0.9	0.9	1.6	2.0	1.5	1.4	1.1	4.4	3.1	1.1	1.1	1.0	2.4	2.4
pH	7.5	7.5	7.6	7.7	7.8	8.0	8.0	8.1	8.2	8.1	7.8	7.8	7.8	7.9	7.9
COD	145	158	85	150	144	336	321	285	256	198	217	254	222	201	209
sCOD	68	60	75	77	83	170	195	160	122	96	100	123	94	85	94
BOD	70	80	55	75	60	215	140	170	115	100	109	129	105	100	101
TN	18	18	24	19	22	48	54	37	40	37	33	34	34	31	31
Po4	8.2	7.9	6.1	8.5	8.6	34.1	32.6	19.6	11.2	12.4	16.7	22.3	14.9	13.1	13.3
TSS	90	105	88	119	103	295	373	326	221	295	185	209	196	166	171
VSS	35.0	40.0	33.4	49.5	44.6	121.0	174.0	154.7	85.6	120.9	74.8	91.7	79.3	67.9	70.0

A: Wastewater coming from Residential Area
B: Wastewater coming from NUST
C: H-12 Campus Wastewater exit point (MBR influent)
D: Wastewater from Rumi hostels and Mosque
E: Wastewater from Boys hostels and NICE

4.3 Wastewater analysis

NUST H-12 wastewater was analyzed during the period March 2013 to December 2013. During the sampling period which included monsoon season also. Several parameters were analyzed which are discussed in detail below. During the monsoon season, wastewater characteristics varied because of the rain water infiltrating sewer system. It was observed that wastewater from the residential areas were most of the time were more polluted than the waste from the other area within the NUST H-12 sector. Overall the concentrations of wastewater characteristics from the campus were lower as compared of wastewater in the surrounding areas. According to the analysis, (Shehzad *et al*., 2015) the wastewater characteristics of Islamabad WWTP were higher as compared to the wastewater characteristics of NUST H-12 campus. The table 4.2 gives a comparison between wastewater characteristics of NUST H-12 Campus and wastewater of Islamabad collected at I-9 WWTP.

Table 4.2 Comparison between NUST H-12 & Islamabad Wastewater

Parameters (mg/L)	NUST H-12	I-9 WWTP
COD	222	225
BOD	105	132
TN	34	40
PO_4	14.9	40
TSS	196	380

4.3.1 Temperature and DO profile of wastewater

During the analysis, the min temperature was recorded 18.3 C in the month of March 2013, whereas, 29.6 C during the month of June. The difference between the locations was found around 10 C due to annual temperature variations. The temperature also varied in monsoon season. Temperature drop was clearly observed after rain. In summers the temperature was observed around 29 ^{o}C. On average, the temperature was observed between the ranges of 20 ^{o}C to 25 ^{o}C.

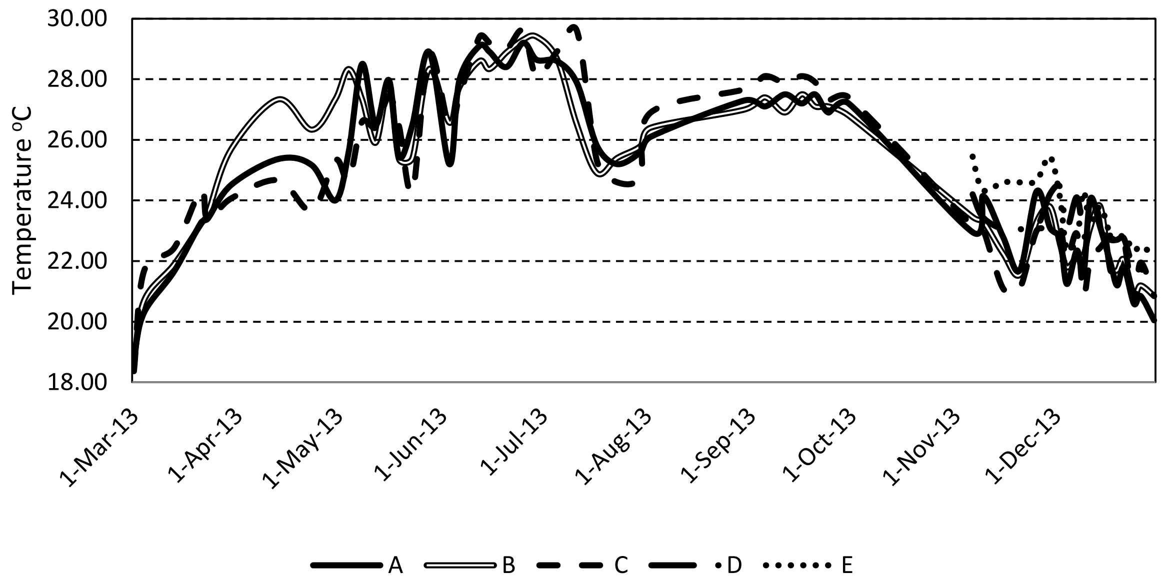


Figure 4.1 Temperature

Dissolved oxygen of the wastewater was around 1 mg/L of the sample near treatment plant areas but DO was high near 4mg/L in locations where wastewater was fresh. DO was observed high near Mosque and boys hostel because of the reason that the wastewater was fresh. DO of wastewater was governed by the amount of rain water infiltration in sewerage system. With infiltration of rain water DO also used to rise.

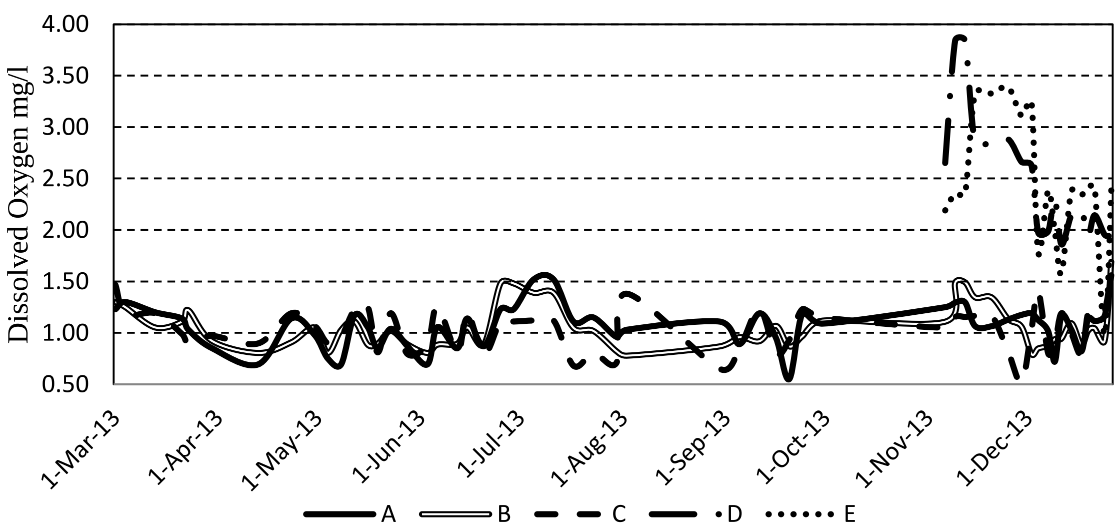


Figure 4.2 Dissolved Oxygen

4.3.2 COD, sCOD and BOD profile of wastewater

Chemical oxygen demand was observed highest in the month of November with concentration of 416 mg/L for sample B. COD average concentration for sample C was around 222 mg/L. with the maximum value of 285 and minimum value of 85 mg/L.

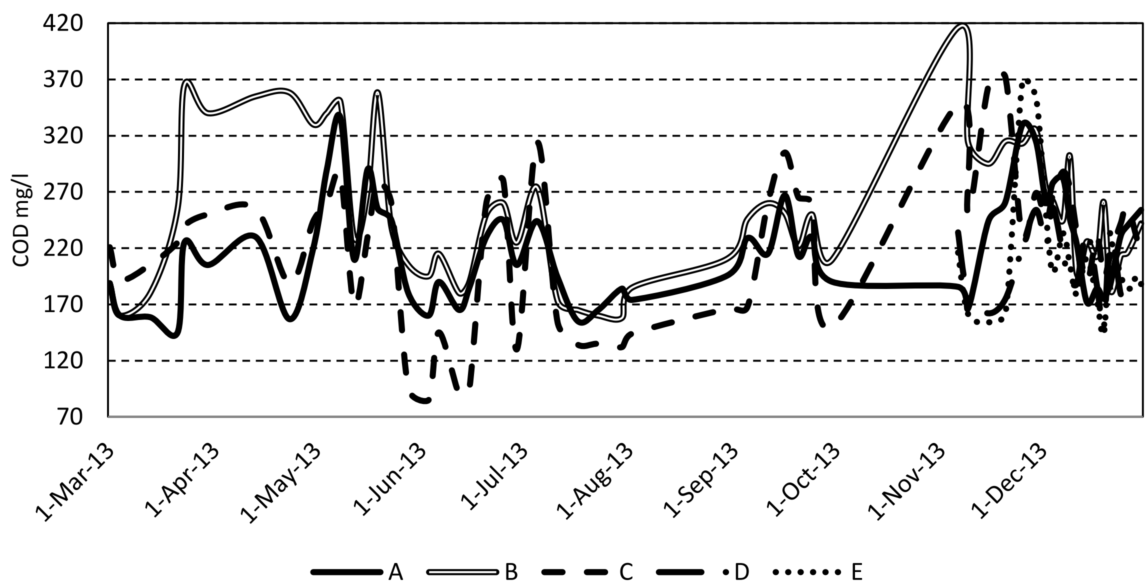


Figure 4.3 Chemical Oxygen Demand

Soluble Chemical Oxygen demand of wastewater samples on average was around 100 mg/L. For sample C the average value is 93 mg/L and maximum value not above 150 mg/L.

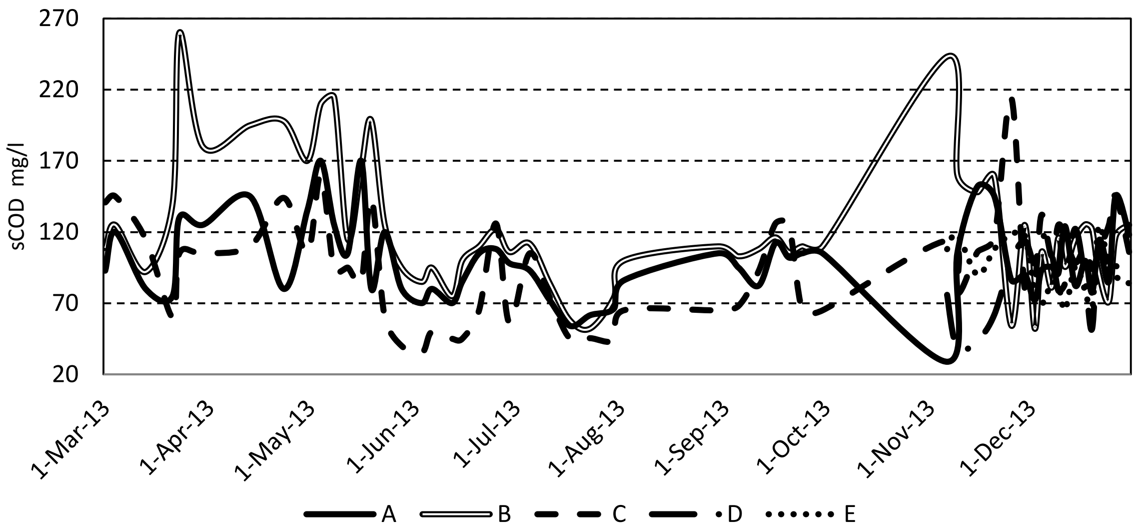


Figure 4.4 Soluble Chemical Oxygen Demand

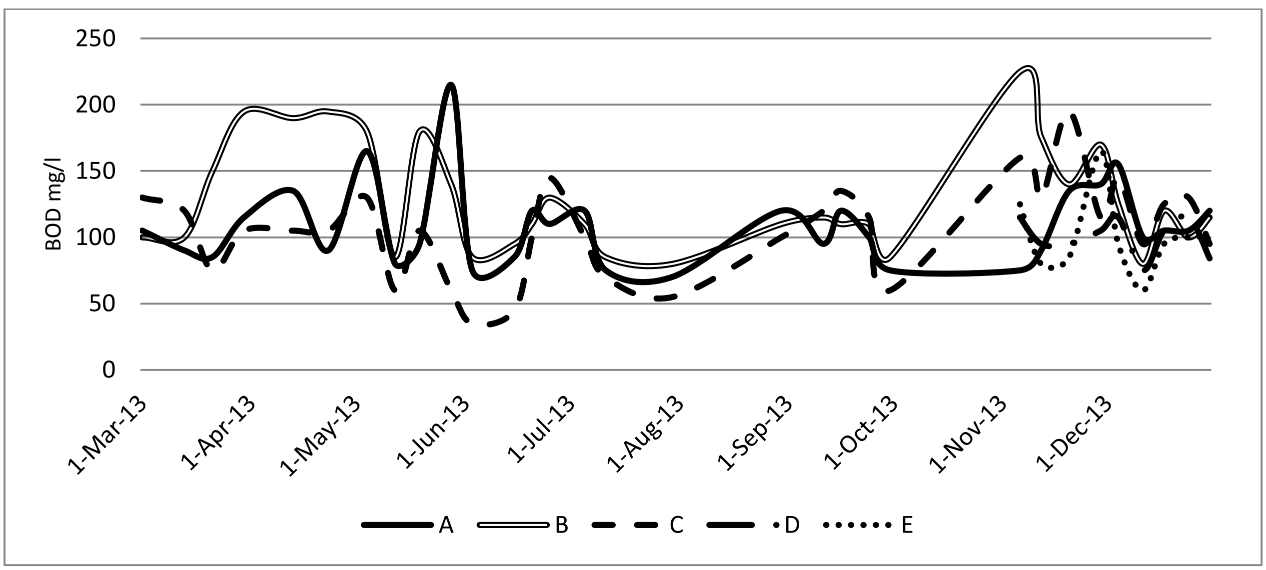


Figure 4.5 Biochemical Oxygen Demand

All the concentration of wastewater parameters increased in the summer season as compared to others seasons. Monsoon in summers highly disturb the concentration. In rainy days the concentrations of pollutants drop as a result of rain water infiltration into sewer system and rise in dissolved oxygen.

4.3.3 pH

Wastewater pH was observed to be around just below 8**.** Almost No variation was observed in pH of the samples, apart from the monsoon season were it did vary but not much**.**

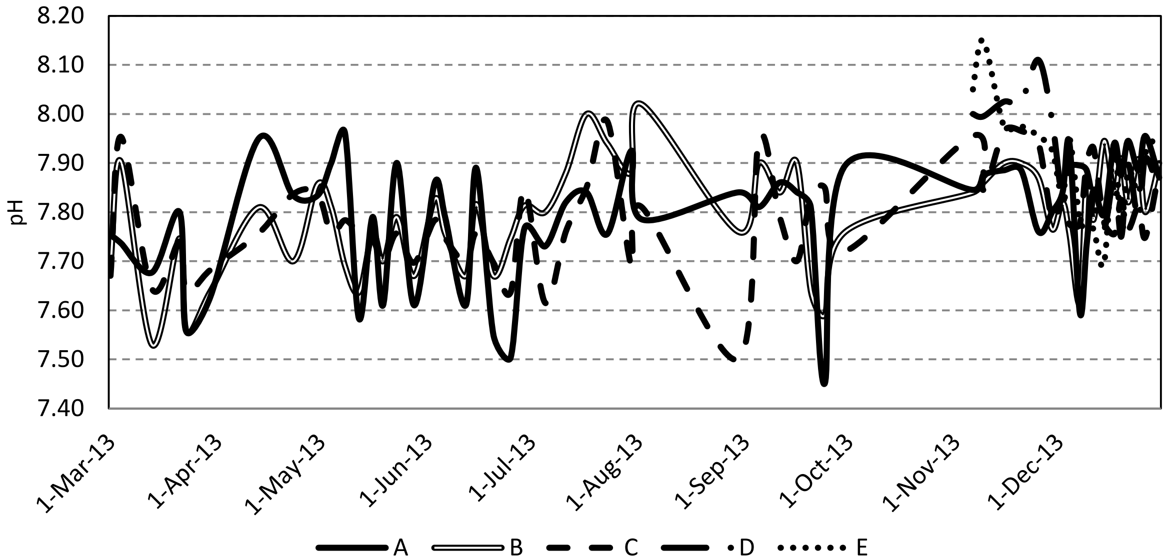


Figure 4.6 pH

4.3.4 TSS and VSS profile of wastewater

Total suspended solids in sample C had maximum value of 326mg/L during the of sampling period and minimum value of 90 mg/L. the average value of TSS was just below 200 mg/L. the value were highly varied because of the seasonal conditions. Monsoon was the main reason which effected the TSS concentration.

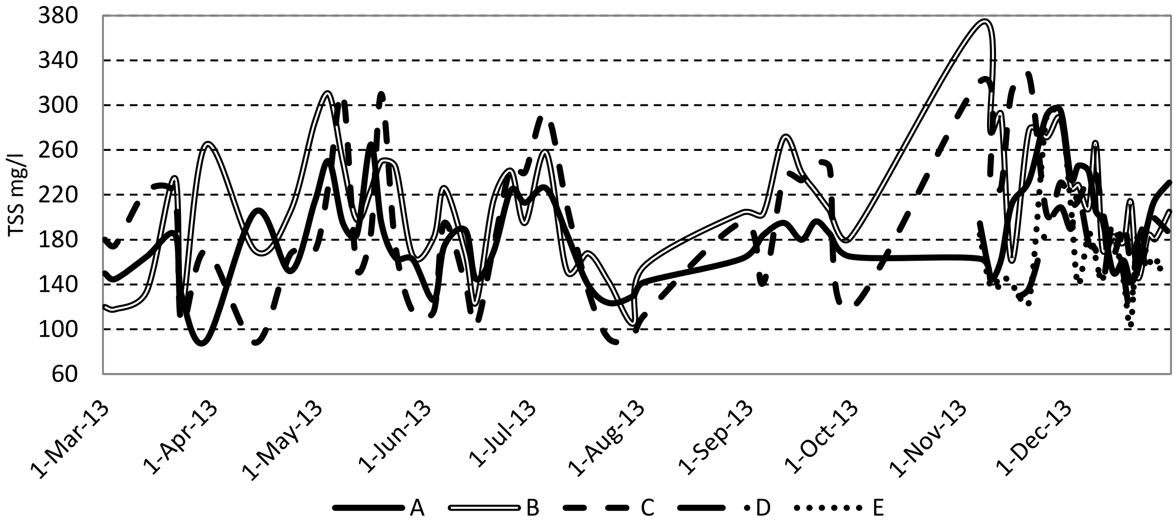


Figure 4.7 Total Suspended Solids

Volatile suspended solids average value observed were around 80 mg/L. the values observed in monsoon were lower than the rest of the year just like the other parameters.

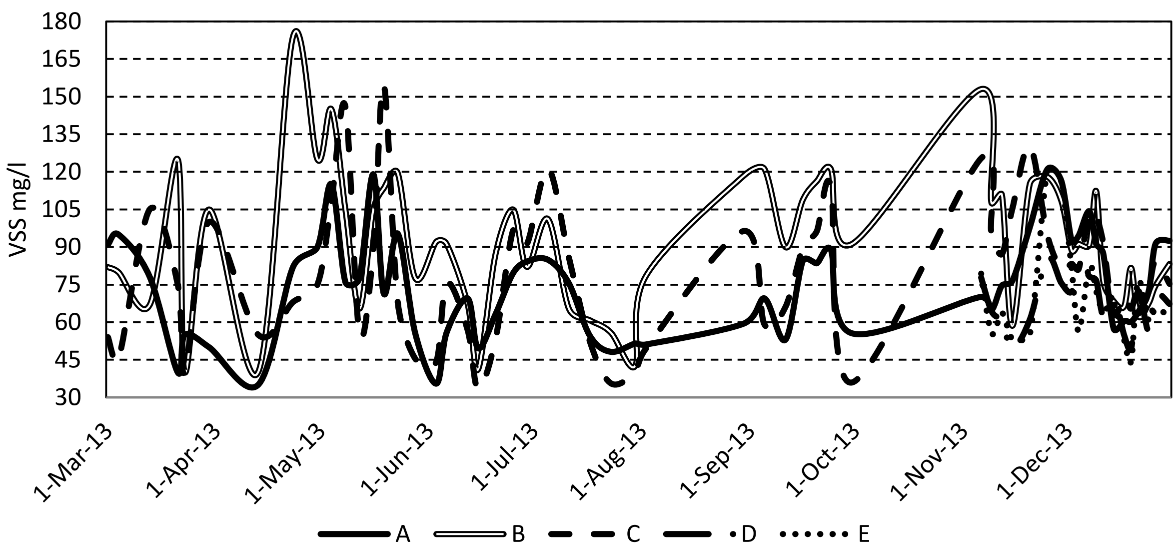


Figure 4.8 Volatile Suspended Solids

4.4 Simulation of wastewater treatment plant

The data acquired from the sampling sites was used for modeling and simulation of MBR treatment plant that is currently installed in H 12 Campus but not operational yet. Sample C is the plant influent. That is the reason why Sample C concentrations are used in GPS-X modeling and simulation. Simulation was done to investigate the plant by finding SRT and LMH for optimized results.

Simulation was done under the following environment

Table 4.3 Simulation Environment

Sr.No	Simulation Environment	Unit
1	Dissolved Oxygen (DO)	2 mg/L
2	Hydraulic Retention Time* (HRT)	6 Hours
3	Flux (LMH)	17 – 24
4	Solid Retention time (SRT)	15-40 days
5	Backwash Interval	14.5 min
6	Backwash Duration	30 sec
7	Model	ASM1

* HRT should vary according to change in flux

4.4.1 Scenarios run on MBR plant using GPS-X

Having built the modified layout, you may proceed with the plant performance investigation. To do this, change the following model Scenarios:

- SRT
- Flux

To find out the plant performance, SRT 20, 30 and 40 were considered for simulation. 23.9 LMH for running different scenarios finding optimized SRT because the plant is designed for treating 50m^3/day of wastewater. Results of each of the runs are shown in detail in the tables below.

Table 4.4 Effluent Quality (SRT 20)

Parameters	Unit	Influent	Effluent	Removal %
COD	mg/L	430	22.69	94.72
BOD_5	mg/L	232.7	1.947	99.16
TSS	mg/L	238.8	0.193	99.91
VSS	mg/L	179.2	0.139	99.92
Ammonia N	mg/L	25	0.528	97.89
TKN	mg/L	40	1.65	95.8
pH			6-9	

Table 4.5 Effluent Quality (SRT 30)

Parameters	Unit	Influent	Effluent	Removal %
COD	mg/L	430	23.81	94.47
BOD5	mg/L	232.7	2.941	98.7
TSS	mg/L	238.8	0.293	99.88
VSS	mg/L	179.2	0.223	99.89
Ammonia N	mg/L	25	0.556	97.7
TKN	mg/L	40	1.614	95.96
pH			6-9	

Table 4.6 Effluent Quality (SRT 40)

Parameters	Unit	Influent	Effluent	Removal %
COD	mg/L	430	20.21	95.3
BOD_5	mg/L	232.7	2.56	98.9
TSS	mg/L	238.8	14.354	93.99
VSS	mg/L	179.2	3.894	97.8
Ammonia N	mg/L	25	0.512	97.9
TKN	mg/L	40	1.545	96.14
pH			6-9	

From the results of simulation it was concluded that the higher the SRT (40) better the effluent quality but high TSS as a result. Effluent quality decreases as SRT was decreased to 20. From the above table 4.6 and literature review it may be concluded that membrane bioreactors operating at higher SRT's give much better results in terms of filterability, cleaning needs and biological activity. SRT of 20 demonstrated comparatively poorest performance, thus the optimal SRT is at 30 days. Another drawback of short SRT known from literature review is that lower the SRT, higher the fouling rates. From the results it was concluded that SRT 30 days should be used for finding the performance of MBR at different LMH.

Following scenarios were run as shown in the Table 4.7

Table 4.7 Flux Scenarios

Sr.No	Flow m3/day	(LMH)
1	35	15.2
2	40	17.4
3	45	19.5
4	50	21.7
5	55	23.9

Following were the results obtained from Simulation Run of 35m^3/day (15 LMH)

Table 4.8 Results Flux 15 LMH

Parameters	Unit	Influent	Effluent	Removal %
COD	mg/L	430	22.69	94.7
BOD_5	mg/L	232.7	1.947	99.16
TSS	mg/L	238.8	0.193	99.91
VSS	mg/L	179.2	0.145	99.92
Ammonia N	mg/L	25	0.528	97.88
TKN	mg/L	40	1.422	96.41
pH			6-9	

Following were the results obtained from Simulation Run of 45m^3/day (20 LMH)

Table 4.9 Results Flux 20 LMH

Parameters	Unit	Influent	Effluent	Removal %
COD	mg/L	**430**	**24.12**	**94.5**
BOD_5	mg/L	**232.7**	**2.503**	**98.7**
TSS	mg/L	**238.8**	**0.2982**	**99.9**
VSS	mg/L	**179.2**	**.2203**	**99.8**
Ammonia N	mg/L	**25**	**0.6076**	**97.7**
TKN	mg/L	**40**	**1.636**	**95.8**
pH			**6-9**	

Following were the results obtained from Simulation Run of 55m^3/day (24 LMH).

Table 4.10 Results Flux 24 LMH

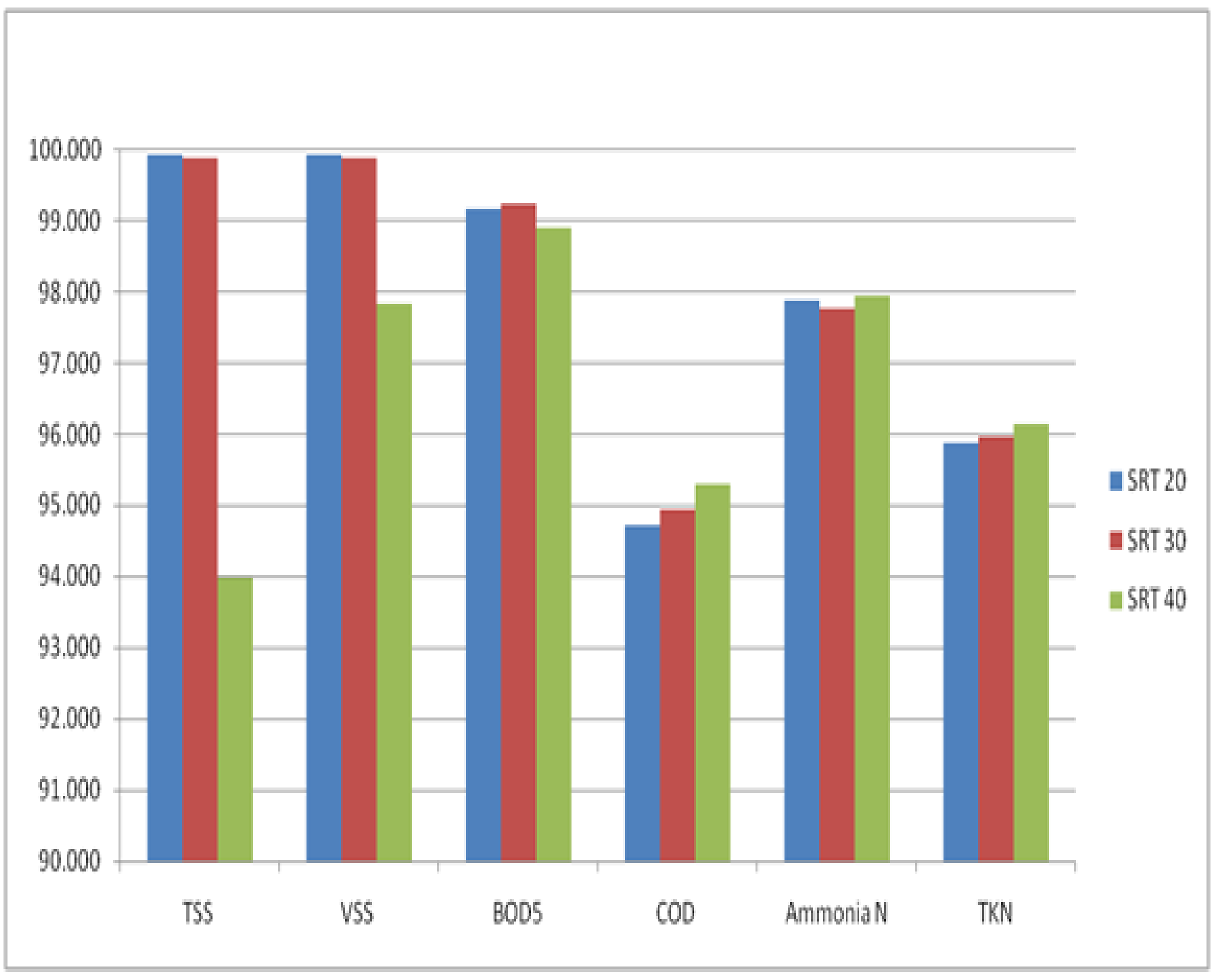
Parameters	Unit	Influent	Effluent	Removal %
COD	mg/L	**430**	**25.39**	**94.09**
BOD_5	mg/L	**232.7**	**3.102**	**98.66**
TSS	mg/L	**238.8**	**0.422**	**99.82**
VSS	mg/L	**179.2**	**0.306**	**99.83**
Ammonia N	mg/L	**25**	**0.6146**	**97.43**
TKN	mg/L	**40**	**1.833**	**94.5**
pH			**6-9**	

Examining the simulation results it was observed that at lower LMH higher the removal efficiency. Removal efficiency was observed high if the water treated was low. As the treated volume was increased it directly affected the effluent quality.

4.4.2 Optimization Using GPS-X

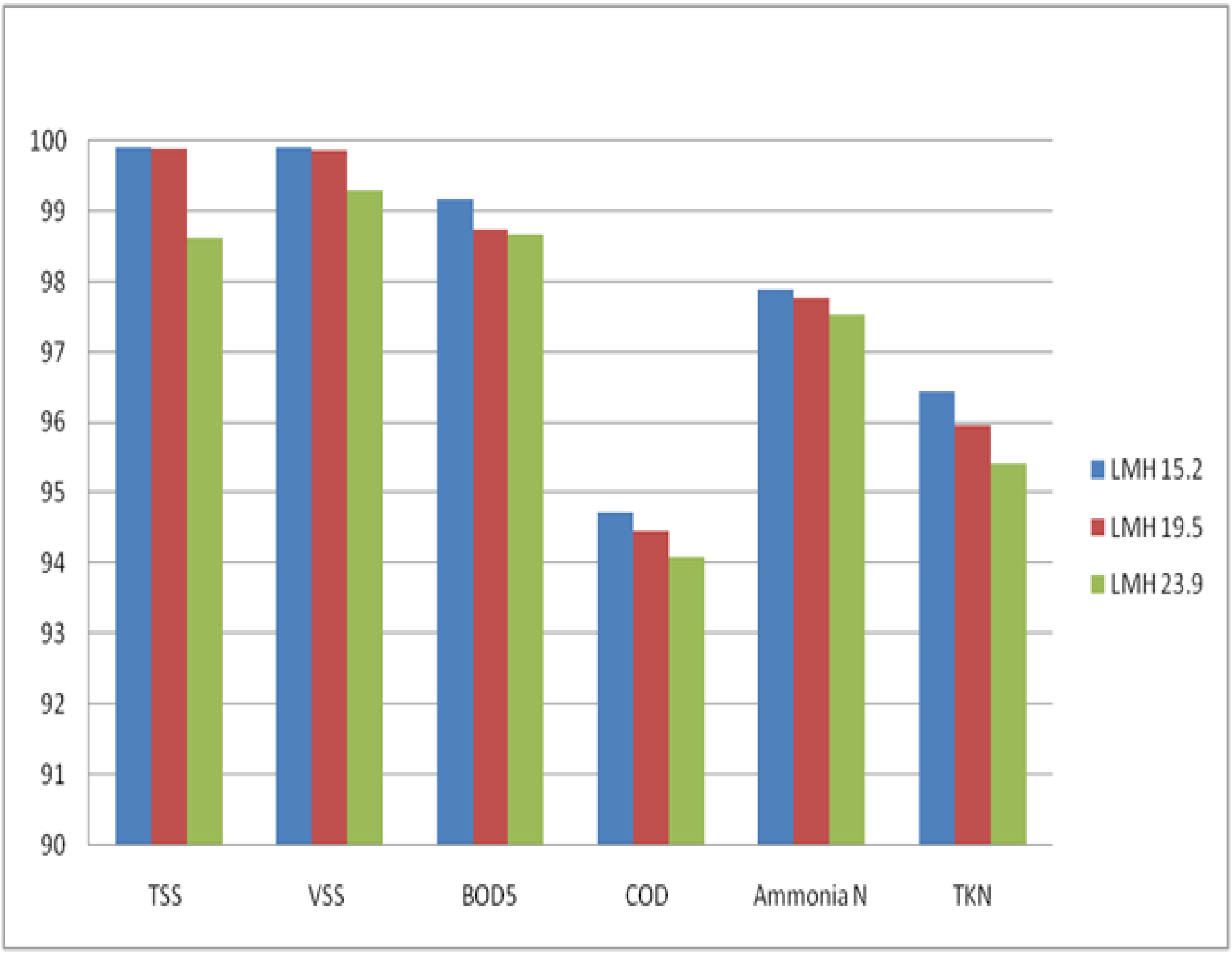
By compiling the results, optimized conditions were known. Optimization was done keeping two operating conditions in mind, flux and SRT. It was concluded that SRT of treatment process should be 30 days to give most efficient results, depending on biomass concentration maintained between 8-10g/L. It was observed that by increasing SRT gives better removal efficiency but with SRT higher than 35 will result in solids particles in the discharge.

Figure 4.9 Removal (%) Efficiency at Different SRT's



Simulation runs to find out the most efficient conditions it was observed that for 23.9 LMH, effluent quality was not good comparatively. Although the removal efficiency was high but higher suspended solids in MBR effluent if SRT was increased. If SRT is set short it will result in high rate membrane fouling and if SRT is set long it results in solid material in effluent.

Figure 4.10 Removal (%) Efficiency at Different Flux



The optimized conditions for NUST H-12 Treatment Plant are as follows:

Table 4.11 Optimized Conditions

Sr.No	Parameter	Unit
1	Volume Treatment	45 m^3/day (19.5 LMH)
2	Solid Retention Time	30 days
3	Dissolved oxygen	2 mg/L
4	Backwash Interval	14.5 min
5	Backwash Duration	30 sec
6	Model	ASM1
7	MLSS ()	6000-9000 mg/L
8	Hydraulic Retention Time	6 hr

Conclusion and Recommendations

In this study, samples were collected from different locations within NUST H-12 campus. Dissolved Oxygen, temperature and pH were investigated on site and for further analysis transported to laboratory for analysis. The chemical and biological characteristics of wastewater were analyzed and variations in concentrations of wastewater constituents in different seasons were investigated. On the basis of data collected, GPS-X software was used for modeling and simulation of pilot scale wastewater treatment plant installed in H-12 campus. Different scenarios were run in GPS-X and establish the most optimized conditions for MBR plant.

5.1. Conclusions

- During the monsoon season wastewater is diluted by rain water infiltration into the drainage lines.
- Longer SRT results higher treatment efficiency but high suspended solids in the effluent. While Low SRT results in high sludge production. Therefore SRT 30 days found to be optimum.
- Lower the flux higher the treatment efficiency and vice versa therefore flux of 20 LMH was found to be optimum.

5.2. Recommendations

- Comparison between GPS-X simulation results and treatment plant actual results.

- Dynamic simulation for further investigation of NUST MBR plant performance.

- Advanced scenarios for accurate prediction of NUST MBR plant.

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