CERTIFICATION OF APPROVAL

Testing The Efficiency And Re-evaluating the design on the Removal of Organics With the Usage of Baffled Integrated Suspended Growth System (i-SGs)

by

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Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements and that the original work contained herein have not been undertaken or done by unspecified sources or person.

Ernest Ho Zhan Shiong

ABSTRACT

In today's modern day wastewater treatment system, civilization is provided with a generous amount of options in its disposal or treatment method. However, there is a lack of integrated wastewater reactor systems to which might help in the modernization of the typical wastewater treatment plants. As society moves towards a more integrated approach, so must wastewater treatment systems. The drawbacks in setting up a sewage treatment plant as well as maintaining it comes to light here in this particular project which aims to explore the design feasibility of a new type reactor that may be the first ever of its kind. The reactor features an integrated design consisting of an Anoxic Tank, Aeration Tank and also a clarifier. The pilot plant integrates an anoxic tank where the anoxic condition is achieved by suspending and mixing the wastewater with sludge via the pumping action of influent wastewater to the bottom of the anoxic tank. Also, aerobic treatment where organic biodegradation happens in the aeration tank with the help of two rings of fine bubble diffusers powered by the air compressor, a clarifier unit to help produce a clarified effluent and to discharge it out. Lastly, there is also an internal recirculation and recycled activated sludge system in the pilot plant to help maintain a constant concentration of biomass in different tanks in the system. All the components were integrated into a compacted single reactor. The design at present, aims to produce a functioning all in mobile transportable sewage treatment plant in the case of emergencies as well as or industrial purposes. Currently, standard sampling tests, such as the Mixed Liquor Volatile Suspended Solids(MLVSS), Mixed Liquor Suspended Solids(MLSS), Chemical Oxygen Demand(COD) and Total Suspended Solids(TSS) are conducted in order to obtain results which will match and hopefully deem the design functioning and working in accordance to the schematics.

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Chapter 1

Introduction

1.1 Background

The constant deterioration of water bodies due to anthropogenic and natural activities comes from many sources and can be attributed from urban and agricultural run-offs, industrial and sewage run-offs. These anthropogenic activities constitute a large percentage of water body contamination due to the presence of certain compounds, i.e: ammonia, nitrate and nitrite. These pollutants tend to vary in terms of composition due to the difference in discharge sources. In order to tackle these problems, men have invented sewage treatment processes and plants specifically designed to treat and dispose of these pollutants in a proper way. The average person wastes about 225L/day and considering the fact that the average population of the world is about 7.4 billion. The amount of area required to properly treat waste water is getting more and more by the minute. Industrialized sewage treatment plants(STPs) are consuming a large portion of the land we have left, therefore, the solution is to come up with a method of wastewater treatment that consumes less land and perhaps even provide proper mobility in the case of emergencies as well as convenience.

The typical method for treating biological wastewater is at present a proven method of removal for nutrients and other wastewater pollutants. It has been widely implemented and successfully used in various type of configurations depending on the objectives of the process. However, as stated in the above paragraph, there are of course certain demerits that exist, such as the requirements of a large area for the setting up of the reactor plant, the odorous smell and the production of high volumes

of sludge. The method of sludge disposal in landfills, land application or incineration constitutes to about 60 % of total costs of typical biological treatment process. At present, the Malaysian Department of Environment(DOE) has revised the effluent discharge limits guideline for sewage treatment plants due to high contamination of water bodies all around the country. Due to the rapid increase in the population, many landfill sites are filled and developing new sites would be difficult without any consequences to the environment. Hence, it is imperative that a new alternative be developed to tackle the uprising problems in biological treatment processes that meet the objectives of regulatory bodies.

In fact the the history of water treatment is indelibly tied to the history of water, itself. As human industry has grown and water has become more contaminated, early water filters have emerged over the centuries in response to the growing recognition of the need for pure, clean water to drink and the realization that such water does not occur naturally. It is only when people have realized the importance of these treatment systems in coherent to their health that they have started investing and searching for ways and means to attain a clean water source. Throughout the centuries, as technology developed, people have gradually gained better control in the treatment of water. They have been able to transport water to arid lands, stop and redirect rivers and even determine when and where rain will fall. Even with increased control of water resources, water still continues to dominate the political, economic, and social structure of all nations. This statement can be verified by looking at political struggles within the United States over water resources or throughout the Middle East over access to limited water. Concerning conflict in the Middle East, former World Bank Vice President Ismail Serageldin stated in 2000, "Many of the wars of this [20th] century were about oil, but the wars of the next century will be about water" (Smith, 2000).

The i-SGs or Integrated Submerged Growth System is a seemingly potential problem solver in this case study due to its unique design and mobile characteristics. Integrated reactors are actually bioreactors that have managed to combine a series of individual reactor’s pathway into a single pathway, therefore overall enhancing not only the overall performance of the bio-reactor but also making it shorter. In present time, integrated reactors are reportedly cost-effective, efficient and give out a smaller

footprint[3]. In terms of mobility and setting up costs, these reactors are able to be dismantled and transported from one place to another in a matter of days due to their integrated bio-reactors.

1.2 Problem Statement

At present, a fabricated design of the Integrated Suspended Growth System exists, however there are certain problems that persist within the system. The first problem being the current design calculations of the system, to which the flow rate might be too high. Due to the high flow rate of the system, the sludge that is added into the system is washed out prematurely through the effluent. The next problem of the I-SGs is to ensure that the integrated system can meet the effluent discharge standards set by the Department of Environment in Malaysia. This i-SGS is a recommended portable sewage treatment system to treat wastewater discharge from these temporary housing in meeting the effluent limits for sewage discharge into receiving waters. In some cases, failure to remove these nutrients from sewage wastewater will lead to eutrophication, a phenomenon where by the water body will amass in an abundance in nutrients such as phosphorus and also nitrogen, which have their own respective side effects.

1.3 Objectives

The objectives of this research are as follows:

a) To re-evaluate the design calculations of the Integrated Suspended Growth System based on the previous design calculations.

b) To test and to evaluate the efficiency of i-SGs in terms of its ability to remove organics(COD) substances from the wastewater.

APPENDIX K1

Extracted from Environmental Quality (Sewage) Regulations 2009 (PU(A) 432)

SECOND SCHEDULE
(Regulation 7)
ACCEPTABLE CONDITIONS OF SEWAGE DISCHARGE OF STANDARDS A AND B

(i) New sewage treatment system

	Parameter	Unit	Standard A	Standard B
	(1)	(2)	(3)	(4)
(a)	Temperature	°C	40	40
(b)	pH Value	-	6.0-9.0	5.5-9.0
(c)	BOD5 at 20°C	mg/L	20	50
(d)	COD	mg/L	120	200
(e)	Suspended Solids	mg/L	50	100
(f)	Oil and Grease	mg/L	5.0	10.0
(g)	Ammonical Nitrogen (enclosed water body)	mg/L	5.0	5.0
(h)	Ammonical Nitrogen (river)	mg/L	10.0	20.0
(i)	Nitrate – Nitrogen (river)	mg/L	20.0	50.0
(j)	Nitrate – Nitrogen (enclosed water body)	mg/L	10.0	10.0
(k)	Phosphorous (enclosed water body)	mg/L	5.0	10.0

Note : Standard A is applicable to discharges into any inland waters within catchment areas listed in the Third Schedule, while Standard B is applicable to any other inland waters or Malaysian waters.

Figure 1: Effluent Quality based on Malaysia's D.O.E

1.4 Scope of Study

Several sets experiments will be conducted in order to test the accuracy of the design parameters while maintaining the wastage in sludge as well as the recycled sludge. The experiments will be conducted with an SRT of 40 days at mesophilic temperature. This particular study will focus on the feasibility of the design at treating waste water. Since the design calculations have been provided, it is now compulsory that we run tests to determine the actual design capabilities of the reactor.

Chapter 2

Literature Review

2.1 Biological Treatment in a Treatment Plan

Arun Mittal (2012), noted that the biological treatment of wastewater is an important and integral part of any wastewater treatment plant that treats waste from either municipality or the industry type wastewater. Biological treatment using aerobic activated sludge process has been in practice for well over a century. According to Tchobanoglous et. Al (2003), the complete stoichiometry of aerobic oxidation; the conversion of organic matter that happens in the aeration tank can be defined as Equation 1.1.

$$CHONS + O_2 + Nutrients \rightarrow CO_2 + NH_3 + C_5H_7NO_2 + Other\ Products \quad (1.1)$$

In an event of longer solid retention time, SRT is used in cases where the extended aeration tank is used, endogenous respiration will occur. Endogenous respiration can be defined in layman's term where there is too high concentration of cells and too low concentration of organic matter which serves as food for the cells, the cells starts to oxidize each other as food. This causes the activated sludge to become less as the end result. The stoichiometry for endogenous respiration is as per Equation 1.2.

$$C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + 2H_2O + NH_3 + energy \quad (1.2)$$

Extended aeration is used so to have a lower sludge yield as endogenous respiration occurs, however, the process of endogenous respiration produces ammonia, NH_3 which is toxic in nature to the environment and public health. Ammonia then undergoes the process of nitrification where it oxidizes into nitrite (Equation 1.4) and then to nitrate (Equation 1.5) with the help of nitrifiers(a type of bacteria) in the extended aeration tank. In the newly designed reactor, the nitrification takes place in a specially designed Anoxic Tank located in the middle of the plant.

$$NH_4^+ \leftrightarrow NH_3 + H^+ \quad (1.3)$$

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O + energy \quad (1.4)$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- + energy \quad (1.5)$$

The final product of oxidation of ammonia in the extended aeration tank is nitrate which again, has to be removed as it causes harm to human health, particularly to infants such as blue baby syndrome and the environment where eutrophication might occur. In order to remove nitrate from the system, internal recirculation from the extended aeration tank to the anoxic tank is required where denitrification will occur. In anoxic conditions, nitrate is broken down into nitrogen dioxide to nitrogen oxide to nitrous oxide and finally to nitrogen gas (Equation 1.6). Free nitrogen which makes up majority of the air's component is harmless, thus causes no greenhouse gas issues (Tchobanoglous et. Al., 2003)

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2 \quad (1.6)$$

2.2 Typical Wastewater Treatment

Wikipedia (n.d.) defined wastewater treatment as conversion of wastewater, which is water that is no longer appropriate for daily usage, into an effluent that can be returned to the natural water cycle without disrupting the environment's ecosystem. Most typical wastewater treatment plants are split up into 3 segments, the preliminary treatment, the secondary treatment and finally the tertiary treatment.

Although there are variations in wastewater treatment plants, most will follow the above segments in treating wastewater.

2.2.1 Preliminary Treatment

During preliminary treatment, the influent or raw sewage is strained in order to remove all large objects during their travel sequence into the sewer system. These objects can range from anything such as sticks, enlarged soil particles, household organic wastes(food), and even live miniature animals. In most cases, the oil and grease chambers are placed at the fore front of the treatment system, its objective, to filter and remove these items from contaminating the rest of the process. And in order to achieve its objectives, these removal chambers come in all shapes and sizes to increase effectiveness and efficiency. The actual main purpose of the primary treatment though is to produce a generally homogenous liquid capable of being treated biologically and a sludge that can be separately treated or processed. The primary clarifiers are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper at the base of the tank. There, it can be pumped to further sludge treatment stages. The clarified water flows on to the next step of treatment.

2.2.2 Secondary Treatment

Here in the secondary treatment process, about 90% of the organic matter in wastewater can be completely removed using the biological treatment processes installed. Over here, the two most common growth processes are the attached growth process and the suspended growth process. In the aeration tank, the wastewater is subjected to treatment by either one of these growths. In our case, it is the integration of the suspended growth system.

2.2.3 Suspended Growth Process

In a suspended-growth system, such as activated sludge processes (also aerated lagoons and aerobic digestion), the waste flows around and through the free-floating microorganisms, gathering into biological flocs that settle out of the wastewater (Westerling.K, 2014). The suspended growth process speeds up the work of aerobic bacteria and other microorganisms that break down the organic matter in the sewage by providing a rich aerobic environment where the micro-organisms behaviour in the wastewater can work more efficiently. In the aeration tank, wastewater is vigorously mixed with air and microorganisms acclimated to the wastewater in a suspension for several hours. This allows the bacteria and other microorganisms to break down the organic matter in the wastewater. Suspended growth process units include variations of activated sludge, oxidation ditches and sequencing batch reactors.

Here, our design uses the water-fall aeration method in which water flows out from the anoxic tank and into the aeration tank. The higher the fall distance, the higher the efficiency of the aeration process.

2.2.4 Tertiary Treatment

Tertiary treatment is the final cleaning process that will help aid in the cleaning process that improves wastewater quality before it is reused again or discharged into the environment. The treatment mainly aims to remove the inorganic compounds, substances from the wastewater. These compounds are sometimes made up off nitrogen, phosphorus, and other minerals. Certain bacteria and viruses area also removed at this stage via the addition of chemical compounds.

Wastewater flows from the biological reactor to a pumping station and meet in the flash mixer. Alum is introduced here to help remove additional phosphorus particles and coagulate the groups of particles that remain in the wastewater. This will cause them to floc together for easy removal in the filters.

Due to the addition of alum, tiny particles will cluster together to form masses called floc. Flox is trapped by the sand, while clear water is gravity fed to the chlorine

contact tank. The filters are backwashed every so often in 24 hours to remove the floc that has accumulated. The backwash water is then retuned to the primary treatment stage to go through full treatment. In thc chlorine contact tank, the disinfection process using chlorine will remove microorganisms from the treated wastewater including bacteria, viruses and parasites.

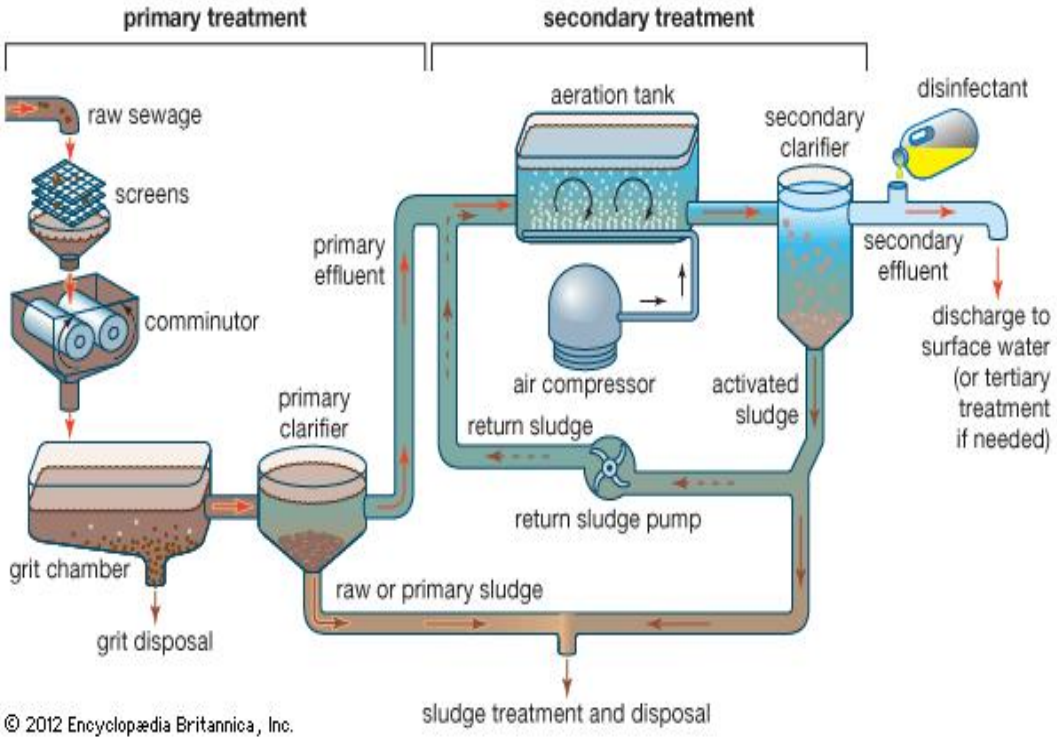

Figure 2: Activated Sludge Treatment Systems

2.3 Integrated Vertical Wastewater Treatment Vessels

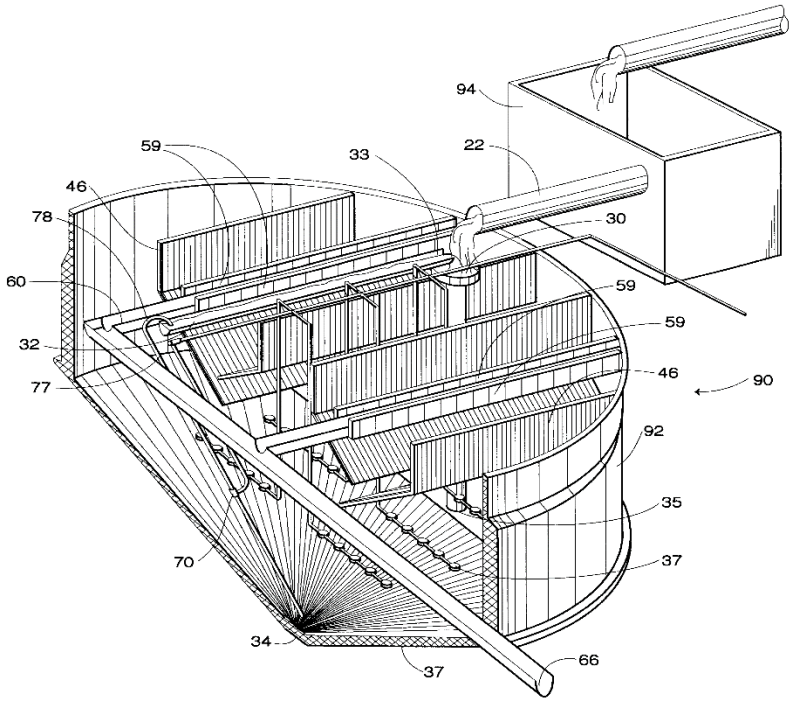

Figure 3: Integrated Vertical Wastewater Treatment Systems

Typical wastewater treatment facilities are rather large complexes for handling tens of millions of gallons of waste water annually (B.Ozyboyd, 2003). These facilities tend to occupy a somewhat huge piece of land, yet also produce a significant volume of solidified waste sludge. Without a doubt, these facilities will produce clean water, but the disposal process of the waste sludge requires special handling and proper disposal in landfill sites or other locations.

In a typical/typical wastewater plant, the influent passes through a series of treatment processes to remove large objects and then reduce the solids and waste particles before separating residual solids from the water. A screen and grit chamber is provided to remove unwanted materials. Having a flow that is low will help facilitate the removal of grit and heavy particulates in the wastewater before entering its primary stage for stage 1 treatment. Primary treatment will include aerating the wastewater in the aeration tank to help remove oil and scum from the surface of the

water. This particular method of treatment however, will combine sedimentation and floatation in order to remove settleable and floatable materials. Thereafter, the wastewater enters the secondary treatment phase, here suspended and dissolved solids will be removed. Thereafter, the secondary treatment will subject the wastewater to treatment with the use of activated sludge which are biologically microorganisms that will assimilate waste materials. The last phase is the tertiary phase which will subject the water to treatment by disinfection in the more clarified wastewater. The resulting effluent is then generally discharged to surface waters.

The integrated vertical treatment system consists of an enlarged vessel having a closed bottom and an open end. Based on (B.Ozyboyd, 2003) the structure has an overall height of about 8 metres and a diameter of about 6 metres. This is of course entirely based on treatment capacity during the design phase. The vessel is designed in the shape that it has an upper Cylindrical Portion (18) and a tapered conical lower portion(20). An inlet (22) will direct the influent wastewater into the vessel for sanitary treatment. The inlet (22) communicates to an open-ended grit collection chamber (24). The grit collection chamber (24) is open at both an upper end (25) and a lower end (26). A collection basin (28) is defined below the lower open end (26). The collection basin (28) receives particulate matter, such as grit or sand from the influent wastewater. Non-organic materials separate from organic solid wastes. FIG. 2 illustrates an airlift (29) that has a lower end in the collection basin (28) and a discharge (not illustrated) outwardly of the vessel (12). The airlift (29) receives air from a supply for creating an uplift in the airlift (29) to remove the material collected in the basin (28).

Fig. 2

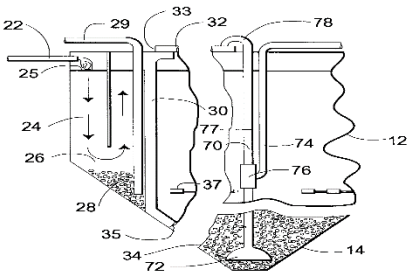

Fig. 3

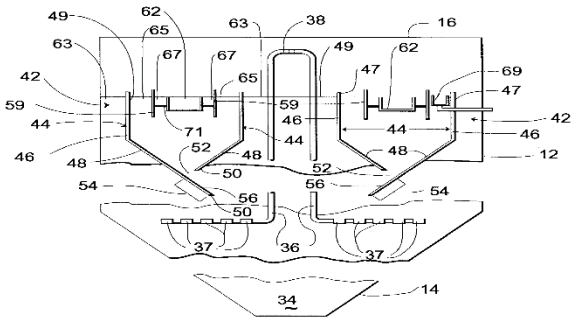

Figure 4: Cross Section view of The Integrated Treatment Unit

With reference to FIGS. 1 and 2, the microorganisms and suspended solids in the secondary clarifiers (42) collect into the larger clumps of material or floc. The gentle rate of rising and the stilling of the wastewater within the still zone (65) allows the floe to settle on the plates 48. Preferably, the zone defined by the angled plates (48) at the bottom of the secondary clarifier(42) accounts for about 20% of the volume of the secondary clarifier. Microorganisms in the floe consume waste and other microorganisms, which reduces the solid waste. The process reduces solid waste to about 1.6 to 1.8 percent with an F/M ratio of about 0.29. As the floc becomes larger and heavier and accumulates due to reduced oxygen, the floe slides down the plates 48 and through the gap (52) towards the bottom of the vessel (12) into the lower aeration zone (42). The oxygen in the aeration zone provides biological support to the microorganisms which assimilate suspended solids in the waste materials. As the floe concentrates in the lower portion of the aeration zone (34), the microorganisms become less active and dormant as they are increasingly deprived of oxygen. The concentration of the biologically active microorganisms however increases towards the bottom of the vessel (12). Generally, sludge becomes more concentrated during the detention period in the vessel(12).

Scum collects on the surface (49) in the skim zone (65) which is less agitated than the agitation zones (63). The skimmers (69) evacuate the scum and foam from the vessel 12. Treated wastewater in the still zones (67) flows over the sides of the trough (62). The treated wastewater flows through the discharge (66) outwardly of vessel (12).

Chapter 3

Methodology

3.1 Reactor Design Concept and Project Activities

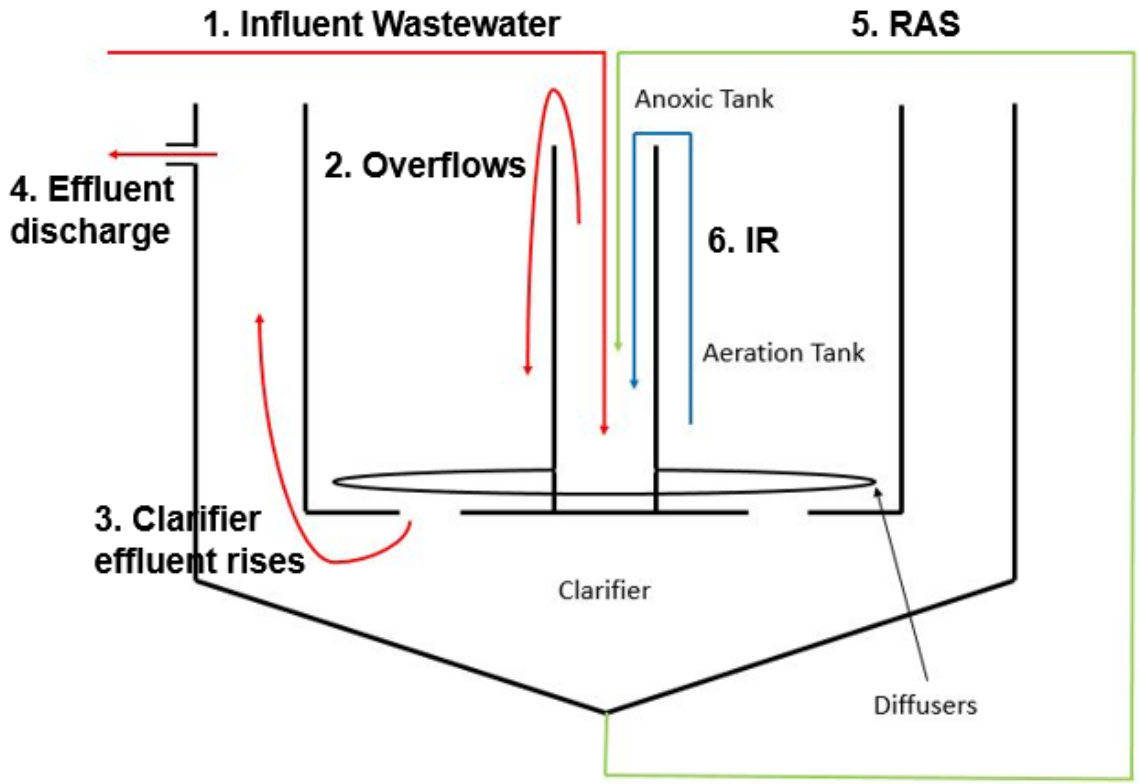

Figure 5: Schematics of the Integrated Suspended Growth System

Following the red arrows in Figure 5, influent wastewater is pumped into the pilot plant directly from the university's sewage treatment plant, specifically from the Oil and Grease tank into the bottom of the anoxic tank where it will then overflow into the aeration tank for further treatment.. The anoxic tank serves as a medium to

remove nitrogen from the influent wastewater which at the end, if untreated will cause algae bloom and also eutrophication if not carefully monitored. The inflow of wastewater in the anoxic tank to the bottom the tank will suspend and mix the activated sludge with influent wastewater, which will induce an anoxic condition whereby the mixing action of the sludge without the presence of free oxygen will turn the bacteria facultative. Facultative bacteria are microorganisms that can tolerate and degrade organic matter in both aerobic and anaerobic condition. The main purpose for the presence of anoxic tank is to remove nitrogen from wastewater which can cause algae bloom and eutrophication if discharged into any water bodies. Under anaerobic conditions where there is no presence of free oxygen, they grow and breakdown organic matter through fermentation and converts nitrate NO_3 and/or nitrite, NO_2 to harmless bubbles of nitrogen gas which is released to the atmosphere in a process called denitrification as seen in Equation 1.6 on page 7. Facultative bacteria in anoxic system uses the nitrate and/or nitrite as an electron acceptor and release nitrogen in the form of nitrogen gas or nitrogen oxides, however, a readily biodegradable carbon source is needed to facilitate an efficient denitrification processes which can be obtained from recycled activated sludge (RAS) and internal recirculation (IR) that is pumped in intervals into the anoxic tank from the bottom of the clarifier and the aeration tank respectively.

Next, the wastewater overflows from the anoxic tank into the aeration tank. The aeration tank is where aerobic degradation of organic matter, usually in the form of biochemical oxygen demand and other pollutants happens, represented by Equation 1.1 in page 6. Activated sludge degrades organic matter using free oxygen that is pumped into the tank via two rings of fine air bubbles diffusers powered by an air compressor, which converts the organic matter into flocs that will eventually settle to the bottom of the clarifier through eight cone shaped holes that is 600 mm in length and 60 mm in length on the shorter arc of the cone. Also, the diffusers serve to suspend and give the mixing action of the biomass in the aeration tank. The nitrification process also occurs where ammonia in wastewater is oxidized to nitrite, NO_2 and then to nitrate, NO_3 with the help of nitrifiers present in the tank as seen in Equation 1.3, 1.4 and 1.5 respectively.

Then the wastewater flows into the clarifier through holes at the bottom of the aeration tank where clarified effluent is produced at the top of the clarifier through sedimentation of sludge. Sludge is naturally heavier than water in weight which will settle at the bottom of the clarifier which has a cone shape while the treated, clarified effluent will overflow into an outflow pipe which discharges the treated effluent back into the environment.

Following the green arrow on Figure 5, at the bottom of the clarifier, the collected activated sludge is recycled via the means of a pump where it will be directed back to the anoxic tank to maintain the concentration of biomass in both the anoxic and aeration tank. Since the reactor is designed as an extended aeration reactor, there is no need for sludge wasting as once the concentration of biomass is too high, endogenous respiration will start to set in and the overall mixed liquor suspended solids, MLSS concentration will be reduced until the concentration is suitable with regards to the food to mass ratio.

The blue lines represent the internal recirculation process where another pump is installed here where it will pump sludge back to the anoxic tank to maintain the activated sludge concentration in the anoxic tank and also nitrate where it will undergo the denitrification process.

The entire project will be divided into several phases for an entire duration of approximately 8 months. The first phase will involve re-evaluating the design calculations of the Integrated Submerged Growth System from scratch. Aspects such as the flow rate and also the volume of the current design will be reverse calculated in order to attain pre-design values in order to check the current design calculations against the designated specs. Herein, this phase, I have used the previously designed schematics and an excel spread sheet/manual hand-written calculations to re-design the system. Whereas, the second phase will involve testing of the design with pre-installed baffles for a revised retention time. Both phases will involve collecting samples from the University's Sewage Treatment Plant as the pilot plant will pump the wastewater directly from the University's Sewage Treatment Plant. The aim is to allow for three to four months period for carrying out sample tests on the quality of the effluent produced by the pilot plant.

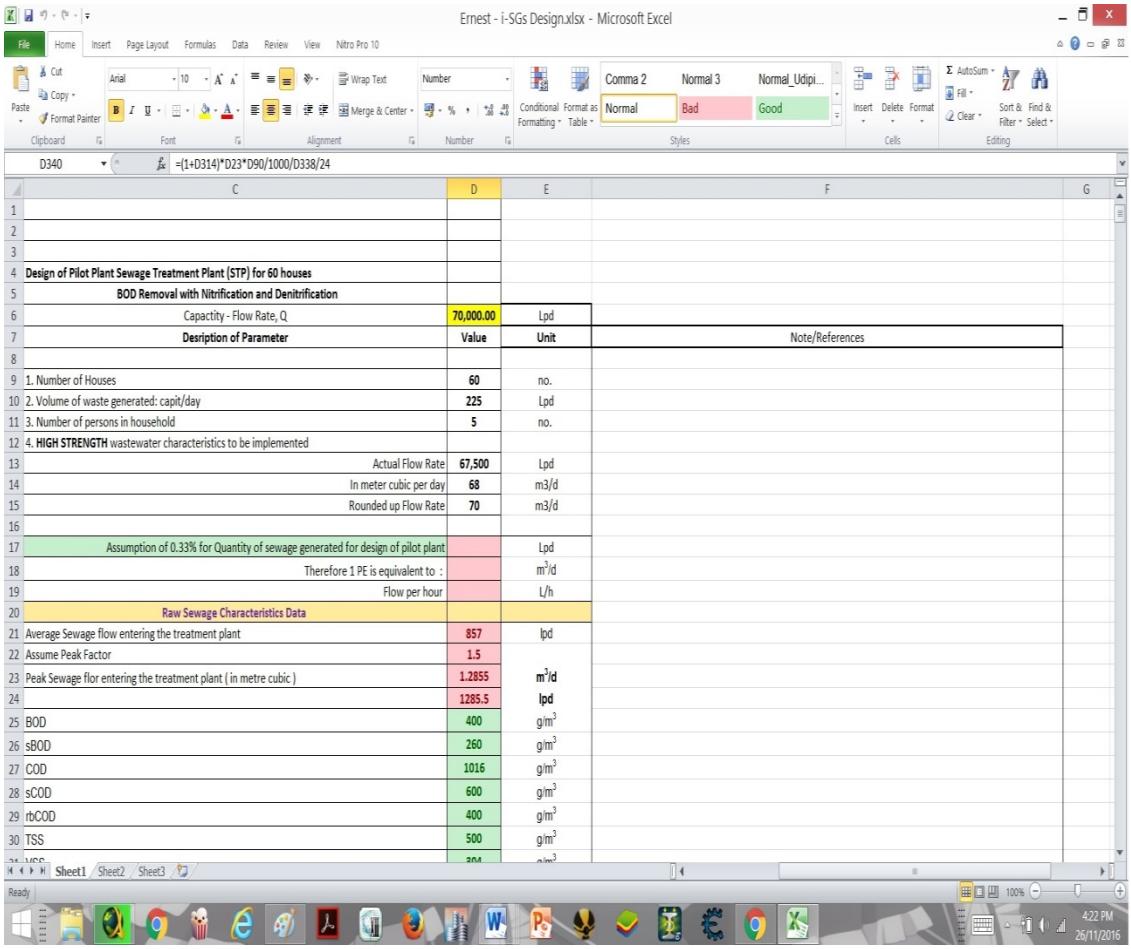

Figure 6: Excel Spreadsheet for Re-Evaluation

3.1.1 Daily testing for sludge settleability and flowrate

Testing for the sludge settleability is done in order to achieve a steady and stable MLSS ratio. The idea of the test is to provide a place where the MLSS can quietly separate from the liquid water. The MLSS solids consist mostly of bacteria with some organic and inorganic debris mixed in. The debris can be finely shredded toilet paper, paper towel fibers, vegetable fibers, plastic material, seeds, insect parts and various other types of waste commonly found.

During the first five minutes of the settleability test, the bacteria clump together, forming large clumps (floc). These floc particles are slightly denser than water — this helps with settling and compaction. After initially clumping together, the floc begins to settle toward the bottom of the container, squeezing the clear liquid out and

up toward the surface. The settleability is taken from the aerator to check the ratio of the sludge against the wastewater treated. Once the sample is taken, it is then left to settle in an undisturbed environment. The reading should produce at least a 3/10 ratio of sludge wastewater.

Aside from that, the flow rate is tested as often as possible in order to achieve the design flow rate. This is important as the reactor is designed to treat at least 67500L/Day. The flow rate is taken using a timer and also a beaker. The timer is set for 60 seconds and the flow rate of the effluent is collected for 60 seconds. The reading is then taken and then calculated to see how it matches with the design.

3.1.2 Determining the effluent quality of the I-SGs

During the testing phase of the effluent and design parameters, samples will be taken from three different discharge points specially allocated to test the design parameters. These three points are deliberately installed onto the reactor so as to allow us to obtain samples for testing. The three spoken points where samples will be taken from are the effluent flowing out from the Anoxic Tank, effluent from the bottom of the clarifier chamber and finally the effluent that is to be discharged from the reactor. The tests to be conducted consists of the normal tests whereby wastewater samples are subjected to characterisation of their parameters and comparison with the design parameters.

3.2 Experimental Methodology

To ensure a controlled environment the following parameters have been set at the beginning of the testing phase:

a) Recycling of the Activated Sludge – Once every 30 minutes for 5 minutes

b) Internal Recycling – Once every 30 minutes for 5 minutes

Note: Both the RAS and Ir are done simultaneously at the same time. Also these are the initial settings, they have since then been altered to fit the design.

3.2.1 Testing, Materials and Equipment

There will be a series of test conducted, therefore, the equipment and materials will vary depending on the procedures and methodology.

3.2.2 Chemical Oxygen Demand (COD)

The most important equipment we will require to run this experiment is the spectrophotometer, an apparatus which will detect the change in colour of the orange dichromate reagent added before the commencing of this experiment. This particular reagent acts as an indicator to display the rate of the micro-organisms digestion process. A lighter colour intensity provides us with a lower COD value. Before the commencement of the experiment, the digestor is switched on and set to COD @ 105 degree celcius, this step is to save time as it takes time for the digestor to warm up. The samples from the Influent and Effluent are carefully separated and then labelled. 7 Low Range Potassium Dichromate Reagents are placed on the test tube stand, 3 sets will be for influent another 3 for effluent and 1 will act as a blank. For the Influent, 2ml of the influent wastewater is micro-pipetted into the digestion solution tube, and then shaken. This step is repeated 3 times.

For the Effluent, 2ml of the effluent wastewater is micro-pipetted into the digestion solution tube, and then shaken. This step is repeated 3 times. A special blank sample is prepared as well but instead using 2ml of distilled water pipetted into the 7^{th} vial of dichromate solution. The 7 samples are then placed in the digestor and then the

digestion process is started and left for one hour will the timer expires. Later on the, samples are placed in a desiccator for 20 minutes to cool down for easy handling. It is then removed and then taken to the spectrophotometer for COD readings. Ensure to calibrate the spectrophotometer first and set it to Low Range COD, before testing the samples. The blank is placed in first and ZERO-ed to act as the standard of testing for the influent and effluent. The samples are wiped clean to ensure that there is no moisture on the vial before being placed in the Spectrophotometer. The readings are then taken and tabulated for further analysis later.

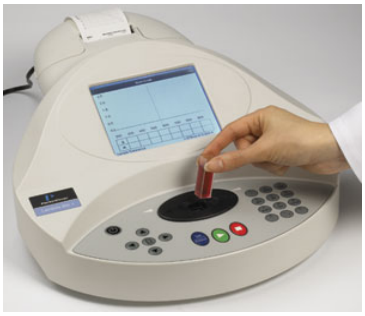

Figure 7: Spectrophotometer together with a sample

3.2.3 Total Suspended Solid, TSS

TSS testing measures the total concentration of suspended (non-soluble) solids in the aeration stabilization basin (ASB) or in effluents. The total suspended solids (TSS) data is critical in determining the operational behaviour of a waste treatment system. For the TSS experiment, the glass fibre filter papers are prepared one day before the commencement of the experiment. Sample are collected from the effluent and the influent and then separately labelled for ease of use later on. In order to test the mixed liquor suspended solids (MLSS) a well-mixed sample should be filtered through a weighed fiber filter paper. The residue left on the filter is dried to a constant weight at a temperature between 103 °C and 105°C. The increase in weight of the filter represents the total suspended solids of the sample.

3.3.4 Mixed Liquor Volatile Solids and Mixed Liquor Suspended Solids

Figure 8: Suspended Solids settling in a 1L beaker

MLSS testing measures the total concentration of mixed liquor suspended (non-soluble) solids in the aeration basin of an activated sludge system. The mixed liquor suspended solids (MLSS) data is critical in determining the operational behaviour and solids inventory of the system and it is used to determine when to waste and/or recycle sludge.

In order to test the mixed liquor suspended solids (MLSS) a well-mixed sample should be filtered through a weighed standard glass-fiber filter. The residue left on the filter is dried to a constant weight at a temperature between 103 °C and 105 °C. The increase in weight of the filter represents the total suspended solids of the sample. Large floating particles or submerged agglomerates of non-homogenous materials from the sample may be excluded in the total suspended solids measurements if it is determined that their inclusion is not representative of the entire sample. The size of sampling should also be limited to a size that yields no more than 200 mg residue. To obtain the MLVSS, the MLSS sample is taken to the Muffled Furnace and heated at a temperature of 550 Degree Celcius for 20 to 30 minutes. It is then taken out carefully and then placed in the desiccator for 20 minutes to cool down and finally to be weighed.

High mixed liquor suspended solids (MLSS) values in effluents are often related to excessive solids generation due to an increase in BOD (Biochemical Oxygen Demand) loading or can indicate problems with the biomass like nutrient deficiency or bulking sludge. High MLSS values can also be attributed to high flows or insufficient settling times.

After the mixed liquor suspended solids value is determined a mixed liquor volatile suspended solids (MLVSS) test may be performed in order to determine the concentration of volatile suspended solids in the aeration basin of an activated sludge system. Mixed liquor volatile suspended solids data is critical in determining the operational 24ehaviour and biological inventory of the system. The filter used for mixed liquor suspended solids (MLSS) testing is ignited at 550 °C for 30 minutes. The weight lost on ignition of the solids represents the volatile solids in the sample.

3.3 Estimated Gantt Chart Sequence

Semester 1

Details	Week												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Selection of Title/SupervisorMeeting													
2. Preparation of Extended Proposal													
3. Submission of Extended Proposal													
4. Preparation for Proposal Defense													
5. Proposal Defense and Progress Evaluation													
6. Preparation of Interim Report													
7. Draft Interim Report Submission													
8. Modifications done to Interim Report													
9. Submission of Interim Report													

Figure 9: Final Year Project I Gantt Chart

Semester 2

Details	Week												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Preparation of the System													
2. Labwork and Experiments													
3. Submission and Preparation of Progress Report													
4. Preparation of Poster													
5. Pre-Sedex													
6. Submission of Final Report													
7. Submission of Technical Paper													
8. Viva Presentation													

Figure 10: Final Year Project II Gantt Chart

Chapter 4.0

Results

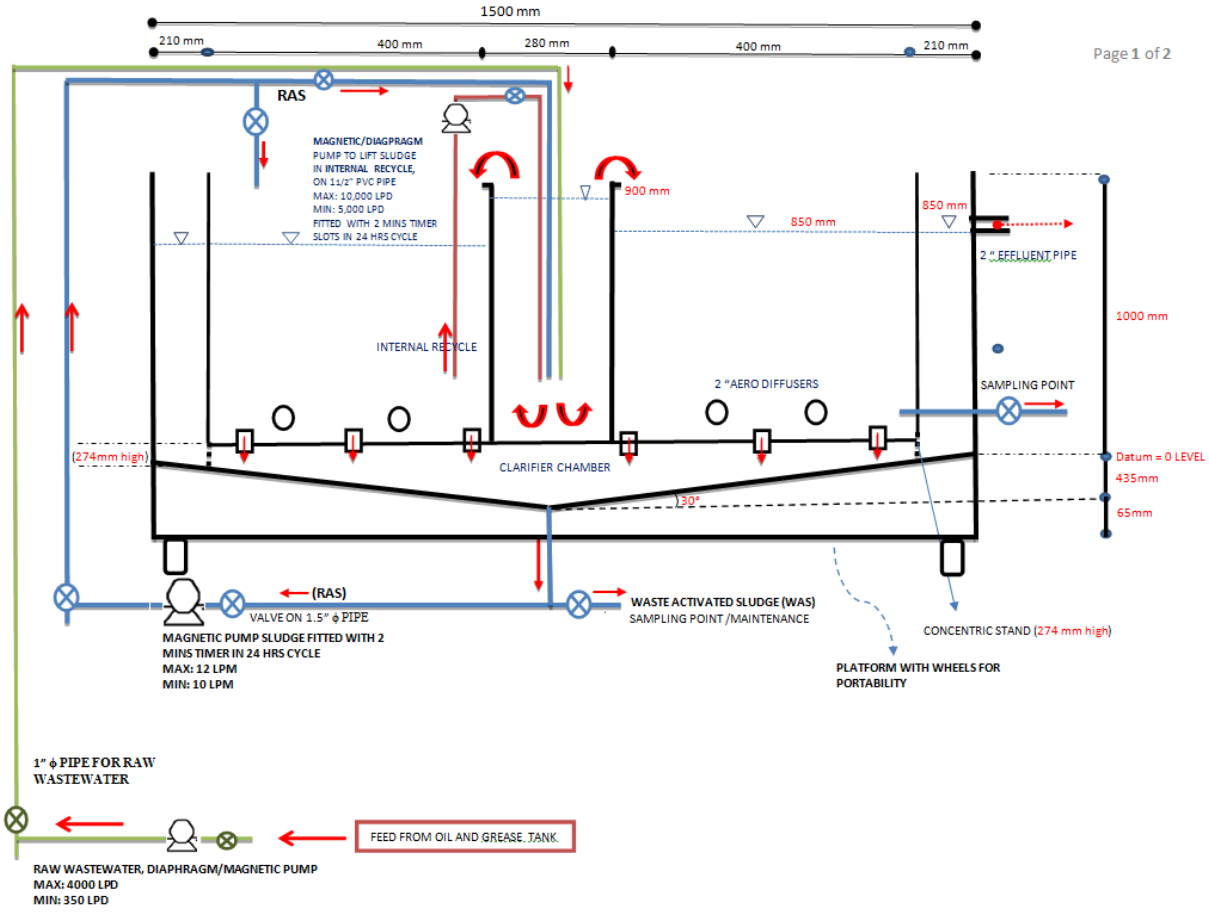

Figure 11: Fabricated Design Schematics

Design Re-evaluation for i-SGs (See Chapter 6: Appendix for Previous Design Calculations)

The reason as to why design re-evaluation was needed is because, we had suspect that the FLOWRATE for the system might be too high, due to the fact that sludge is often being washed out the day it is added. By re-checking the flow rate and the volume, it is found that there are no problems with the flow rate. I have then proceeded to physically alter the RAS pump for the first few days before testing to checking whether or not it was the Recycling rate that was affecting the washout of

sludge. At present during the entire trial for this time round's experiment using a newly set RAS, the system no longer experiences any form of sludge washout from the system, as can be seen in the result section for the MLSS and MLVSS. Also, another thing to note is that the **aerators might have been set too low during previous trials** causing sludge to not float but sink and washout through the clarifier at the end.

Design using an Excel Spreadsheet (Trial and Error Method)

The **current** Aeration Tank Parameters are as follows:
Radius – 540mm (0.54m)
Height – 750mm (0.75m)
Volume – 3.142 x 0.54^2 x 0.75 = 0.92m^3 (920L)
Previous Detention Time, T: 62 hours (2.58 days)
Using: T=Q/V, we have a Q of: T/V = 356 Lpd (Which was the previous Flowrate)

Since this is similar to the calculated Flowrate, therefore, the design is correct.

Testing with Installed Baffles

As one of the main reasons we suspect the system to not perform at optimum capacity is due to the fact that, it has an extremely short retention time. Meaning that influent wastewater along with the sludge does not retain in the system for long. As such is the case, we have decided to install baffles into the system, hence allowing for longer retention times. The experiments conducted on my part are the following:

Figure 12: Fabricated Baffle

Figure 13: Installed baffle in clarifier unit

Chemical Oxygen Demand (COD)

The COD is a measurement regarding the amount of organic compounds in wastewater. Samples are collected from both the Effluent and Influent portion of the reactor. Later on 7 vials of Potassium Dichromate Solution @ Low Range is prepared on standby. The COD digestor is turned on and set for COD testing, as it will take time for the Digestor to warm up, we leave it as it is for the time being. Out of the 7 vials prepared, 1 vial Is used as a blank vial, meaning that, 2ml of distilled water is pipetted into it. For the remaining 6 vials, they are split into groups of 2 with 3 each, one being the effluent and the other influent. 2ml of Effluent is added into each of 3 vials labelled as effluent 1,2 and 3, and 2 ml of the Influent is added into each vial labelled as the influent. These 7 vials are then shaken vigorously and placed into the warmed up digestor @ 150 degree celcius for 2 hours. Later on they are taken out and placed into a test tube rack and placed into the dessicator to cool them down as the digesting process is exothermic(heat released). Once workable, we will then calibrate the Spectrophotometer to low range COD readings. The Blank vial is placed in first and zeroed to act as a standard for the effluent and influent. The vials for effluent and influent are placed in one by one in the Spectrophotometer and then readings are taken and recorded accordingly.

The results for all sampling days for COD are as follows:

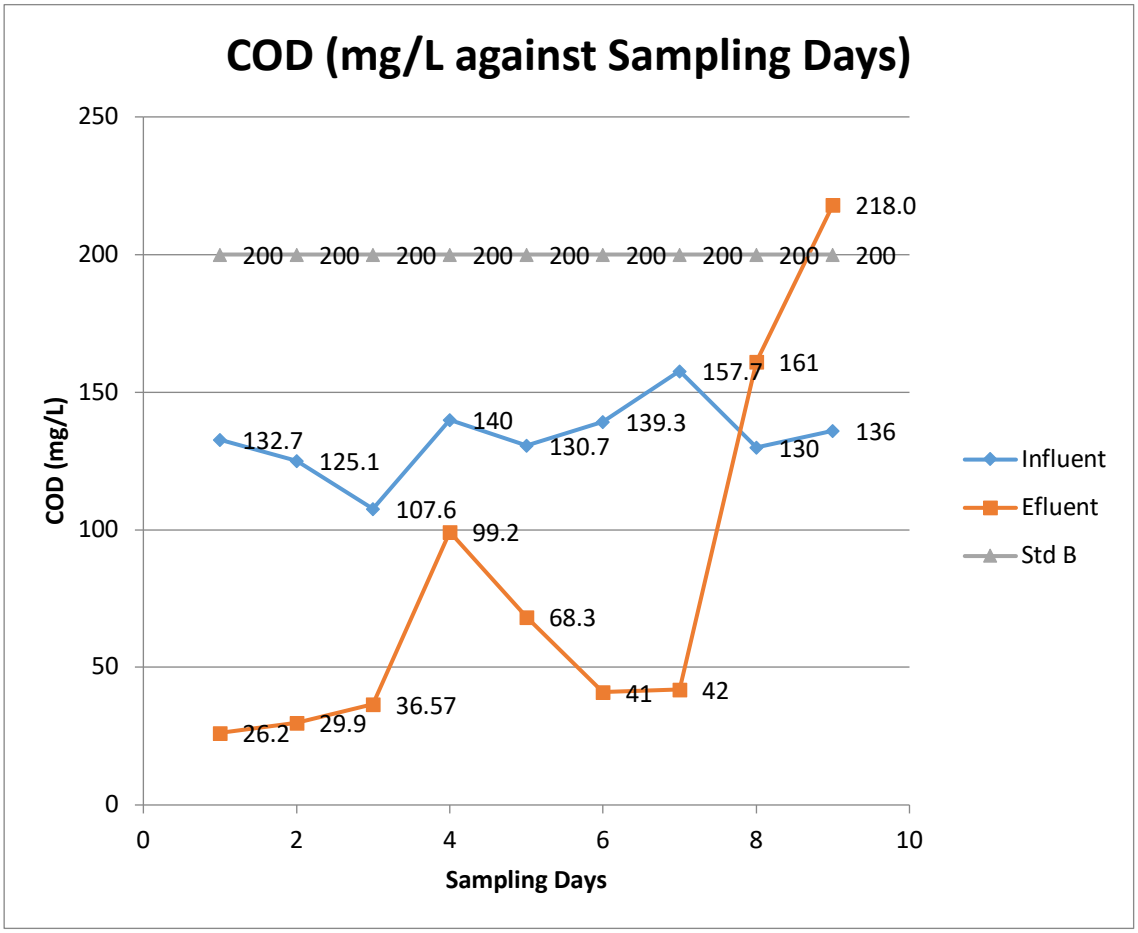

Figure 14: COD (mg/L against Sampling Days) - 1

Sample Testing No.1 - Remarks and Observations regarding the COD experimentation:

1. Experiment began without a hitch, all 3 COD readings manage to achieve the Malaysia DOE standard A effluent discharge.

2. Influent produces a stable reading, constant reading with non-influential changes in the graph.

3. During the 4th testing period, the clarifier seems to have a decent amount of sludge built up in it, for whatever reasons unknown. I took the liberty of sampling the effluent together with sludge in it. After the samples were taken, I took the liberty of cleaning the clarifier up partially, meaning that there is still some sludge in the effluent. The reason as to why there is sludge seems unknown.

4. During the 5th to 6th testing period, I manage to fully clean the clarifier, meaning that it is clear, no traces of sludge seems to be present in the clarifier anymore. It can also be seen that the COD readings have improve to Std A effluent discharge standards.

5 During the duration between the 7th and 9th sampling dates, the RAS pump for our reactor suffered a blow, causing it to not function properly, hence reciprocating the following results on the graph.

6. However, as the system is left alone, the system has accumulated more sludge in the clarifier again. As such, the COD readings have skyrocketed again, due to some sludge discharge in the effluent.

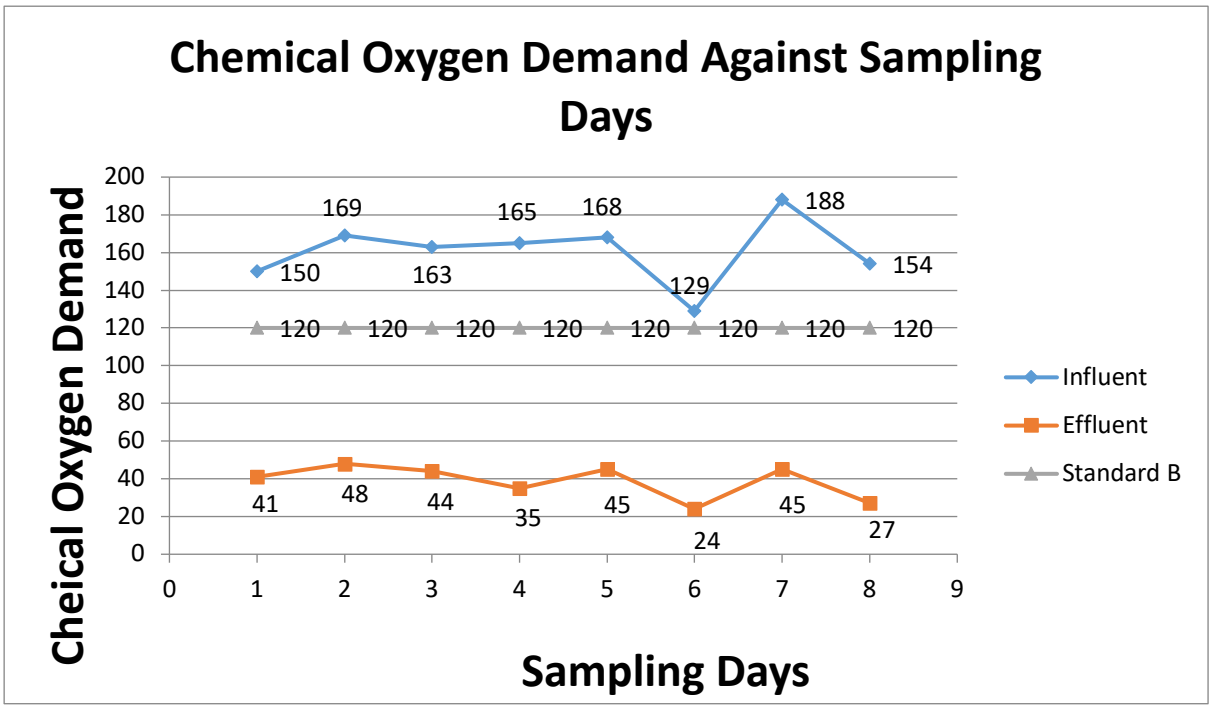

Figure 15: COD (mg/L against Sampling Days) - 2

Sample Testing No.2 - Remarks and Observations regarding the COD experimentation:

1) Took place between **7th November 2016 till 18th November 2016.**

2) A baffle to prevent sludge from exiting via the effluent was installed.

3) The following parameters were switched:

Previous
IR: Every 10 mins (3mins IR)
RAS: Every 15 mins (3 mins RAS)
Current
IR: Every 10 mins (5mins IR)
RAS: Every 16 mins (5 mins RAS)

4) After **sludge was re-added to the system we have left it for about 1 week**, before beginning with experiments again to find the efficiency. This time round, experiments did not begin immediately after sludge was added, but instead was given one week to condition itself.

Total Suspended Solids (TSS)

The total suspended solids is the amount of suspended solids found in the influent and effluent of treatment system.

For this experiment, one day before testing, the required amount of filter papers are prepared by placing them on the filter apparatus and flushing them with distilled water. The suction pump is turned on and the distilled water is filtered out, the filter papers are then placed on the aluminium dishes once again and placed in to the oven @ 105 degree celcius for 24 hours. On the next day, samples are collected for both the influent and effluent to be tested. The aluminium dish and filter papers are then removed from the oven on the next day and weighed using an analytical balance, the readings are the Initial Weight. Later on, we place the filter papers on the filtering apparatus once again. The influent and effluent sample is individually allocated into 2 beakers one for the effluent and one for the influent. As for our experiment, the author has chosen 100ml as the Sample volume. Out of the 6 available filter space available, 3 are used for the influent and the other 3 are used for the effluent. Each filter slot is filled with 100ml of either influent or effluent depending on label provided. The filter is turned on to drain the wastewater samples and once drained. Using deionized water, the filter papers are flushed with deionized water to clean the filtering apparatus as well as to remove unwanted salts from the paper itself. They are then placed again on the aluminium dishes and into the oven for 1 hour @ 105 degree celcius. Once done, they are placed in the desiccator for cooling down for about 20 minutes and then removed for individual weighing. The readings are then taken down as the Final weight.

The results for all sampling days for TSS are as follows:

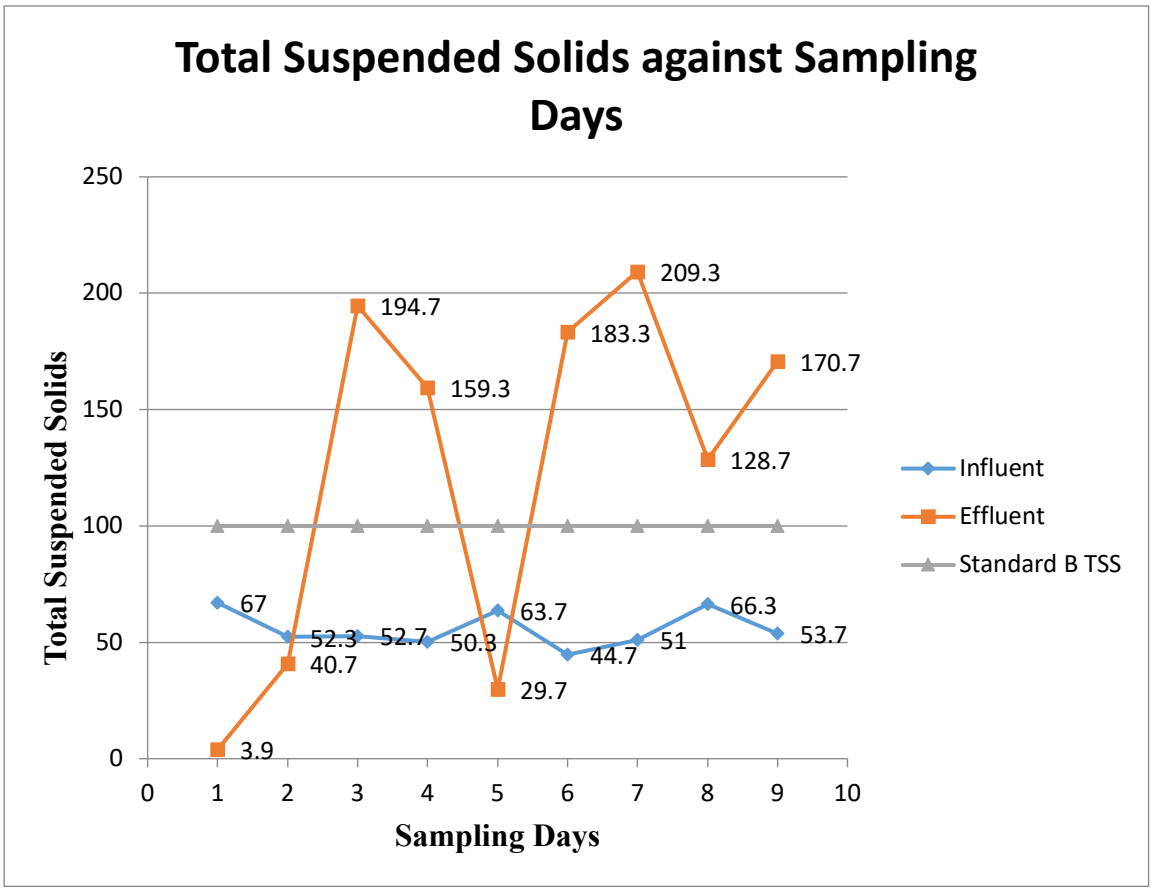

Figure 16: Total Suspended Solids against Sampling Days - 1

Sample Testing No.1 - Remarks and Observations regarding the TSS experimentation:

1. Experimentation began with an extremely clear effluent with a sudden spike and rise in the TSS readings on the 3rd sampling day.

2. During the 4th testing period, the clarifier seems to have a decent amount of sludge built up in it, for whatever reasons unknown. I took the liberty of sampling the effluent together with sludge in it. After the samples were taken, I took the liberty of cleaning the clarifier up partially, meaning that there is still some sludge in the effluent. The reason as to why there is sludge seems unknown. (Similar pattern in COD readings)

3. The readings provided good positive results once the sludge in the clarifier was cleaned and removed.

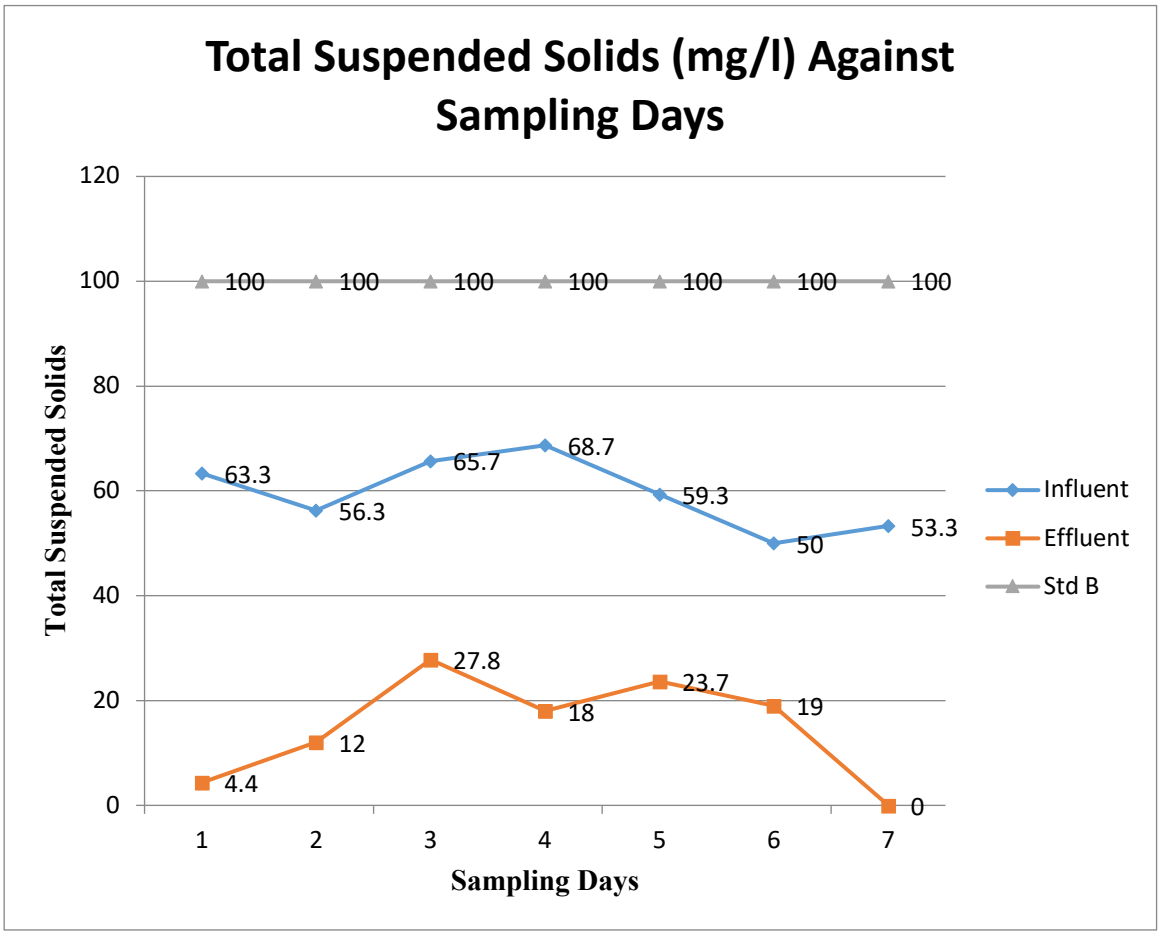

Figure 17: Total Suspended Solids against Sampling Days - 2

Sample Testing No.2 - Remarks and Observations regarding the TSS experimentation:

1) Took place between **7th November 2016 till 18th November 2016**.

2) A baffle to prevent sludge from exiting via the effluent was installed.

3) The following parameters were switched:

Previous
IR: Every 10 mins (3mins IR)
RAS: Every 15 mins (3 mins RAS)
Current
IR: Every 10 mins (5mins IR)
RAS: Every 16 mins (5 mins RAS)

4) After **sludge was re-added to the system we have left it for about 1 week**, before beginning with experiments again to find the efficiency. This time round, experiments did not begin immediately after sludge was added, but instead was given one week to condition itself.

Mixed Liquor Suspended Solids (MLSS)

The MLSS is known as the amount of suspended solids found in the activated sludge. Readings for these parameters are sampled from the aeration tank and the anoxic tank as they are the main components which houses microbes.

The following is used for MLSS design:

MLSS (mg/L) = [SV(1000 mg/g)]/SVI
SVI= sludge volume index (mL/g)
SV= Volume of settled solids per 1 litre

To conduct the experiment all preparation work is done a day before readings are taken, the preparation work in regards are the glass fibre filter papers which require their pores to be opened. On the next day, samples are collected for both the Aeration effluent and Anoxic effluent to be tested. The aluminium dish and filter papers are then removed from the oven on the next day and weighed using an analytical balance, the readings are the Initial Weight. Later on, we place the filter papers on the filtering apparatus once again. The influent and effluent sample is individually allocated into 2 beakers one for the ANX effluent and one for the Aeration Effluent. As for our experiment, the author has chosen 100 ml as the Sample volume. Out of the 6 available filter space available, 3 are used for the effluent and the other 3 are used for the influent. Each filter slot is filled with 100ml of either influent or effluent depending on label provided. The filter is turned on to drain the wastewater samples and once drained. Using deionized water, the filter papers are flushed with deionized water to clean the filtering apparatus as well as to remove unwanted salts from the paper itself. They are then placed again on the aluminium dishes and into the oven for 1 hour @ 105 °**C** Once done, they are placed in the desiccator for cooling down for about 20 minutes and then removed for individual weighing. This experiment is

done continuously with MLVSS as such the samples will be prepared for the next stage of testing.

The readings are then taken down as the Final weight.

The results for all sampling days for MLSS are as follows:

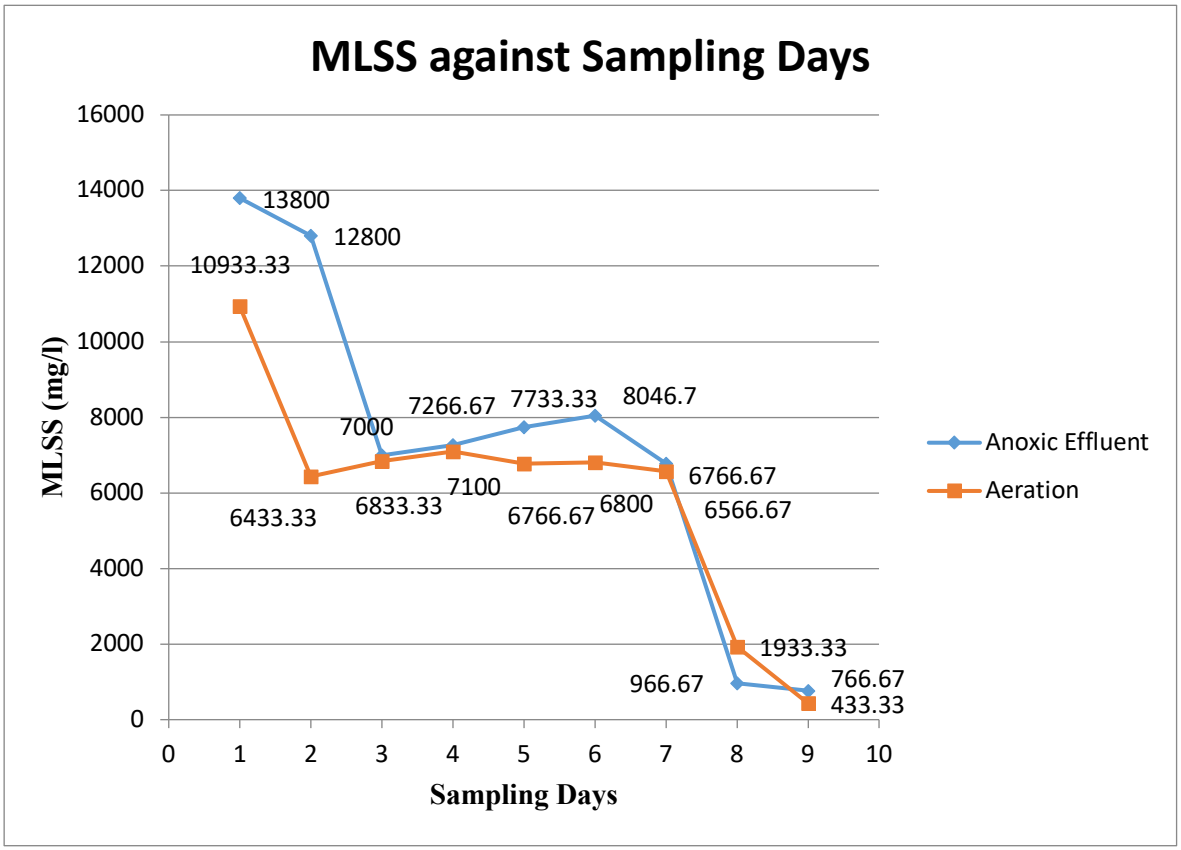

Figure 18: MLSS against Sampling Days

Sample Testing No.1 - Remarks and Observations regarding the MLSS experimentation:

1. Sludge does not seem to be escaping anymore. Readings seem to have stabilized as well.

2. However, unfortunate as it is, the RAS pump showed signs of malfunction, thus causing the results for sampling days 8 to 10 to change drastically.

3. The reason to this is because, the pump suffered a burst or leakage, all the biomass meant to be recycled leaked out of the system, instead of it being recycled.

4. The experiment was halted after those 2 readings, as there is no longer sludge to treat the wastewater.

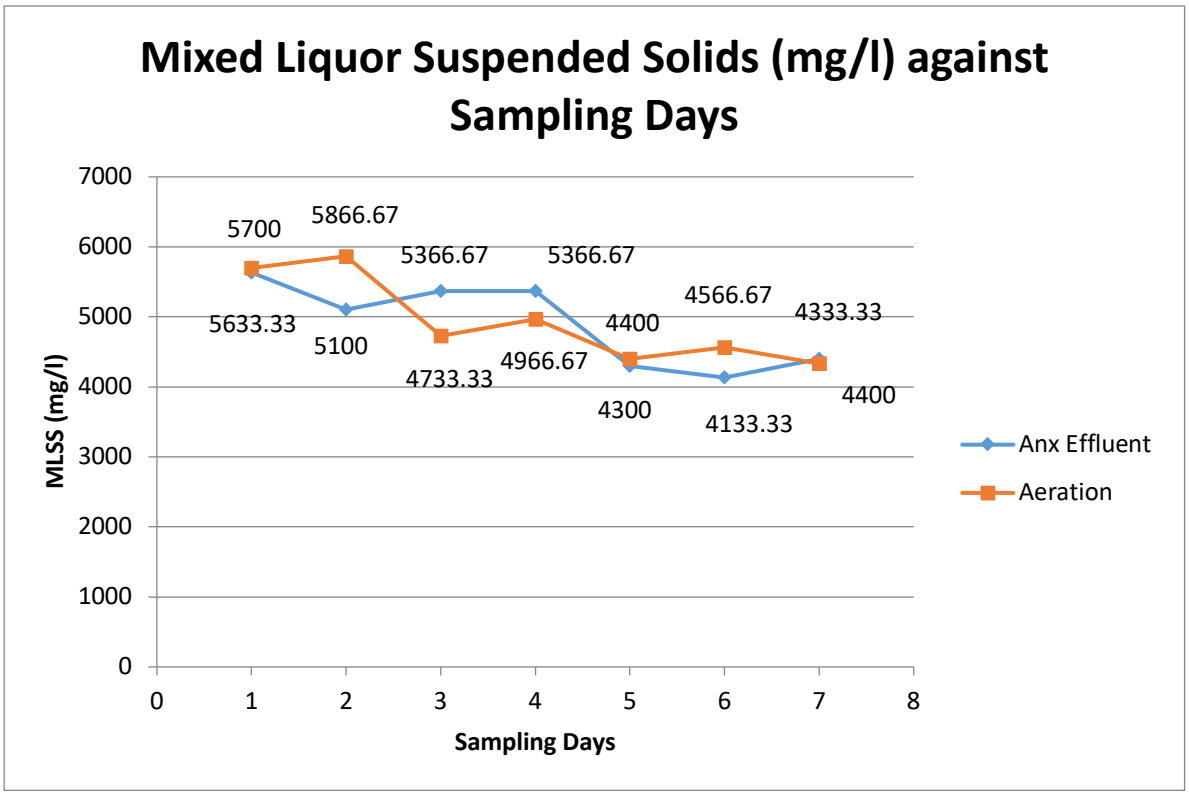

Figure 19: MLSS against Sampling Days

Sample Testing No.2 - Remarks and Observations regarding the MLSS experimentation:

1) Took place between **7th November 2016 till 18th November 2016**.

2) The following parameters were switched:

Previous
IR: Every 10 mins (3mins IR)
RAS: Every 15 mins (3 mins RAS)
Current
IR: Every 10 mins (5mins IR)
RAS: Every 16 mins (5 mins RAS)

3) After **sludge was re-added to the system we have left it for about 1 week**, before beginning with experiments again to find the efficiency. This time round,

experiments did not begin immediately after sludge was added, but instead was given one week to condition itself.

Mixed Liquor Volatile Suspended Solids (MLVSS)

The MLVSS is basically the amount of volatile organic compounds in the suspended solids from MLSS

Continuing with the MLSS experiment, after we have weighed the MLSS, we then place the samples in to the Muffled Furnace at a temperature of 550 degree celcius for about 20 minutes. Once the timer stops, immediately remove the samples with care as the surrounding air will have a rise in temperature as well when the muffled furnace is opened to remove the samples. The samples as per usual, are placed inside the desiccator in order to cool them down to increase handling efficiency. After about 20 minutes they are remove and weighed accordingly to obtain the results of MLVSS. The MLVSS for the experiment can be calculated using the following formula:

The results for all sampling days for MLVSS are as follows:

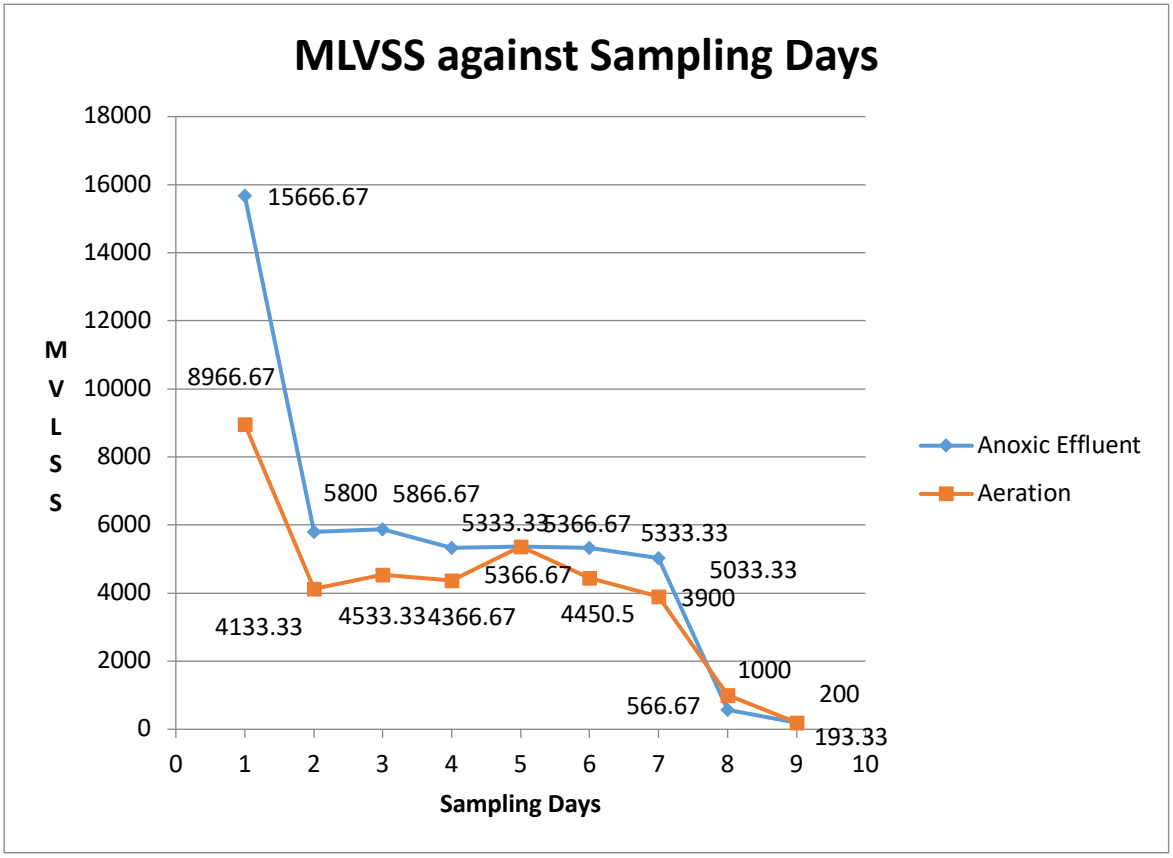

Figure: 20: MLVSS against Sampling Days

Sample Testing No.1 - Remarks and Observations regarding the MLVSS experimentation:

1. Sludge does not seem to be escaping anymore. Readings seem to have stabilized as well
2. However, unfortunate as it is, the RAS pump showed signs of malfunction, thus causing the results for sampling days 8 to 10 to change drastically.
3. The reason to this is because, the pump suffered a burst or leakage, all the biomass meant to be recycled leaked out of the system, instead of it being recycled.
4. The experiment was halted after those 2 readings, as there is no longer sludge to treat the wastewater.

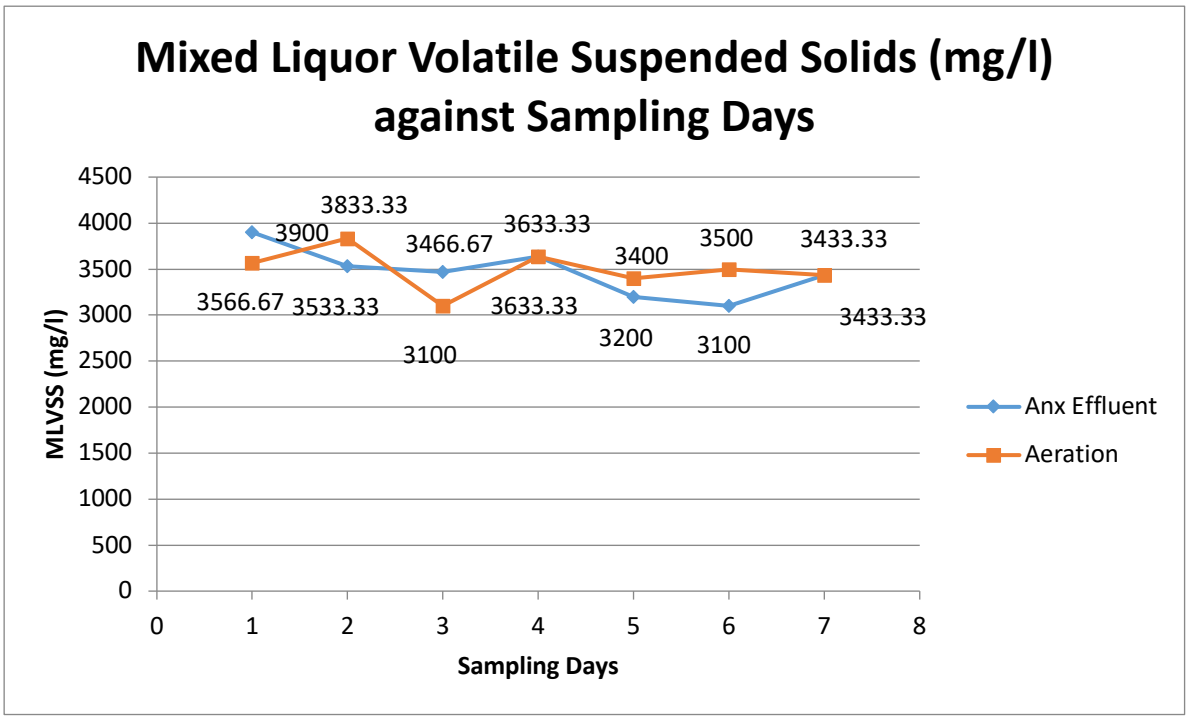

Figure 21: MLVSS against Sampling Days

Sample Testing No.2 - Remarks and Observations regarding the MLVSS experimentation:

1) Took place between **7th November 2016 till 18th November 2016**.

2) The following parameters were switched:

Previous
IR: Every 10 mins (3mins IR)
RAS: Every 15 mins (3 mins RAS)
Current
IR: Every 10 mins (5mins IR)
RAS: Every 16 mins (5 mins RAS)

3) After **sludge was re-added to the system we have left it for about 1 week**, before beginning with experiments again to find the efficiency. This time round, experiments did not begin immediately after sludge was added, but instead was given one week to condition itself.

Chapter 5.0

Conclusions and Recommendations

In conclusion, the integrated submerged suspended growth system project can be beneficial to society since the system can produce a quality effluent. In order for this reactor to be of more benefit to society, the next stage of tests should involve incorporating the design into actual situations whereby we can prove that the system leaves a small amount of carbon footprint during decommissioning or commissioning. Aside from that, since the University's influent COD is rather low, it would be good if we can test the reactor with different quality influent samples.

Recommendations

One particular recommendation for further study for the project could be of an additional treatment for heavy metals removal, looking into integration of natural means of removal using certain types of plants integrated in the existing system. It would further enhance the quality of the effluent wastewater as the existing system has little means in removing heavy metals from the sewage that it is treating. Perhaps an addition of another part is required to treat the metals which will likely be done in the future.

Aside from that, testing with using attached growth process is highly recommended as well to attain different results from the reactor. At present, the reactor uses suspended growth microbes, which is usually used for large area wastewater treatment. However since our treatment system is miniature in size. It is preferred

that we use attached growth for ease of mobility (small area). One last problem we have been facing is the constant bothersome sludge that ends up floating in the clarifier. The recommendation I have submitted to try and curb the problem is by manipulating the Recycled Activated Sludge System so as to obtain various new readings based on the manipulated variables.

Appendix

Design of iSGS

Assumptions:	Value	Unit
1. Number of houses	60	no.
2. Volume of waste generated / capita / day	225	Lpd
3. Number of persons in household	5	no.
4. Medium strength wastewater characteristics for design		

i. Raw Sewage Characteristics Data

Flow rate of an actual sewage treatment plant

$$60\ x\ 5\ x\ 225 = \frac{67500}{1000} = 67.5\ \mathrm{m^3/d}\ \approx\ 70\ \mathrm{m^3/d}$$

Assume 0.33% for Quantity of sewage generated for design of pilot plant

$$Q = 0.33\% * 70 = 0.231\mathrm{m^3/d}$$

Assuming Peak Factor = 1.5

Peak Sewage flow entering the treatment plant, Q = $1.5\ x\ 0.231\ = 0.35\ m^3/d$

Medium strength wastewater characteristics

Characteristics	Value	Unit
BOD	190	g/m^3
sBOD	83	g/m^3
COD	430	g/m^3
sCOD	179	g/m^3
rbCOD	113	g/m^3
TSS	210	g/m^3
VSS	146	g/m^3
TKN	40	g/m^3
NH_4-N	25	g/m^3
Ne (Assumed effluent Ammonia concentration)	0.5	g/m^3
TP	7	g/m^3
Alkalinity	140	as $CaCO_3$
bCOD/BOD ratio	1.6	

ii. Develop the Wastewater Characteristics needed for Design

i. bCOD

$$\boldsymbol{bCOD = 1.6(BOD)}$$

$$= 1.6\,x\,190 = 304\ \text{g/m}^3$$

ii. nbCOD

$$\boldsymbol{nbCOD = COD - bCOD}$$

$$= 430 - 304 = 126\ \text{g/m}^3$$

iii. sCOD effluent

$$\boldsymbol{sCOD\ eff.= sCOD - 1.6sBOD}$$

$$= 179 - (1.6\,x\,83) = 47\text{g/m}^3$$

iv. nbVSS

$$\boldsymbol{nbVSS = \left(1 - \frac{bpCOD}{pCOD}\right) VSS\ whereby\ \frac{bpCOD}{pCOD} = (1.6)\frac{BOD - sBOD}{COD - sCOD}}$$

$$= \left(1 - (1.6)\frac{190-83}{430-179}\right) x\ 146 = 46\text{g/m}^3$$

v. iTSS

iTSS = TSS – VSS

$$= 210 - 146 = 64\ \text{g/m}^3$$

iii. Kinetic Coefficients, DO, MLSS and Temperature for Design

Characteristics	Value	Unit
Y	0.4	g VSS / g bCOD
So	304	bCOD / m^3
Ks	20	g / m^3
SRT	40	Days
fd	0.15	
X_{TSS}	2300	g / m^3
N	0.5	g / m^3
DO	2	g / m^3
Ko	0.5	g / m^3
Yn	0.12	g VSS / g NH4-N
T	28	°C

iv. Determine the specific growth rate for the denitrifying organisms

$$\mu n = \left(\frac{\mu n, mN}{Kn + N}\right)\left(\frac{DO}{Ko + DO}\right) - kdn$$

where:

μ_n = specific growth rate of nitrifying bacteria, g new cells/g cells.d

$\mu_{n,m}$ = maximum specific growth rate of nitrifying bacteria, g new cell/g cell.day

N = nitrogen concentration, g/m^3

K_n = half-velocity constant, substrate concentration at one-half the maximum specific substrate utilization rate, g/m^3

K_o = half-saturation coefficient for DO, g/m^3

kd = endogenous decay coefficient, g VSS/g VSS.d

DO = dissolved oxygen concentration, g/m^3

k_{dn} = endogenous decay coefficient for nitrifying orgaism, g VSS/g VSS.d

i. Find μn,m at T=28 °C

μn,m = $0.75\ x\ (1.07^{(T-20)})$

= $0.75\ x\ \left(1.07^{(28-20)}\right) = 1.289\ g/g.d$

ii. Find Kn at T=28 °C

Kn = $0.74\ x\ (1.053^{(T-20)})$

$= 0.74\ x\ \left(1.053^{(28-20)}\right) = 1.119\ g/m^3$

iii. Find kdn at T=28 °C

kdn = $\mathbf{0.08\ x\ (1.04^{(T-20)})}$

$= 0.08\ x\ \left(1.04^{(28-20)}\right) = 0.110\ g/g.d$

iv. Find kd at T=28 °C

kd = $\mathbf{0.12\ x\ (1.04^{(T-20)})}$

= $0.12\ x\ \left(1.04^{(28-20)}\right) = 0.164\ g/g.d$

v. Find μn

$$\mu n = \left(\frac{\mu n, mN}{Kn + N}\right)\left(\frac{DO}{Ko + DO}\right) - kdn$$

$$= \left(\frac{1.289\ x\ 0.5}{1.119 + 0.5}\right)\left(\frac{2}{0.5 + 2}\right) - 0.110 = 0.209\ g/g.d$$

v. Determine SRT.

Assume design SRT to be according to maximum for extended aeration ASP $=$ $40\ days.$

vi. Determine biomass production.

i. Determine S.

Given that $\mu m = 6g/g.d$

$\mu m, T = \mu m \; x 1.07^{(T-20)}$

$= 6 \; x \; 1.07^{(28-20)} = 10.31 g/g.d$

$$S = \frac{Ks[1 + (kd)SRT]}{SRT(\mu m, T - kd) - 1}$$

$$= \frac{20[1 + (0.164)40]}{40(10.31 - 0.164) - 1} = 0.374 g \; bCOD/m^3$$

ii. Determine NO_x

Assume NOX is 80% of TKN as nitrogen balance cannot be done yet. The error in assuming that the NOX is 80% TKN is small as nitrifier VSS yield is a small fraction of total MLVSS concentration.

$NOx = 0.8(TKN)$

$= 0.8(40) = 34 g/m^3$

iii. Calculate $P_{x,bio}$

$$Px, bio = \frac{QY \; (So - S)}{1 + (kd)SRT} + \frac{(fd)(kd) \; Q \; (Y)(So - S)SRT}{1 + (kd)SRT} + \frac{QYn \; (NOx)}{1 + (kdn)SRT}$$

Part A	Part B	Part C

Part A (Heterotrophic bacteria biomass)

$$= \frac{0.35 \; x \; 0.4 \; (304 - 0.374)}{1 + (0.164)40} = 5.623 \frac{g \; VSS}{d} = 0.00562 \frac{kg \; VSS}{d}$$

Part B (Cell debris)

$$= \frac{(0.15)(0.164)0.35(0.4)(304 - 0.374)40}{1 + (0.164)40} = 5.53 \frac{g \; VSS}{d} = 0.00553 \frac{kg \; VSS}{d}$$

Part C (Nitrifying bacteria biomass)

$$= \frac{0.35 * 0.12(34)}{1 + (0.11)40} = 0.264 \frac{g\ VSS}{d} = 0.00026 \frac{kg\ VSS}{d}$$

Therefore, $P_{x,bio}$

$$= 5.623 + 5.53 + 0.264 = 11.417 \frac{g\ VSS}{d} = 0.0114 \frac{kg\ VSS}{d}$$

vii. Determine the amount of nitrogen oxidized to nitrate.

$$\boldsymbol{NOX = TKN\ influent - Ne - 0.12\ Px,bio\ /\ Q}$$

$$= 40 - 0.5 - \frac{0.12\ x\ 0.0114}{0.35} = 39.5\ g/m^3$$

viii. Determine the concentration and mass of VSS and TSS in aeration basin.

i. Calculate the concentration of VSS and TSS in aeration basin

$$\boldsymbol{Px,vss = Px,bio + Q(nbVSS)}$$

Part D

$$= 0.0114 + 0.35(0.046) = 0.0275\ kg/d$$

$$\boldsymbol{Px,tss = \frac{Px,bio}{0.85} + Q\ (nbVSS)\ + Q(TSSo - VSSo)}$$

Part D Part E

$$= \frac{0.0114}{0.85} + 0.0275 + 0.35(0.064) = 0.05\ kg/d$$

ii. Calculate the mass of VSS and TSS in the aeration basin.

Mass of MLVSS

$$\boldsymbol{(Xvss)(V) = (Px,vss)SRT}$$

$$= (0.0275)40 = 1.1kg$$

Mass of MLSS

$$\boldsymbol{(Xtss)(V) = (Px,tss)SRT}$$

$$= (0.05)40 = 2kg$$

ix. Select a design MLSS mass concentration and determine the aeration tank volume and detention time using the TSS mass computed in previous step.

i. Aeration tank volume

$$\boldsymbol{V(Xtss) = 2kg}$$

At MLSS = 2300 g/m^3

$$V = \frac{2 * 1000}{2300} = 0.87 m^3$$

ii. Detention time

$$\boldsymbol{T = \frac{V}{Q}}$$

$$= \frac{0.87}{0.35} = 2.5\ days = 59.66\ hours$$

iii. Determine MLVSS

Fraction VSS = Mass of MLVSS / Mass of MLSS = 0.53

$$\boldsymbol{MLVSS = (0.53)MLSS}$$

$$= (0.53)2300 = 1219 g/m^3$$

x. Determine F/M and BOD Volumetric loading

i. Determine F/M

$$\boldsymbol{\frac{F}{M} = \frac{QSo}{XV}}$$

$$= \frac{0.35 * 304}{2300 * 0.87} = 0.053 g/g.d$$

The F/M ratio is acceptable as the range is 0.04 – 0.1 g/g.d when medium strength wastewater is used.

ii. Determine L organic

$$\boldsymbol{Lorg = \frac{QSo}{V}}$$

$$= \frac{0.35 * 304}{0.87} = 122.3\ g/m^3 d = 0.122\ kg/m^3 d$$

xi. Determine the observed yield based on TSS and VSS.

$$\boldsymbol{Observed\ yield\ =\ g\ TSS\ /\ g\ bCOD\ =\ kg\ TSS\ /\ kg\ bCOD}$$

$$\boldsymbol{Px,tss = 0.05kg/d}$$

$$\boldsymbol{bCOD\ removed\ =\ Q\ (So - S)}$$

$$= 0.35(304 - 0.374) = 106.\frac{27g}{d} = 0.1063kg/d$$

i. Observed yield based on TSS

$$\boldsymbol{Yobs,TSS\ =\ (2032.4\ kg/d)\ /\ (5009.5\ kg/d)\ =\ (0.41\ kg\ TSS/kg\ bCOD)}$$

$$= \frac{0.05}{0.1063} = 0.470g\ TSS/g\ bCOD$$

$$= 0.47 * 1.6 = 0.753\ g\ TSS/g\ BOD$$

ii. Observed yield based on VSS

$$\boldsymbol{Yobs,VSS = VSS/TSS\ =\ 0.53}$$

$$= \frac{0.05}{0.53} = 0.094\ g\ VSS/g\ bCOD$$

$$= 0.094 * 1.6 = 0.151\ g\frac{VSS}{g}BOD$$

xii. Calculate the O2 demand.

$$\boldsymbol{Ro\ =\ Q\ (So\ -\ S)\ -\ 1.42\ Px,bio\ +\ 4.33Q\ (NOx)}$$

$$= 0.35(304 - 0.374) - 1.42 * 0.0114 + 4.33 * 0.35 * 39.5 = \frac{166.12g}{d} = \frac{0.166kg}{d} = \frac{0.0069kg}{hr}$$

xiii. Check alkalinity in the aerobic system.

i. Prepare an alkalinity balance

Alkalinity to maintain pH - 7 = Influent Alk - Alk used + Alk to be added

Characteristics	Value	Unit
Influent Alkalinity	140	g/m^3 as $CaCO_3$
Amount of nitrogen to be converted to nitrate, NO_X	39.5	g/m^3
Alkalinity used for nitrification	$7.14 * 39.5 = 282.03$	g/m^3 used as $CaCO_3$

ii. Substitute known values and solve for alkalinity needed

Residual alkalinity concentration needed to maintain pH in range 6.8-7.0 is 70 to 80 g/m3 as $CaCO^3$.

Hence,

$$Alkalinity\ to\ be\ Added\ = 282.03 - 140 + 80 = 222.03 g/m^3$$

$$= 222.03 * \frac{0.35}{1000} = 0.0777 kg/d\ as\ CaCO^3 = 77.7 g/d\ as\ CaCO^3$$

iii. Determine the alkalinity needed as sodium bicarbonate

Equivalent weight of $CaCO^3$ = 50g / equivalent

Equivalent weight of $Na(HCO^3)$ = 84g / equivalent

Hence,

$$Na(HCO3)needed\ = \frac{223.03 * 84}{50} = 374.7\ g/d\ Na(HCO^3)$$

xiv. Estimate effluent BOD.

Assume $sBODe = 3g/m^3$ and $TSSe = 10g/m^3$

$$\boldsymbol{BOD = sBODe + \frac{g\ BOD}{1.42 g\ VSS} * \frac{0.85 g\ VSS}{g\ TSS}(TSS, g/m^3)}$$

$$= 3 + \frac{1}{1.42} * 0.85 * 10 = 9 g/m^3$$

$$\boldsymbol{Removal\ Efficiency}, \% = \frac{190-9}{190} * 100\% = 95.3\%$$

xv. Secondary Clarifier design for both BOD removal and Nitrification.

i. Define return sludge recycle ratio

$$\boldsymbol{Qr + Xr = (Q + Qr)X \quad assuming\ waste\ sludge\ mass\ is\ insignificant}$$

Qr = RAS flowrate

Xr = return sludge mass concentration

R = RAS recycle ratio = Qr / Q

$$\boldsymbol{R = X/(Xr - X)}$$

ii. Determine size of clarifier

Assume, Xr = 7000 g/m3

$$R = \frac{2300}{7000 - 2300} = 0.49$$

Assume a hydraulic application rate of 24m^3/m^2.d. HAR ranges from 24 to 32 m^3/m^2.d.

$$A = \frac{Q}{HAR} = \frac{0.35}{24} = 0.0146m^2$$

Use only 1 clarifier unit.

$$Diameter\ of\ clarifier = \sqrt{\frac{0.0146}{3.142}} = 0.068m = 6.82cm$$

$$Radius\ of\ clarifier = \frac{6.82}{2} = 3.4cm$$

Using the above area and dimensions for the clarifier, the solid loading value will be in the unacceptable range. Therefore, a higher A of clarifier is used.

$$\boldsymbol{Area\ of\ clarifier\ as\ per\ constructed = 0.8546m^2}$$

$$Diameter\ of\ clarifier = \sqrt{\frac{0.8546}{3.142}} = 0.5215m = 52.15cm$$

$$Radius\ of\ clarifier = \frac{52.15}{2} = 26.08cm$$

iii. Check solids loading

$$\boldsymbol{Solids\ Loading = \frac{kg\ TSS\ applied}{m^2\ clarifier\ area * H} = \frac{(1+R)Q(MLSS)}{A}}$$

$$= \frac{(1 + 0.49)(0.35)(2300)}{0.8546} = 0.0585\ kg\ MLSS/m^2.h$$

iv. Determine flow rate and time required to pump return sludge

$$\boldsymbol{R = \frac{Qr}{Q}\ [Assuming\ Xr = 7000g/m^3}$$

$$\boldsymbol{R = 0.49}$$

$$\boldsymbol{Qr = QR}$$

$= 0.35 \times 0.49 = 0.172 m^3/d$

$$\boldsymbol{Qw} = \frac{\boldsymbol{Vaeration}}{\boldsymbol{SRT}}$$

$$= \frac{0.87}{40} = 0.0218 m^3/d$$

$$\boldsymbol{Qr} + \boldsymbol{Qw} = 0.172 + 0.0218 = 0.194 m^3/d$$

$$\boldsymbol{RAS\ to\ be\ recycled} = 0.194 m^3/d \times 7000 g/m^3 = 1.358\ kg/d$$

$$\boldsymbol{Capacity\ of\ pump} = 43.2 m^3/d \times 7000 g/m^3 = 302.4\ kg/d$$

$$\boldsymbol{In\ 1\ day, the\ pump\ needs\ to\ be\ turned\ on\ for} = \frac{1.358 kg}{302.4 \frac{kg}{d}}$$

$$= 0.004491\ days = 0.1078\ hours = 6.5\ minutes$$

$$= 388\ seconds$$

Design Summary

Design Parameter	**Value**	**Unit**
Average wastewater flow	0.35	m^3/d
Average BOD load	66.5	g/d
Average TKN load	14	g/d
SRT	40	d
Aeration volume	0.87	m^3
MLSS	2300	g/ m^3
MLVSS	1219	g/ m^3
F/M	0.053	g/ g.d
BOD loading	0.038	kg BOD/ m^3.d
Sludge production	0.05	kg/d
Observed yield	0.47	g TSS/ g bCOD
	0.151	g VSS/ g BOD
Oxygen required	0.0069	kg/ h
RAS ratio	0.49	unitless
Clarifier HAR	24	m^3/ m^2.d
Alkalinity addition as NA(HCO_3)	0.375	kg/d
Effluent BOD	9	g/ m^3
TSSe	10	g/ m^3
Effluent NH_4-N	0.5	g/ m^3

Denitrification

1. **Raw Sewage Characteristics Data**

Characteristics	Value	Unit
Q	0.35	m^3/d
BOD	190	g/m^3
bCOD	304	g/m^3
rbCOD	113	g/m^3
NOx	39.5	g/m^3
Ne (Assumed NO_3-N concentration in RAS)	4	g/m^3
TP	7	g/m^3
Alkalinity	140	as $CaCO_3$
Residual Alkalinity	80	as $CaCO_3$

2. **Design Condition**

Characteristics	Value	Unit
Influent flowrate	0.35	m^3/day
Temperature	28	°C
MLSS	2300	g/m^3
MLVSS	1219	g/m^3
Aerobic SRT	40	d
Aeration basin volume	0.89	m^3
Mixing energy	10	kW/10^3 m^3
RAS ratio	0.49	Unitless
R_o	0.0069	kg/h

3. **Determine the active biomass concentration.**

Note: Substitute V/Q for τ

$$\boldsymbol{Xb} = (\frac{\boldsymbol{Q} * \boldsymbol{SRT}}{\boldsymbol{V}})(\frac{\boldsymbol{Y} * (\boldsymbol{So} - \boldsymbol{S})}{\boldsymbol{1} + \boldsymbol{kd} * \boldsymbol{SRT}})$$

$$= \left(\frac{0.35 * 40}{0.89}\right)\left(\frac{0.4 * (304 - 0.374)}{1 + 0.16 * 40}\right) = 248.87 g/m^3$$

4. **Determine the IR ratio due to Aerobic tank.**

$\boldsymbol{Aerobic\ tank\ NO3-N\ concentration, Ne = 4g/m^3}$

$\boldsymbol{IR = \frac{NOx}{Ne} - 1 - R}$

$= \frac{39.5}{4} - 1 - 0.49 = 8.4 \approx 9$

5. **Determine the amount of NO3-N fed to the anoxic tank from Aeration tank.**

$\boldsymbol{Flow\ rate\ to\ anoxic\ tank\ = IR * Q + R * Q}$

$= 9 * 0.35 + 0.49 * 0.35 = 3.3$

$\boldsymbol{NOX\ feed = Q\ to\ anoxic\ tank * Ne}$

$= 3.3 * 4 = 13.2 g/d$

6. **Determine the anoxic volume.**

$\boldsymbol{Detention\ time = 8hrs}$

$= 8/24 = 0.33$

$\boldsymbol{Vanoxic = 0.33 * Q}$

$= 0.33 * 0.35 = 0.1167 m^3$

Provide 55 liters for denitrification.

7. **Determine Food to microorganisms' ratio (F/Mb).**

$\boldsymbol{\frac{F}{Mb} = (\frac{QSo}{Vnox * Xb})}$

$= \left(\frac{0.35 * 190}{0.055 * 248.87}\right) = 4.86 g/g.d$

8. **Determine the SNDR using the curve with an F/Mb range of 0 to 4.**

$\boldsymbol{Fraction\ rbCOD = \frac{rbCOD}{bCOD} = \left(350\frac{g}{m^3}\right)\left(960\frac{g}{m^3}\right) = 0.37\%}$

$\boldsymbol{From\ Figure\ 8-23, \quad SDNRb = 0.35\ g/g.d\ at\ 20℃}$

$\boldsymbol{SNDR28 = 0.35\ (1.026)^{28-20} = 0.43\ g/g.d\ at\ 28℃}$

9. **Determine the amount of NO_3-N that can be reduced.**

$\boldsymbol{NOr = (Vnox)\ (SDNR)\ (MLVSS, biomass)}$

$= 0.1167(0.43)(248.87) = 12.5 g/d$

10. Determine the Oxygen saving and net oxygen for Nitrification.

$$\boldsymbol{Ro\ (without\ denitrification) = 0.0069\ kg/h}$$

$$Oxygen\ credit\ = \left(\frac{2.86\ O2}{g\ NO3-N}\right)\left(\frac{[112.1\ -\ 6.0]g}{m^3}\right)\left(\frac{0.045m^3}{d}\right)\left(\frac{1kg}{10^3 g}\right) = 0.0352kg/d$$
$$= 0.0015kg/hr$$

$$Net\ Oxygen\ Required = 0.0069 - 0.0015 = 0.0054\ kg/hr$$

Note: The required aeration rate will decrease in proposrtion to a lower Ro. The oxygen required can be reduced by 20 percent.

11. Check alkalinity.

i. Prepare an alkalinity balance

Alkalinity to maintain pH - 7 = Influent Alk - Alk used + Alk to be added

Characteristics		Value	Unit
i.	**Influent Alkalinity**	440	g/m^3 as $CaCO_3$
ii.	**Alkalinity used**	$7.14 * 39.5 = 282.03$	g/m^3 used as $CaCO_3$
iii.	**Alkalinity produced**	$3.57 * (39.5 - 4)$ $= 126.74$	g/m^3 used as $CaCO_3$
iv.	**Alkalinity needed to maintain neutral pH**	80	g/m^3 used as $CaCO_3$

ii. Solve the above equation for alkalinity to be added

$$Alkalinity\ to\ be\ added = (iv\ -\ i\ +\ ii\ -\ iii)above$$
$$= 80 - 440 + 282.03 - 126.74$$
$$= -204.71\ g/m^3\ (excess\ alkalinity)$$

$$Mass\ of\ alkalinity\ needed = \frac{-204.71 * 0.35}{1000} = -0.0717\ kg/d\ \text{as CaCO3.}$$

iii. Compare to alkalinity needed for nitrification

For the nitrification only design, the alkalinity needed was 0.0777kg/d as $CaCO_3$.

$$Alkalinity\ savings = 0.0777 - (-0.0717) = 0.149\ kg/d$$

Sampling Dates and Raw Results

Chemical Oxygen Demand

Sampling Run No.1 :

Date	Influent Avg (COD mg/L)	Effluent Avg (COD mg/L
12th Oct 2016	132.7	26.2
14th Oct 2016	125.1	29.9
16th Cct 2016	107.6	66.9
18th Oct 2016	140.0	99.0
20th Oct 2016	130.7	68.3
22nd Oct 2016	139.3	41.3
24th Oct 2016	157.7	42.3
26th Oct 2016	130.0	161.7
28th Oct 2016	136.0	218.0

Table 1: Average COD readings for Samplig Run No.1

Sampling Run No. 2:

Date	Influent Avg (COD mg/L)	Effluent Avg (COD mg/L
7th Nov 2016	150.3	41.3
9th Nov 2016	169	58.3
11th Nov 2016	136	44.6
13th Nov 2016	159.6	35
15th Nov 2016	168.6	45.3
17th Nov 2016	129.0	24.3
19th Nov 2016	188.67	45.6
21st Nov 2016	154.3	41..3
23rd Nov 2016	170.3	48.3
25th Nov 2016	168.6	57.3
27th Nov 2016	161.3	53
29th Nov 2016	157.3	53.6

Table 2: Average COD readings for Sampling Run No.2

Total Suspended Solids

Sampling Run No.1 :

Date	Influent TSS Avg (mg/L)	Effluent TSS Avg (mg/L)
12th Oct 2016	67	3.9
14th Oct 2016	52.3	40.7
16th Cct 2016	52.7	194.7
18th Oct 2016	50.3	159.3
20th Oct 2016	63.7	29.7
22nd Oct 2016	44.7	183.3
24th Oct 2016	51.0	209.3
26th Oct 2016	66.3	128.7
28th Oct 2016	53.7	170.7

Table 3: Average TSS readings for Sampling Run No.1

Sampling Run No. 2:

Date	Influent TSS Avg (mg/L)	Effluent TSS Avg (mg/L)
7th Nov 2016	63.3	4.4
9th Nov 2016	56.3	12.0
11th Nov 2016	65.7	27.8
13th Nov 2016	68.7	18.0
15th Nov 2016	59.3	23.7
17th Nov 2016	50.0	19.0
19th Nov 2016	53.3	12.3
21st Nov 2016	63.0	24.0
23rd Nov 2016	50.7	12.7
25th Nov 2016	52.0	13.7
27th Nov 2016	64.3	10.0

Table 4: Average TSS readings for Sampling Run No.2

Mixed Liquor Suspended Solids

Sampling Run No.1 :

Date	Anx Eff MLSS (mg/L)	Aeration MLSS (mg/L)
12th Oct 2016	13800.00	10933.33
14th Oct 2016	12800.00	6433.33
16th Cct 2016	7000.00	6833.33
18th Oct 2016	7266.67	7100.00
20th Oct 2016	7733.33	6766.67
22nd Oct 2016	8046.67	6800.00
24th Oct 2016	6766.67	6566.67
26th Oct 2016	966.67	1933.33
28th Oct 2016	766.67	433.33

Table 5: Average MLSS readings for Sampling Run No.1

Sampling Run No. 2:

Date	Anx Eff MLSS (mg/L)	Aeration MLSS (mg/L)
7th Nov 2016	5633.3	5700.0
9th Nov 2016	5100.0	5866.6
11th Nov 2016	5366.67	4733.3
13th Nov 2016	5366.67	4966.67
15th Nov 2016	4300.0	4400.00
17th Nov 2016	4133.3	4566.6
19th Nov 2016	4400.0	4333.3
21st Nov 2016	4266.67	4566.67
23rd Nov 2016	4600.0	4466.67
25th Nov 2016	4066.6	4633.33
27th Nov 2016	4866.6	4500.00

Table 6: Average MLSS readings for Sampling Run No. 2

Mixed Liquor Volatile Suspended Solids

Sampling Run No.1 :

Date	Anx Eff MLVSS (mg/L)	Aeration MLVSS (mg/L)
12th Oct 2016	15666.67	8966.67
14th Oct 2016	5800.00	4133.33
16th Cct 2016	5866.67	4533.33
18th Oct 2016	5333.33	4366.67
20th Oct 2016	5366.67	4800.00
22nd Oct 2016	5333.33	4450.00
24th Oct 2016	5033.33	3900.00
26th Oct 2016	566.67	1000.00
28th Oct 2016	193.33	200.00

Table 7: Average MLVSS readings for Sampling Run No.1

Sampling Run No. 2:

Date	Anx Eff MLVSS (mg/L)	Aeration MLVSS (mg/L)
7th Nov 2016	3900.0	3566.67
9th Nov 2016	3533.33	3833.33
11th Nov 2016	3466.67	3100.00
13th Nov 2016	3633.33	3633.33
15th Nov 2016	3200.00	3400.00
17th Nov 2016	3100.00	3500.00
19th Nov 2016	3433.33	3433.33
21st Nov 2016	3133.33	3500.00
23rd Nov 2016	3400.00	2166.67
25th Nov 2016	3433.33	3500.00
27th Nov 2016	3933.33	3433.33

Table 8: Average MLVSS readings for Sampling Run No.2

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