TAMPERE UNIVERSITY OF APPLIED SCIENCES
Environmental Engineering

Final Thesis

Daniele Pennese

# A GUIDE FOR BUILDING, OPERATING, CONTROLLING AND MAINTAINING A COMPLETE MIX ACTIVATED SLUDGE PILOT REACTOR

Supervisor Head of the Degree Programme Marjukka Dyer
Commissioned by Prof. Raghida Lepistö, Tampere University of Technology, Institute of Environmental Engineering & Biotechnology

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## ABSTRACT

The aim of this bachelor thesis is to familiarize the reader with a complete mix activated sludge pilot reactor. It is by no means comprehensive and should thus work only as a starting point. However, by reading this "guide" the reader would be able to build, operate, control, and maintain an activate sludge pilot reactor, which could be used for different studies.

Some parameters for the operation of the pilot have been set according to its dimensions. As a consequence the pilot should be built as described in this paper. These particular parameters are thus not described in detail because they require a considerable amount of study.

The pilot has been used for a study, which is not covered in this paper due to a confidentiality agreement. Thus no results will be showed, only few examples whenever possible.

TAMPERE UNIVERSITY OF APPLIED SCIENCES
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Daniele Pennese

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# TIIVISTELMÄ

Tämän tutkintotyön tarkoituksena on selvittää lukijalle täyssekoitteisen aktiivilieteperiaatteeseen perustuvan koelaitteen toimintaa, sen periaatteita ja siihen liittyviä käytänteitä. Havainnot perustuvat työn tekijän omiin kokemuksiin, eikä suinkaan pyri olemaan täydellinen käyttöopas eikä avain reaktorin toimintaan. Kuitenkin kirjattujen havaintojen avulla vastaavaa laite voidaan rakentaa ja käyttää, sen toimintaa voidaan säädellä ja ylläpitää sen toimintaa erilaisia tutkimuksia varten

Muutamat reaktorin asetuksista ovat riippuvaisia sen mittasuhteista, joten oppaan ohjeita voidaan soveltaa sellaisenaan vain tähän reaktorityyppiin. Tarvittavat asetukset on esitelty oheisessa selvityksessä, mutta sen puitteissa ei ollut mahdollista kehittää yksityiskohtaisia laskukaavoja.

Käsittelemäni reaktori on ollut osana tutkimusta, jota ei voida esitellä tässä työssä luottamuksellisista syistä. Reaktorin toimintaa kuvataan esimerkein, mutta edellä mainitun tutkimuksen tuloksia ei kuvata tässä julkisessa työnosassa.

# FOREWORD

I would like to thank my supervisor during my laboratory work Raghida Lepistö for the opportunity she gave me to work in a wonderful laboratory environment filled with helpful as well as friendly people, for her full support given throughout my training period (and after) even though she was really busy with other projects as well.

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Tampere, April 2008

Daniele Pennese

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AFS | Ammonium Ferrous Sulfate |
| ASP | Activated sludge process |
| ANOXIC | Denitrification tank |
| BNR | Biological Nutrient Removal |
| CMAS | Complete-mix activated-sludge |
| COD | Chemical Oxygen Demand |
| CSO | Combined Sewer Overflow |
| F/M | Food to Microbe ratio |
| MLSS | Mixed-Liquor Suspended Solids |
| MLVSS | Mixed-Liquor Volatile Suspended Solids |
| OUR | Oxygen Uptake Rate |
| OXIC | Oxygen tank |
| SA | Sulfuric Acid |
| SETTLER | Settling tank |
| SRT | Solid Retention Time |
| TDML | Total Maximum Daily Load |
| TKN | Total Kjeldahl Nitrogen |
| TS | Total Solids |
| TSS | Total Suspended Solids |
| VSS | Volatile Suspended Solids |

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# 1. INTRODUCTION

The idea for this bachelor thesis topic came as a consequence of a training period of about 10 months at the University of Technology in Hervanta (Tampere) under the supervision of Professor Raghida Lepistö.

This thesis should ideally work as some kind of “guide” on how to build, control, and maintain an activated sludge wastewater pilot reactor but it is by no means comprehensive. The aim is firstly be able to stabilize the pilot plant for few days while recording important factors such as chemical oxygen demand, nitrogen content, pH, temperature etc. and then to use the stabilized pilot to study eventual disruption the introduction of an alien compound could do to the biota, color, odor etc. The tests needed and the ideal conditions to stabilize the reactor are explained in detail in the following chapters.

Only few factors are needed to be able to stabilize the reactor so many tests have not been carried out for this particular purpose. The student or whoever is going to use this guide has of course freedom to run any kind of test deemed necessary for his or her particular study.

For example the metallic constituents present in the pilot have not been analyzed because they were not needed. Also the biota present inside the pilot was not observed under the microscope even though it could have been a huge help in preventing some bad situation to occur. The approach has been more “down to earth” so to speak.

A general background chapter is included at the beginning of this thesis even though it is not strictly needed. What this work is concerned mostly about is the work done with the activated sludge pilot reactor so most information found here is about that. Every section includes a discussion whenever possible. In the end there are also some additional notes.

# 2. BACKGROUND

We as humans produce all sort of waste, one of it is the liquid waste referred to as wastewater, which is a mix of water wastes from residences, industrial establishments together with storm waters, ground water and surface water in combined treatment systems. /7/

Untreated wastewater not only produces smelly gasses (a serious environmental concern) but also is full of unwanted substances which are usually dangerous for human health and for the environment as a whole. For example pathogenic microorganisms, nutrients which will cause unwanted growth of aquatic plants, and even mutagenic or carcinogenic substances just to name but a few. /7/

It is evident that wastewater should thus be treated as much as possible before being released back to the environment or reused when the supply of fresh water is inadequate to meet the needs of the population for agricultural purposes and/or non potable uses. /7/

*United States*

From the 70's wastewater treatment was focused mainly on the removal of floatable material, biodegradable organics, and pathogenic organisms. Followed later on, during the 80's, with the removal of nutrients like nitrogen and phosphorous. These improvements and demands were an answer to the growing concern and knowledge about the environment during that period. /7/

During the 90's the use and disposal of biosolids started to be regulated. Biosolids are organic semisolid wastewater products biologically and chemically inert used for various purposes, like for example agriculture. This is a way to limit the dumping of wastewater solid waste into already crowded landfills or their incineration, which is rarely seen as a good thing by local public and as a consequence has to meet stricter regulations every year. /7/

In 2000 a regulation called TDML (Total Maximum Daily Load) started to be promulgated. It concerns the maximum acceptable pollutant load that a body of water can sustain and still meet water quality standards. /7/

*Finland*

Waste water in Finland has to be biologically treated and the minimum requirements at present are 70% BOD, 75% COD, and 90% total suspended solids (TSS). Phosphorus and recently also nitrogen have to be removed and the minimum requirements are 80% for total phosphorus and 70% for total nitrogen (organic nitrogen + $NH_4$, nitrate, nitrite). These requirements can be changed at any time by the Environmental Protection Act if required. These regulations came into force in Finland in 2006 and replace the ones issued in 1994 by the Finnish government. /4/

Lots of new constituents are discovered inside treated and untreated wastewater every year. What previously was undetected and thus untreated because of insufficient advances in technology might be a concern nowadays and in the near future. Lots of wastewater treatment plants are not able to deal promptly with these new unwanted compounds discovered and/or released into the sewer system. /7/

That is why it is important that wastewater discharged from the industry, for example, goes through a pretreatment before reaching the treatment plant, not to mention that new or existing compounds, which cannot be treated with the present technology should not be used altogether. /7/

## 2.1. DIFFERENT ACTIVATED SLUDGE PROCESSES

This paper is mainly focused on one type of biological treatment, namely activated sludge process (ASP), which is targeted at the removal of biodegradable organic constituents and nutrients. However, generally speaking, wastewater treatment process is divided into primary, secondary, and sometimes tertiary phases. Advanced treatment techniques are included into every phase if required by regulations and if the treatment plant is equipped with the additional equipments needed. /7/

At the beginning there is a preliminary phase where the largest solid waste is mechanically removed, like for example plastic bags and such, which could damage the equipment. /7/

During the primary phase non dissolved organic matter and floatable or settleable materials are removed, in this phase chemicals are sometimes used to enhance the solid removals and to some extent even some dissolved solids. In the secondary phase the organic matter and nutrients like nitrogen and phosphorus are to most extent removed with the help of additional processes and/or operations. At this point it is worth mentioning that BNR (biological nutrient removal) is getting nowadays more common in conventional treatments. /7/

Finally, during the tertiary phase, the remaining suspended solids are removed. The disinfectants are added now if this phase is present otherwise they are usually added after the second phase. The tertiary phase has become more common in recent years while until the 80s only the secondary treatment was used to remove organic and solid suspended waste. /7/

As already mentioned biological treatment processes are focused on the removal of nutrients such as nitrogen and phosphorus as well as the oxidation of biodegradable constituents into harmless byproducts and the formation of flocks of non settleable colloidal matter. This is achieved by use of microbes (bacteria and protozoa) and the basic principle is presented in the following formula: /2/ /7/

$$organic\ matter + O_2 + NH_3 + PO_4^{3-} \xrightarrow{Bacteria} new\ cells + CO_2 + H_2O$$

Oxygen, ammonia and phosphate are needed by the microbes to convert organic material into carbon dioxide and water; biomass is also produced in the form of new cells.
Nitrogen removal is achieved mainly by two kinds of bacteria, one takes care of the nitrification of ammonia to nitrite and then to nitrate while another one converts it to a gaseous form in the absence of oxygen (denitrification). /7/

Most often the bacteria present in the activated sludge process are *Pseudomonas, Zoogloea, Achromobacter, Flavobacterium, Nocardia* (responsible for the formation of foam on ASP tanks), *Bdellovibrio, Mycobacterium, Nitrosomonas,* and *Nitrobacter.* These bacteria belong to the Gram negative species. /2/

The protozoa present in waste water (more than 200 species found and observed) do not actually have anything to do with the waste water as such. They control the bacteria population since they feed on them. The ratio between the amount of bacteria and protozoa in waste water depends on its nature. However a healthy protozoa population in waste water is attributed to good treatment plant operation since they are very susceptible to toxins. /2/

These biological treatments are divided into suspended-growth and attached-growth processes. Activated sludge is a suspended-growth process where the microbes are maintained in liquid suspension with the use of mixing methods. This method has been developed around the 1914 in England /2/ /7/

In municipal wastewater there are usually enough nutrients for the microbes to utilize but in the case of certain industrial wastewaters sometimes the nutrients have to be added in order for the bacteria to perform efficiently. /7/

## 2.2. CONTROL, MAINTENANCE AND PROBLEMS

There are many concerns when talking about maintenance and the biggest one is probably the renewal of aging infrastructures, from the collecting sewers to the treatment plants themselves. /7/

As already mentioned before, the introduction of new constituents in the influent wastewater needs to be addressed continuously and the treatments need to be updated to deal with these new treats in an efficient as well as in a reliable way, not to mention new stricter requirements that might come every now and then, which have to be followed. /7/

All this comes at a cost which is usually paid by local tax payers, that's why the best possible technology is usually used to be able to waste energy as little as possible. A huge amount of electricity, typically one-half of the entire plant, is used for aeration purposes in biological treatments for instance. So energy efficient equipments plus energy recovery to be used in-plant are carefully considered when designing a treatment plant. /7/

The disinfectant used during the second or the tertiary phase of the wastewater treatment is usually chlorine based, such as $ClO_2$ (chlorine dioxide) but lately the use of ultraviolet radiation and membrane filtration for disinfection purposes have been implemented. This ultraviolet technology is improving every year and it seems to be reliable and effective not to mention the fact that it does not create byproducts which will have to be treated. Basically the radiation damages the microorganisms' DNA or RNA so they will not be able to replicate. The problem is that the method is still too expensive for the treatment of large quantity of waste water. Also ozone and in some cases acids and alkalies are used since low and high pH are very toxic to most bacteria. /2/ /3/ /7/

Chlorine disinfected waste water, however, needs to be treated and dechlorination systems have to be designed, which of course add to the costs of running a plant. /7/

Another problem to be addressed is when the inflow of wastewater from combined systems reaches the point where it becomes an overflow. This is because combined systems carry a mixture of wastewater and storm waters, of which the volume cannot be predicted all the time. This problem is referred to as CSOs (Combined Sewer Overflows) and is quite common in old systems that have not received proper maintenance or upgrades. /7/

The control of odors is another key problem. Hydrogen sulfide not only has a quite unpleasant odor but also is corrosive and damages the collecting systems as well as the equipments. The control of this problem is getting more and more important where residential areas are close to the treatment plant. To address this problem the facilities include ventilation and treatment of odorous gasses. /7/

# 3. METHODOLOGY

The wastewater used for this study was taken from the Viinikanlahti treatment plant in Tampere and specifically from the return sludge canals that go from the clarifier back to the aeration tank.

For this study the pilot reactor built was a complete-mix activated-sludge reactor (CMAS) made of three tanks called 1)Anoxic (denitrification tank), 2)Oxic (aeration tank) and 3)Settler (clarifier, settling tank.). This kind of reactor is very common and adaptable to almost any kind of waste water. It is also very easy to build and easily aerated.
In this particular case the CMAS reactor contained also a nitrogen removal process, which is carried out by denitrification in the anoxic tank.

In this chapter the basic principles about the pilot used are explained and in the following subchapter the actual instructions on how to build such an equipment are presented, which of course are just indicative since they depend on the equipment and material available.

In the aeration tank the wastewater is mixed with the bacteria present in suspension, which is referred to as MLSS (mixed liquor suspended solids) and MLVSS (mixed liquor volatile suspended solids) and where nitrification and the formation of flocks take place. Nitrification is the process by which ammonia ($NH_4^+$) is oxidized to nitrite ($NO_2^-$), which in turn is oxidized to nitrate ($NO_3^-$). In this particular case the mixing and the introduction of oxygen was achieved by aerators exactly like to the ones used in domestic aquariums.

Part of this liquor goes back to the anoxic tank because after nitrification it is rich of nitrate, which in turns is used by the bacteria together with the influent, to reduce nitrate to nitrogen gas in the absence of oxygen (denitrification). /7/

Another part goes to the settler (clarifier, settling tank) through a tube where it usually settles at the bottom. Part of this biomass (referred to as activated sludge because of the bacteria present inside it) is removed out of the system, another part is returned to the anoxic tank for denitrification and then again to the aeration tank for nitrification. /7/

The following diagram synthesizes the process, which is referred to as complete mix activated sludge process.

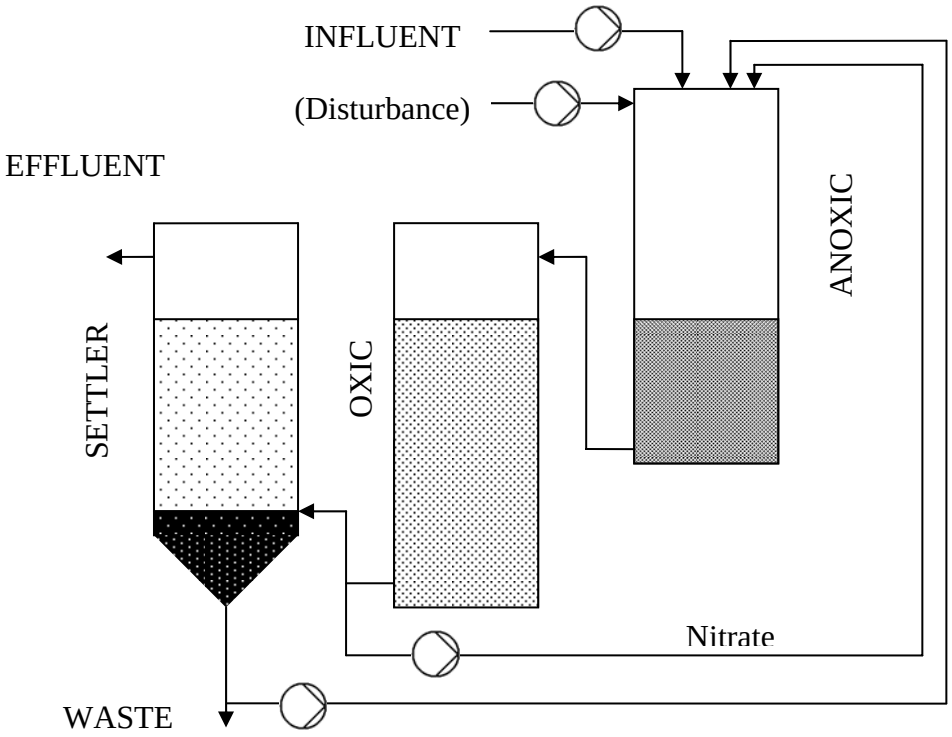


**Figure 1** Schematic view of the pilot CMAS reactor built for the study.

The influent used, also referred to as feed, was prepared according to the needs of the microbes since the optimum carbon:nitrogen:phosphorus ratio for activated sludge is 100:5:1, the feed should be made according to that. It really depends on the chemicals available in the laboratory. /12/

## 3.1. REACTOR BUILD UP AND OPERATION

As already mentioned the pilot built was made of three tanks. They were cylinders approximately 60cm tall with a diameter of 18cm and basically able to contain around 10 liters of wastewater each. The settler tank is designed in a different way to let the effluent go out from the top.

The connections can be seen from figure 1 and pumps have been used only from the oxic and settler back to the anoxic tank, otherwise the sludge was able to travel between the tanks by gravitational force only.

A mixer is used to mix the anoxic tank all the time. The aeration tank is mixed with the oxygen diffusers. These diffusers should be set up so that they would be able to mix the entire content of the tank. Not much oxygen is needed so one or two diffusers should be enough for the microorganisms (too much oxygen would be just a waste of energy).

The settling tank is also mixed very gently with a mixer. The mixing primarily facilitates the homogeneous circulation of the sludge back to the anoxic tank. It has been noted that if there is no mixing or if the mixing speed is too low most of the solid sludge stays inside the settler. This of course depends on the shape of the settler.

The influent is kept refrigerated and pumped into the anoxic tank, the speed of the flow should be around 12 liters/day but it depends on the desired food to microbe ratio (F/M), refer to chapter 3.2.3. chemical oxygen demand (cod) for further details. This flow speed was to ensure a proper load on the nitrifiers and denitrifiers. The speed of the circulation from the aeration back to the anoxic tank was 24 liters/day. Finally the speed of the circulation from the settler back to the anoxic was 9 liters/day. All these values were based on the total amount of wastewater used and on preliminary studies.

The tanks should be positioned so that only 4 liters should be present inside the anoxic tank. The rest should be divided equally between the oxic and settling tank. See figure 1 for a schematic representation of their relative positions. The general rule of thumb is that the amount of waste water present inside the anoxic and inside the oxic should have roughly a 1:2 ratio so in this case 4 liters in the anoxic and 8 liters in the oxic tank.

Since the feed is pumped into the pilot equipment continuously throughout the day the effluent that comes out from the top of the settling tank needs to be collected inside a tank, which has to be emptied on a daily basis to avoid overflowing.

## 3.2. ANALYSIS TECHNIQUES AND INSTRUMENTATION

### 3.2.1. pH, OXYGEN AND TEMPERATURE

**Theory**

pH is classified as an inorganic nonmetallic constituent and basically express the hydrogen-ion concentration, which is defined as its negative logarithm: $pH = -\log_{10}\left[H^{+}\right]$. /7/

In these kind of experiment pH monitoring is used to control nitrification systems where the suitable range should be from 6 to 9 even though the optimal range is much narrower being from 7,5 to 8,0. /7/

Being an aerobic biological treatment, oxygen plays a major part since the microorganisms present in the wastewater need it to be able to do their job. It also helps to eliminate the generation of bad odors. The amount of dissolved oxygen depends, among other things, on the temperature since biochemical reactions increase with the increment of temperature. /7/

The right temperature is thus an important factor in wastewater because it affects chemical reactions. In biological treatment, like activated sludge the temperature

should be in the range from 25 to 35 $°C$ because aerobic digestion and nitrification work best in that range. /7/

**Measurements**

pH, oxygen (mg/l), and temperature ( $°C$ ) have been measured every day using an oxygen meter model Oxi325 manufactured by WTW. The device has been calibrated and cleaned on a weekly basis.

**Discussion**

To adjust the pH two chemicals have been used: sodium hydroxide ( $NaOH$ ) also known as caustic soda, to raise the pH and hydrochloric acid ( $HCl$ ) to lower it. In a laboratory environment these two chemicals are usually quite expensive and so are suitable only when dealing with small systems. The concentration of them needs to be lowered to have more control during pH adjustment.

The chemicals have been added directly inside the reactor when the adjustments needed to be quite fast, otherwise the influent has been adjusted to a neutral pH. Sometimes the reason why the reactor was a bit acidic was because of the influent. So it is a good idea to check the pH of the influent as well every day and after its preparation. The pH usually changes considerably when it is stored in a fridge for a longer time so it is a good idea to make it again in the morning even if there is some left.

Since the tanks were quite big and contained a lot of waste water the pH did not change straight away when the chemicals have been added. This does not mean that the pH will not be different by the time the reactor is checked again the following day. Personal experience will guide to the right amount to add.

### 3.2.2. SOLIDS

**Theory**

The solids content is probably the most important factor in wastewater. There are different solids classifications in wastewater depending on their size and also on the treatment these solids go through in the laboratory. /7/

The types of solids used during this laboratory work were the TS (Total Solids), MLSS (Mixed Liquor Suspended Solids), and MLVSS (Mixed Liquor Volatile Suspended Solids). The TS is the residue that remains after a sample of wastewater is dried under $\sim 105\,°C$ whereas the MLSS is the residue that remains on a filter with a specific pore size and dried under $\sim 105\,°C$. The MLVSS shows the amount of solids that volatilize after the MLSS are burned inside a muffler at $\sim 550\,°C$. /7/

**Measurements**

The sludge taken (also referred to as "wasted" in everyday laboratory language) from the clarifier and oxygen tanks to keep the SRT (Solid Retention Time) under a certain limit has been used to run this test. The amount being taken depends on the desired SRT and can be easily calculated with a formula, which is illustrated later on.

The filters to be used, in this case GF/A with $1{,}6\,\mu m$ pore size manufactured by Whatmann, need to be muffled. To do that they will have to be kept for an hour inside an oven at $\sim 550\,C°$ and stored the whole time inside a desiccator. The weight of the clean filters needs to be known in order to calculate the MLSS.

2 ml samples from the oxic and from the settler were filtered using these filters, which are then kept for roughly an hour inside an oven at $\sim 105\,C°$ temperature. Aluminum dishes can and should be used to support the filters. After that the filters are kept for a while inside a desiccator until they reach room temperature before weighting them again. With the weight obtained a formula has been used to calculate the MLSS:

$$MLSS = \frac{1000 \cdot (a - b)}{V} \quad /10/$$

Where:

| | |
|---|---|
| *a* | is the mass of the filter after the filtration, in milligrams |
| *b* | is the mass of the filter before the filtration, in milligrams |
| *V* | is the volume of the sample, in milliliters. |

Example:

$$MLSS_{sample}(mg/l) = \frac{1000 \cdot (1250{,}7 - 1242{,}9) mg}{2ml} = 3900\, mg/l$$

After this stage the filters were then kept again for roughly an hour inside a muffler at $\sim 550\, C°$. Again they were allowed to reach room temperature afterwards so that their weight could be measured. With the value thus obtained the following formula has been used to calculate the MLVSS:

$$MLVSS = MLSS - \frac{(d - b)}{V} \quad /10/$$

Where:

| | |
|---|---|
| *d* | is the mass of the filter and residue, in milligrams |
| *b* | is the mass of the filter before the filtration, in milligrams |
| *V* | is the volume of the sample, in milliliters. |

Example:

$$MLVSS_{sample}(mg/l) = 3900\, mg/l - \frac{1000 \cdot (1243{,}7 - 1242{,}9) mg}{2ml} = 3500\, mg/l$$

The MLVSS of the oxic sample is used to calculate the SRT of the pilot using the following method:

First the amount of MLVSS (mg) taken out from the two tanks (oxic and settler) needed to be calculated separately and then added together to get the total amount of MLVSS taken out from the pilot. Next another formula is used to calculate the amount of MLVSS present inside the oxic and settler tanks, which is essential, together with the MLVSS of the oxic sample, to finally calculate the SRT. The following steps have been used:

Step 1: Amount of MLVSS (mg) taken out from the oxic tank

$$MLVSS_{TakenOxic}(mg) = MLVSS_{OxicSample}(mg) \cdot amount\ taken\ from\ oxic(l)$$

Example:

$$MLVSS_{TakenOxic}(mg) = 3500mg \cdot 0{,}300l = 1050mg$$

Step 2: Amount of MLVSS (mg) taken out from the settler tank

$$MLVSS_{TakenSettler}(mg) = MLVSS_{SettlerSample}(mg) \cdot amount\ taken\ from\ settler(l)$$

Example:

$$MLVSS_{TakenSettler}(mg) = 5100mg \cdot 0{,}500l = 2550mg$$

These 2 values are then added together to find the total amount of MLVSS taken out from the pilot. Finally we need the total amount of MLVSS present inside the pilot and then use it, together with the last value obtained, to find the SRT. These are the steps:

Step 1: Amount of MLVSS (g) present in the pilot

$$MLVSS_{Pilot}(mg) = MLVSS_{OxicSample}(mg) \cdot Total\ volume\ of\ Oxic\ and\ Settler(l)$$

Example:

$$MLVSS_{pilot}(mg) = 3500mg \cdot 12l = 42000mg = 42g$$

Step 2: SRT (days)

$$SRT(days) = \frac{MLVSS_{Pilot}(mg)}{MLVSS_{Taken(Oxic+Settler)}(mg)}$$

Example:

$$SRT(days) = \frac{42000mg}{(1050 + 2550)mg} = 11{,}6 = 12days$$

The MLVSS taken out of the reactor can be controlled by getting a known amount of waste water and the SRT in turn can be adjusted to the desired value and kept that way as long as required during the experiment period.

**Discussion**

Any support or container that can sustain high temperatures could be used to support the filters during handling, like for example crucibles made of ceramic. However it is a better idea to use aluminum dishes (the ones used for baking muffins should do) since being a metal it cools down faster inside the desiccator. In fact just after roughly 30 minutes inside the desiccator the dishes can already be taken out and the filters weighed.

The aluminum containers and the clean filter should be muffled beforehand and stored inside a desiccator to ensure that the MLVSS is correct. This is because the clean filters and the aluminum dishes out of the box have some impurities on them that will affect greatly the values once weighed. It is also extremely important to never touch the dishes or the filters with bare hands otherwise they will have to be muffled again.

The sample from the settler should be taken from the recirculation tube that goes back to the anoxic tank. In case the speed of the pump could be set higher for this purpose. This is to ensure that the sample is homogeneous. It is also a good idea to homogenize the samples using a domestic blender

### 3.2.3. CHEMICAL OXYGEN DEMAND (COD)

**Theory**

The chemical oxygen demand test measures the amount of oxygen in the waste water that can be oxidized chemically. This value is not the same as the BOD value (biological oxygen demand) because some substances are very difficult to oxidize biologically not to mention that some of them are even toxic to the micro organisms (=the inoculum) used for the BOD test. The COD test takes few hours to complete whereas the BOD test even a week or more. /7/

Between the two tests there is an interrelation. If the BOD/COD ratio of the waste water is higher than 0,5 then it can be easily treated. If the ratio is below 0,3 the waste water might contain unwanted components. /7/

During this laboratory work only the COD test has been performed because it was more practical and faster since it had to be run every other day.

**Measurements**

The sludge taken from the settling and oxygen tanks to keep the SRT under a certain limit was used to run this test. Only the sludge from the oxic is used to measure the COD.

First the waste water taken from the oxygen tank is divided into two parts; one part is centrifuged and filtered using the same kind of filters used for the solids test. The other one is homogenized for roughly a minute using a domestic blender. These two parts are respectively the so called “solubles” and “totals”.

Ten samples were usually tested: 2 blanks, 2 cold blanks, 2 from influent, 2 solubles, and 2 totals. It is a good idea to also test the effluent to be able to compare it with the influent. In every Hach tube there was 3 ml of a mixture of sulfuric acid + silver sulfate ($H_2SO_4 + AgSO_4$), 1 ml of 0.04mol/l potassium dichromate ($K_2CrO_7$), and 2 ml of the sample, either:

distilled water (preferably MQ water) for the blanks and cold blanks, the solution used to feed the reactor (1:10 dilution), the solubles (usually 1:50 dilution), and the totals (also 1:50 dilution).

These samples were then mixed gently and then cooked for about 2 hours inside a COD reactor at $150\,C°$; the cold blanks are not cooked, that is why they are referred to as “cold”. The caps of the Hach tubes were kept not too tight to allow the samples to breath.

Next, the samples were left outside the reactor to reach room temperature in order to run the titration phase of the test. In every sample an addition of 2 drops of ferroine indicator (1, 10-phenanthroline iron (II) sulfate, $\left[Fe\left(C_{12}H_8N_2\right)_3\right]SO_4$) was made and then titrated with 0.07mol/l ammonium ferrous sulphate $\left(NH_4\right)_2Fe\left(SO_4\right)_2$. The end point is reached when the sample turns red; the transition to red is really easy to notice because it is rather accurate, just a drop of titrant is needed. The value obtained is used in a formula to calculate the COD. Before doing that the concentration of the titrant in mol/l needed to be checked, the cold blanks were used for this purpose with the following formula:

$$C_{Fe} = \frac{6 \cdot 0{,}0400 \cdot V_1}{V_2} = \frac{0{,}24 \cdot V_1}{V_2} \quad /8/$$

Where:

$C_{Fe}$ is the concentration of potassium dichromate, in mol/l

$V_1$ is the volume of potassium dichromate used for titration, in milliliters

$V_2$ is the volume of ammonium ferrous sulphate used to titrate the blank, in milliliters

6 is an equivalent value because a mole of potassium dichromate is equal to 6 moles of ammonium ferrous sulfate

0,0400 is the concentration of potassium dichromate, in mol/l

This value should be as close as 0,07.

Example:

$$C_{Fe}(mol/l) = \frac{6 \cdot 0{,}0400\, mol/l \cdot 1ml}{3{,}54ml} = \frac{0{,}24\, mol/l \cdot 1ml}{3{,}54ml} = 0{,}067 = 0{,}07\, mol/l$$

The following formula is used to calculate the COD of every sample:

$$COD_{Cr} = \frac{8000 \cdot C_{Fe} \cdot (V_3 - V_4)}{V_5} \quad /8/$$

Where:

$COD_{Cr}$ is the chemical oxygen demand value, in mg/l

8000 is a conversion factor

$C_{Fe}$ is the concentration of potassium dichromate, in mol/l

$V_3$ is the volume of ammonium ferrous sulfate used to titrate the blank, in milliliters

$V_4$ is the volume of ammonium ferrous sulfate used to titrate the sample, in milliliters

$V_5$ is the volume of the sample, in milliliters

Example:

$$COD_{CrSample}(mg/l) = \frac{8000 \cdot 0{,}067\, mol/l \cdot (3{,}48 - 2{,}98)ml}{2ml} = 134\, mg/l$$

The result needs to be multiplied by the dilution. For example 50 if the dilution was 1:50

The COD of the influent (feed) and the MLVSS of the oxic are used to calculate the Food to microbe ratio (F/M) with the following formula:

$$F/M_v = \frac{Q^0 S^0}{VX_v} \quad /1/$$

Where:

$F/M_v$ is the food to microbe ratio on volatile solids basis, kg BOD or COD per day per kg of volatile suspended solids in aeration tank

$Q^0$ is the influent (feed) flow rate ( $m^3/d$ )

$S^0$ is the COD or BOD of the influent (feed), in mg/l

$V$ is the volume of the aeration tank (oxic), in $m^3$

$X_v$ is the MLVSS of the aeration tank, in mg/l

Example:

$$F/M_v \left( \frac{kgCOD}{kgMLVSS \cdot d} \right) = \frac{0{,}012\, m^3/d \cdot 1315\, mg/l}{0{,}008 m^3 \cdot 3500\, mg/l} = 0{,}56 \frac{kgCOD}{kgMLVSS \cdot d}$$

The ideal F/M ratio for a complete mix process should be from 0,2 to 0,6 for a 3 to 15 days SRT range. /7/

**Discussion**

Some might argue that the Hack tubes should be very tight when cooked inside the reactor. However, if the tubes are really tight there might be the possibility to squirt hot acids after the cooking period when they are finally opened.

It is important not to homogenize with the domestic blender the sample needed for the solubles because only the liquid part is needed and the blender brakes down the cells. As a result it can be seen that the liquid is not anymore clear after the centrifugation but greenish because some particles do not get centrifuged to the bottom of the vial.

The dilutions used have been the result of trial and error. It depends on the kind of waste water analyzed. However the dilution used in this exercise should be good enough at least to have an idea and to see if it needs to be changed.

The F/M ratio can be easily controlled, as it can be noted from the formula used to calculate it, by modifying the flow speed of the influent. That is not the only parameter that can be changed, as it can be seen from the formula. However changing the speed of a pump is much easier and achieves the same result.

The COD results from the influent and effluent can be compared to see how efficiently the pilot plant reduces the organic matter supposedly released into the environment.

### 3.2.4. TOTAL KJELDAHL NITROGEN (TKN)

**Theory**

Nitrogen, like phosphorus is one of the most important nutrients and biostimulants for biological growth. Thus wastewater, to be able to be treated biologically needs of a certain quantity of nitrogen present. /7/

Nitrogen is very complex and can have different oxidation states depending on various conditions. However, in wastewater the prevailing forms of nitrogen are organic nitrogen, ammonia $NH_3$, nitrite $NO_2^-$, and nitrate $NO_3^-$. /7/

Nitrite is important to mention because even if it is present in wastewater in very small concentrations (usually no more than 1mg/l) it is very toxic to fish and other aquatic organisms. The nitrite is usually oxidized with chlorine ($Cl_2$). /7/

The principle in the Kjeldahl process is that the organically bound nitrogen is digested into ammonium salts $\left(NH_4^+\right)$ with concentrated sulfuric acid. During the distillation process the ammonia is released with sodium hydroxide. The ammonia is then collected into boric acid, which then is titrated to determine the amount of nitrogen. /11/

**Measurements**

Also here the sludge that was taken from the settler and oxic tanks to keep the SRT under a certain limit was used to run this test. Only the sludge from the oxic tank is needed to measure the nitrogen content.

Here like previously the oxic is also divided into two parts; one part is centrifuged and filtered using the same kind of filters used for the solids test. The other one is homogenized for roughly a minute using a domestic blender. These two parts are respectively the so called “solubles” and “totals”.

This test is divided in three phases: digestion, distillation, and titration, and in this particular laboratory work the procedure, which depends on the equipment used and the method, was as follows:

*Digestion*

It depends on the size of the reactor but the samples were at least 1 blank (MQ or DI water), 1 standard ($5 mg/l$ ammonium chloride $NH_4Cl$), 2 solubles (1:5 dilution), and 2 totals (1:25 dilution). If there is enough space it is also a good idea to run 2 samples from the influent and effluent to be compared later on. The sample size was 50ml.

In every Tecator digestion tube there was a 50ml sample plus 10ml concentrated sulfuric acid ($H_2SO_4$), 5ml $100\,g/l$ copper sulphate ($CuSO_4 + 5H_2O$), and a third of a teaspoon devarda alloy

These samples were then left to cool down to room temperature for about 45 minutes while the devarda takes the ammonia gas ($NH_3$) out of the samples. It is important that the tubes with the samples get into the reactor with almost no trace of ammonia. The samples have been gently shaken every now and then to help the ammonia gas dissipate completely.

In the meantime the reactor will reach the desired temperature which is around $200\,°C$. The samples were inserted into the reactor and left there cooking for about an hour under this temperature and then another hour under $350°C$.

*Distillation*:
After the cooking the samples were taken out from the reactor and left to cool down to room temperature before the distillation phase. See the discussion part about the end of the cooking phase.

A Kjeltec 2100 distillation unit manufactured by FOSS has been used. The process is quite straight forward because everything is done by the unit. In this particular case the sample to be distilled was inserted on the left side of the unit while a flask with $0{,}3\,mol/l$ boric acid ($B(OH_3)$) plus 4 drops of indicator (bromocresol-green) was inserted on the right side.

50 ml MQ water should be poured into the tubes with the residue and mixed gently before inserting it into the distillation unit. During the process the unit adds automatically a certain quantity of alkali (a 30% solution of sodium hydroxide $NaOH$) inside the tube with the sample, in this case 40 ml. Every sample takes 5 minutes to distillate completely and should hopefully turn black while the distillate inside the flask should turn bluish; if it turns red then that

particular sample cannot be titrated since the end point is reached when the sample turns reddish.

*Titration*:

The flasks with the distillate are then titrated with $0{,}005\,mol/l$ sulfuric acid ($H_2SO_4$) until the samples turn reddish. The transition from bluish to reddish is really difficult to notice and needs a lot of practice to familiarize with, it is important thus to decide before hand what shade of red to reach for every single sample.

The concentration of the sulfuric acid used for the titration should be tested. To do that the following process has been used. 5ml of 2.1g/l sodium carbonate ($Na_2CO_3$) is mixed with 100ml MQ water inside a flask. This solution is then titrated with the same SA needed to be tested. The value obtained is used in the following formula:

$$C = \frac{\rho \cdot V_1}{V_2 \cdot 106} \quad /9/$$

Where:

| | |
|---|---|
| $C$ | is the concentration of sulfuric acid, in mol/l |
| $\rho$ | concentration of sodium carbonate used, in g/l |
| $V_1$ | is the volume of sodium carbonate uses, in milliliters |
| $V_2$ | is the volume of sulfuric acid used to titrate the sample |
| 106 | is the molecular mass of sodium carbonate, in g/mol |

Example:

$$C_{SA}(mol/l) = \frac{2{,}1\,g/l \cdot 5ml}{20{,}13ml \cdot 106\,g/mol} = 0{,}0049 = 0{,}005\,mol/l$$

The numerical value should be as close as possible to 0,005 mol/l

The values obtained are then used inside the following formula to calculate the amount of nitrogen that was present inside the original sample:

$$x = \frac{(V_3 - V_4) \cdot c \cdot 14 \cdot 2 \cdot 1000}{V} \quad /9/$$

Where:

| | |
|---|---|
| $x$ | is the concentration, in mgN/l |
| $V_3$ | is the volume of sulfuric acid used to titrate the sample, in milliliters |
| $V_4$ | is the volume of sulfuric acid used to titrate the blank, in milliliters |
| $c$ | is the concentration of sulfuric acid, in mol/l |
| $V$ | is the volume of the sample, in milliliters |
| 14 | is the molecular mass of nitrogen, in g/mol |
| 1000 | is a conversion factor |
| 2 | is a conversion factor |

Example:

$$x(mgN/l) = \frac{(5{,}84 - 0{,}42)ml \cdot 0{,}0049\, mol/l \cdot 14\, g/mol \cdot 2 \cdot 1000}{50ml} = 14{,}83\, mgN/l$$

The result needs to be multiplied by the dilution. For example 25 if the dilution was 1:25

The values obtained from the influent and effluent can be compared to see how much total nitrogen the system is able to reduce from the waste water and supposedly release into the environment.

**Discussion**

It has been noted that the samples splash considerably during the distillation phase if too much devarda is used (in some cases the splashes can get out of the tecator tube spoiling the sample and basically mess the all digester). It is extremely

important that the quantity of devarda inserted into the tubes is just a tip or a third of a teaspoon.

It is very important to stay away from the tubes while the devarda takes out the ammonia gas before the digestion phase because it is very dangerous. Ammonia is very harmful if inhaled and it is typically very hot when boiling out of the tubes. It is also very important to try and let the devarda do its job for at least 30-45 minutes and shake the tubes gently every now and then to help it dissipate the ammonia because under certain conditions it might detonate.

The reason why 50 ml MQ water is poured into the tubes and shacked after the digestion phase is because the residue might get very tough and the alkali might not be able to melt it completely for the analysis. However it has been noted that the alkali in its undiluted form (that is without the addition of 50 ml of MQ water beforehand) is still able to melt the residue because it is much stronger.
Note that even with the addition of MQ water the nitrogen content of the sample should not change because MQ water does not contain (or should not contain) nitrogen.

The Tecator tubes are very resistant to changes in temperature and could be taken out from the reactor after the cooking phase. However the quality of some tubes used in this experiment might differ greatly and could actually start cracking when taken out from the reactor because of the sudden difference in temperature exposure. It is a good idea to ask the people working in the laboratory before take them out. Alternatively the tubes can be left inside the reactor to cool down slowly.

### 3.2.5. OXYGEN UPTAKE RATE (OUR)

**Theory**

The oxygen uptake rate measures the rate by which the oxygen is used by the microorganisms to oxidize the organic matter present in the waste water and it is closely related to their growth rate. /7/

**Measurements**

The sample used to run this test has been taken out from the oxygen tank and taken to the OUR unit as soon as possible so that the results would be as accurate as possible.

The sample needed to be diluted so that the TS (total solids) present inside would be roughly between 1000 to 1500 mg/l. To check the TS present in the oxic sample the same test described in chapter 3.2.2. solids has been carried out but without the use of the filters and only inside the oven at ~105$C°$ for about an hour.

The diluted sludge is mixed with a standard which is similar to the influent used inside the pilot and it is made of a mixture 16g peptone, 16g dextrose, 3g urea, and 2,8g dipotassium hydrogen phosphate ($K_2HPO_4$) in one liter of preferably tap water.

The unit comprised of a software (multi/ACHAT II developed by WTW) and a computer with an oxymeter connected to it. The rest depends on the kind of equipment used but generally it is a small plastic container where the diluted sludge is poured into and then hermetically sealed so that only the oxymeter could access the sludge.

The software reads from the oxymeter and plots a graph in which the amount of oxygen (mg/l) consumed by the bacteria inside the sample can be seen. This is why it is important that the container is sealed so that no extra oxygen will reach the sample.
When the oxygen content reached around 2,0mg/l the test is stopped since there is no need to get under that value.

An example can be seen on the following figure.

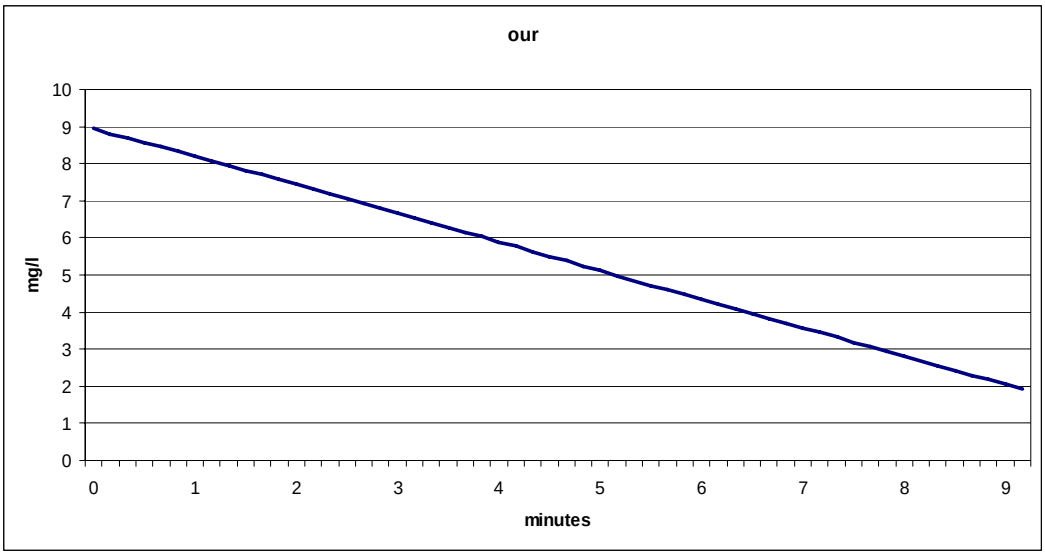


**Figure 2** Example of how an OUR graph should look like.

**Discussion**

It is important to start the test straight away before the bacteria uses up the oxygen present inside the sample so it is a good idea to set up the equipment and the software before hand.

Care should be taken in the sealing of the sample when measuring since no extra traces of oxygen should be present in the form of bubbles because it might disrupt the results.

## 3.3. CONTROL AND MAINTENANCE

First of all it is essential that a diary is kept where every detail is recorded every day. Even the most seemingly insignificant change or activity should be recorded. Tests results and daily measurements from the tanks should thus be recorded there, like pH, temperature, oxygen content etc. It is essential also to record if the influent for that day will be different and if there has been some problems during the day. A record of pictures should be also taken if possible to monitor changes in color for example.

As already mentioned the aim is to stabilize the biota inside the reactor to be able to see changes once other chemicals are poured into the system after the tests have been done. A certain SRT should be decided before hand and at least two cycles should be done (for example if 10 days SRT is decided then the operation and maintenance should be kept for roughly 20 days) before adding the disturbance. After the disturbance addition another one or two cycles with the same SRT is done. This is to see what the impacts of the disturbance actually are.

The first thing to do, after an overnight operation, is to clean the walls of the tanks. The sludge collected in this way should not be put back inside the tanks because it was not circulating through the system like the rest of the sludge.

The tubes also need to be checked because it is very common that some heavy sludge get stuck inside them. This sludge becomes anoxic most of the time because the oxygen cannot reach it very well, it is very easy to notice because the sludge assumes a black color. This black sludge should be removed and also taken away from the system. This sludge also does not need to be recorded for calculation purposes.

Depending on how the tubes are set there might be the possibility of air getting stuck inside them. This usually does not prevent the water passing through; however it is not good for the solid sludge that sometimes does not pass uniformly through it. This situation is not acceptable because the system needs to flow smoothly. A way to eliminate the formation of air bubbles inside the tubes is essential. Thus if there are any bubbles they should be eliminated in some ways.

The tube transporting the influent (feed) into the anoxic tank should be cleaned on a daily basis since the organic matter particles present inside the feed will eventually gather and get stuck inside the walls of the tube. This organic matter needs to be in continuous contact with the micro organisms.
After the cleaning and after the system is checked so that the wastewater is circulating in a good way, the measurements can be taken.

pH, oxygen and temperature are recorded for every tank and the amount of waste water to be taken out of the system is then taken and recorded. This “waste”, as already mentioned, is used to run the daily tests such as the solids, COD, TKN etc. or it is just poured into the sink if not needed.
This waste should be taken out first from the settler and preferably from the tube that goes back to the anoxic, as already mentioned. This is to make sure that no extra water is taken and that the sample will be homogeneous, the speed of the pump can be set higher for this purpose since otherwise it will take hours. After this the settler tank can be mixed and let sediment again.

From the oxic tank the waste should be taken from near the bottom of it with the use of a tube and a syringe.

It is a good idea though to make solubles and totals with this “waste” or otherwise freeze them to be then used later on if needed. It has been noted however, that it is best for the sample to be frozen to not be filtered in the case of the solubles nor centrifuged in the case of the totals.

The amount to be taken depends on the desired SRT. This procedure is explained in chapter 3.2.2. solids. Since it is not possible to determine the SRT just before taking out the sludge, the previous value obtained is used. This should not be a problem though if the pilot has been taken care well. Thus it is also an effective way to see if the reactor has not been handled correctly.

In order to have some kind of meaningful data it is a good idea to run tests on a daily basis. COD and TKN can be alternated and run every other day. Solids should be run every day. OUR a couple of time per SRT cycle

The pumps should also be cleaned every now and then to ensure a constant flow and in general to lengthen their longevity.

## 3.4. COMMON PROBLEMS AND COMMENTS

A CMAS reactor is quite easy to build and operate. However, the biggest problem that might occur with such a reactor is the formation of filamentous bacteria (*Sphaerotilus, E. coli*) because the needed F/M ratio encourages their growth. /2/ /7/

What follows is a list of possible problems encountered during the laboratory work and is divided by the different tanks for ease of consultation:

*Denitrification tank (Anoxic)*:
The tank is mixed gently and the oxygen content is very low, as a consequence the formation of clumps of anoxic sludge can be seen forming at the bottom and on the walls of the tank. It is important to remove this black sludge away from the system because it is not needed, not to mention that it could get stuck inside the tube that goes to the oxic tank.

This black sludge does not usually recuperate their former healthy state even if it is moved to the aeration tank. This is because the clumps are too tight and do not let the oxygen penetrate.

The mixer should be cleaned every now and then because the sludge gets stuck around it and eventually turns anoxic.

*Oxygen tank (Oxic)*:
The diffusers should be set so that there is no splashing of wastewater outside the tank; it is not a problem since the oxygen level needed by the microorganisms to perform their tasks is really low. A laboratory film could be used on top of the tank to protect the pumps and the mixers from getting any wastewater on them.

The diffusers are the ones responsible for the mixing of the tank and should be positioned so that the entire content of the tank mixes uniformly. This might be a

bit tricky to achieve but it is important that no sediments form at the bottom because they might turn anoxic and then would need to be taken out.
The shape of the diffusers is thus very important. It has been noted that medium size, spherical diffusers are the best because they usually swing inside the tank and mix the content nicely.

Eventually some solid sludge will accumulate on the top part of the tank, just remove that from the system. Also on the walls of the tank some solid sludge might get stuck, it is important to also eliminate this from the system not to mention any heavy sediment present at the bottom.

Sometimes the formation of algae can be seen on the walls of the tank, remove that as well. As already mentioned there is no need to record the total amount of this solid sludge removed from the system since it is not important for the final SRT calculation.

The tube from the oxic to the settler should be empty of any air bubble. The air might get into the tube from the diffusers, that is why it is important to set them so that no air would be able to reach the tube. This is important because if there is a bubble inside the tube then only the liquid will be able to pass leaving the sludge behind. The consequence would be that the activated sludge is not able to travel inside the system smoothly.

*Settling tank (Clarifier, settler)*:
The most typical of problems involving the settler is of course when the sludge does not settle because of filamentous bacteria present inside the tanks. In this case a very down to earth method has been used and it showed pretty good results all considered.

Basically the entire content of the settler (only the sludge) is homogenized with a domestic blender for roughly 5 minutes. This will brake down the big flocks and disrupts the filamentous bacteria. Eventually the sludge, when poured back into the

settler, will be able to settle a little bit better. In some cases the entire content of the pilot has been homogenized with the blender.

The problem with this method is that the sludge will get lots of nitrogen from the atmosphere during the mixing process, which will actually make the sludge rise into the settler and float on the surface. Small nitrogen bubbles will be clearly visible transporting the sludge from the bottom of the settler to the surface.

This will be more evident the following day where a thick layer of solid sludge will be floating on the surface sometime blocking the effluent and overflow the all system. This thick layer needs to be eliminated from the system and not recorded since it did not circulate inside the pilot.

Alternatively a more scientific method could be used. The food to microbe F/M ratio could be lowered since it is linked to the formation of these filamentous bacteria. The F/M ratio can be changed by modifying the speed of the influent flow. Refer to chapter 3.2.3. chemical oxygen demand (cod) for detail.

Its important to empty the effluent container at the bottom of the pilot otherwise the tube could get stuck and since the pressure is not enough the settler will eventually overflow.

Sometimes the sludge does not collect uniformly inside the tube to go back to the anoxic tank. It is important for the flow to be steady and uniform, just make sure of this. The settler could be mixed strongly with a stick and let sediment again for example, or the tube could be manually squeezed few times to make sure that no bubbles or big flocks block it.

Another problem, which is not evident, is that some of the sludge does not move through the system even though it settles. This sludge will stay at the bottom walls of the settler and inevitably turn anoxic (black). This sludge needs to be taken out and will be quite a lot depending on the last time this cleaning procedure has been done. The amount of this sludge should be recorded and used normally for testing and to calculate the solids concentration.

# 4. ADDITIONAL NOTES

During the laboratory work a total of three different SRTs has been used (7, 10, and 14 days) and for each one of them 4 full cycles have been carried out, 2 cycles without the disturbance and 2 cycles with the disturbance, which in our case was a very low concentration (20-25 $\mu g/l$) of an antibacterial called Triclosan, or 5-chloro-2-(2,4-dichlorophenoxy)phenol, ($C_{12}H_7Cl_3O_2$).

The test results obtained during this study where really encouraging showing some kind of difference between the stages before and after the introduction of Triclosan. However the results could not be included in this thesis due to their confidentiality.

The color of the sludge collected from the treatment plant was very dark in the beginning but gradually the color turned lighter until very light brown at the end of the SRT cycles. Also the consistency was really different between the beginning and end period of the SRT cycles. In fact the sludge was really dense once collected and poured into the pilot. As a consequence it was very tricky to keep the waste water circulating smoothly.

During the first days the reactor needed a lot more attention because it was rich of nitrogen gas, which transported the solid sludge up to the surface of the tanks forming a layer. This layer was able to block the effluent so the pilot needed to be checked also in the night time. It was really important to check the pilot so late as well because otherwise it could have over flown during the night. It actually happened a couple of times during the training period.

The filamentous bacteria forming, which are quite common in these kinds of activated sludge processes are quite difficult to predict and eliminate once they start forming inside the pilot. Few methods have been used, as already mentioned: The homogenization of the entire pilot, lower the F/M ratio by modifying the speed of the influent flow, and by adding some chlorine into the system.

The biota could also be observed under the microscope to see if the filamentous bacteria might start growing. However such an observation was not carried out during the training period but it is believed to be quite useful and could be performed during those typical dead periods in the laboratory where there is nothing to do besides waiting for a test to be finished.

The addition of chlorine to the system has been achieved by a shock treatment. Basically domestic bleach has been used and poured directly into the oxic tank. This might actually ruin the pilot if done carelessly but could actually solve the filamentous bacteria problem once and for all. Eventually a lot of foam is going to form on top of the oxic tank. This foam will overflow and needs to be controlled.

The introduction of a liquid able to float on the surface of the water (domestic olive oil) has been used once to try to solve this foamy problem after the addition of the bleach. The result was that the foam was not able to form so much as to overflow. However, this “solution” ended up to be a disaster since the following day the content of the entire pilot was incredibly oily and needed to be discarded. Another trip to the treatment plant was in order to start another pilot. Moreover the tanks needed to be cleaned thoroughly since they were oily. Apparently the bacteria were not able to “eat” the oil.

The “black” sludge visible inside the reactor should be eliminated, as already mentioned. Usually it will be no more than 100ml from the anoxic and oxic tank. This sludge can be thrown away and should not be recorded or used for the SRT calculation, solids and so on. However the “black” sludge taken from the bottom of the settler could be a considerable amount, even 500ml if the cleaning process was not done regularly. This sludge should be recorded and used normally for testing.

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