SAVONIA

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TECHNOLOGY, COMMUNICATION AND TRANSPORT

OPERATING AND OPTIMIZING THE PILOT WASTEWATER TREATMENT PLANT

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THESIS
Abstract

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Abstract

With the attention paid to wastewater treatment, the process of wastewater treatment has been developing rapidly. Activated sludge process has been widely used in wastewater treatment in recent years. The purpose of this study is to research how to start, run and optimize the pilot sewage treatment plant built for educational and research purposes in Savonia UAS. The wastewater and sludge used in the study come from local wastewater treatment plant situated in Lehtoniemi (Kuopion Vesi) in Kuopio, Finland.

The object of this study is the gain the knowledge needed for operating the pilot wastewater treatment plant. Through studying and researching the pilot, we can have a certain understanding of the treatment of wastewater by activated sludge process and at the same time we are getting familiar with the equipment, automation system and basic principles and the connections of the unit operations taking place in the pilot process.

The most important thing of activated sludge process is the activity of sludge, and the activity of sludge is related to the number of micro-organisms and the living environment of micro-organisms. In order to keeep the activity of activated sludge at a high level, it is necessary to keep the amount of activated sludge in the process in a certain range and at the same time control pH, temperature, oxygen and other conditions under the requirements of microbial survival. Optimal conditions for each activated treatment plant are unique, so testing and optimizing of the process is needed in all activated sludge wastewater treatment plants.

Keywords
Wastewater treatment, Activated Sludge process, Operating, Optimizing

CONTENTS

1 INTRODUCTION

Water is the basis of human survival, but with the development of human society, the pollution of water environment is becoming more and more serious, especially in China.Treatment of sewage by activated sludge method is the most widely used method for municipal sewage treatment. Although this method is also used on a large scale in China, our school lacks knowledge of related aspects.

It is well known that Finland's water environment is of the highest standard in the world, not only because it is well protected, but also because it has advanced wastewater treatment methods and equipment. The starting point of this thesis is to study Savonia's advanced wastewater treatment equipment and methods. First the author has to learn and master activated sludge wastewater treatment methods then understand the operating principles of its equipment, learn how to operate the equipment, and then master the equipment in an all-round way.

As an exchange student coming to Finland from Shanghai Polytechnic University, China, one can communicate with the professors of the University (SSPU, Pudong, China) to promote the development of advanced wastewater treatment methods in this very rapidly developing university. The way to improve wastewater treatment in China can slow down water pollution in China. The theme of the thesis is Operating and Optimizing The Pilot Wastewater Treatment, which requires full knowledge and familiarity with the equipment.

2 LITERATURE REVIEW

2.1 Activated sludge process in wastewater treatment

Activated sludge process is a kind of aerobic biological treatment of sewage, which was invented and applied by Clark and Gage in England at Lawrence sewage Test Station in Manchester in 1913. Nowadays, activated sludge process and its derivative improvement process are the most widely used methods for municipal wastewater treatment. It can remove soluble and colloid biochemical organic matter, suspended solids and other substances that can be absorbed by activated sludge, and can also remove part of phosphorus and nitrogen.

Activated sludge process is a kind of biological treatment technology of wastewater, and it is the main method of biological treatment of wastewater with activated sludge as the main body. This technology mixes the wastewater with activated sludge (micro-organisms) and aeration, decomposing the organic pollutants in the wastewater, and then separating the bio-solids from the treated wastewater. The activated sludge method is a sludge-like flocculant formed by the aerobic micro-organism propagation after a certain period of time, which is a kind of sludge -like flocculant which is continuously fed into the waste water and propagated by aerobic microorganisms after a certain period of time. It has a strong ability to adsorb and oxidize organic matter because of its microbiota, which is dominated by micromicelles and has a strong ability to adsorb and oxidize organic matter.

Activated sludge process is a method for biological treatment of wastewater. The activated sludge was formed by continuous mixed culture of sewage and various microbial groups under the condition of artificial aeration. Biological coagulation, adsorption and oxidation of activated sludge are used to decompose and remove organic pollutants from wastewater. Then the sludge is separated from the water, most of the sludge is returned to the aeration tank, and the excess part is discharged from the activated sludge system.

The most important pollutant in municipal wastewater is organic matter. In addition to organic matter, other important compounds in wastewater are usually different forms of phosphorus and nitrogen. It is very important to remove phosphorus and nitrogen from wastewater. Nitrogen is an important element of plant growth, which will make algae grow in large quantities in water and lead to eutrophication of water body. This secondary growth of algae leads to the need of more oxygen in water body. (Niemelä & Stendahl, Helsinki)

Most of the phosphorus and nitrogen in the wastewater exist in the form of organic compounds, and there are only a few soluble phosphorus and nitrogen in the inorganic compounds in the influent. When organic matter is treated, phosphorus and nitrogen form inorganic and water-soluble nutrients. (Niemelä & Stendahl, Helsinki)

Phosphorus exists as different phosphoric acid salts (orthophosphate PO $_4^{3-}$), polyphosphates (PO $_3$)^n and bound to organic compounds in wastewater. The majority of phosphorus in wastewater is orthophosphate as e.g. polyphosphates (generally in detergents) hydrolyse easily and revert to orthophosphates. Orthophosphates together with metal ions (e.g. aluminium and iron) form poorly soluble phosphates. Phosphorus removal from sewage water is usually done by chemical precipitation using Fe, Al and Ca salts. The re- sulting metal salts simultaneously precipitate suspended organic matter and the concentration of organically bound phosphorus decreases. In Finland the most commonly used compounds in precipitation are Fe II (ferrous) or Fe III (ferric) compounds, mostly ferrous sulphate. (Niemelä & Stendahl, Helsinki)

In addition to phosphorus, nitrogen is also one of the primary nutrients and can be used as a micronutrient. The oxidation of ammonia nitrogen in wastewater needs to consume a lot of oxygen and alkalinity. And ammonium ions are toxic to all kinds of organisms. (Niemelä & Stendahl, Helsinki)

Biological oxidation (nitrification= oxidation of ammonium to nitrites and then converted to nitrates) is a two-step process caused by two different groups of bacteria. The first step is the oxidation of ammonium to nitrite by bacteria of the genus Nitrosomonas. In the second step nitrite is further oxidized to nitrate by bacteria of the genus Nictobacter. The first step is significantly slower and determines the total process rate. Nitrite is oxidized to nitrate much faster and, consequently, the nitrite concentration in waters is low. Nitrifying bacteria also compete with other bacteria all the time and become easily inhibited. Both bacterial species are autotrophic meaning that they obtain the required carbon from inorganic carbon (carbon dioxide, carbonate). (Niemelä & Stendahl, Helsinki; Karttunen & Tuhkanen, 2003)

Nitrification steps:

$$NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 2\ H^+ + H_2O + \text{energy}$$

$$NO_2^- + 0.5\ O_2 \rightarrow NO_3^- + \text{energy}$$

$$NH_4^+ + 2\ O_2 \rightarrow NO_3^- + 2\ H^+ + H_2O + \text{energy (total reaction)}$$

The production of many hydrogen ions in this process means that the pH of wastewater will be reduced, but the pH used for nitrification is preferably between 7 and 8.5, which means that substances such as NaOH are added to control pH.

The typical activated sludge process (Figure 1) is composed of aeration tank, sedimentation tank, sludge back-flow system and residual sludge removal system. Sewage and refluxed activated sludge enter the aeration tank together to form a mixture. The compressed air sent from the air compressor station enters the sewage in the form of small bubbles by means of an air diffusion device laid at the bottom of the aeration tank, in order to increase the dissolved oxygen content in the sewage, and also to keep the mixture in a state of violent agitation. In a suspended state dissolved oxygen, activated sludge and sewage are being mixed with each other, so that the activated sludge reaction can be carried out normally. In the first stage, the organic pollutants in the wastewater are adsorbed on the surface of the micelles by activated sludge particles, which is due to their large specific surface area and the viscosity of polysaccharides. At the same time, some macromolecular organic matter is decomposed into small molecular organic matter under the action of bacterial extracellular enzyme. In the second stage, microorganisms absorb these organic compounds under the condition of sufficient oxygen, and oxidize and decompose to form carbon dioxide and water, some of which supply their own proliferation and reproduction. As a result of the activated sludge reaction, the organic pollutants in the sewage are degraded and removed, the activated sludge itself can multiply and grow, and the sewage can be purified and treated. After purification of activated sludge, the mixture enters the secondary sedimentation tank, where the suspended activated sludge and other solid substances are precipitated and separated from the water, and the clarified sewage is used as the treatment water discharge system. Sediment-concentrated sludge is discharged from the bottom of the sedimentation tank, most of which is made up of In order to inoculate sludge to return to aeration tank to ensure suspended solid concentration and microbial concentration in aeration tank, proliferated microorganisms are discharged from the system, called "surplus sludge". In fact, pollutants are largely transferred from sewage to this excess sludge. (Activated sludge,Baidu encyclopedia)

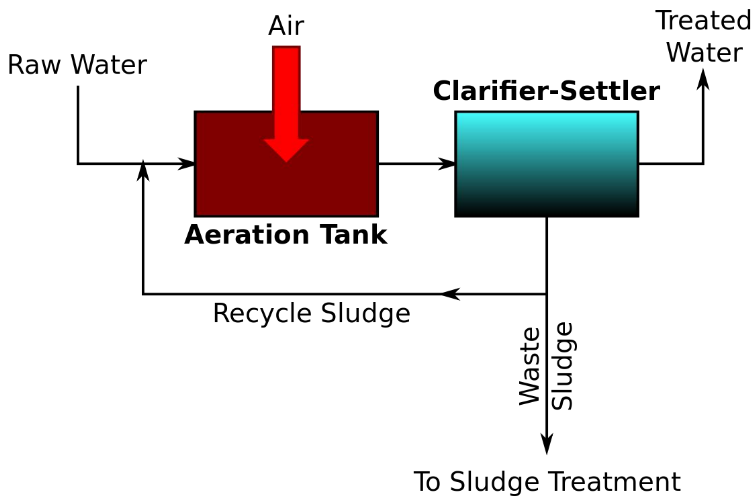

Figure 1. A generalized, schematic diagram of an activated sludge process. (Wikipedia)

2.2 China's situation of wastewater treatment

This chapter mainly introduces the development of municipal wastewater treatment based on the number of treatment facilities in China. At the same time, it also gives a brief introduction to the technological development of wastewater treatment plants in China.

2.2.1 The present situation of municipal wastewater treatment

Municipal wastewater is basically composed of domestic sewage, industrial wastewater and sewage caused by rainfall. This municipal wastewater is usually discharged into the natural water body after the treatment of the sewage treatment plant. The main pollutants of municipal wastewater are organic substances, such as fatty acids, proteins, etc. Other pollutants include suspended solids, pathogens and the like.

In recent years, the process of urbanization in China has been developing rapidly. The number of urban population is increasing and there are many problems in the treatment of municipal wastewater.

The present situation of urban sewage treatment in China basically includes the following aspects: the municipal wastewater treatment technology is relatively backward, the municipal wastewater treatment equipment is not advanced enough, and the professional level of urban municipal wastewater treatment personnel is not high enough. (Present situation and Development trend of Urban sewage treatment in China 2017,Weijie Guo and Yan Liu)

2.2.2 Development of municipal wastewater treatment

Almost all countries in the world are at the expense of the environment in the early stage of national development, that is to say, they pay little attention to the treatment of sewage in the pre-development period, and China is no exception. The development of sewage treatment in China is relatively late compared with other countries, so the treatment of municipal wastewater is somewhat lacking behind when compared with many western countries. Moreover, in the early stage of China, the treatment of municipal wastewater did not pay much attention to the development of urban sewage, which led to the development of urban sewage treatment lagging behind other countries by a large margin.

There were only about ten wastewater treatment plants in China around 1960's. At that time the treatment process was relatively simple and not so efficient in today's standarsd and the scale of treatment was also small. With the emergence of many health diseases caused by wastewater pollution in the world, governments paid great importance to wastewater treatment. At this stage, China also begun to develop wastewater treatment processes and also started large-scale construction of wastewater treatment plants. By the end of 2000, 427 urban wastewater treatment plants were built in China of which 282 were secondary treatment plants, with a secondary treatment rate of 15%. (History and present situation of urban sewage treatment in China)

At present, the biophysical process is still used for municipal wastewater treatment in China and activated sludge process is widely used. Although the municipal wastewater treatment technology in China is developing rapidly, the sewage treatment is usually only for the purpose of pursuing the quality of the effluent, not considering the factors of sustainable development, which does not meet the requirements of the world environment for sewage treatment. (Present situation and Development trend of Urban sewage treatment in China 2017,Weijie Guo and Yan Liu)

In the process of treating municipal wastewater, a number of treatment processes that meet the sustainable development of the large tidal current should be selected. At the same time, the government should pay attention to the treatment of municipal wastewater, not just to say so. It is necessary to adopt a reasonable treatment process according to the current situation of the development of the city in China and the current situation of the ecological environment.

2.3 Opreating activated sludge wastewater treatment plant

Wastewater treatment is generally performed in a series of well-choreographed stages. These stages are called: perliminary treatment; primary treatment; secondary treatment; tertiary(or advanced) treatment. In addition all wastewater treatment plants generate waste solids. It is called "sludge", "biological solid" or other names. (Hopcroft & Francis, Wastewater Treatment Concepts and Practices)

The preliminary treatment is generally to remove large floats, rags and other items that possibly can damage the facilities process equipment. In addition, large gravel, stones and others (Most of them are inorganic) entering the system should be removed. The primary treatment includes a sedimentation tank that precipitates heavier objects, while others, such as plastics, grease, fat and oil, float to the top. Most of this stage is organic, and a small number of inorganic substances may be mixed with them. The secondary treatment part of sewage treatment plant is mostly biological treatment system, that is, activated sludge treatment part. In this stage, micro-organisms in activated sludge are used to treat organic matter in wastewater, and phosphorus and nitrogen in wastewater are reduced as much as possible, so that the treated wastewater can reach the discharge quality. The tertiary system includes nutrient removal or other more esoteric treatment operations. It is not needed at all on some plants. (Hopcroft & Francis, Wastewater Treatment Concepts and Practices)

Table.1 shows the typical design parameters for a secondary treatment system, including those applicable to a trickling filter. Among those is the BOD5 loading. This value relates the concentration of BOD5 in the primary effluent to the surface area of the trickling filter media.(Wastewater Treatment Concepts and Practices,Hopcroft,Francis,2014)

Table 1. Typical secondary system design parameters

Process	Lbs.BOD_5 loading per cubic foot per day(kg/m^3/d)	Lbs.of BOD_5 loading per Ib.MLVSS per day(kg/kg/d)	Mean cell residence time(sludge age),days	Recirculation ratio	Air supplied in cf of air per Ib.of BOD5 (m^3/kg)

Complete mix activated sludge			3~15	0.25~1.0	
Conventional activated sludge	0.56(8.99)	0.2~0.5	3~15	0.25~0.70	45~90(2.79~5.58)
Extended aeration	0.32(5.1)	0.05~0.20	20~40	0.5~1.5	90~125(5.58~7.75)
Contact stabilization	1.12(17.98)	0.2~0.5	5~10	0.5~1.5	45~90(2.79~5.58)
High rate activated sludge	1.6~6.4(25.68~102.7)	0.5~3.5	0.8~4	1.0~1.5	25~45(1.55~2.79)

Table 2. Requirements for laboratory wastewater treatment plants (Laura)

	pH	O_2,(mg/l)	Temperature(℃)
Sampling tank	5.5~9.0	＜0.5	20±1
Reaction tank	6.5~8.5	2~3	20±1

2.4 Laboratory analyses for studying pilot activated sludge wastewater treatment plant

2.4.1 CODcr

COD is a chemical method to measure the amount of reductive substances that need to be oxidized in water samples. The oxygen equivalent of a substance (generally organic) that can be oxidized by a strong oxidant in wastewater, effluent from a wastewater treatment plant and polluted water. In the study of river pollution and industrial wastewater properties, as well as the operation and management of wastewater treatment plants, it is an important and rapid determination of organic pollution parameters. COD is an index to measure the content of organic pollutants in water, the bigger the COD is, the more serious the water is polluted by organic matter. (Water Conservancy Dic-tionary: Shanghai Dictionary Press, 2015)

High chemical oxygen demand means that water contains a large amount of reducing substances, among which the main four organic pollutants. These organic pollutants may come from pesticides, chemical plants, organic fertilizers, etc. Without treatment, many organic pollutants can be adsorbed by sediment and deposited on the bottom of the lake, which will cause long-term toxicity to aquatic organisms in the years to come. If people feed on organisms in water, they will absorb a lot of toxins in these organisms and some of the toxins accumulate in the body. These poisons are often carcinogenic, abnormal and mutagenic, which is extremely dangerous to human beings. In addition, if irrigated with contaminated water, plants and crops will also be affected. They are prone to poor growth and people cannot feed on these crops. (Baidu encyclopedia)

The HT-COD method of HACH Company was used in this research (Figures 2 and 3). The appropriate amount of sample was added into the corresponding reaction tube after heating and digesting with the required time and temperature, and then measured by DR2800 visible light spectrophotometer.

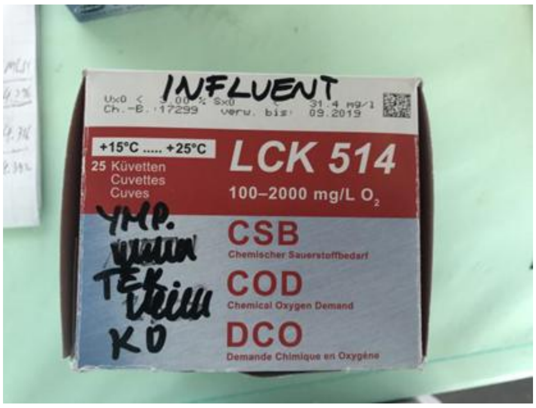

Figure 2. INFLUENT(100-2000mg/l O2)

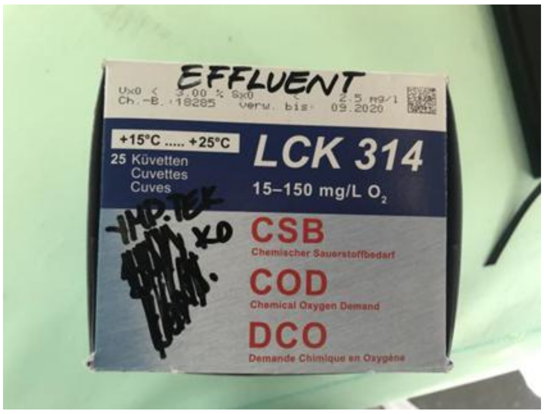

Figure 3. EFFLUENT(15-150mg/l O2)

2.4.2 BOD_7

Biological oxygen demand (BOD) refers to the amount of dissolved oxygen consumed during the bi-ochemical reaction of biodegradable organic matter in water by microbial decomposition under certain conditions. It is expressed in mg / L or percentage, ppm. It is a comprehensive index to reflect the content of organic pollutants in water. If the biological oxidation time is five days, it is called five days biochemical oxygen demand (BOD_5). (Quality control of five-day biochemical oxygen demand determination in water and wastewater. Jun Zhang;Wenwu Yang;2011) This research measures BOD_7.

Pollutants in surface water consume dissolved oxygen in water during microbial-mediated oxidation, and the amount of dissolved oxygen consumed is called biochemical oxygen demand (or biological oxygen consumption, or BOD, in mg/L units). It indirectly reflects the amount of biodegradable organic matter in water. It indicates the total amount of dissolved oxygen consumed by the organic matter in the water when it is inorganic or vaporized due to the biochemical action of microorganism in the process of oxidative decomposition. The higher the value, the more organic pollutants in the water, and the more serious the pollution. (Biochemical oxygen demand [J]. Energy Saving and Emission reduction of Petroleum and Petrochemical Industry.2012)

2.4.3 Phosphate (PO_4-P)

This research needs to measure the total phosphorus content in and out of the water, but we replace the total phosphorus content with the phosphorus content of phosphate radical. In general, the phosphate content in natural water is not high. Chemical fertilizer, metallurgy, synthetic detergent and other industries of industrial wastewater and domestic sewage often contain a large amount of phosphorus. Phosphorus is one of the essential elements for biological growth. But too much phosphorus in the water (such as more than 0.2 mg/L) can cause algae to overmultiply until the amount reaches a harmful level (known as eutrophication), resulting in reduced transparency in lakes and rivers. The total phosphorus is the form of orthophosphate, condensed sulfate, pyrophosphate, metaphosphate and organic group-bound phosphate, which is the main index of eutrophication of water body. (Baidu encyclopedia)

The method of HACH Company was used in this research (Figures 4 and 5). The appropriate amount of sample was added into the corresponding reaction tube after heating and digesting with the required time and temperature, and then measured by DR2800 visible light spectrophotometer.

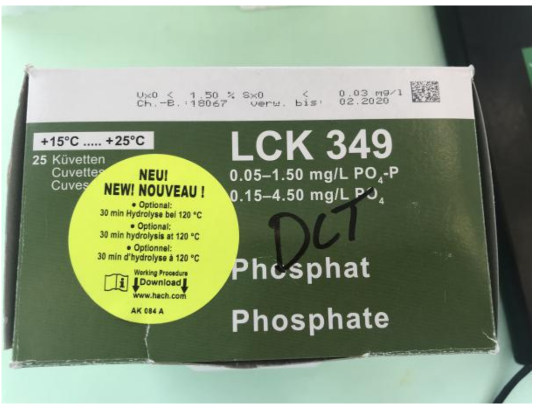

Figure 4. EFFLUENT: HACH –method used in this research.

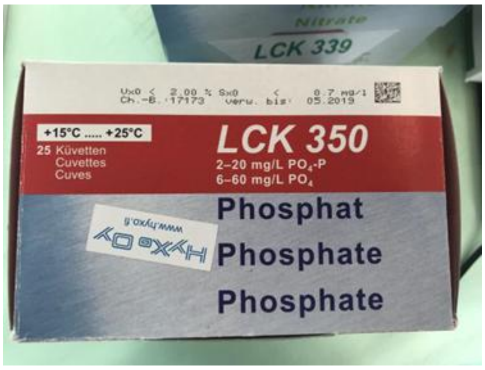

Figure 5. INFFLUENT: HACH –method used in this research.

2.4.4 Nitrate(NO3-N)

Pollution of water by nitrates. Mainly from tannery, chemical wastewater and biochemical treatment facilities drainage and farmland drainage. It can also be produced by oxidation or microbial action of nitrogen-containing organic matter. Nitrate pollution caused eutrophication and decreased water quality.(Dazhihai;Shanghai Dictionary Publishing House)

The method of HACH Company was used in this research (Figure 6). The appropriate amount of sample was added into the corresponding reaction tube after heating and digesting with the required time and temperature, and then measured by DR2800 visible light spectrophotometer.

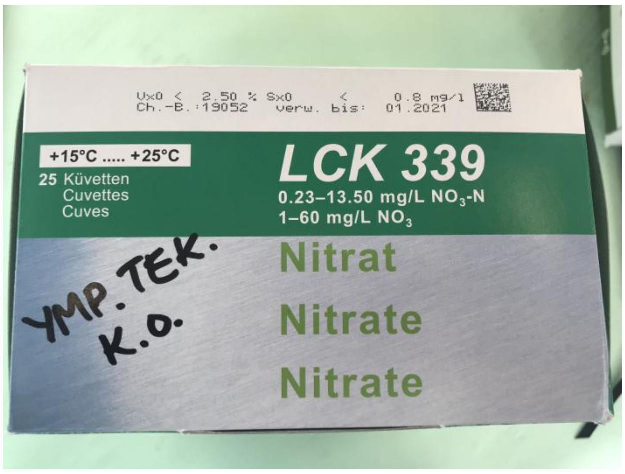

Figure 6. INFLUENT AND EFFLUENT HACH –method used in this research.

2.4.5 Ammonium(NH_4-N)

Ammonia-nitrogen in water exists in the form of ammonium radical (NH-4) and non-ionic ammonia (NH3). The proportion of these two components varies with water temperature and pH value, mainly ammonium. Up to now, there have been no reports that ammonia nitrogen in drinking water is harmful to human health. However, if there is high ammonia nitrogen in surface water, it can cause toxicity to aquatic organisms. The toxic effect is mainly caused by non-ionic ammonia (NH3) in water. (Author unknown)

The method of HACH Company was used in this research (Figures 7 and 8). The appropriate amount of sample was added into the corresponding reaction tube after heating and digesting with the required time and temperature, and then measured by DR2800 visible light spectrophotometer.

Figure 7. EFFLUENT: HACH –method used in this research.

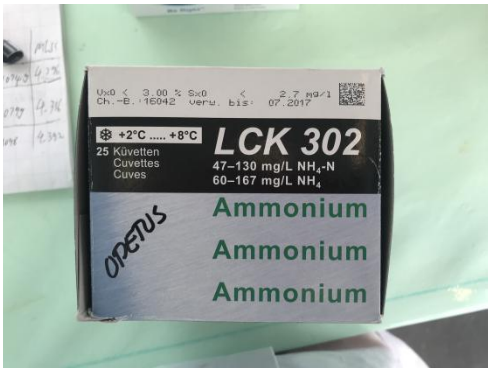

Figure 8. INFLUENT: HACH –method used in this research.

2.4.6 Nitrite (NO_2-N)

Nitrite pollution of water mainly comes from the discharge of industrial wastewater and the transformation of nitrate by microorganism. Nitrite is unstable and can be oxidized to nitrate or reduced to nitrogen under certain water conditions. Nitrite enters the human body to oxidize hemoglobin to methemoglobin, which destroys the oxygen delivery capacity of hemoglobin and causes tissue hypoxia. If the reaction takes place with secondary amines, the formation of carcinogenic nitrosamines compounds happens. (Dazhihai;Shanghai Dictionary Publishing House)

The method of HACH Company was used in this research (Figure 9). The appropriate amount of sample was added into the corresponding reaction tube after heating and digesting with the required time and temperature, and then measured by DR2800 visible light spectrophotometer.

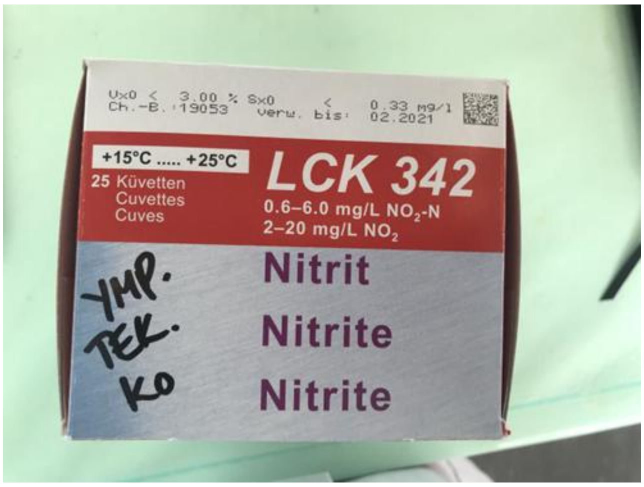

Figure 9. INFLUENT AND EFFLUENT: HACH –method used in this research.

2.4.7 Nitrogen (Total N)

Nitrogen in water mainly comes from metabolism and corruption of organisms, industrial wastewater, discharge of domestic sewage, loss of nitrogen fertilizer and so on. There are four forms of nitrogen in wastewater, namely organic nitrogen, ammonia nitrogen, nitrite nitrogen (a small amount) and nitrate nitrogen (the final product of nitrification process). The total nitrogen content in typical wastewater is about 40 ~ 50 mg / L . Excessive nitrogen in the water will cause eutrophication, aggravate the water quality and affect the growth and reproduction of aquatic organisms. The most serious impact is the "dead waters" caused by rich water, which contains too much nitrogen. Nitrogen flows into rivers and lakes, providing an abundance of algae in the waters. Nutrition, which leads to its rapid growth, consumes most of the oxygen in the water, and any aquatic animal is unable to survive because of hypoxia, so that the water becomes "stagnant water". At the mouth of the Mississippi River in the Gulf of Mexico there is a 8000 square mile of dead water (about 20480 square kilometers). According to statistics, there are about 400 such areas in the world, covering a total area of 245000 square kilometers. (Baidu encyclopedia)

2.4.8 Mixed Liquid Suspended Solids (MLSS)

The solid content describes the quantity of organic and inorganic solids in the sample. The organic share of the solids can be defined as ignition loss and the inorganic matter as ash content. By monitoring the solids, any changes to the operation of the activated sludge plant can be detected.

The principle of the work is to filter the known quantity of the sample through a filter, dry the filter and weight the mass. The result is given in g/l (MLSS). Solids consist of particles in the water sample which will remain on the filter when filtered according to this instruction.

2.4.9 SVI

When evaluating the quality of activated sludge, indexes describing the settling features of the sludge are used, such as the Sludge Volume Index i.e. SVI. SVI describes the settling and condensation features of the sludge. SVI is the volume of one sludge gram (dry weight) when it has been settled in a measuring glass for 30 minutes. The great value of the sludge index indicates the weak settling features of the sludge and it complicates the treatment of the sludge to be removed. The SVI of adequately settling sludge is below 100 ml/g. At SVI between 100 - 150 ml/g, the sludge is still in normal state, a slight bulking state is over 150 mg/l and when the index is over 200 ml/g, the bulking is clear. The definition is made of the activated sludge from the pilot plant. A well-mixed sludge is poured to a 100 ml measuring glass and let to settle for 30 min, after which the volume of the settled sludge is read (x ml/100 ml).

SVI [ml/g]=L/MLSS

,where

L=the volume taken by the settled sludge, ml/L

MLSS=Mass Liquid Suspended Solids of the activated sludge, g/L

2.4.10 PIX

Iron(III) sulfate or ferric sulfate is the chemical compound with chemical formula of $Fe_2\ (SO_4)_3$. Kemira PIX-322 is a liquid precipitator for water purification that contains active trivalent iron compounds. Kemira PIX-322 is suitable for cleaning drinking water and industrial process water. PIX is a dark brown liquid. In table Table 3 there is some chemical data from PIX.

Table 3. Chemical data from PIX

Iron (Fe3 +)	12,5 ± 0,3	%
Iron (Fe2 +)	<0,1	%
Active substance (Me3 +)	2,2 ± 0,1	mol/kg
Sulphate (S042-)	30 ± 1	%
PH	<1	
Density	1575 ± 50	Kg/m3
Viscosity (23 ° C)	30	cP
Solid	<0.04	%

The parts that come into contact with Kemira PIX-322 should be plastic (PE, PP, PVC), fiberglass re-inforced polyester, titanium, rubberized or acid resistant steel. This must be taken into account when selecting pumps, piping and storage parts. Aluminous and copper materials are quick to burn.

Kemira PIX-322 is conceiving. Harmful if swallowed. When handling the product, protective clothing, protective gloves and eye or face protection should be used.

2.4.11 Sludge Age

Sludge age is defined as the average time in days the suspended solids remain in the entire system. The common range for sludge age for a conventional activated sludge plant is between 5 and 15.
Sludge Age [d]=V/Q , where

V=Total capacity of reaction tank, 10L
Q=Amount of sludge added every day, L/d

3 RESEARCH OBJECTIVE

This chapter is mainly to introduce the purpose of this research. The main topic of this paper is Operating and Optimizing the pilot wastewater treatment plant. The focus is on starting up, running, and optimizing the pilot process. This is also the purpose of this paper.

3.1 Defining the pilot wastewater treatment plant

The object of this study is a simple sewage treatment plant in the laboratory. Its basic process is basically the same as that of a real sewage treatment plant, but it is simplified, and the treatment process is relatively simple. Of course, the quality of the treatment is very different from that of the real sewage treatment plant, but the treatment effect of the laboratory wastewater treatment plant is determined by measuring the same indexes of the influent (municipal sewage from the sewage treatment plant) and the effluent (the purified water). Figure 10 presents a simple schematic diagram of the laboratory sewage treatment plant.

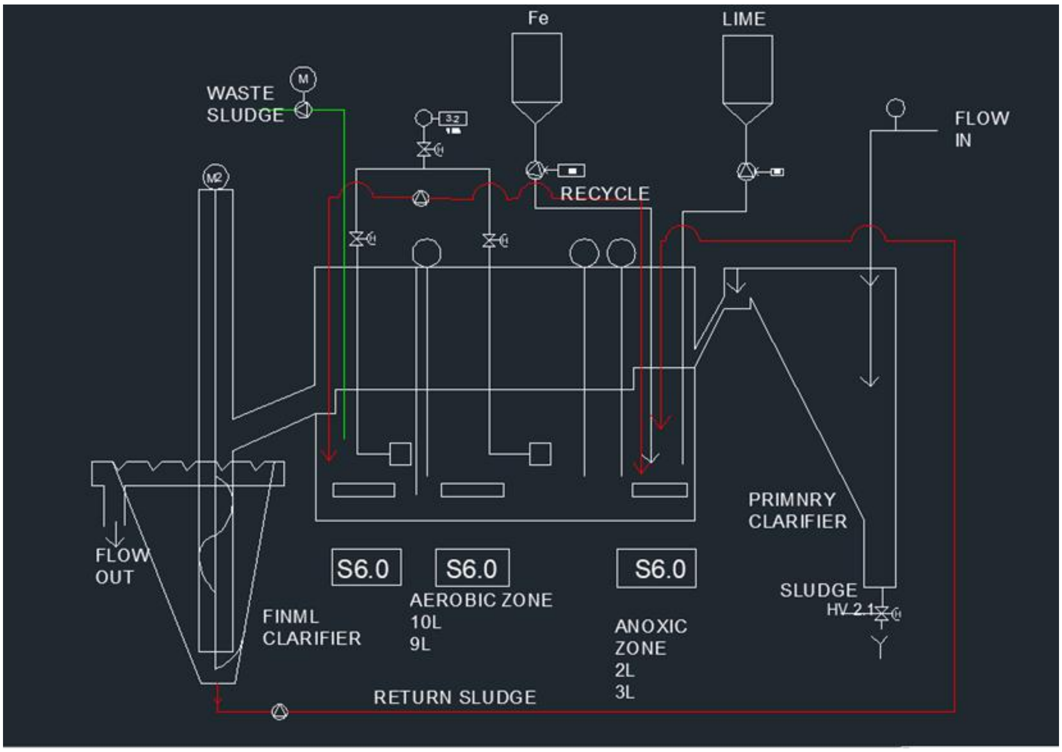

Figure 10. A simple schematic diagram of the laboratory sewage treatment plant used in this research .

3.2 Starting up the process

3.2.1 Automation system

In the operation of the equipment, many conditions need to be controlled, such as controlling the pH, keeping the oxygen level in the reaction pool within a certain range. Therefore, the automation system is used to complete it. At the same time, the automation system can also add some necessary reagents to the reaction cell on a regular and quantitative basis.

The starting page display contains also the so called main menu. Fig. 11 displays the complete structure of the menu. The main menu contains access to 6 submenus and to main power switch.

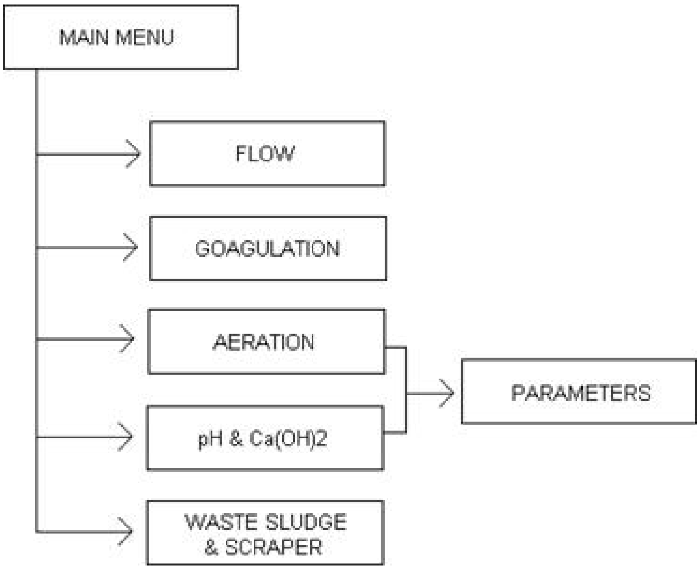

Figure 11. Menu structure of the automation system.

Besides submenus, the main menu display (Figure 12) shows the process diagram with its main measurement devices and numeric values (rpm of the influent pump, pH value, oxygen concentration and water temperature). The values are displayed above each measurement device.

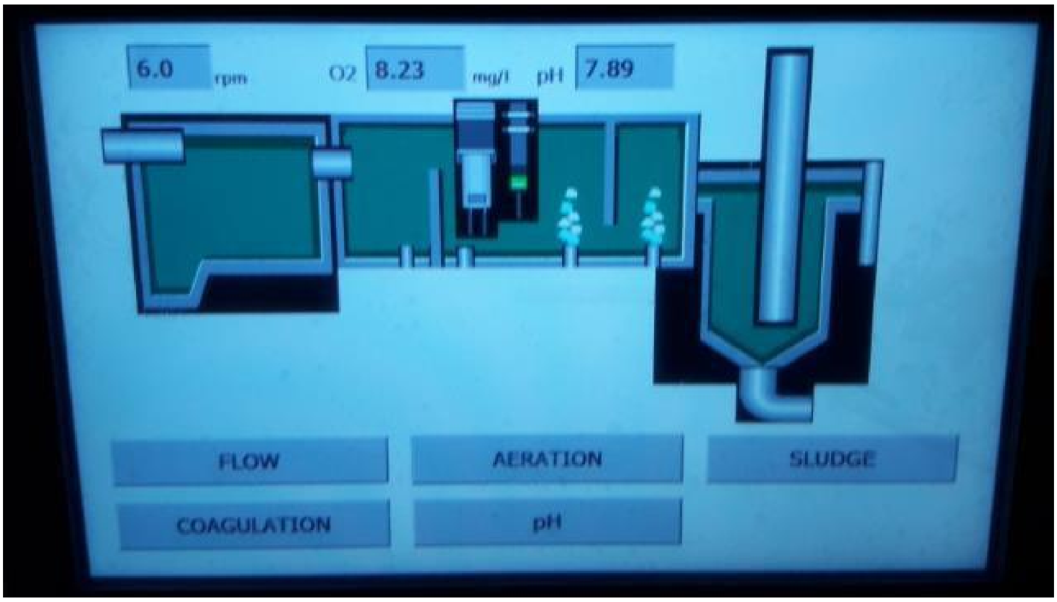

Figure 12. Main menu display

3.2.2 Flow

Flow menu display (Figure 13) indicates the setting of the influent hose pump. The required rounds per minutes are fed to the setpoint data field. The pump is switched on from the on/off button. The dosing pumps do not work unless the influent pump has been switched on.

Figure 13. Flow menu display

3.2.3 Coagulation

Dosing of $Fe_2(SO_4)_3$ is adjusted from the coagulation menu (Figure 14). The display indicates an automatic set value (auto) that can be programmed to automatically maintain the correct dosing setpoint value with respect to the flow. This, however, requires logic programming. The required value is fed into the dosing setpoint data field. Power is regulated from the on/off button. Current signal 4-20 mA in coagulation corresponds to a dose of 0-50 ml/h.

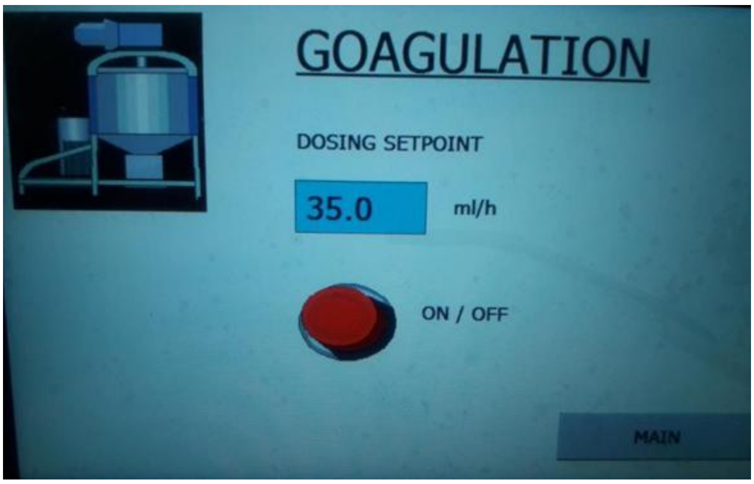

Figure 14. Coagulation menu display

3.2.4 pH

pH menu display (Figure 15) indicates the measurement value, i.e. process value produced by the sensor. Setpoint value determines the desired pH value functioning as default value in the process. This menu allows straight access to the parameter submenu for managing the controller activity.

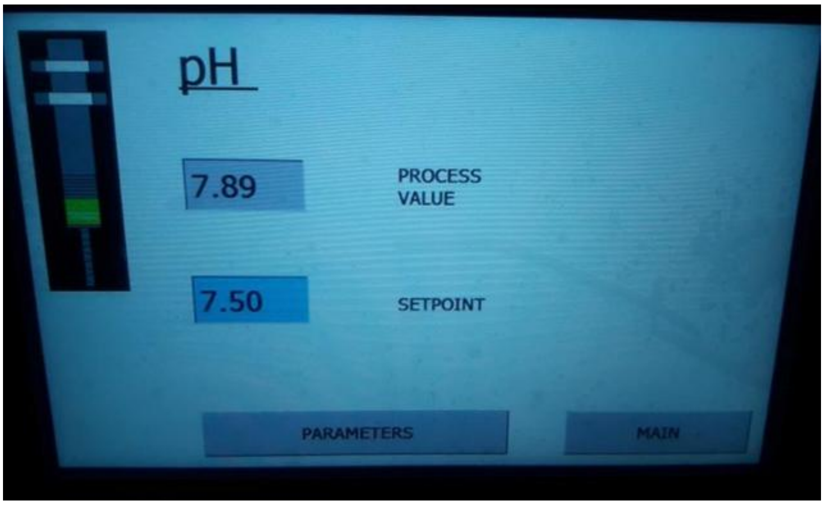

Figure 15: pH menu display.

3.2.5 Aeration

Aeration menu display (Figure 16) indicates the process value, which is the oxygen concentration measured by the oxygen sensor. The desired oxygen concentration value in the water is fed to the setpoint data field. The menu display also indicates the airflow in the air control valve.

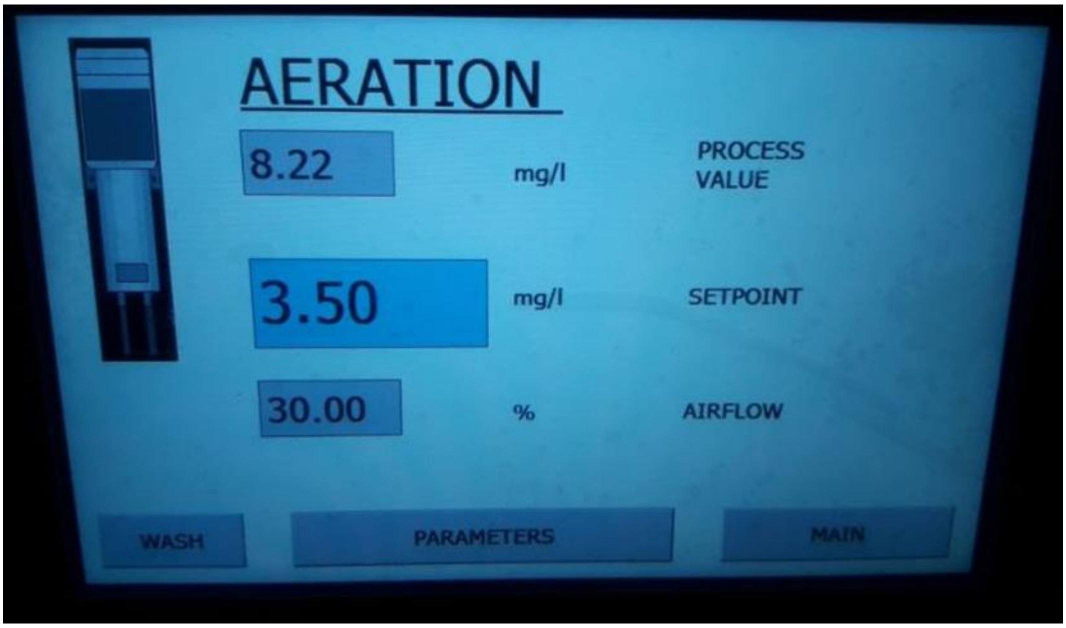

Figure 16. Aeration menu display.

3.2.6 Parameters

Parameter menu display (Figure 17) shows the PID controller GAIN and TI values and their % value for dosing of both oxygen and lime. TI value is managed from its start/stop button.

GAIN controller strengthening ***MLN*** % value of controller start

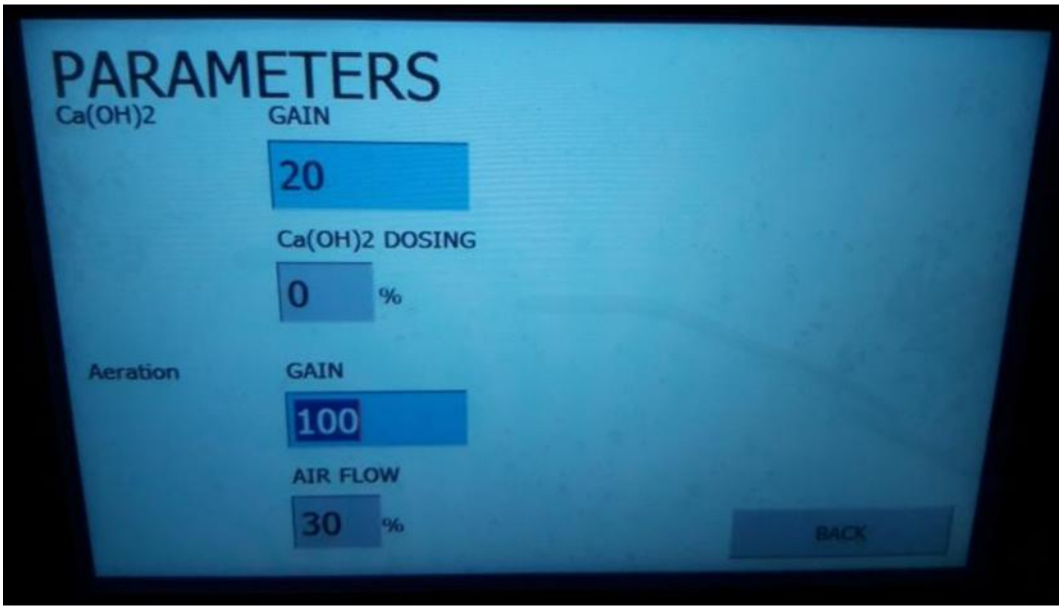

Figure 17. Parameters menu display

3.2.7 Waste sludge & scraper

Menu (Figure 18) displays the settings of waste sludge and scraper. A specific lapse of waste is determined for the sludge removal pump. In other words, the pump will operate at intervals indicated in the data field. The elapsed time data field indicates the minutes elapsed from the previous removal. The desired number of seconds for duration of the sludge removal pump operation is fed to the Duration of waste data field. By pressing the Sludge start button the sludge removal pump starts immediately overriding the removal settings. The setting data fields of the scraper are similar to those of the sludge removal except that the elapsed time is minutes.

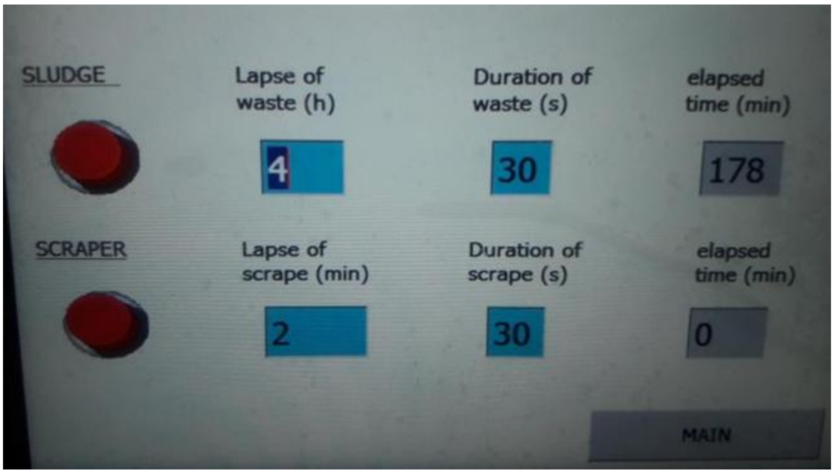

Figure 18 : Waste sludge and scraper setting

3.3 Running and optimizing the process

The equipment can be simply divided into three parts: influent device, reaction device and effluent device. The influent device in the laboratory is composed of a large bucket and a pump (Figure 19), which are returned from the Lehtoniemi wastewater treatment plant and added to the bucket and transported to the reaction device through the pipeline connected to the pump. The laboratory reactor is divided into two parts: the first part is the wastewater, the mixture of ANOX and return sludge; The second part is the reaction part between the wastewater and the microorganism, where there is stirring at the bottom of the part that has been stirring slowly to make the wastewater fully in contact with the microorganism. At the same time, it is necessary to use air compressor to continuously add oxygen to the reaction tank so that the oxygen concentration in the reactor can reach 2 ~ 3 mg /L, at which the microorganism can decompose the organic matter in the wastewater better. In addition to adding oxygen, we should also add NaOH and PIX to empty the pH in the reactor at 6.5 ~ 8.5 so as to make the reaction in the reaction pool better. The effluent device is directly connected to the sewer, and part of the effluent is to be used in the 5000ml container if there is need to do some tests or experiments on the effluent.

Figure 19. The pump of Influent, ANOX and return sludge

4 LABORATORY WORK

This chapter focuses on the laboratory work of the study including the preparations of the operation equipment and a simple analysis of the experimental process.

4.1 The preparations for operation equipment

In order to make the equipment run more smoothly and the experimental results to be better, we need to do a lot of preparatory work. The simplest preparation is that we need to ensure that the reaction conditions in the reaction tank, such as temperature, pH, oxygen and so on, are suitable for activated sludge reaction. Although our intelligent system can reflect the values of these conditions in the reaction pool in real time, sometimes the values that can only be displayed by the system do not match the actual situation, which requires us to use portable devices to measure temperature and pH in the reaction pool. Also oxygen is determined to ensure that it is within the required range.

In order to ensure that the pH in the reaction tank is within the required range, we need to add 1% NaOH solution to the reaction tank regularly and quantitatively through the intelligent system, so we need to prepare 1% NaOH solution. Because of the need for a lot of use, we also have a large amount of one-off preparation, which is generally 10L. We usually use dilution method to obtain 1% NaOH solution, so 200ml of 50% NaOH solution is put into the container and then tap water is added to 10L to get 1% NaOH solution.

In addition to preparing the 1% NaOH solution, we also need to prepare the PIX solution. We need PIX solution mainly to have iron ion in the solution. The main function of ferric ion is to remove phosphorus from wastewater. The ferric ion in PIX solution is in the form of ferric sulfate. The amount of soluble phosphorus in the wastewater and the flow rate determine the amount of ferric sulfate added. In order to ensure that the phosphorus in the wastewater can be removed as efficiently as possible, the amount of iron added to process should be around 50 mg Fe /1 L influent/day.

4.2 Some simple analysis of the research

The detection results of activated sludge wastewater treatment plant include two parts: one is detection indexes of wastewater (Infﬂuent and Effluent), the other is the detection index of sludge. The main detection indexes of sludge are SVI and MLSS. The main detection indexes of sewage are COD, BOD, N and so on.

MLSS is an important index to measure the number of microorganisms in activated sludge, and the number of microorganisms determines the ability to treat wastewater. The reasons for the low MLSS value are as follows: too little sludge in the reaction tank, too low or too high pH, too low oxygen concentration, too high temperature and so on. SVI reflects the loose degree and coagulation performance of sludge and is an index to measure sludge activity. Too low SVI indicates that the activity of sludge is too low and the number of microorganisms is too small, which may be due to the un-suitable pH, temperature, oxygen and other factors.

COD reflects the content of organic matter in wastewater and is an important index of wastewater purification. By measuring the COD, of influent and effluent and calculating the reduction rate of COD, the reduction rate can reflect the activity of sludge. There may be some reasons why the low rate is too low: the COD of influent exceeds the purification capacity of sludge, the conditions such as pH are not suitable, the amount of sludge is too small, and so on. BOD is also an important index to measure organic matter in wastewater, and the reason for its low reduction rate is basically the same as that of COD. N is the main purification in wastewater treatment. The purification of N is divided into two steps. The first step is the conversion from NH_4^+ to NO_2^-. The second step is the conversion from NO_2^- to NO_3^-. According to the comparison of influent and effluent data, we can know which step is wrong.

5 RESULTS

The results of this research are composed of three parts: our own experimental results, the experimental results of SAVONIA's courses and the results of school teachers' test equipment.

We do the experiment once a week and get the results. The wastewater and sludge used in the experiment come from Lehtoniemi wastewater treatment plant. The school tests the equipment every week, and we intercepted some of the experimental data. The course data comes from an experimental course of our own. The course is divided into two parts: the wastewater tests are experiments 2, 4, 6, and the drinking water tests are experiments 1, 3, 5. The members of the course are divided into six groups, and the experiments are carried out every Tuesday. The same contents are carried out by different groups in the morning and afternoon, but the contents of the three experiments are different, and the total content of the three experiments is basically the same as that of our weekly research experiments.

The experimental results are divided into two parts, one is the experimental results of the course (Tables 4 and 5), the other (tables 6, 7 and 8) is the synthesis of all the experimental results. Our own experimental results are 3.29 ~4.17 in the synthesis table.

Table 4. Course results 1

COURSE LAB RESULTS	GROUP	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
	DATE	E2:1.29 E4:2.26 E6:3.26	E2:1.22 E4:2.19 E6:3.19	E2:2.5 E4:3.12 E6:4.2	E2:1.22 E4:2.19 E6:3.19	E2:2.5 E4:3.12 E6:4.2	E2:1.29 E4:2.26 E6:3.26
E2	Flow l/h	0.65	0.758	0.65	0.758	0.65	0.65
	MLSS g/l	3.8	3.601	4.07	3.79	4.05	3.56
	SVI ml/g	180	161	196.6	166	203.7	177
	Sludge age days	8	11.4	9.85	13	9.8	13.4
	Retenion time in aeration tank h	15.4	12.8	15.4	13.2	15.4	15.4
E4	MLSS g/l	4.5	4.93	3.5	4.5	3.61	4.5
	SVI ml/g	146.7	172	84.3	185	99.7	129.8
	Sludge lading, g CODcr/g Mlss*d	0.2	0.24	0.16	0.3	0.16	0.17
	Sludge lading, g BOD7/g Mlss*d	0.07	0.16	0.058	0.15	0.045	0.068
	Organic matter loading, g Codcr/g Mlss*d	0.79	1.2	0.58	1.3	0.56	0.78
	Organic matter loading, g BOD7/g Mlss*d	0.32	0.77	0.2	0.69	0.163	0.31
	CODcr Influent mg/l	506	774	401	733	392	500
	CODcr Effluent mg/l	64.7	76.5	44.5	75.4	44	66.1
	BOD7 Influent mg/l	203	425.5	141	380	113	197
	BOD7 Effluent mg/l	11.5	11.35	3.6	12.2	5.3	11.2
	CODcr-reduction %	87.2	90.1	88.9	89.7	88.8	86.8
	BOD7-reduction %	94.3	97.3	97.4	96.8	95.3	94.3
	BOD7/CODcr-ratio	0.401	0.549	0.352	0.518	0.288	0.394

Table 5. Course results 2.

COURSE LAB RESULTS	GROUP	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
	DATE	E2:1.29 E4:2.26 E6:3.26	E2:1.22 E4:2.19 E6:3.19	E2:2.5 E4:3.12 E6:4.2	E2:1.22 E4:2.19 E6:3.19	E2:2.5 E4:3.12 E6:4.2	E2:1.29 E4:2.26 E6:3.26
E6	Influent PO4-P mg/l	11.7	4.08	9.92	5.84	14.7	16.1
	Influent concentrations of total soluble phosphorus mg/l	2.77	2.8	3.17	3.82	3.26	2.8
	Influent phosphorus concentration fixed to solid matter mg/l	8.93	1.21	6.75	2.02	11.44	13.3
	Effluent PO4-P mg/l	1.81	1.41	1.14	1.42	0.959	1.8
	Effluent concentrations of total soluble phosphorus mg/l	1.57	1.28	0.79	1.1	0.539	1.5
	Effluent phosphorus concentration fixed to solid matter mg/l	0.24	0.68	0.35	0.33	0.42	0.3
	PO4-P reduction %	84.5	65.5	88.5	75.6	93.5	88.8
	Influent TOT-N mg/l	108.5	120.5	58.5	100	61.75	118.75
	Effluent TOT-N mg/l	43	66	36.5	74.6	35.25	45.25
	TOT-N Reduction %	60.37	99.8	37.6	25.5	42.9	61.9
	Influent NH4-N mg/l	57	28.7	46.5	66.2	46.7	64.2
	Effluent NH4-N mg/l	0.006	0.108	0.041	0.092	0.041	0.042
	NH4-N Reduction %	99.9	99.6	99.9	99.9	99.9	99.9
	Influent NO2-N mg/l	0.269	0.234	0.107	0.074	0.156	0.284
	Effluent NO2-N mg/l	0.078	2.65	0.334	2.9	0.308	0.075
	Influent NO3-N mg/l	1.71	1.49	0.639	0.732	0.77	7.55
	Effluent NO3-N mg/l	40.85	63.5	37.3	60.5	36.4	41.35

Fig. 21 Course results 2

Table 6. Total results 1.

LAB results Combine																	
Note: The wastewater samples were taken from lehtoniemi wastewater treatment plants in Kuopio at 02.15.2019 1 % NaOH solution is added to process when needed to keep pH around 7 SLUDGE AGE Sludge age was approximately 10 days (8 - 13 days) from January to March. In April there were more worms than usually so I changed the sludge age to 6,25 days. Additional sludge Amount of additional sludge removed was 0,7 - 1,6 L/day																	
DATE	1.22	1.29	2.05	2.19	2.26	3.04	3.12	3.19	3.22	3.24	3.26	3.29	4.1	4.2	4.5	4.10	4.17
RPM									5	5	5	5	5	5	6	6	5
PIX									30	30	30	30	35	35	35	37	30
CODcr Influent mg/L				774	506	485	401		1015			468	413		348	619	824
CODcr Effluent mg/L				76.5	64.7	63.1	44.5		57.9			45.9	47.2		44.8	43.5	67.4
CODcr Reduction %				90.1	87.2	87.0	88.9		94.3			90.2	88.6		87.1	92.9	91.8
PO4-P Influent mg/L								4.08	14.6		11.7	7.93	7.21	9.92	10.9	7.66	7.8
PO4-P Effluent mg/L								1.41	0.288		1.81	0.311	1.38	1.14	0.895	0.636	0.643
PO4-P Reduction %								65.5	98		84.5	96.1	80.8	88.5	91.8	91.7	91.8

Table 7. Total results 2

LAB results Combine																	
Note: The wastewater samples were taken from lehtoniemi wastewater treatment plants in Kuopio at 02.15.2019 1 %																	
NaOH solution is added to process when needed to keep pH around 7																	
SLUDGE AGE																	
Sludge age was approximately 10 days (8 – 13 days) from January to March. In April there were more worms than usually so I changed the sludge age to 6,25 days.																	
Additional sludge																	
Amount of additional sludge removed was 0,7 – 1,6 L/day																	
DATE	1.22	1.29	2.05	2.19	2.26	3.04	3.12	3.19	3.22	3.24	3.26	3.29	4.1	4.2	4.5	4.10	4.17
TOT.N Influent mg/L								120.5	25.6 *5=128	118.8	108.5	13.0 *5=65	58.5	58.5	14.8 *5=74	5.23 *10=52.3	18.9 *5=94.5
TOT.N Effluent mg/L								66	8.8*5=44	45.25	43	8.7*5=43.5	36.5	36.5	10.8 *5=54	5.13 *5=25.65	5.2*5=26
TOT.N Reduction %								99.8	65.6	61.9	60.37	33.1	37.6	37.6	27	51	72.5
NO2-N Influent mg/L								0.234	0.401	0.284	0.269	0.215	0.334	0.107	1.02	0.19	0.309
NO2-N Effluent mg/L								2.65	0.39	0.075	0.078	0.102	0.107	0.334	0.257	0.447	2.04
NO3-N Influent mg/L								1.49	1.57	1.55	1.71	0.84	0.635	0.639	1.11	0.829	0.965
NO3-N Effluent mg/L								63.5	7.35 *5=36.75	41.35	40.85	8.22 *5=41.1	37.3	37.3	10.7 *5=53.5	4.38 *5=21.9	1.08 *5=5.40

Table 8. Total results 3.

LAB results Combine

Note: The wastewater samples were taken from lehtoniemi wastewater treatment plants in Kuopio at 02.15.2019

1 % NaOH solution is added to process when needed to keep pH around 7

SLUDGE AGE

Sludge age was approximately 10 days (8 - 13 days) from January to March. In April there were more worms than usually so I changed the sludge age to 6,25 days.

Additional sludge

Amount of additional sludge removed was 0,7 - 1,6 L/day

DATE	1.22	1.29	2.05	2.19	2.26	3.04	3.12	3.19	3.22	3.24	3.26	3.29	4.1	4.2	4.5	4.10	4.17
NH4-N Influent mg/L								28.7	75.4	64.2	57	50.2	47.7	46.5	51.6	46.3	70.4
NH4-N Effluent mg/L								0.108	1.04	0.042	0.006	0.051	0.003	0.041	0.047	0.071	
NH4-N Reduction %								99.6	98.6	99.1	99.9	99.8	99.9	99.9	99.9	99.8	
BOD7 Influent mg/L				425.5	203		141		603			175					
BOD7 Effluent mg/L				11.35	11.5		3.6		5.3			2.5					
BOD7 Reduction %				97.3	94.3		97.4		99.1			98.6					
Settling ml/100ml	58	68	80	85	66	45	30		77	72		45	19		65	25	20
MLSS g/L	3.601	3.8	4.07	4.93	4.5		3.5		5.138			4.335			4.46	3.548	3.17
SVI ml/g	161	180	196.6	172	146.7		84.3		149.9			103.8			145.7	70.46	63.1

In the whole study, we kept the whole equipment in the suitable reaction conditions. We controlled the pH in the reaction cell by automatic system at 6.5 ~8.5, O_2 at 2 - 3 mg / l, and the temperature at 19 ~20 ℃. Compared with our own experimental results, according to the reduction rate of each index, we can see that the 4.1 result is the worst. With the exception of NH_4^+, the reduction rate of other indicators is too low. And the settling is only 19 ml /100 ml. From this one knows that 4.1 the activity of sludge in the reactor is too low and the number of microorganisms in the sludge is too low. However, the microorganisms that promoted the conversion of NH_4^+ to NO_2^-, were at a normal level, because the reduction rate of $NH_4^+$was 99.9 %. Compared with the results of the experimental course, the results of our own experiments are poor except for the first time, which may be due to the decrease of sludge activity due to the long storage time of the sludge obtained from the sewage treatment plant. Because the settling value is very low, the SVI and MLSS values are also low.

The activity of activated sludge is closely related to the number of microorganisms in sludge and the living conditions of microorganisms. Whether it is a real sewage treatment plant or a simple sewage treatment plant in the laboratory the main goal is to ensure that the amount of microorganisms is big enough and their living environment is suitable for the survival.

6 CONCLUSIONS

The purpose of this study was to study how to start, operate and optimize activated sludge wastewater treatment plants. After several months of study, I have learned the basic process of wastewater treatment plant, the principle of activated sludge treatment of wastewater, how to operate the wastewater treatment plant and how to determine and analyze the treatment results of wastewater treatment plant.

Micro-organisms are extremely sensitive to environmental requirements. Optimal pH is at 6.5~8.5, O_2 is optimal at 2-3 mg / l, and for temperature the optimal conditions is about 20 degrees Celsius.

For educational or research purposes, in pilot activated wastewater treatment plants it is best to get the wastewater from real wastewater treatment plant together with sludge. Also it is necessary that these are replaced frequently, because long storage may greatly reduce the activity of the sludge.

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