EFFECTIVENESS OF LAGOONS IN IMPROVING WATER QUALITY OF DISCHARGE FROM PIG FARM IN KOTA SAMARAHAN AREA

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Bachelor of Science with Honours (Resource Chemistry)
2005
EFFECTIVENESS OF LAGOONS IN IMPROVING WATER QUALITY OF DISCHARGE FROM PIG FARM IN KOTA SAMARAHAN AREA

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This project is submitted in partial fulfillment of the requirements for the degree of Bachelor of Science with Honours (Resource Chemistry Program)

Faculty of Resource Science and Technology
UNIVERSITI MALAYSIA SARAWAK
2005
DECLARATION

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree of qualification of this or any other university or institution of higher learning.

Andrew Bin Modingin

Program of Resource Chemistry
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ACKNOWLEDGEMENT

I would like to express my sincere gratitude and appreciation to Dr. Ling Teck Yee for her constant guidance, counsel and supervision throughout this project. Without her perseverance and leadership, the success of this project would not have been achieved.

I would also like to thank Sarawak Agriculture Department for the provision of permit to carry out this study in pig farms at Kota Samarahan area. I would especially like to thank the agriculture officer of Siburan district, Mr. Queh for his valuable assistance in providing useful information throughout the research. Not forgetting to greatly appreciate the efforts and willingness of Mr. Daud and Mr. Simon as drivers. In addition, I would like to thank Mr. Jahina as the lab assistant for his assistance in samplings.

Furthermore, I benefited from additional contributions from my colleagues especially Mr. Wee Boon Hong, Vivien Liew, Khoh Sze Yun and Sylvia through their generosity in supplying advice and support. Finally, I would like to dedicate the success of this project to my parents, for their constants prayers, encouragement and support throughout my life.
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Effectiveness of Lagoons in Improving Water Quality of Discharge from Pig Farm in Kota Samarahan Area

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ABSTRACT

Effectiveness of lagoons in improving water quality of discharge from pig farm was studied. The wastewater parameter examined were the physical and chemical of wastewater, temperature, pH, dissolved oxygen (DO), total solids (TS), total volatile solids (TVS), chemical oxygen demand (COD) and total nitrogen (TN). There were four types of lagoons treatment system studied, single lagoon, double lagoon with separator, double lagoon without separator and triple lagoon. Only outflow was examined in the single lagoon. Temperature ranged from 25.3 °C to 32.7 °C. pH mean values ranged from pH 6.23 to 7.96. The mean concentration of DO ranged from 0.06 mg/l to 1.93 mg/L. Double lagoon without separator reduced 63.0 % of TN, 83.4 % of COD, 36.9 % of TS and 52.3 % of TVS. Triple lagoon system reduced 88.1 % of TN, 98.2 % of COD, 81.4 % of TS and 73.1 % of TVS. However, in double lagoon with separator, there was an increase of 13.2 % of TN and small reduction of COD (9.3 %), TS (6.7 %) and TVS (8.0 %). Triple lagoons treatment system was found to be more effective in improving water quality of discharge from pig farms.

Key word: lagoon, pig farms, water quality.

ABSTRAK

Kajian dilakukan terhadap keberkesanan lagun dalam meningkatkan kualiti air dari air kumbahan ladang babi. Parameter air kumbahan yang dikaji dari ladang babi melibatkan parameter fizikal dan kimia iaitu suhu, pH, oksigen terlarut, jumlah pepejal, jumlah pepejal merup, keperluan oksigen kimia dan jumlah nitrogen. Terdapat empat jenis sistem rawatan lagun yang dikaji iaitu sistem satu lagun, sistem dua lagun tanpa alat pemisah, sistem dua lagun dengan alat pemisah dan sistem tiga lagun. Hanya air keluar sahaja dikaji dalam ladang satu lagun. Suhu ladang babi di antara 25.3 °C hingga 32.7 °C. Nilai pH ladang babi di antara 6.23 hingga 7.96. Julat bagi kepekanan oksigen terlarut di antara 0.06 mg/l hingga 1.93 mg/L. Sistem dua lagun tanpa alat pemisah mengurangkan 63.0 % TN, 83.4 % COD, 36.9 % TS dan 52.3 % TVS. Sistem tiga lagun mengurangkan 88.1 % TN, 98.2 % COD, 81.4 % TS dan 73.1 % TVS. Walau bagaimanapun, sistem dua lagun yang mempunyai alat pemisah menambahkan jumlah nitrogen sebanyak 13.2 %. Sistem dua lagun yang mempunyai alat pemisah hanya mengurangkan 9.3 % COD, 6.7 % TS dan 8.0 % TVS. Didapati ladang babi sistem tiga lagun lebih berkesan dalam meningkatkan kualiti air kumbahan dari ladang babi.

Kata kunci: lagun, ladang babi, kualiti air.
Chapter 1 Introduction

1.1 Introduction

Pig farming which started as backyard family activities among the Chinese population of Malaysia has grown rapidly to become an important industry which contributes over 30% of the total gross value of livestock produce (Ahmad et al., 1983). In Malaysia, one of the industries identified as causing serious water pollution is the pig industry (Kinson et al., 2001).

Where intensive livestock farming does occur, pollution from nutrients namely phosphorus and nitrogen is the most serious problem (Hooda et al., 2000). It leads to excess algae growth and reduce oxygen concentration in water. When oxygen concentration is reduced, it may in turn lead to mass fish kills. Manure production as excreted in kg/animal/day for mature pigs of an average weight of 150 kilogram, would amount to approximately 21.1 kg/animal/day of solid material and 15.9 liters/animal/day of liquids (Kinson et al., 2001).

Whenever the farms are being cleaned, the feaces of pigs would normally be washed into nearby streams or waterways. This would certainly pose a major health risks as the large amount of organic material enhance the bacteria’s growth. The decomposition process would eventually uses up available oxygen in the streams or waterways. Indiscriminate discharge of pig waste has polluted rivers, drains, other waterways and the surrounding land. A little river in Serian, Sarawak, Sungei Rayang had been declared a ‘dead river’ as a result of pollution by nearby pig farms (Davidson, 2002). Many disease resulted from unhealthy surrounding created by pig farms like Japanese Encephalitis (JE), Encephalomyocarditis, Vesicular
Stomatitis and Foot and Mouth Disease (Abdullah, 2003) which may not only kill animals but also humans (Davidson, 2002).

Odour pollution in the form of ammonia nitrogen from intensive pig farm can cause respiratory illness in neighbors living up to two miles away (Kinson et al., 2001). Ammonia is formed as a result of decomposition of most nitrogenous organic materials. Ammonia concentration in surface water are generally very small due to the average pH of most surface waters being sufficiently low to convert all ammonia to ammonium ion; however as little 0.02 mg L⁻¹ ammonia maybe toxic to fish and other aquatic life particularly at high pH (Cooper, 1993). Ammonium ion can be directly from pig urine. Ammonium ion and ammonia become readily available by the breakdown of organic nitrogen compound in the presence of oxygen. It produces various nitrogen compounds as nitrite and nitrate which are implicated in aquatic eutrophication. The loss of nitrate in agricultural runoff has potentially serious implication for the quality of potable water in human health problems including infant methemoglobinemia 'baby syndrome' (WHO, 1985).

Pig manure has a significant impact on nitrate leaching (Hooda et al., 2000). Manure generally composed of ammonium ion and organic nitrogen often in equal ratio. While manure borne ammonium is readily available to plants, organic nitrogen must undergo mineralization to become available. Organic nitrogen has to biologically oxidized to nitrate before manure nitrogen can contribute to nitrate leaching (Hooda et al., 2000).

Water pollution resulted from agricultural farm was reported to be a problem in Sarawak (State Veterinary Authority, 2001). There are estimated 2,340 farms in Sarawak with an estimated animal population of 500,000 (Kinson et al., 2001) compared only 207 farms in 1996 (NREB, 1996). This study was carried out in Sarawak because the increasing number of pig farm may contribute to deterioration of water quality in Sarawak.
The results and outcomes of this research may be used as a reference to the local authorities and Sarawak government to plan and propose waste treatment systems. This research also may provide information for local authorities such as the Natural Resource and Environment Board, Sarawak to make decisions on waste management of pig farm in future.

1.2 Objective

The objectives of this research were to investigate the effectiveness of pig farm lagoons in improving water quality parameter namely totals nitrogen, total solid, total volatile solid and chemical oxygen demand and to propose wastewater management practices.
Chapter 2 Literature Review

2.1 Lagoon

Lagoon also known as oxidation pond is a relatively shallow body of wastewater contained in an earthen basin (Tchobanoglous and Burton, 1991). Lagoons are basin designed for biological treatment of wastewater (Vernick and Walker, 1981). Lagoon is biologically complex (McGhee, 1991). Lagoon also defined as an earthen structure designed for storage and biological treatment of livestock or poultry waste (Mukthar, 1999).

Lagoon became popular for animal waste treatment as historic interest to utilize manure fertilizer constituents by direct land application was replaced by desires to have more convenient waste management system. Originally, lagoon were viewed as a total disposal system, it is now recognized that in moisture excess regions, lagoons are one pretreatment in the overall manure management plant (Humenik et al., 1980). Where ample land is available without causing public nuisance and in favorable climate condition, disposal by lagooning on at least a short term basis is usually the economic solution (Pentius, 1990).

Lagoons are not all the same. Some lagoon design provides adequate treatment for certain methods of discharge while other should be used in combination with other lagoons or with additional treatment. There are some common types of lagoons such as anaerobic lagoons, aerobic lagoons, aerated lagoons and facultative lagoons.

Anaerobic lagoons means that the conditions inside this type of lagoon without oxygen. Anaerobic lagoons are often used to treat animal’s wastes from diaries and pig farms and commercial or industrial wastes (Tchobanoglous and Burton, 1991). This types lagoon also employ as the first treatment step in systems using two or more lagoons in are series. Inside an aerobic lagoon, solids in wastewater separate and settle into layers. The top layers
consist of grease, scum and other floating materials. This layer keeps oxygen out, allowing bacteria and other organisms that thrive in aerobic conditions to work to treat the wastewater. The bottom layers of an aerobic lagoons consists the layer of sludge which eventually accumulates and must be removed periodically (Anon, 1997). The wastewater that leaves aerobic lagoons requires further treatment. Odor pollution can be a problem with anaerobic lagoon but can be managed through a variety of method such as made a larger lagoons and regular maintenance (Humenik et al., 1980).

Aerobic lagoons tend to be much shallower than other lagoons. The shallower depth of aerobic lagoons allows sunlight and oxygen from air and wind can better penetrate the wastewater (Anon, 1997). Aerobic lagoons are better suited for warm and sunny climates. Wastewater treatment takes place naturally in aerobic lagoons with the aid of aerobic bacteria and algae (Tchobanoglous and Burton, 1991). The bottom of aerobic lagoons needs to be paved or lined with materials that will prevent weeds from growing in them because aerobic lagoons too shallow (Anon, 1997). The wastewater in aerobic lagoons often needs to mix to allow sunlight to reach of the algae. Aerobic lagoons are generally constructed to operate at a depth between 1.0 and 1.5 meters (McGhee, 1991).

Aerated lagoon systems are use aerators to mix the contents of the pond and add oxygen to the wastewater. Aerated lagoons are used in small communities. Depend on the extent of aeration, aerobic lagoons referred to as partial mix or complete-mix lagoons. Aerated lagoons require energy to operate. Aeration makes treatment more efficient. Aerated lagoons require less land area and shorter detention times for wastewater than other lagoons (Anon, 1997).

Facultative lagoons also are called stabilization ponds, oxidation ponds, photosynthetic ponds and aerobic-anaerobic ponds. Both aerobic anaerobic conditions exist in
facultative lagoons (Tchobanoglous and Burton, 1991). Facultative lagoons are the common type of wastewater treatment lagoon used by small communities and individual households. Facultative lagoons can be adapted for use in most climates (Anon, 1997). Facultative lagoons do not require machinery. Facultative lagoons treat wastewater naturally using both aerobic and anaerobic processes (McGhee, 1991).

2.2 Removal of nitrogen

As a biological treatment, lagoon is used to remove nutrient with biological process involving the use of both algae and bacteria (Tchobanoglous and Burton, 1991). Biological process is reliable and effective in removing nitrogen (Tchobanoglous and Burton, 1991). Two principal mechanisms for the removal of nitrogen are assimilation and nitrification-denitrification. Microbes in a treatment process will assimilate ammonia nitrogen and incorporate it into cell mass. In nitrification process, the first step are ammonia is oxidized by converting it to nitrate in the presence of oxygen but nitrogen only changed form and is not removed. In the second process, the denitrification process, nitrogen is removal by converting nitrate to a gaseous product.

Bacteria are responsible to decompose the origin waste (McGhee, 1991). For nitrification, nitrosomonas and nitrobacter bacteria are involved (Tchobanoglous and Burton, 1991). Nitrosomonas oxidizes ammonia to nitrite. Nitrite then is converted to nitrate by nitrobacter. The reaction that occurs can be written as follows.

For nitrosomonas the equation is

$$\text{NH}_4^+ + \text{O}_2 + \text{HCO}_3^- \rightarrow \text{C}_5\text{H}_7\text{O}_2\text{N} + \text{NO}_2^- + \text{H}_2\text{O} + \text{H}_2\text{CO}_3$$
For nitrobacter the equation is

\[ \text{NO}_2^- + \text{NH}_4^- + \text{H}_2\text{CO}_3 + \text{HCO}_3^- + \text{O}_2 \rightarrow \text{C}_3\text{H}_7\text{O}_2\text{N} + \text{H}_2\text{O} + \text{NO}_3^- \]

Denitrification process also accomplished by several genera of bacteria as aerobacter, bacillus, achromobacter, pseudomonas and spirillum. Denitrification is the removal of nitrate by conversion to nitrogen gas with accomplished biologically under anoxic condition (Tchobanoglous and Burton, 1991). Denitrification occurs in two steps process. The first step is the conversion nitrate to nitrite followed by the production of nitric oxide, nitrous oxide and nitrogen gas. The reactions for nitrate reaction are

\[
\begin{align*}
2\text{HNO}_3 & \rightarrow 2\text{HNO}_2 + \text{O}_2 \\
2\text{HNO}_2 & \rightarrow 2\text{NO} + 2\text{H} \\
2\text{NO} & \rightarrow \text{N}_2\text{O} \\
\text{N}_2\text{O} & \rightarrow \text{N}_2 + \frac{1}{2}\text{O}_2
\end{align*}
\]

The overall reactions are

\[ \text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2 \]

Nitric oxide, nitrous oxide and nitrogen gas can be released to the atmosphere.

### 2.3 Removal of organic matter

The symbiotic relationship between bacteria and algae leads to stabilization of the incoming waste (McGhee, 1991). Incoming organic matter from washed streams is oxidized by bacteria to yield materials as CO\textsubscript{2}, H\textsubscript{2}O and the other end products of aerobic metabolisms. Then, these materials are then used by algae to produce more algae cells.

The biological conversion of the organic matter in the treatment occurs in three steps such as hydrolysis, acidogenesis and methanogenesis (Tchobanoglous and Burton, 1991). The
hydrolysis step involves the enzyme-mediated transformation of higher molecular mass
compounds into suitable compound for use as the source energy and carbon cell such as fatty
acids, amino acids and monosaccharide. The second step (acidogenesis) involves the bacterial
conversion of the compounds resulting from hydrolysis step to identifiable lower molecular
mass intermediate compounds such as methanol, methylamines and acetic acid. The third step
(methanogenesis) involves the bacterial conversion of the intermediate compounds into
simpler end product such as methane and carbon dioxide (Tchobanoglous and Burton, 1991).

2.4 Water quality parameters
An increase in the amount of organic matter entering the system increases biological and
chemical oxygen demand (BOD and COD). BOD is defined as the amount of oxygen required
by bacteria while stabilizing decomposable organic matter under aerobic condition (Kinison et
al., 2001). It widely used to determine the pollution strength of domestic and industrial
waters. COD is defined as the amount of a specified oxidant that reacts with the sample under
controlled condition (Clesceri et al., 1998). The quantity of oxidant consumed is indicated by
COD. Organic matter is converted to CO₂ and H₂O regardless of the ability of the substances
to be broken down by biological process. The advantage of the COD test is the short time
required for evaluation than BOD (Kinison et al., 2001).

In water and wastewater nitrogen occurs in several form including dissolved molecular
nitrogen, ammonia/ammonium, nitrate, nitrite and organic nitrogen. Total nitrogen comprised
organic nitrogen, ammonia, nitrate and nitrite.

Solid refer to matter suspended or dissolved in water or wastewater. Water with high
dissolved solid generally is of inferior palatability and may induce a favorable physiological
reaction in transition consumer. High mineralized water not suitable for drinking and
Industrial application (Clesceri et al., 1998). Total solids content of wastewater is defined as all the matter that remains as residue upon evaporation at 103°C to 105°C (Clesceri et al., 1998). Total solid include total suspended solid and total dissolved solid. Total suspended solid is the portion of total solid retained by a filter. Total dissolved solid is the portion that passes through the filter. Total volatile solid refer to the weight loss on ignition of water or wastewater material residue (Clesceri et al., 1998). Solid analysis is important in the control of biological and physical wastewater treatment process and for assessing compliance with regulatory agency wastewater effluent limitation.

4.5 Previous studies on wastewater in pig farm

There are several previous studies about pig farm in Malaysia. Taiganides et al. (1986) studied the characteristics of wastes from pig farm in Malaysia. This research carries out composites sample of pig farm wastewaters in four different pig farming areas in Malaysia over a period of one year. The area is Bukit Pelandok, Negeri Sembilan, Tanjung Layang, Sungai Buloh, and Serdang, Selangor. The samples were tested for major parameter as total solids, total volatile solids, total suspended solid, biochemical oxygen demand, chemical oxygen demand and total kjeldahl nitrogen. The result of the research from three sites, Bukit Pelandok, Tanjung Layang and Serdang shows BOD running mean converged toward 3000 mg/L. Total suspended solid running mean converged toward a concentration of 6000 mg/L. Total volatile solid running mean converged toward 6000 mg/L.

Engineering design parameters of wastes from pig farms was reported by Teoh et al. (1988). This research was carried out a composite sampling in four typical pig farming operations in Malaysia. There were in Bukit Pelandok, Negeri Sembilan, Tanjong Layang, Selangor, Sungai Buloh, Kuala Lumpur and in an institutional research farm. This research
formed to develop an engineering design parameters values and waste generation rates per standing pig population (SPP) and per animal population unit (APU) based on arithmetic means values using projected mean animal live weight (ALW) of future farms. The design values was calculated to be 49 kg ALW SPP$^{-1}$ in a 6000 SPP farm.

The effectiveness of lagoon in two pig farms in Kota Samarahan district was conducted by Abdullah (2003). This research collected samples from one-lagoon and three-lagoon system. This research found that the three-lagoon system effectively reduced water quality parameter as total suspended solid (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen and nitrate. The result of the research shows BOD range 50 mg/L to 62 mg/L, COD range 480.0 mg/L to 559.0 mg/L, TSS range 205.0 mg/L to 300.0 mg/L, ammonia nitrogen range 400.0 mg/L to 456.0 mg/L and nitrate range 0.05 mg/L to 1.18 mg/L for a farm one-lagoon system. For three-lagoon system, the result shows BOD range to 30.0 mg/L to 58.0 mg/L, COD range 250.0 mg/L to 500.2 mg/L, TSS range 130.0 mg/L to 298.0 mg/L, ammonia nitrogen range 175.0 mg/L to 399.0 mg/L and nitrate range 0.005 mg/L to 1.90 mg/L.

2.6 Government regulation/legislation on discharge quality

In 1984, the National Agricultural Policy of Malaysia proclaim that pig farming should be carried out in suitable sited areas incorporated with wastewater treatment facilities to control the water pollution from pig industry (Kinson et al., 2001). Waste characterization was initiated in 1984 to quantify the amount of water pollution caused by pig farming operations and to develop engineering parameters for the design of wastewater management systems in
However, published information regarding pig farm waste management in Sarawak is scarce.

In Sarawak, farms having more than 100 animals are required to obtain license to operate under the Natural Resources and Environment (Control of Livestock Pollution) Rules 1996. There are estimated 2,340 farms in Sarawak with an estimated animal population of 600,000 (Kinson et al., 2001). The Natural Resources Environment Board (NREB), Sarawak, have gazette the standards for the permitted discharge of treated waste (Appendix A and B).
Chapter 3 Materials and methods

1 Sampling location

Wastewater samples were collected from four pig farms in Kota Samarahan area. Two of the farms have two lagoons system and the other farms have three lagoons system and one lagoon system. One of the farms which have two lagoons system has a separator and another one has no separator.

1.1 Single lagoon farm

This farm has 1330 standing pig population (SPP) and started operating since 22 years ago. The length of the lagoon was 50 feet and the width was 30 feet. Depth the lagoon when constructed was 30 feet. When sampling was done, the lagoon was already filled with the sludge. No maintenance was done. This pig farm bathed the pigs three times per day.

1.2 Double lagoon farm with separator

This farm has 1200 standing pig population (SPP). This farm has two bathing times per day. Both lagoons were of the same size. The length of both lagoons was 20 feet. The width of that both lagoons also was 20 feet. Depth during research was 3 feet. Both of the lagoons on this farm had lots of sludge on the surface. This farm has a separator.
1.3 Double lagoon farm without separator

This farm has 923 standing pig populations. The farm was 8 years old. This pig farm has two thing times per day. The first lagoon was 50 feet length and 25 feet width. Depth the first goon when constructed was 25 feet. The depth at sampling was 2 feet. The second lagoon as 30 feet length and 25 feet width. The depth of second lagoon when constructed was 25 feet. The depth at sampling was about 2 feet.

1.4 Triple lagoon farm

This farm has 1915 standing pig population (SPP) and was 8 years old when researched. This farm has two bathing times per day. This farm has three lagoons treatment with all lagoon are same sizes. The length of the lagoon was 50 feet and the width was 20 feet. Depth of lagoon when constructed was 15 feet. Depth at sampling was 4 feet for the first and second lagoon. The depth of third lagoon at sampling was 2 feet.

2 Samples collection

Wastewater sample were taken at the depth of 0.1 meter from water surface of the monitoring location by using a pail. Polyethylene bottle (2.0 liters) was rinsed with wastewater samples before wastewater was taken. A wastewater sample from the pail was poured into the polyethylene bottle until it was full. Right after the polyethylene bottle was filled with the water sample, the polyethylene bottle was closed without leaving any bubbles. The polyethylene bottle contained wastewater samples were then placed inside sample storage container with ice before being brought to UNIMAS laboratory for further analysis. Sampling was done from September 2004 to January 2005. Wastewater samples were collected three
Composite samples were taken from inflow and outflow of each lagoon on the farm.

3 Samples preservation

Samples were preserved by reducing pH to 2 with 2 M sulfuric acid. Samples were stored at 4 °C in the refrigerator. Before analysis, samples were warmed to room temperature and were neutralized with 5 N sodium hydroxide.

4 Samples analysis

Samples were analyzed for pH, total nitrogen, and total solid and chemical oxygen demand parameter.

4.1 pH

Analysis of pH done by using CyberScan pH100 meter. pH was measured from each inflow and outflow of the lagoon for each farm during each sampling trip.

4.2 Total nitrogen (TN)

Analysis of total nitrogen follows that of the procedure for total nitrogen parameter method 0071 (Hach, 1996). Two milliliter of wastewater sample was added to total nitrogen hydroxide reagent vial which contained of total nitrogen persulfate reagent powder pillow. The vial was placed in the COD reactor where temperature was 105°C for 30 minutes. After cooling to room temperature, the sample vial was added with TN reagent A powder pillow and TN reagent B powder pillow. DR/2010 spectrophotometer was used to measure total nitrogen in the sample vial by using of wavelength 410 nm.
4.3 Chemical oxygen demand (COD)

Analysis of chemical oxygen demand follows that of the procedure for chemical oxygen demand parameter method 8000 (Hach, 1996). COD reactor was heated to 150°C. Two milliliter of wastewater sample was added into the vial which contained COD digestion agent. After that the sample vials was heated for 2 hours. After cooling to room temperature, DR/2010 spectrophotometer was used to analyze COD value in the sample by setting the wavelength of 620 nm.

4.4 Total solid (TS)

Analysis of total solid follows that of method 2540B of Standards Method (Clesceri et al., 1998). Clean evaporating dish was ignited at 550 °C for 1 hour in a muffle furnace. Evaporating dish was stored and cooled in the desiccator until needed. Evaporating dish was weighed before use. Twenty milliliter of well-mixed sample was pipette to a preweighed evaporating dish. A well-mixed sample is evaporated in a weighed dish and dried to constant weight in oven at 103 to 105 °C at one hour. The increase in weight over that empty dish presents of total solids. The determination of total solid follows that the equation:

\[
\text{Total solids (mg/L) = } (A-B) \times 1000
\]

Sample volume, 20 mL.

Where,

\[A = \text{weight of dried residue + dish}
\]

\[B = \text{weight of dish, mg.}\]
4.5 Total volatile solid (TVS)

Analysis of total volatile solid follows that of the method 2540E of Standard Methods (lesceri et al, 1998). The residue produced by analysis of total solid is ignited to constant weight at temperature 550 °C for 30 minutes in a muffle furnace. The weight lost on ignition is the volatile solids. The determination of total volatile solid follows that equation:

\[ \text{Volatile solids (mg/L)} = \frac{(A-C)}{1000} \]

\[ \text{(2)} \]

Sample volume, 20 mL.

Where,

A = weight of residue + dish before ignition, mg and

C = weight of residue + dish after ignition, mg.