THE PHYSICAL, CHEMICAL AND BIOLOGICAL ANALYSIS OF FISH POND WASTE WATER: A CASE STUDY OF ABUAD FARM, ADO-EKITI, EKITI STATE NIGERIA.

BY

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DEDICATION

This project is dedicated to God almighty for the strength, provision, and perseverance throughout the course of writing this project and to my entire friends and family members.

CERTIFICATION

This is to certify that **ADEPOJU**, Timilehin Adewunmi, an undergraduate student in the Department of Agricultural and Bioresources Engineering, Federal Universiy Oye-Ekiti with Matriculation Number ABE/13/1037, has successfully carried out and completed this project work in partial fulfilment of the requirements for the award of the degree of Bachelor of Engineering in Agricultural and Bioresources Engineering. The work embodied in this report is original and has not been submitted in part or full for any other Diploma or Degree in this University or any other University.

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ABSTRACT

Water released from ponds has greater concentrations of nutrients, organic matter and suspended solids. This study investigated the physical, chemical and biological characteristics of fish pond waste water harvested from a source which served as the control, three different ponds and at the point of discharge in Afe Babalola University Ado Ekiti (ABUAD) farm, Ekiti State. The samples were collected in 50 ml capacity polypropylene containers. Parameters investigated include temperature, pH, colour, odour, turbidity, TDS, calcium, copper, potassium, sodium, magnesium, DO, BOD, COD, faecal coliform count. The laboratory analysis were carried out in the Department of Chemistry (Analytical Laboratory), Federal Polytechnic Ado-Ekiti. The results were compared with the Acceptable Environmental Standards (FEPA, 1991) and it's observed that the measured parameters were within standards. The water has deep green colour at the point of discharge but it is a bit green at both fish ponds and light brown at the point of entry since it comes in from a stream, its change in colour is suspected to be a result of the fish and feeding activities carried out in the pond. The pH for this work ranges from 6.8 to 7.13, most fish species do well within the pH range of 6.5 to 9.5. Also, the presence of a small amount of faecal coliform group parameters in the source indicate the presence of human and livestock faeces since it is from a flowing stream but this increases as the water enters the pond and at the point of discharge, faeces of fish might have increased the concentration in the water. Sedimentation tank, also called settling tank or clarifier. A sedimentation tank allows suspended particles to settle out of water or wastewater as it flows slowly through the tank, thereby providing some degree of purification. In view of the physical, chemical and biological results, harvested fish pond waste water should be further treated using the sedimentation tank and other appropriate methods before it is being discharged to the environment for both domestic and non- domestic use. Further researches should be done to ascertain the extent of groundwater pollution by the fishpond wastewaters.

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CHAPTER ONE
INTRODUCTION

1.1 GENERAL OVERVIEW

The fisheries sector has played a vital role in the socio-economic development of Nigeria since independence. The sector has the potential to contribute substantially to the national economy through employment, gross domestic product (GDP), foreign exchange earnings, food security and poverty reduction. Aquaculture is an important economic activity in many countries and offers opportunities that contribute to poverty alleviation, employment, community development, reduction of exploitation of natural resources and food security in tropical and subtropical regions. Also, aquaculture can have direct negative impacts on wild populations of fish, birds and mammals such as seals and sea lions (Siyanbola and Adebayo, 2012).

Nigeria is endowed with good natural resources such as land and water (rivers, lakes and the sea) that can support aquaculture production. There are a number of constraints affecting the expansion of aquaculture. These include lack of adequate supply of seed, lack of quality fish seed and suitable feeds. Low investment from the private sector is also listed as one of the major problems as well as lack of information concerning economic profitability of aquaculture.

Water released from ponds that are partially or completely drained has greater concentrations of nutrients, organic matter and suspended solids than overflow from ponds following storms. However, some ponds are drained each year such as: most fry and fingerling ponds. Concentrations of most water quality variables are highest in the final 20 to 25% of water released when ponds are completely drained. Thus, particular attention should be given to techniques for enhancing the quality of pond draining effluent and especially the final effluent from ponds (BMP, 2002). Pollution of water by fish farm effluents is probably the most common complaint, and this concern has attracted the greatest amount of official attention in most nations (Boyd, 2003). Four main components of aquaculture wastewater of interest include: nutrients (including nitrogen (N) and phosphorus (P)), biochemical oxygen demand (BOD), suspended solids, and pathogens (Cripps and Kelly, 1996). Up to 80% of feed ingested by fish is released to the pond environment as faecal solids, dissolved nutrients and organic matter, with just about 20% retained as fish biomass (Boyd and Tucker, 1998; Tucker and Hargreaves, 2003). Nitrogen and phosphorus are the key nutrients generated in aquaculture systems (Boyd and Massaut, 1999). Increase in concentration of organic matter, nutrients and suspended solids in culture ponds leads to an increase in oxygen demand, eutrophication and turbidity in receiving waters (Naylor *et al.*, 2000).

With the current high rate of global population growth, the reliance on farmed fish production as an important source of protein is likely to increase (Naylor *et al.*, 2000 and FAO, 2007). The rate of waste generation within the system also increases. The concentration of organic matter, nutrients and suspended solids in ponds increases, and this directly increases oxygen demand, eutrophication, and turbidity in receiving waters (Naylor *et al.*, 2000, Lin and Yi, 2003). This is especially the case in developing countries where there is a high reliance on organic fertilizer and natural feeding in the mostly semi- intensive systems (Diana *et al.*, 1997; Ofori, 2000). These effluents can pose serious threat to environmental media such as water.

1.2 STATEMENT OF PROBLEM

The most significant environmental issue resulting from fish farming operations is the discharge of wastewater into the environment without proper treatments. Like many other food-processing activities, the necessity for hygiene and quality control in fish farming results in high water usage and consequently high levels of wastewater generation, having high biochemical and chemical oxygen demand (BOD and COD) due to the presence of organic materials such as blood, fat, flesh, and excreta which in turn may lead to reduced levels of activity or even death of aquatic life. Residues of chemicals such as chlorine, used for washing and disinfection also affect the water. In addition, process wastewater may contain high levels of nitrogen and phosphorus which may cause eutrophication of the affected water bodies.

In most cases, regardless of a direct or indirect discharge, the majority of the soluble and particulate organic material in fish pond wastewater must be removed prior to discharge from the plant in order to achieve compliance with established environmental regulations.

1.3 OBJECTIVES

The objectives of the study are to;

1. Evaluate the physical, chemical and biological properties of wastewater from a fish farm, to establish the parameters that are detrimental to the environment from the wastewater.

2. Investigate the variation of the physical, chemical, and biological properties at the control point, three different ponds and the point of discharge.

1.4 JUSTIFICATION

Fish farming activities have direct and indirect impacts on the built-up environment and health of people especially residents in the vicinity. It has also a negative impact on water qualities of residents within the vicinity especially where special or effective waste water disposal system is not practiced (Bello and Oyedemi, 2009). The most significant environmental issues associated with fish farming operations are high consumption of water and energy, generation of high-strength effluent streams and byproducts, for some sites odour may also be concerns (Cowi, 2001; ECDGJRC, 2003). Discharge of wastewater to surface waters affects the water quality (FAO, 1996). One of the environmental effects of discharging fishpond wastewater causes deoxygenation of rivers (Quinn and Farlane, 1989) and the contamination of groundwater (Sangodoyin and Agbawhe, 1992). Moreover, discharge of high levels of biodegradable organics into receiving streams results in increased microbial activity associated with excessive nutrient loadings which requires greater amounts of oxygen than natural aeration processes. This decreases the available dissolved oxygen which negatively affects aquatic organisms (USEPA, 2002).

Fish pond wastewater contains phosphorus (P) and nitrogen (N) nutrients which primarily cause eutrophication of surface water that can reduce dissolved oxygen content of water bodies to levels insufficient to support fish and invertebrates. Therefore, this present study attempts to expose the impact of fish pond processing waste water on the environment in Nigeria.

1.5 SCOPE OF THE STUDY

The study takes into account the impact of fish farming waste water on the environment in Ekiti State, Nigeria.

CHAPTER TWO

LITERATURE REVIEW

2.1 AQUACULTURE

Aquaculture may be defined as the "farming and husbandry of economically important aquatic animals and plants under controlled conditions". Aquaculture is sufficiently expressive and multifaceted. It includes the following aspects:

1. The type of organism cultured. For example, the culture of fish, prawn, oyster, mussel, seaweed, etc.
2. The type of culture technique, such as pond culture, raceway culture, cage culture, pen culture, raft culture, etc.
3. The aquatic environment in which the culture is done such as freshwater, brackish water or salt water.
4. A specific factor of the environment used for culture, such as cold water or warm water aquaculture.

Aquaculture has been showing a tremendous growth during past decades (FAO, 2004). Fish produced by farming activities currently accounts for over one third of all fish directly consumed by human (FAO, 2004). This huge growth resulted in competition for natural resources (i.e. land and water), (Piedrahita, 2003), and consequently intensification of aquaculture system and environmental problems (Pillay, 2004). Since inland aquaculture contributes to 70% of total global fish production (FAO, 2004; Santos Simoes *et al.*, 2008), the environmental problem related to the increased production in land-based aquaculture system is going to be more serious.

Aquaculture similar to other animal production system generates waste. The amount and quantity of waste depends on production system and feed quality (Cho and Bureau, 1997). Aquaculture waste can be divided into solid and dissolved waste, particularly carbon, nitrogen and phosphorous (Cripps and Bergheim, 2000; Piedrahita, 2003). Solid waste mainly originates from uneaten or spilled feed by the fish and from the feces. Dissolved waste is coming mostly from metabolites excreted by fish (through gill and urine). Accumulation of these pollutants deteriorates water quality in the system (Amirkolaie *et al.*, 2005) and can increase the incidence of disease in fish (Liltved and Cripps, 1999).

The aquaculture industry has become an axis for criticism from environmental groups because of an apparent negative effect on the environment from the release of wastewater (Doupe *et al.,* 1999). An aquaculture industrial management plan has been developed for the treatment and disposal of wastewater in recent years (Fernandes *et al.*, 2001). Aquaculture not only requires the supply of clean water, but also, the release of clean water into the environment is important for the protection of the aquatic environment and reuse of water sources. Enormous pressure is exerted from environmental control institutions worldwide for wastewater treatment in aquaculture before water is released into the environment (Bunting 2001). Hyper-nutrification and eutrophication with resultant algal blooms, oxygen depletion and deprivation of benthic habitat in the surrounding area of open cage operations with no waste collection system and limited flushing are the principle wastewater issues (Boyd 2001). Thus, the aquaculture industry has recognized that, in addition to the requirement of a continuous supply of clean water, they also must develop technology for the treatment of wastewater. The development of wastewater treatment technology in the aquaculture industry will minimize ecological and social problems and provide greater long-term economic safety for operation of the industry (Doupe *et al.*, 1999).

2.2 TYPES OF AQUACULTURE PRACTICE

I. **Depending on Hydro Biological Features:** Depending on hydro biological features (particularly salinity) aquaculture is divided into following:

i. Freshwater.
ii. Brackish water.
iii. Mari culture.
iv. Methaline.

i. Freshwater Aquaculture: Freshwater aquaculture includes culture of various economically important aquatic organisms in small impoundments.

ii. Brackish Water Aquaculture: Brackish water areas are rich in oxygen and plankton. Brackish water organisms such as milkfish (Chanos chanos), Latès calcarifer, Mugil sp. cages or by rack, raft or rope culture (mainly in case of oysters). Mangrove crab, Scylla serrata, are also cultured in the shallow brackish water regions by constructing bamboo cages.

iii. Mariculture: India has a long coastal and open sea area, which offers wide scope for culture operations of fin fishes and shellfishes. For the culture of fish, prawns and lobsters floating cages are used. Racks, rafts, rope, pole and long lines are used for culture of mussels, particularly pearl oysters. Sea-weeds also are widely cultured with the help of nets or webbings.

iv. Metahaline Culture: In off seasons of salt manufacture, the salt pans are utilized for fish culture. Culture of brine shrimp (Artemia salina) can be undertaken in these super saline salt pan (salinity more than 200%) area. The nauplii of Artemia serve as a protein-rich live food for the fin fishes and shellfishes. The dormant eggs (cysts) of Artemia formed under unfavourable conditions also can earn good foreign exchange.

II. Depending on Motive of Farming: Depending upon the motive of farming, based on economic and commercial considerations, fish culture practices may be classified under:

i. Extensive Fish Culture: Large ponds, beels, etc. are brought under this culture where little care is taken with regard to its improvement. So it is the least managed fish farming. Here, the yield is modest and the expenditure is less as it is raised on natural food.

ii. Intensive Fish Culture: In this fish culture an all-out attempt is made to achieve maximum production of fish from a minimum quantity of water. It is the best managed form of fish farming and the fishes are fed on artificial food in addition to the natural feed. Here the yield is very high (over 6000 kg/ha/year). Although the cost of investment is high, the earnings from this culture far exceed the cost, so as to ensure high profit.

iii. Semi-Intensive Fish Culture: Intensive culture possesses certain hazards, for which a culture between the first two, called semi-intensive culture, is generally practised. Here certain amount of management is required and the net profit is in between the above two.

III. Depending on Special Operational Techniques: Based on special operational techniques, fish culture practices may be classified as below:

i. Cage Culture: In this culture the fishes are held in a section of water, either in a flowing river or in a big impoundment. The fishes are imprisoned in a cage made of galvanised steel wire frames with nylon meshes or simply of bamboo frames with split bamboo mats. The cages are of various sizes and the commonly used size is about 10 sq. meters. Cage culture has proved a boon for reclaiming extensive waste waters, i.e., swamps and derelict waters of Assam, Bihar and Karnataka. Air breathing fishes (Clarias, Heteropneustes, Anabas, Channa, etc.) have responded well to cage-culture practices.

ii. Pen Culture: Pens generally refer to small enclosures used for confinement or safe keeping of domestic animals. In fisheries pens are formed by damming a bay, cove, fjord (an arm of a sea), estuary, river, lake or reservoir. Sites are selected where the barriers can be constructed across narrow sections or channels in order to reduce costs and increase the ease of operation.

2.3 WATER

Water is essential to all forms of life. It is second in ranking, next to air, in the list of human daily needs (NEST, I99I). Water is an indispensable substance to man and all life processes. It is widely referred to as universal solvent (Eletta and Oyeyipo, 2008). Water is the essence of life. Without water, human beings cannot live for more than a few days. It plays a vital role in nearly every function of the body, protecting the immune system - the body's natural defences - and helping remove waste matter. Undoubtedly, water represent unique and significant feature in any settlement: for drinking, sanitation, washing, planting, fishing recreation, industrial process- and the list continues. In order words, all sector of human endeavour and in every human settlement (be it farmstead, village, town, city, metropolitan area or whatever), water is greatly important and it is in great demand (Aderogba, 2005). Lack of access to safe water has a major effect on people's health. Water is essential for farming and for manufacturing services. Making more water available to communities can improve families' incomes, for instance by boosting crop production and the health of livestock (WHO, 2003). Water sources have been put under great pressure by population increases in developed and developing countries, through pollution by agricultural, domestic and industrial waste, and by environmental change (WHO, 2003).The past 20 years have seen increasing water use for food and energy production to meet the demands of a growing population and to enhance human wellbeing, a continuing global trend (WWAP, 2006). However, the changes in the way water is used have significant adverse impacts, which require urgent attention to ensure sustainability. Agriculture is by far the biggest user. The expansion of hydropower generation and irrigated agriculture, now happening mostly in developing countries, is vital for economic development and food production.

In Nigeria, as it is difficult to ascertain the total water supply to people so it is also difficult to ascertain peoples demand of water for various purposes. However, the ways people go in search of water in most areas of the country for drinking purposes attest to the fact that supply of improved water in both urban and rural areas is grossly inadequate. Water is the home of the fish and its quality is one of the most over looked aspect of pond management until it affects fish production. Water quality generally means the component of water which must be present for optimum growth of aquatic organisms (Ehiagbonare and Ogundiran, 2010). Water quality is made up of physical, chemical and biological factors which influence the use of water for fish culture purposes. These factors include dissolved oxygen, pH, hardness, turbidity, ammonia and temperature. Other parameters such as biological oxygen demand and chemical oxygen demand indicate the pollution level of a given water body (Ehiagbonare and Ogundiran, 2010). Productivity depends on the physio-chemical characteristics of the water body (Huct, 1986). In recent years, the inland waters and the terrestrial life in the Niger Delta region of Nigeria which Bayelsa State is part of have been subjected to alteration ecologically. This is partly due to the human activities, population growth, oil exploitation and exploration which resulted in the pollution of the environment. The components of the pollution contribute to greater oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to destabilized aquatic ecosystem (Morrison *et al.*, 2001). Water of such poor quality may be acidic, rich in nutrients and organic matter, high in suspended solids or polluted with industrial or agricultural chemicals. Such deterioration in water quality can result in fish being stressed and vulnerable to disease (ICAR, 2006).

2.4 USES OF WATER

Water can be used for agricultural, industrial, household, recreational and environmental activities. Uses of fresh water can be categorized as consumptive and non-consumptive (sometimes called "renewable"). A use of water is consumptive if that water is not immediately available for another use. Losses to sub-surface seepage and evaporation are considered consumptive, as is water incorporated into a product (such as farm produce). Water that can be treated and returned as surface water, such as sewage, is generally considered non-consumptive if that water can be put to additional use.

2.5 SOURCES OF WATER

Over 70% of our Earth's surface is covered by water. Although water is seemingly abundant, the real issue is the amount of fresh water available. Ninety percent of water on the Earth is salt water, and only 3% as fresh water of which slightly over two thirds is frozen in glaciers and polar ice caps (USGS, 2009). Nearly 70% of that fresh water is frozen in the icecaps of Antarctica and Greenland; most of the remainder is present as soil moisture, or lies in deep underground aquifers as groundwater not accessible to human use. Less Than 1% of the world's fresh water (-0.007% of all water on earth) is accessible for direct human uses. This is the water found in lakes, rivers, reservoirs and those underground sources that are shallow enough to be tapped at an affordable cost. Only this amount is regularly renewed by rain and snowfall, and is therefore available on a sustainable basis (Coleridge, 2006). Water is one of the essentials that supports all forms of plant and animal life (Vanloon and Duffy, 2005) and it is generally obtained from two principal natural sources; Surface water such as fresh water lakes, rivers, streams, etc. and Ground water such as borehole water and well water (McMurry and Fay, 2004).

2.6 FISH POND WASTE WATER

2.6.1 Aquaculture Wastewater

The quantity and quality of wastewater from aquaculture operations vary according to the type and location of the aquaculture system (Dochoda *et al.*, 1999). The wastewater from a hatchery is different from that of a production farm in terms of quality and quantity of waste (Oberdorff and Porcher 1994). Pond or tank systems, such as those characteristically used to raise catfish and tilapia, also need better technology for control of wastewater (Rebecca and Triplett 1997). The cage and pen systems, used for the production of salmon and other species, are comparatively open to natural water and, therefore, can release wastewater into the environment, entirely untreated (Rebecca and Triplett 1997). In intensive commercial aquaculture operations, the sources of wastewater are primarily from uneaten food and fish faeces, which is 30 percent unconsumed dry feed and 30 percent consumed food egested as faeces (Axler *et al.*, 1996). The production of aquaculture waste in water can be estimated on the basis of several factors: growth, nutrients, energy gains, energy nutrient needs and excretory feed waste output by the systems in operation (Cho and Bureau, 1997). The waste in water fróm the aquaculture industry can be classified in two categories; soluble and solid waste.

2.6.2 Aquaculture Wastewater Composition

Aquaculture wastewater composition is directly related to the nature and quantity of feed fed to the species being reared and also, to the type system in operation. The major sources of waste from aquaculture consist of untreated water with excreta, faecal matter and uneaten feed from fish. However, it has been estimated that total organic output from a salmon farm may be close to 2.5 tons wet weight per ton live weight fish (Ackefors and Enell, 1994). There are two major elements in aquaculture wastewater, nitrogen and phosphorus (Axler *et al.,* 1996). The food and faecal waste constitute the majority of the suspended solids. Thus, aquaculture waste depends on the feed composition and feeding technology. If the concentration of the chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen and total phosphorus in the outlet from the aquaculture facility are lower than in the inlet, it means that wastes produced are retained within the system. Thus, wastewater treatment technology in aquaculture is not only dependent on the system of culture but, also on the composition of wastewater produced by the particular fish production facility.

2.6.3 Wastewater Treatment Technology for Cage Aquaculture

The wastewater production from cage aquaculture can be classified into two main sources: soluble waste and transport and dispersal waste from cages (Tlusty *et al.,* 2001). The waste is a voluminous group that is made up of dispersal particles larger than those considered to be soluble (Tlusty *et al.,* 2001). Various apparatus designed to collect the waste from cages have been developed. However, many of them restrict water flow and are difficult to maintain, particularly in uncovered marine sites (Pillay, 1992). Thus, a well-flushed location of cages in the marine environment reduces wastewater production by allowing time for diffusion of nutrients (Pillay, 1992). Aquaculture Waste Transport Simulator (AWATS) is a model that has been developed for the estimation of dispersal of waste in coastal waters from cages and net pens (Robert *et al.,* 2000). Applications of this model provide a complete picture of flow-field, which is required for cage culture site selection. The installation of cages in the marine environment is one of the main factors in controlling wastewater.

Recently, one aquaculture facility began using polyvinyl chloride bags as replacements for net cages (Stephen, 2000). They created a system of impermeable enclosures. In this technology water pumped into the bag through a single opening created a steady counter clockwise current. A swirl separator system used centrifugal force to collect faeces and wastes feed which sank to the bottom of the bag and were collected by waste traps before being sent to a clarifier. From the large floating clarifier, wastes were pumped to shore. Nutrient-rich water from the clarifier was pumped to a lagoon before it was returned to the pit. A solution of *nitrosomas* and *nitrobacteria* was added to the inflow pipe that filled the bag, thus maintaining constant ammonia levels in the wastewater. Similarly, another company, Future SEA, developed waste capture technology in the treatment of wastewater for the aquaculture industry. The technology can be applied to freshwater and marine systems.

2.6.4 Wastewater Treatment Technology for Land Based Aquaculture.

Wastewater treatment technology for land based aquaculture is adapted largely from municipal wastewater treatment. Sedimentation is one of the simplest methods to reduce the waste from the aquaculture industry. The basic principle in this system is to allow solid particles, mainly uneaten feed and faeces, to settle out of the waste prior to release of effluent water into the environment. In this system, settleable substances can sink and floatable particles can collect on the water surface (Czysz *et al.*, 1989). The separated wastes are removed from surface and bottom of the aquaculture chambers and may undergo further treatment before disposal. Many technologies have been applied to the treatment of aquaculture wastewater during the growth of the industry (Daniel and Trudell, 1990). Sedimentation is widely applicable in commercial fish farming, as it requires no energy input and no specialized operation skills (Daniel and Trudell, 1990). The disadvantage of sedimentation systems is that they typically require large areas of land (Pilay, 1992). The degree of waste removal by sedimentation in aquaculture depends on system design, type of construction and operation. The diameter and the density of the suspended particles determine the sinking velocity (Czysz *et al.*, 1989). Also, sedimentation is not very effective at removing extremely small particles or dissolved waste in water. A device called a low-head-swirl concentrator can remove suspended solids in water using centrifugal force (Pillay, 1992).

Recently, one experiment demonstrated that appropriate management in pond draining and fish harvesting would reduce the effects of wastewater on the environment (Line *et al.*, 2001). In that experiment, teased cake was used to anesthetize tilapia and allowed effective harvest by seining, without draining the ponds. The wastewater management technology of land-based systems depends on design criteria.

2.6.5 Bio Engineering Technology for Wastewater Treatment

Advances in bio engineering have tendered most methods of wastewater treatment technology effective in the aquaculture industry. Bioengineering also offers one strategy to reduce the waste production in water through the process of oxygen injection, automated feeding, on site re-pelleting technology and recirculation technology (Mayer *et al.*, 1995). The principal treatments of wastewater involve solids removal, ammonia oxidation, aeration and disinfection. Recently, one technology has been proposed that would use solid waste from aquaculture for the production of biogas. The results of the experiment showed that production of biogas and methane increased as feeding rates and volumetric loads increased in fish farms (Lanari and Franci, 1997). The experiment was conducted to evaluate the potential for use of waste removed from the water of fish farms to produce biogas in lock systems where water was partially recirculated for rainbow trout culture. The system components were two 1.4 m3 fish tanks with sloping bottoms, each connected to a sedimentation column and containing 50 kg trout biomass. Biogas production was 158 l/day with methane content higher than 80 percent. Specific load on the digester was 0.45 kg COD/m3 with a gas yield of 0.96m3 /kg COD and specific gas production of 0.41m3/m3 of digester. This was an integrated approach for the use wastewater in the production of energy within the aquaculture industry, particularly for earthen pond management systems.

2.6.6 Biological Treatment of Wastewater

Bio filtration is another technology recently being applied in aquaculture for the treatment of wastewater. The basic principle of this technology is the formation of a filter bed through the attachment and growth of beneficial bacteria that extract dissolved chemicals from the water and convert them to particulate biomass or harmless dissolved compounds (Geoffrey, 2000). The two major bacterial genera involved in the processes of waste removal are nitrosomonas *and* nitrobacter. Nitrosomonas is responsible for nitrifying ammonia to nitrite, while nitrobacter converts nitrite to nitrate (Geoffrey, 2000). Given a proper environment, the bacteria grow in a thin film covering the surface filter beads. Each cubic foot of packed media contains approximately 600,000 beads that provide a large amount of surface area for the propagation of bacterial films (Geoffrey, 2000). Management of bio filtration is critical at the high loadings typical of recirculating aquaculture systems used for the production of food and/or ornamental fish.

2.7 Environmental Impacts of Aquaculture

2.7.1 Aquaculture waste

The quality and quantity of waste from aquaculture depends mainly on culture system characteristics and the choice of species, but also on feed quality and management (Wang *et al.*, 2005). From intensive aquaculture systems, the principal wastes are solid wastes, chemicals, and therapeutics. The release of bacteria, pathogens and farmed species escapees should also be included as waste components (Liu *et.al.*, 2002). Solid wastes, otherwise known as particulate organic matter, often consist of faeces or uneaten food. A build-up of solid wastes within the system should be prevented as it can cause oxygen depletion and ammonia toxicity when it decomposes. Organic wastes are present in three main forms in the recirculation system: settled solids-accumulate on the bottom of the tank; suspended solids-float in the water column which does not settle out of water; and fine and dissolved solids- float in the water column which can cause gill irritation and health damage to fish. The urine and faeces from the aquatic animals can cause high content of ammonia nitrogen and an increase of BOD (biological oxygen demand). Ammonia is the main nitrogenous waste that is produced by fish via metabolism and is excreted across the gills. Nitrite is a naturally occurring intermediate product of the nitrification process. The nitrate ion (폭폭ᄆ) is the most oxidized form of nitrogen in nature and is relatively non-toxic to fishes (Zhang and Chen, 2004). However, when nitrate concentrations become excessive and other essential nutrient factors are present, eutrophication and associated algae blooms can become a serious environmental problem. A wide range of chemicals is used in aquaculture industry, including compounds applied to construction materials (stabilizers, pigments, antifoulants etc.), pigments incorporated into feeds, disinfectants and chemotherapeutants. Antimicrobials are administered in the diet and most end up in the environment in association with uneaten food and faeces. Many studies reported increases in resistance and even multiple resistances in pathogens as a result of the widespread use of antimicrobials by aquaculture (Kerry *et al.*, 1994).

The abuse of chemicals can also kill the effective microbes which probably accounts for an unbalance of the aquatic ecology system. It is widely argued that translocated species or strains may carry exotic diseases that could spread and devastate indigenous wild populations and that farmed stock escape and become established, again to the detriment of wild stocks. There is little quantitative information on the numbers of animals that escape from aquaculture operations. Penczak *et al.,* (1982) estimated that about 5% of caged rainbow trout escaped each year. The fear is that feral animals become established and reduce biodiversity through habitat modification, competition, or by interbreeding with native stocks.

2.7.2 Pollution caused by aquaculture wastewater

If wastewater is continuously discharged without treatment, it contains high concentration of nitrogen and phosphorus nutrients, which may result in a remarkably chronic elevation of the total organic matter contents, especially in badly managed or poorly located sites. Consequently, a series of negative ecological impacts may occur:

1. Serious oxygen deficit caused by the decomposing of organic substances.
2. Eutrophication or algae bloom caused by the accumulation of organic nutrients like nitrogen and phosphorus, which promotes a high biomass in the superficial water. Apart from increased phytoplankton production, eutrophication can cause many other effects which may be more sensitive and relevant indicators such as changes in: energy and nutrient fluxes, pelagic and benthic biomass and community structure, fish stocks, sedimentation, nutrient cycling, and oxygen depletion (Gregory and Zabel, 1990; Fang *et al.*, 2004).
3. Water deterioration will bring about low productivity.
4. Diseases may break out. Aside from this, inadequate handling of wastewater has serious consequences for human health, the environment and economic development (Enelld and Lof, 1983). It contaminates water supply, increasing the risk of infectious disease and deteriorating groundwater and other local ecosystems, for instance after flooding.

2.8 New approaches of waste treatment

A number of new approaches to aquaculture effluent management are being innovated. Nevertheless, most of them have been mainly based on laboratory tests. The commercial and practical values of these new approaches are needed to be evaluated before applied. The potential of ultra-low pressure polyether sulfone (PES) membranes for the treatment of aquaculture wastewater were investigated recently. It was found that the membranes prepared exhibited an excellent performance in terms of a high rejection of total ammonium and total phosphorus up to 85.70% and 96.49%, respectively (Nora'aini *et al.*, 2005). Whether this approach can be utilized on a large scale still needs further investigation because of the costly expenses. One of the most advanced techniques for wastewater treatment and reuse is the reverse osmosis (RO) process, which is widely used to produce potable water from brackish water and seawater in order to reclaim contaminated water sources and to reduce water salinity for industrial applications (Asano 1998; Gang *et al.*, 2005). But the application of RO membrane for aquaculture wastewater treatment has been largely limited. One of the major problems is the energy cost during the membrane filtration process. In order to reduce the energy, cost for RO membrane operation, researchers have turned to renewable energy sources for solutions. According to Gang *et al.,* (2005), the wind-driven RO system for nitrogen removal was technically feasible and environmentally friendly. The most unique and important feature of this system was that it could treat and recycle aquaculture wastewater using renewable energy, making it suitable for use in remote areas where electricity was hard to obtain. The system was able to work at an average wind speed as low as 3.0 m/s. Depending on the wind speed, it can generate and recycle freshwater at a flow rate of 228– 366 L/h. The permeate production increased linearly with the wind speed. About 70–84% of aquaculture wastewater can be recycled using this system, which was capable of removing 90–97% of nitrogenous waste present in tilapia culture effluent. The average recovery rate of the membrane used in this system is about 39.2–57.5%. Although producing water using the wind driven RO system seems too expensive in the current situation, this technology has great promise once the system scale can be upgraded.

2.9 Proposals for sustainable aquaculture development

2.9.1 Feed quality and feeding improvement

Feed wastage is one of the most important sources contributing to organic and nutrient loadings. Wastage may range from 1–38%, depending on the feed type, feed practices, culture method and species (Wu, 1995). Improving feed quality by feed additives in recent years, such as microbial phytase, has resulted in enhanced bioavailability of phosphorus and nitrogen, at lower concentrations (Cripps and Bergheim 2000; Cao *et al.*, 2007). Thus, the quantity of faecal solids produced by fish was reduced and there was less phosphorous load to the ambient aquatic environment. Research has shown that a significant reduction in the level of incorporation of fish meal is possible without affecting the growth rates or flesh quality in several species of interest to aquaculture (Mente *et al.*, 2006; Cao *et al.*, 2007). Improved pellet integrity, with subsequent slower breakdown rates, further reduced feed losses. The development of high energy diet with increased fat content, reduced carbohydrate levels, reduced protein levels, and improved digestibility will significantly decrease waste production. The close relationship between feed quality and feed derived waste production has been demonstrated in several reports (Cripps and Bergheim, 2000). Optimized feeding systems and protocols have also reduced wastage. There are three ways possible to achieve control of feed impacts from aquaculture:

1. Control of the sites where the culture farms are located.
2. Control of the released effluents
3. Monitoring of impacts generated by effluents once the farm begins its work. Polyculture, or integrated aquaculture associating shellfish and algae culture with fish culture, may be part of the solution (Mente *et al.*, 2006).

The feeding regime and technology used to both deliver rations to the stocks and monitor its intake can be used to minimize waste losses. Feed utilization should be maximized by optimally supplying feed to the fish stock to minimize the uneaten quantity. The required capacity of treatment systems can then be reduced, thus saving capital and operating costs. Additionally, in water reuse systems that generally have a fixed carrying capacity based on the ability of the system to handle the daily feed application, removing the waste feed load can effectively increase fish rearing capacity. Technology for monitoring uneaten pellets has been shown to be a useful means of reducing wastage (Summerfelt *et al.*, 1995). When pellets are detected in the tank effluent, the devices discontinue feeding. A pre-set timer is then activated to control the interval between feedings. As well as optimizing the timing of feeding, the feeding location can affect both the quantity of solids wasted and their distribution within the culture facility. Fish usually do not graze feed pellets off the bottom, thus tank hydrodynamics, pellet structure and feeder location need to be adjusted to maintain the feed solid suspension as long as possible. Feed development may need to place increased emphasis on the efficient use of resources and the reduction of feed waste and nutrient discharge. One of the limits of aquaculture expansion is likely to be the availability of feeds derived from fish meal or fish oil resources. Concerns about contamination and possible risk to humans such as level of dioxins in fish have been expressed. Future studies aimed at gaining an understanding of the physiological basis of observed growth in terms of anabolic and catabolic processes will enable informed decisions to be made on the modification of diets and feeding regimes. Research is still needed to improve feed quality and usage in aquaculture, which will result in better fish growth and survival. Feeds should be designed to contain high digestibility, low rates of N excretion and less dietary protein to minimize nutrient discharges from aquaculture to the environment and ensure the sustainability of the aquaculture.

CHAPTER THREE

METHODOLOGY

3.1 THE STUDY AREA

The study area Afe Babalola University Ado-Ekiti (ABUAD) is located in Ado-Ekiti, Ekiti State in South-western Nigeria. Ado-Ekiti is the capital of Nigeria's Ekiti State with population of 308,621 as at 2006 census. It is located between 7.670929°N and 5.307051°E and at an elevation of 439 meters above sea level. Ekiti State generally is mainly an upland zone which lies on an area underlain by metamorphic rock. It is generally an undulating part of the country with a characteristic landscape that consists of old plains broken by step-sided out-crops that may occur singularly or in groups or ridges. The State enjoys tropical climate with two distinct seasons. These are the rainy_season (April–October) and the dry season (November–March). Temperature ranges between 21°C and 28 °C with high humidity. Ekiti land is naturally endowed with numerous natural resources. The state is potentially rich in mineral deposits. These include granite, kaolinite, columbite, channockete, iron ore, baryte, aquamine, gemstone, phosphate, limestone, gold among others.

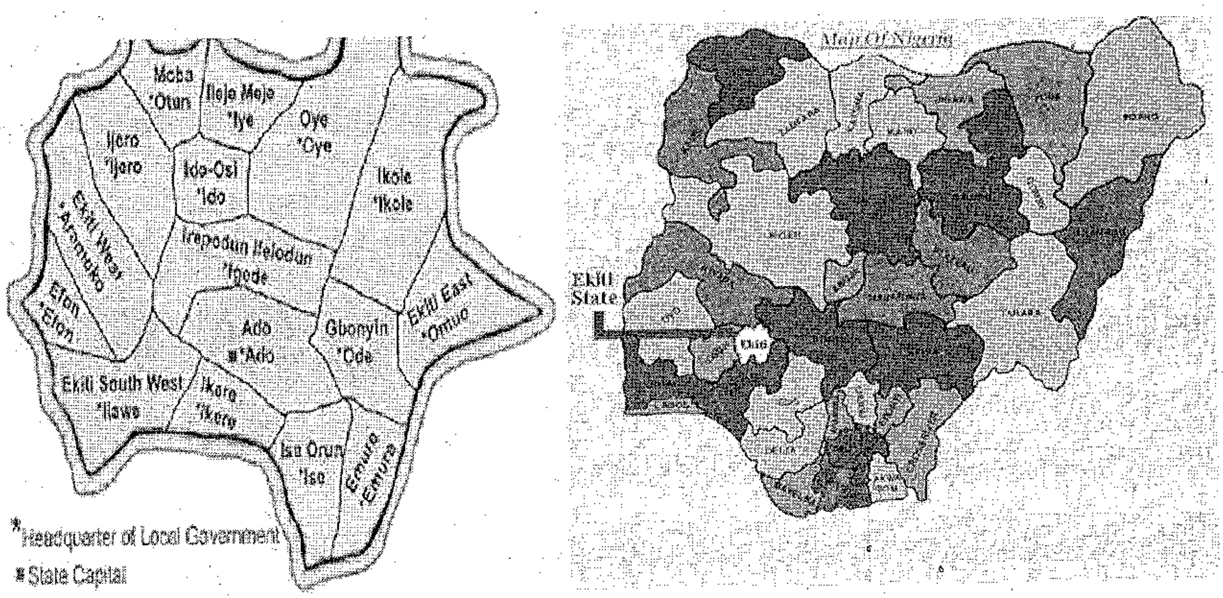


Fig. 3.1: The Geological Map of Ekiti State (Ademola *et al.*, 2017).

3.2 MATERIALS

All the reagents used for this project were of analytical grade with some of the reagents purchased from a scientific laboratory outside. All apparatus used are all in good condition. This include erlenmeyer flasks, burette, pipette, retort stand with clamp, reagent bottles, standard flasks, measuring cylinder, sample bottle, weighing balance as well as the equipment used for the chemical and biological analysis.

3.2.1 Sample collection

The samples were collected from three different fish ponds and at the point of discharge in the farm. Direct sample from the reservoir was also collected which served as the control for analysis. The new plastic bottles used for this analysis were purchased from a nearby market and were thoroughly washed and rinsed with distilled water before they were used for sample collection to avoid physical or chemical contamination of the samples. The samples were collected in 50 ml capacity poly propylene containers. The bottles were labelled A, B, C, D and E, where A is the sample from the control point, B is the sample from fishpond 1 (f.p.1), C is the sample from fishpond 2 (f.p.2), D is the sample from fish pond 3(f.p.3) and E is the sample from the point of discharge (p.d). The samples collected were well covered and taken to the laboratory to be processed and analysed. The samples were collected and were immediately assessed for their pH, temperature, colour and odour.

3.2.2 Laboratory Analysis

The laboratory analysis were carried out in the Department of Chemistry (Analytical Laboratory), Federal Polytechnic Ado-Ekiti. Total Dissolved Solids, total hardness, carbonate and chloride were done according to APHA, 1998 standards for water analysis. Calcium (in form of mg $CaCO_3$/L and Ca^{2+}) and bicarbonate were done according to Standard Analytical Procedures for Water Analysis, 1999 by FSSAI, 2015. Sodium was analysed using Flame

Photometer. Other metal parameters were analysed using AAS (Atomic Absorption Spectrophotometer, Buck Scientific, 210VGP).

3.2.2.1 Determination of pH (APHA, 1998)

The pH was measured using a handheld pH meter. The electrode was washed thoroughly first with distilled water and then with the sample. The pH meter was standardized using buffer 4, 7, 10, solution. The pH of the samples was measured and the readings were recorded on site.

3.2.2.2 Total Dissolved Solids (TDS)

Total dissolved solids were determined as the residues left after evaporation of the filtered sample. As reported for TS, an evaporating dish of 100 ml capacity was ignited at 550 ± 50 C in muffle furnace for half an hour, cooled in desiccators and weighed. 100 ml of filtered sample was added to it and evaporated in a pre-weighed evaporating dish on the hot plate at 98 C. The residues collected were heated at 103-105 C in an oven for one hour and final weight was taken after cooling the evaporating dish in a desiccator. TDS was calculated as,

$$TDS\left(\frac{mg}{L}\right) = \frac{(\text{A} - \text{B}) \times 1000}{\text{V}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; eqn\ 3.1$$

Where, A = Final weight of the dish (g)

B = Initial weight of the dish (g)

V = Volume of sample taken (mL).

3.2.2.3 Estimation of Na, Cu, Ca, K and Mg

The samples were analysed for sodium, copper, calcium, potassium and magnesium using Atomic Absorption Spectrophotometer (AAS) Buck Scientific 210 VGP.

3.2.2.4 Determination of Chlorides (Cl^-)

In 100 ml. of sample, 1 ml. of K_2CrO_4 indicator was added and was titrated against 0.02M $AgNO_3$ till brick red precipitates were formed (APHA, 1998). The formula used to calculate mg. of Cl^-/L is as follows:

$$Chloride\left(\frac{mg}{L}\right) = \frac{A \times N \times 35.45 \times 1000}{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\,3.2$$

Where, A = Burette reading (Amount of titrant used).

N = Normality of Silver Nitrate.

35.45 = Equivalent weight of Chloride.

V = volume of sample.

3.2.2.5 Determination of Nitrate

Procedure:

a) 0.7218g of KNO_3 was weighed and dissolved in 100ml of distilled water (stock nitrate solution).

b) From the stock nitrate solution, 0,5,10,15,20,25 were diluted in 50ml of distilled water, 2ml was taken from each and 2ml of sodium salicylate was added into each and was evaporate into dryness (standard).

c) 2ml was taken from each standard and 2ml of sodium salicylate was added into each and also evaporate into dryness on hot plate.

d) 2ml of conc. $H_2SO_4$was added into both sample and standard.

e) It was allowed to stand for 10minutes.

f) 15ml of distilled water was added into both sample and standard

g) 2ml of sodium hydroxide-potassium tartrate solution was added into both sample and standard.

h) Yellow colour was observed.

i) The absorbance was read on u.v spectrophotometer with 420 nanometer.

3.4.2.6 Determination of Dissolved Oxygen (DO)

Procedure:

Dilution water was prepared by adding 1ml of each of the following reagents: phosphate buffer, Magnesium sulphate, Calcium chloride, and Iron (III) Chloride solution to 1L of distilled water, and then aerated with a supply of clean compressed air. Several dilutions of the prepared sample were made so as to obtain drop in oxygen content. The prepared sample was then put into a DO bottle, filled to the brim. 2 ml $MnSO_4$ solution and 2 ml ikali-iodide-azide reagent were added well below the surface of the liquid stopper with care to exclude air bubbles and mixed by inverting the bottle a number of times until a clear supernatant water is obtained. (If the reagents were added at the site of the sampling, the solution may be left at this stage until it got to the laboratory). It was then allowed to settle for about 2 minutes. Add 2 ml concentrated H_2SO_4 to neck of the bottle stopper and then mixed by gentle inversion until dissolution is completed. Add 1-2 ml starch solution to ensure uniform solution before the quantity needed for titration was decanted.

$Na_2S_2O_3$ was then titrated with the solution and the colour changed from blue to original colour of sample.

The DO is measured using a sensor and a meter.

3.4.2.7 Determination of chemical oxygen demand (COD)

Procedure: .

10 ml of water sample was pipette; 5 ml of 0.025 m potassium dichromate was measured with a measuring cylinder. 15 ml of concentrated sulphuric acid was added and diluted with 40 ml of distilled water to get 70 ml solution. 7 drops of phenothroline ferrous sulphate indicator was added. This was allowed to cool.

Observation: the colour changed from greenish blue to orange colour, and then titration was done on the blank sample.

N.B The tire value for the blank sample is higher than the titre value of the sample.

Table 3.1: Acceptable Environmental Standards (FEPA, 1991).

Parameter	Untreated waste water	Normal value
TEMPERATURE (°C)	36.9	21.8-33.4
pH	8.26	6.5-8.5
BOD (mg/l)	39.0	5.0
DO (mg/l)	6.21	5.0
NITRATE (mg/l)	55.720	50
PHOSPHATE (mg/l)	3.413	-
SULPHATE (mg/l)	130.440	150
T.D.S (mg/l)	1099.0	500
TURBIDITY	Turbid	Clear
ODOUR	Offensive	Odourless

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULT

The result of the physical, chemical and biological analysis of fish pond waste water sample from the control point, the three different fish ponds and the point of discharge are represented in the table 4.1-4.3 below.

Table 4.1: Physical properties.

	A (control)	B (pond 1)	C (pond 2)	D (pond 3)	E (discharge)
ODOUR	Odourless	Offensive	Offensive	Offensive	Offensive
TEMPERATURE (°C)	26.8	31.2	30.2	31.7	32.4
TDS (mg/l)	76.67	543.00	420.67	352.33	247.67
COLOUR	Light brown	Greenish	Greenish	Greenish	Greenish
TURBIDITY	Clear	Turbid	Turbid	Turbid	Turbid

Table 4.2: Chemical properties.

	A (control)	B (pond 1)	C (pond 2)	D (pond 3)	E (discharge)
PH	7.13	6.8	6.8	6.93	7.03
Calcium, ca (mg/l)	33.31	28.56	28.72	29.28	31.31
Chloride, cl^- (mg/l)	7.80	8.70	7.87	8.42	7.41
Magnesium, mg^{2+} (mg/l)	4.31	4.10	3.97	4.06	4.15
Phosphate, PO_4^{3-} (mg/l)	0.61	0.55	0.54	0.55	0.58
Nitrate, no_3^- (mg/l)	11.14	12.30	12.15	11.86	11.60
Sodium, na^+ (mg/l)	5.09	6.74	6.39	6.53	5.71
Potassium, k^+ (mg/l)	2.23	2.08	1.97	2.04	2.02
Copper, cu^+ (mg/l)	0.02	0.017	0.01	0.017	0.017
Cod (mg/l)	136.33	137.31	123.61	137.29	130.92

Table 4.3: Biological properties.

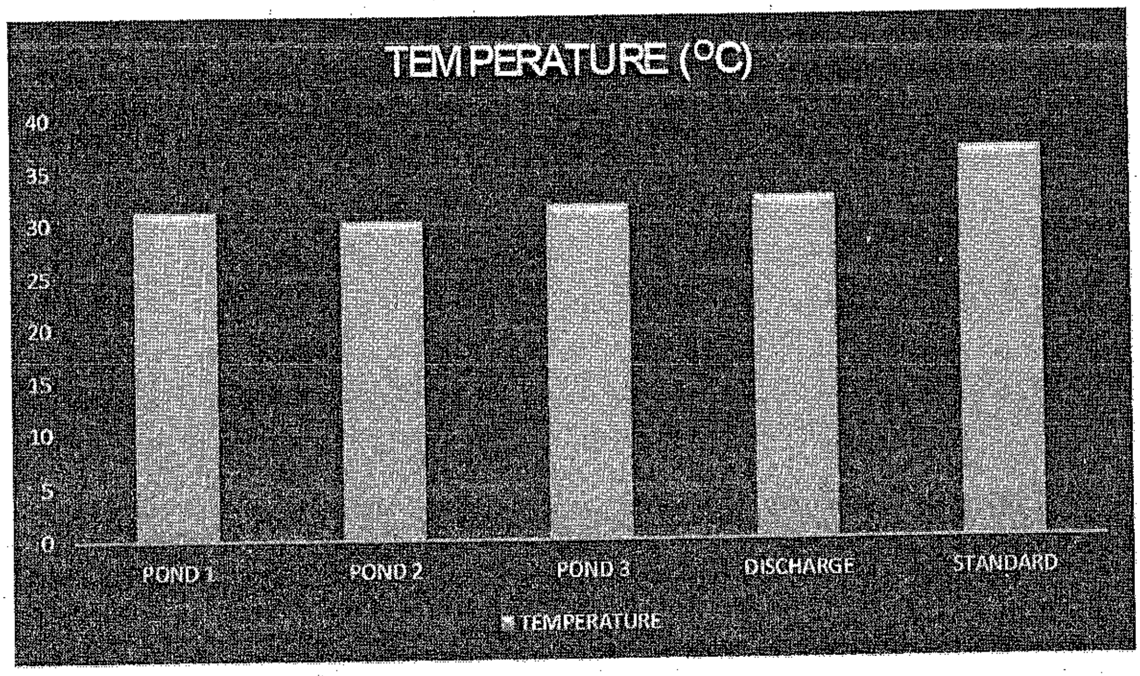
	A (control)	B (pond 1)	C (pond 2)	D (pond 3)	E (pond 4)
DO (mg/l)	13.43	7.10	7.34	7.03	8.45
BOD (mg/l)	5.01	4.24	4.34	4.29	5.02
Faecal Coliform (cfu/ml)	27.67	86.33	80.00	89.67	87.33

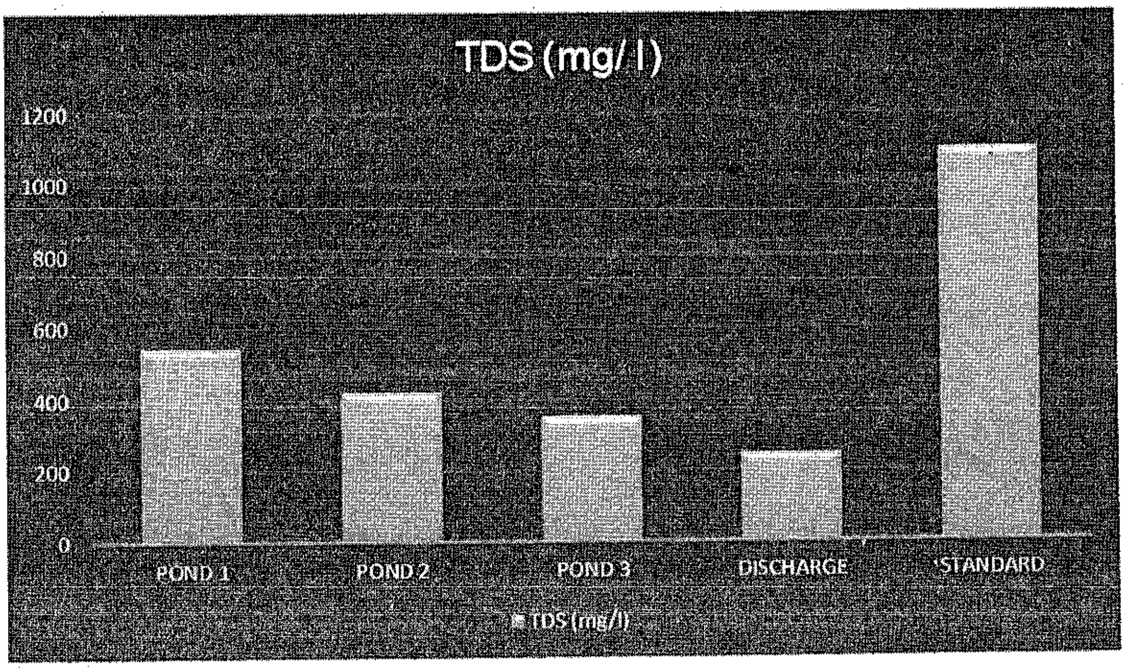
4.2 DISCUSSION

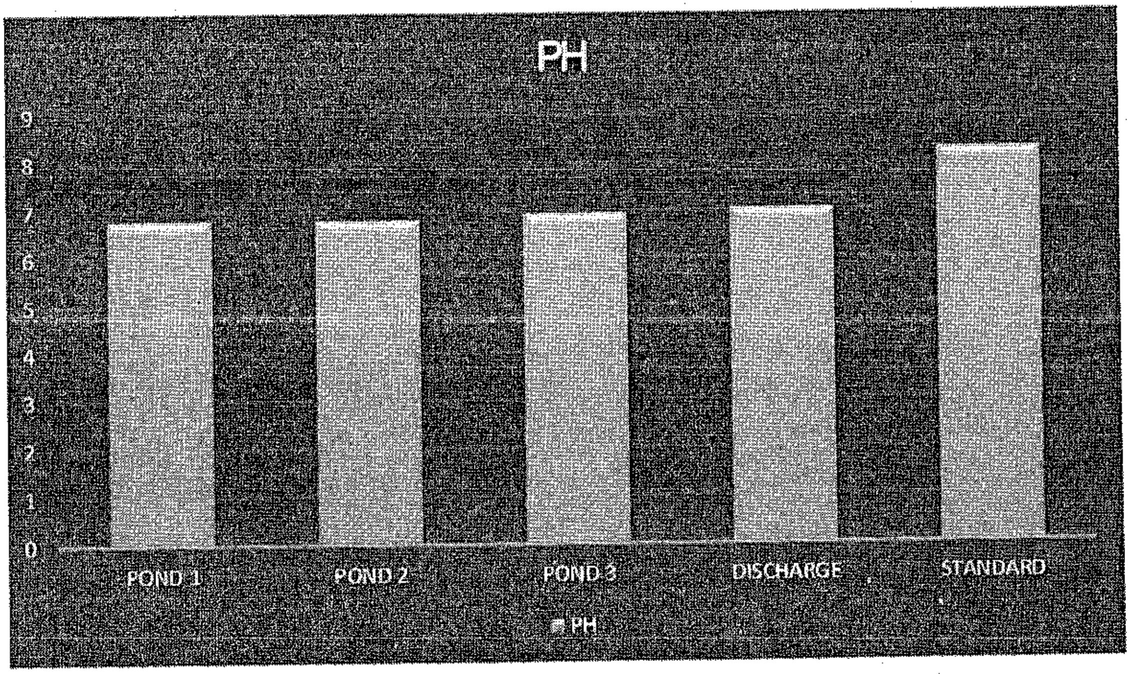
The physical characteristics measured were odour, turbidity, colour, total dissolved solid, and temperature. From Table 4.1, it was observed that the temperature of the measured parameters increased from point of entry to the ponds and from there it increased at the point where it was discharged. This is accounted for by the metabolic activities that took place in the pond and the period of the day the fish pond waste water was collected. The water has a mild odour at the point of entry, but becomes offensive as it gets to the pond and at the point of discharge and this is caused by the feeding activities and the release of feaces from the fishes in the pond. The water has deep green colour at the point of discharge but it is a bit green at both fish ponds and light brown at the point of entry since it comes in from a stream, its change in colour is suspected to be a result of the duration at which the water stayed in the pond as well as the feeding activities carried out in the pond. Turbidity of the water is very high at pond 1, pond 2, pond 3, and the point of discharge but it's clear at the point of entry. The total dissolved solids value at the control point is 76.67 mg/l and changes to 543.00 mg/l, 420.67 mg/l, 352.33 mg/l and 247.67 mg/l for pond 1, pond 2, pond 3 and the point of discharge respectively. This is accounted for by the feeding rate of the fish and other remnants of feeds left in the water. The pond with the highest total dissolves solid value was observed to have the biggest fishes in the pond.

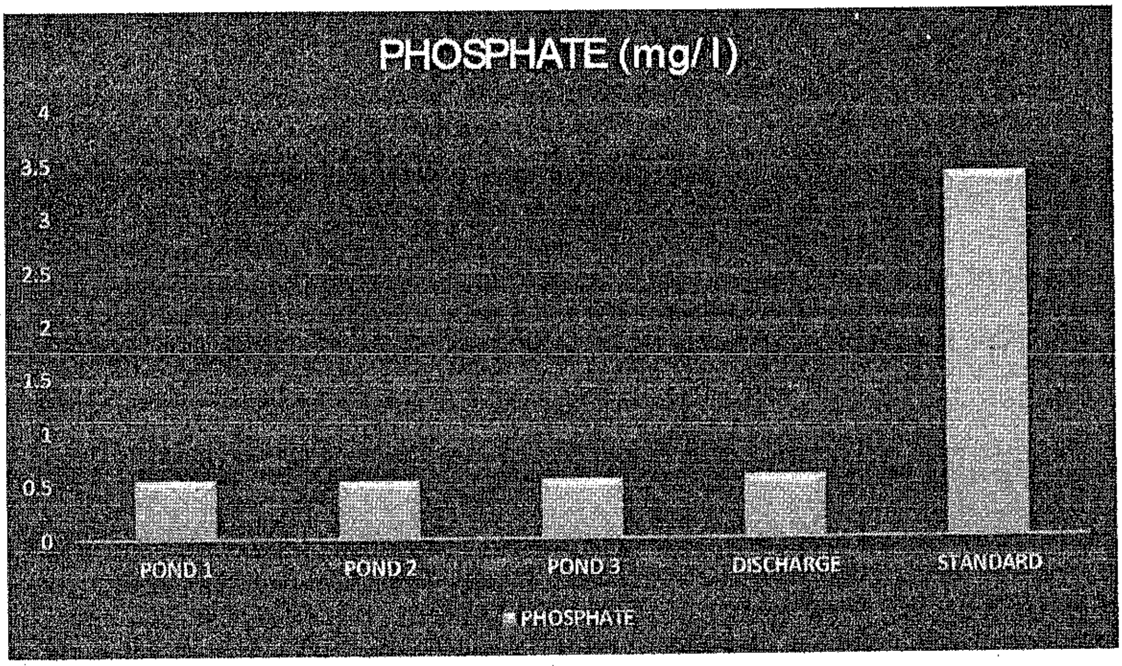
From Table 4.2, it was observed that the wastewater contains potassium, sodium and nitrate, which are essential macro-elements for crop growth and therefore can be used for irrigation purposes if they are within standards. The presence of excess amount of magnesium, copper, calcium and chlorine ions will lead to salinity of the soil if used, directly; therefore, the wastewater cannot be used for irrigation without proper treatment or dilution. Also, the presence of nitrate and phosphate in the wastewater is suspected to having nitrates and phosphates being leached from the adjacent soil as a result of yearly application of nitrogen, phosphorous, and potassium (NPK) fertilizer on the surrounding farmland. The pH of water is a measure of how acid or basic it is given on a scale of 0 – 14 with 7 being the neutral point. The pH for this work ranges from 6.8 to 7.13. As plants in the water remove carbon dioxide for photosynthesis, the pH will increase. At night, the pH will decrease as carbon dioxide accumulates. In this work, the water was collected during the day. However, most fish species do well within the pH range of 6.5 to 9.5. Table 4.3 gives the results of biological analysis of the wastewater. There is high concentration of dissolved oxygen but it drops sharply as a result of increased fish activities and organic activities taking place in the pond. Also, the presence of a small amount of faecal coliform group parameters in the source indicate the presence of human and livestock faeces since it is from a flowing stream but this increases as the water enters the pond and the discharged faeces of fish might have increased the concentration in the water.

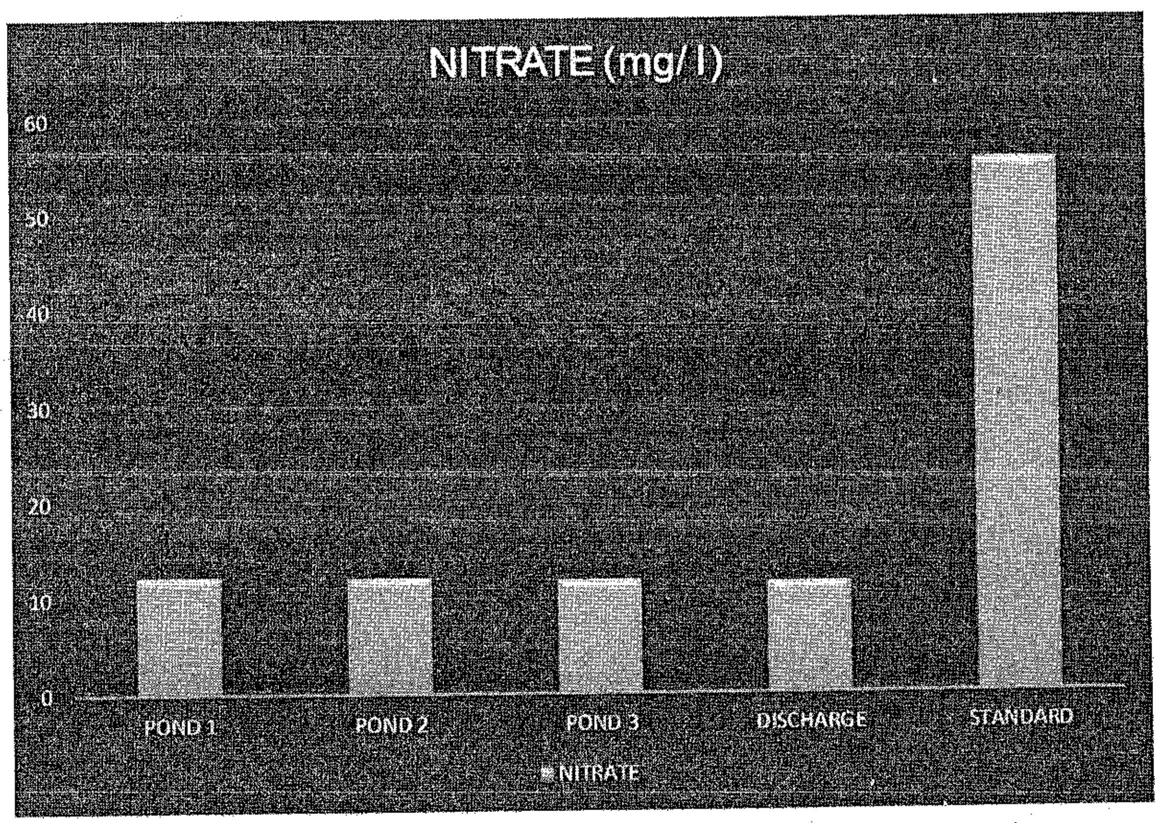
4.3 CHARTS SHOWING COMPARISON OF MEASURED PARAMETERS OF WASTE WATER WITH ACCEPTABLE ENVIRONMENTAL STANDARD VALUES.

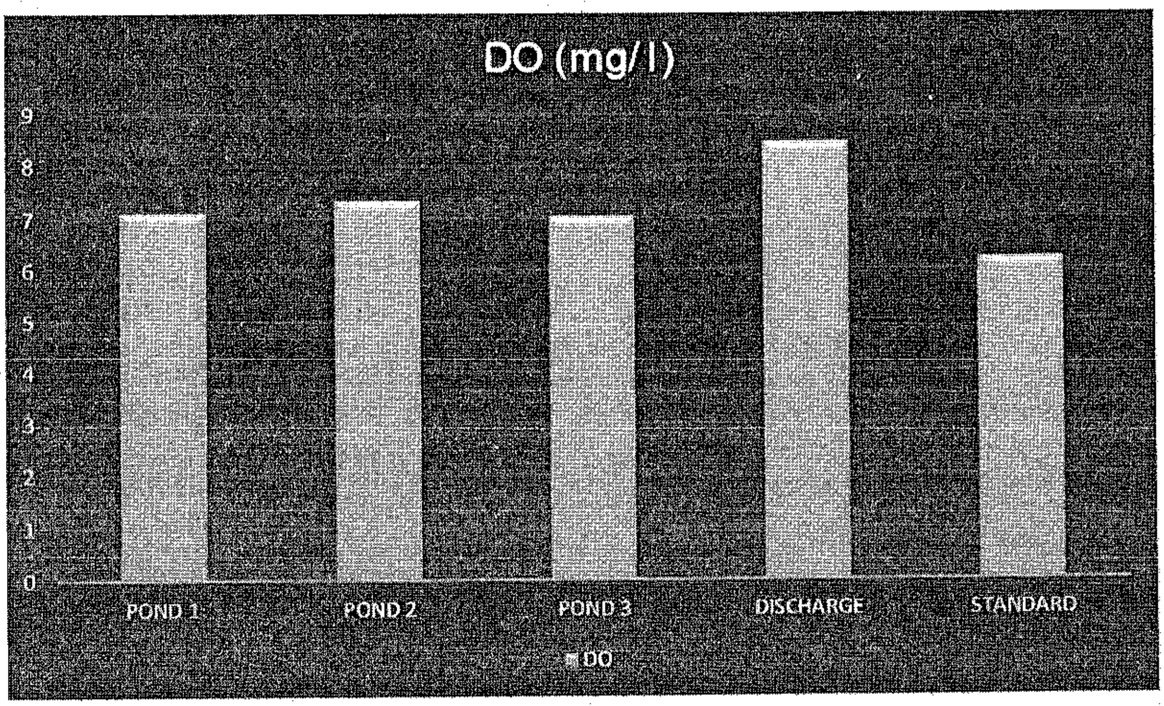



TDS (mg/ l)
1200
1000
800
600
400
200
0
POND 1
POND 2
POND 3
DISCHARGE
STANDARD
TDS (mg/l)


PH
9
8
7
6
5
4
3
2
1
0
POND 1
POND 2
POND 3
DISCHARGE
STANDARD
PH


PHOSPHATE (mg/ l)
4
3.5
3
2.5
2
1.5
1
0.5
0
POND 1
POND 2
POND 3
DISCHARGE
STANDARD
PHOSPHATE


NITRATE (mg/ l)
60
50
40
30
20
10
0
POND 1
POND 2
POND 3
DISCHARGE
STANDARD
NITRATE



4.4 SEDIMENTATION TANK

Sedimentation tank, also called settling tank or clarifier. A sedimentation tank allows suspended particles to settle out of water or wastewater as it flows slowly through the tank, thereby providing some degree of purification. A layer of accumulated solids, called sludge, forms at the bottom of the tank and is periodically removed. In drinking-water treatment, coagulants are added to the water prior to sedimentation in order to facilitate the settling process, which is followed by filtration and other treatment steps. Sedimentation is usually preceded by treatment using bar screens and grit chambers to remove large objects and coarse solids. Sedimentation tanks can be circular or rectangular in shape.

Sewage treatment has a number of benefits. For example, sewage treatment ensures that the environment is kept clean, there is no water pollution, makes use of the most important natural resource; water, the treated water can be used for cooling machines in factories and industries, prevents the outbreak of waterborne diseases and most importantly, it ensures that there is adequate water for other purposes like irrigation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The wastewater samples taken from the control point, three fishponds and the point of discharge were analyzed and studied to determine their physical, chemical and biological parameters. Also, based on the result of the analysis, it was discovered that the water needs to be treated before it can be used for domestic purposes like washing, cooking, etc.

5.2 RECOMMENDATIONS

1. It is recommended that the fish pond waste water be treated and tested with sedimentation method as discussed in chapter four to ascertain how effective the method is.
2. It is also recommended that fish pond waste water be generally treated using any appropriate method before discharging finally to the environment to further enhance the health assurance. This will help improve the water quality thereby providing portable water for households in communities.
3. Finally further researches should be done to ascertain the extent of groundwater pollution by the fishpond wastewaters.

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