TREATMENT OF FISH WASTEWATER BY USING WATER SPINACH (IPOMOEA AQUATICA) IN AN AQUAPONIC SYSTEM

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ABSTRACT

An aquaponic system was designed to investigate the effect of HRT towards water quality. Water spinach (*Ipomoea Aquatica*) was cultivated in medium growth bed to examine for its ability to remove nutrients from aquaculture wastewater. The effectiveness of quantity of water spinach also investigated in this project to see how does the number of water spinaches affect the contaminated water. The plants were fed wastewater from Catfish (*Pangasius Sutchi*) production facility. The aquaponic system was investigated in 2-, 4- and 6-d hydraulic retention times (HRTs) with particular emphasis on nitrogen conversion and removal through the system. Although substantial amounts of soluble and insoluble substances were released by the roots accommodation, the plants were able to remove the pollutants in wastewater. Both BOD_5 and COD removals were enhanced by the longer HRT as well as the decreasing of concentration of NH_3-N, NO_3-N, and NO_2-N. The present findings highlight the effectiveness of water spinach and the HRT in improving the pollutant removals in the aquaponic system.

ABSTRAK

Satu sistem aquaponic telah direka untuk mengkaji kesan HRT terhadap kualiti air. Kangkung (Ipomoea Aquatica) telah ditanam di bekas untuk memeriksa keupayaan untuk mengeluarkan nutrien dari air sisa akuakultur itu. Keberkesanan kuantiti kangkung yang ditanam juga dikaji dalam projek ini untuk melihat bagaimana keberkesanan bilangan kangkung dalam merawat air yang tercemar. Tumbuh-tumbuhan menyerap air sisa dari ikan patin (pangasius Sutchi). Sistem aquaponic telah disiasat dalam masa 2 -, 4 - dan 6-d masa tahanan hidraulik (HRTs) dengan penekanan khusus kepada penukaran nitrogen dan pembuangan melalui sistem. Walaupun sejumlah besar bahan-bahan larut dan tidak larut yang dikeluarkan oleh penginapan akar, tumbuhan yang dapat mengeluarkan bahan pencemar dalam air sisa. Kedua-dua peratusan penyingkiran BOD_5 dan COD telah dipertingkatkan dengan penahanan air HRT lebih lama sekaligus mengurangkan kepekatan NH_3-N, NO_3-N, dan NO_2-N. Hasil kajian ini mengetengahkan keberkesanan kangkung dan masa tahanan hidraulik HRT dalam meningkatkan penyingkiran bahan pencemar dalam sistem aquaponic.

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%	Percent

LIST OF ABBREVIATION

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
HRT	Hydraulic Retention Time
N	Nitrogen
NH_3-N	Ammonia Nitrogen
NO_2-N	Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
P	Phosphorus
RAS	Recirculation Aquaponic System
UMP	Universiti Malaysia Pahang
d	Day
mg/L	Miligram per Liter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The word 'aquaponics' is derived from a combination of both 'aquaculture' and 'hydroponincs' (Hamid R. Roosta and Yaser Mohsenian, 2012), which the aquaculture is means as the culture of aquatic life or more specific for this study is fish farming while hydroponics is the process of growing plants in a medium other than soil. Aquaponic system is one of the methods that are used to treat contaminated water. The system was designed to investigate the effect of Ipomoea Aquatica in improving the quality of wastewater.

Aquaculture systems produce large quantities of organic matter and nutrients (nitrogen, phosphorus and other elements) that require treatment and/or disposal (A.E Ghaly , M. Kamal and N.S Mahmoud, 2005). Boyd (1985) and A.E Ghaly , M. Kamal and N.S Mahmoud, (2005) stated that the production of 1ton (1000 kg) of live channel catfish releases 1190 kg of dry matter, 60kg of nitrogen and 12 kg of phosphorus to the culture water as metabolic wastes. Aquaculture wastewaters exert adverse environmental impacts when the effluent from these systems discharges to receiving water as organic matter loading reduces dissolved oxygen levels and contributes to the buildup of bottom sediments and high nutrient loading impairs water quality stimulating excessive phytoplankton production (Joyner, 1992; A.E Ghaly , M. Kamal and N.S Mahmoud, 2005).

The hydroponics control the accumulation of waste nutrients from fish culture (Rakocy and Hargreaves, 1993; Hamid R. Roosta and Yaser Mohsenian, 2012), which may lower the overall consumption of water (McMurtry et al, 1997) and produce additional, saleable crops (Rakocy and Hargreaves, 1993). Fish feed provides most of the nutrients required for plant growth. Majority of fish species utilize 20–30% of nitrogen (N) supplied by the diet (Penczak et al., 1982; Hall et al., 1992; Shpigel et al., 1993; Piedrahita, 2003; Schneider et al., 2005; Hamid R. Roosta and Yaser Mohsenian, 2012). This means that about 70–80% of the N supplied by the feed is being released as waste into the water (Krom et al., 1995; Hamid R. Roosta and Yaser Mohsenian, 2012).

Hydroponic production systems have potential for the treatment and reuse of wastewater in intensive aquaculture systems. Combining aquaculture with the hydroculture technique may serve the double purpose of reducing the pollution caused by fish farming and the demand for commercial fertilizers, thereby helping to preserve surface and ground water quality (Pettersen, 1987; A.E Ghaly , M. Kamal and N.S Mahmoud, 2005). Aquaculture systems integrated with plant culture involve the use of nutrient-rich effluent from aquaculture production tanks to provide water and nutrients to plants (Mathieu and Wang, 1995; A.E Ghaly , M. Kamal and N.S Mahmoud, 2005).

In simple explanation, aquaponic system occur when wastewater from fish tank is pumped up to the plant growth bed, nutrients in the water will be absorbed by the plants which acts as a biofilter, then clean water will be conveyed back to the tank.

As for my research project, the raw sample of fish wastewater is taken from an organization of aquaculture farming. Catfish is the living organism in this study will fed food and produce nutrients through excretion. Water spinach (I.quatica) as a hydroponic plant will absorbs the nutrients in water.

1.2 PROBLEM STATEMENT

Water and land resources for agriculture are diminishing and world fisheries are at or past their maximum sustainable yields. To feed humanity for the next 40 years it is speculated that more food must be produced than all the food produced since the beginning of recorded history (Parker, 2002). Extractive resources are taken from nature and then consumed in some applications for food or energy. Renewable resources such as trees and fish exist in finite quantities at any point in time but can regenerate (Rasband et al., 2004).

Fisheries are an extractable renewable resource when managed properly. Recent consumption and demand for seafood primarily driven by technological fishing development and market demand (arising from recent knowledge of the health benefits from fish and increasing populations) has led to a mismanaged system. There are multiple reasons for the mismanagement of fisheries. First, increases in consumer demand has skyrocketed past what natural fish stocks can support. Second, pollution, climate change and the lack of global enforcement in fisheries management has led to severely depleted fish stocks. Some predict commercial fish stocks to disappear within the next decade or even sooner if problems are not addressed (FAO, 2007). The majority of commercially fished species is at or past their maximum sustainable yields meaning that fish populations cannot naturally rebound on their own. Aquaculture yields promise for sustaining fishery resources. However this cannot be done by simple mass production via aquaculture.

Environmental problems that arise from aquaculture include: biological pollution (escaped fish); fish for fish feed ingredients, farm discharge pollution leading to eutrophication, habitat modification and chemical pollution from antibiotics and pesticides. Aquaculture practices must be coupled with sound environmental and fisheries policies to yield a productive and sustainable management system.

Farming a number of fish is a common thing and it can be carried out indoor or outdoor and a system as small as a bowl of fish to a full business size can be used. When it comes to fish farming, even from a bowl of fish to acres of fish pond, it will face the same difficulty. Aquaculture probably the fastest growing food-producing sector, now accounts for almost 50% of the world's food fish and is perceived as having the greatest potential to meet the growing demand for aquatic food. It is estimated that at least an additional 40 million tons of aquatic food will be required by 2030 to maintain the current per capita consumption (FAO, 2006; Azizah Endut, A. Jusoh, N. Ali, W.B Wan Nik and A. Hassan, 2010).

Around 90% of wastewater produced globally remains untreated, causing prolonged water pollution, especially in low-income countries. The problem is when the water we used to grow the fish frequently becomes contaminated by the presence of fish waste and uneaten feed. Fishery wastewater becomes toxic and will affect the quality of the fish itself.

1.3 RESEARCH OBJECTIVES

This study aimed to treat fishpond wastewater using Ipomoea Aquatica in an aquaponic system. This study outlines the following objectives:

1.3.1 To study the effect of hydraulic retention time to water quality in aquaponic system.

1.3.2 To study the effectiveness of water spinach (I.Aquatica) in reducing the pollution potential in aquaponic system.

1.3.3 To study the effectiveness of water spinach (I.Aquatica) quantity in treating wastewater.

1.4 SCOPE OF STUDY

The scope of the proposed study is focuses on environmental management which is more emphasized on how to treat wastewater in fish tank using aquaponic system. An amount of fish wastewater is taken from Abu Bakar stall in Pekan. The wastewater is transfer to a tank nearly environmental lab in UMP. Ipomoea Aquatica is used in treating the wastewater in the aquaponic system. The quality of wastewater before and after treatment process was tested. Parameters of water quality for this study are biochemical oxygen demand (BOD), chemical oxygen demand (COD), Nitrogen-Nitrite, Nitrogen-Nitrate, and Ammonia Nitrogen.

CHAPTER 2

LITERATURE REVIEW

2.1 AQUAPONIC SYSTEM

2.1.1 Introduction

The contribution of aquaculture to the world food supply has been increasing significantly during the past decades. In 2009, it is estimated that the aquaculture provides 51 million tons MT (41%) of global human fish consumption (J.M. Webb, R. Quintã, S. Papadimitriou, L. Norman, M. Rigby, D.N. Thomas & L. Le Vay, 2012). In order to keep up with population growth and increasing per capita fish consumption, aquaculture output is set to increase by a further 60–100% over the next 20–30 years. It is expected to increase in the future because fishery production from natural sources is becoming limited (Boyd, 2003). At the same time, the impacts of aquaculture on the environment and natural resources need to be controlled because of the large amount of water that aquaculture production uses and the effluent that it discharges into the environment. The development has always associated with the water pollution.

Aquaculture probably the fastest growing food-producing sector, now accounts for almost 50% of the world's food fish and is perceived as having the greatest potential to meet the growing demand for aquatic food. It is estimated that at least an additional 40 million tonnes of aquatic food will be required by 2030 to maintain the current per capita consumption (FAO, 2006; and Azizah Endut, A. Jusoh, N. Ali, W.B. Wan Nik, and A. Hassan, 2010). Aquaculture is the culture of aquatic organisms, commonly referred as animals, in a designated water body. The water needs to be treated whenever toxicants in it have built up beyond animal's safe level (Jung Yuang Liang and Yew Hu

Chien, 2013). Toxicants such as ammonia and nitrite are derived from decomposition of unconsumed feed and metabolites or waste of the animals. Hydroponics is the culture of aquatic plants in soilless water where nutrients for plant's growth come entirely from a formulated fertilizer. Aquaponics is a portmanteau of the terms aquaculture and hydroponics integrates aquaculture and hydroponics into a common closed-loop eco-culture where a symbiotic relationship is created in which water and nutrients are recirculated and reused, concomitantly fully utilized and conserved (Jung Yuang Liang and Yew Hu Chien, 2013). In aquaponics system, waste organic matters from aquaculture system, which can become toxic to animals, are converted by microbes into soluble nutrients for the plants and simultaneously, hydroponics system has already treated the water and recirculates back to aquaculture system with cleansed and safe water for the animals.

2.1.1 Effects of Water Spinach (Ipomoea Aquatica) on Wastewater

Jung Yuang Liang and Yew hu Chien (2013) stated that water spinach was effective in fish waste water treatment. Nitrogen (N) and phosphorus (P) contained in agricultural effluents and industrial wastewaters are mainly responsible for eutrophication (Smith et al., 1999; and Miao Li, Yue Jin Wu, Zeng Liang Yu, Guo Ping Sheng, and Han Qing Yu, 2007). Both of them are considered to be the limiting elements of primary productivity in most freshwater ecosystems, and therefore to be the control target for the restoration of freshwater ecosystems (Garland et al., 2004; and Miao Li, Yue Jin Wu, Zeng Liang Yu, Guo Ping Sheng, and Han Qing Yu, 2007). A hydroponic-culture system was used to investigate the feasibility for the three cultivars of water spinach to remove nitrogen from eutrophic water. Water spinach, as an edible and floating plant, can grow in polluted water bodies, and has a higher marketable value compared with many other aquatic macrophytes (Miao Li, Yue Jin Wu, Zeng Liang Yu, Guo Ping Sheng, and Han Qing Yu, 2007).

The study by Miao Li, Yue Jin Wu, Zeng Liang Yu, Guo Ping Sheng, and Han Qing Yu, (2007) examined the N removal of three cultivars of water spinach with ion implantation, and demonstrated the feasibility of applying ion-beam biotechnology to phytoremediation. The NH_4-N removal efficiency of the three cultivars of water spinach with ion implantation was greater than that of the aquatic plants. They said experimental results also showed that water spinach with ion implantation was very effective through combining with floating bed, and that such a system had a good potential to remove N from water.

2.1.2 Hydraulic Retention Time (HRT)

Hydraulic retention time (HRT), also known as hydraulic residence time or t (tau) is a measure of the average length of time that a soluble compound remains in a constructed bioreactor. Hydraulic retention time is the volume of the aeration tank divided by the influent flow rate. Hydraulic retention time is one of the effects that will change the nutrients contents in water. Plants grew actively in the hydroponic trough and did not identify any nutritional deficiencies or mineral imbalances. Plant production increased as the hydraulic loading rate increased (Azizah Endut, A. Jusoh, N. Ali, W.B. Wan Nik, and A. Hassan, 2010). The waste discharged was found to be strongly dependent on hydraulic loading rate. Chong-Bang Zhang, Wen-Li Liu, Jiang Wang, Bin-He Gu, and Jie Chang, (2012) said that the longer HRTs and the species richness × HRT interaction were benefit to removals of both BOD_5 and COD, while the species richness had not the significant effect.

2.1.3 Advantages of Aquaponic System

Aquaponics system can obtain extra economic advantages. One of them is saving cost (input) on water treatment for aquaculture system because the system will recirculated and reused water with the presence of plant which will uptake the nutrient in water. Other than that is, saving another cost on formulated fertilizer for hydroponics system, since the plants will absorb nutrients from wastewater which acts as food for hydroponics plants. Its benefit from double outputs, harvest of animal and plant, by a single input, fish feed (Jung Yuang Liang and Yew Hu Chien, 2013). Indoor RAS are usually operated according to different treatment protocols in which emphasis is placed on solid capture and ammonia transformation to nitrate within the recirculation loop with optional onsite treatment of the concentrated effluent before discharge (Jaap Van Rijn, 2013).

CHAPTER 3

METHODOLOGY

3.1 APPROACH OF RESEARCH

The study intends to analyze the water quality of an aquaponic system. This research is based on the effect of retention time of water to the water quality of the system. Besides that, the quality of water in the fish tank also will be based on the effectiveness and quantity of water spinach in reducing pollution in wastewater by uptake the nutrients in water. To run an aquaponic system, a system must be built to place the fish wastewater and hydroponic plants.

3.2 METHODS OF SAMPLING

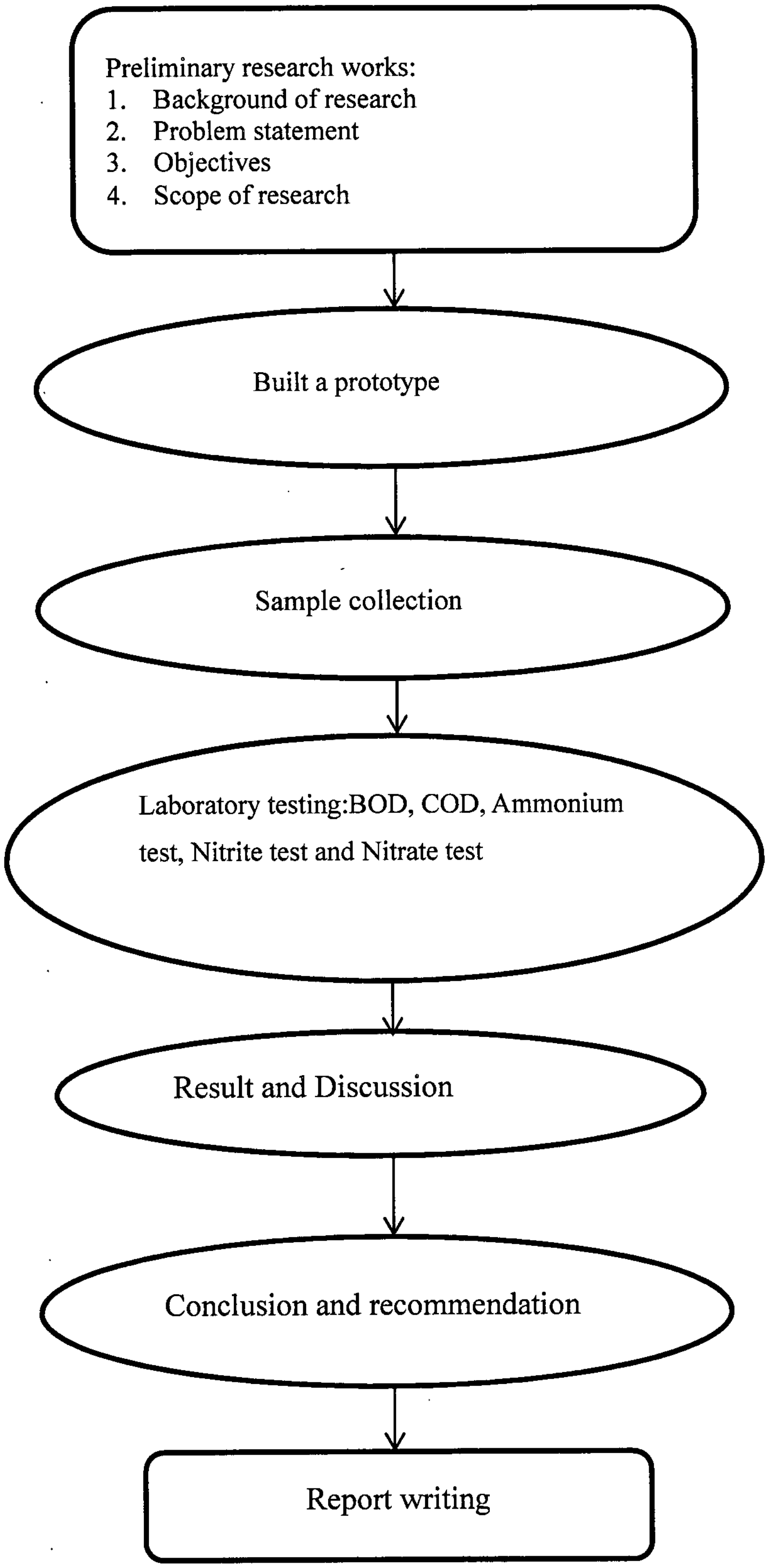

Figure 3.1: Methodology of Sampling

According to the figure 1 above the procedure of the research was started by the preliminary works: background of research, problem statement, research objective, and scope of the study. Done with the first step, I follow up to the next stage which is to build an aquaponic system. An aquaponic system consists of growth bed to planted hydroponic plant with rock pebbles as growth medium, stand to hold the growth bed which made from woods, aquarium to placed fish wastewater, piping, tubing and pumps for water flow system in pumping water from tank to growth bed meanwhile the flow of effluent from growth bed to the aquarium tank was supported by gravity force and syphon system. After finish with the aquaponic system, a test on water must be run to ensure there is no leakage in the system.

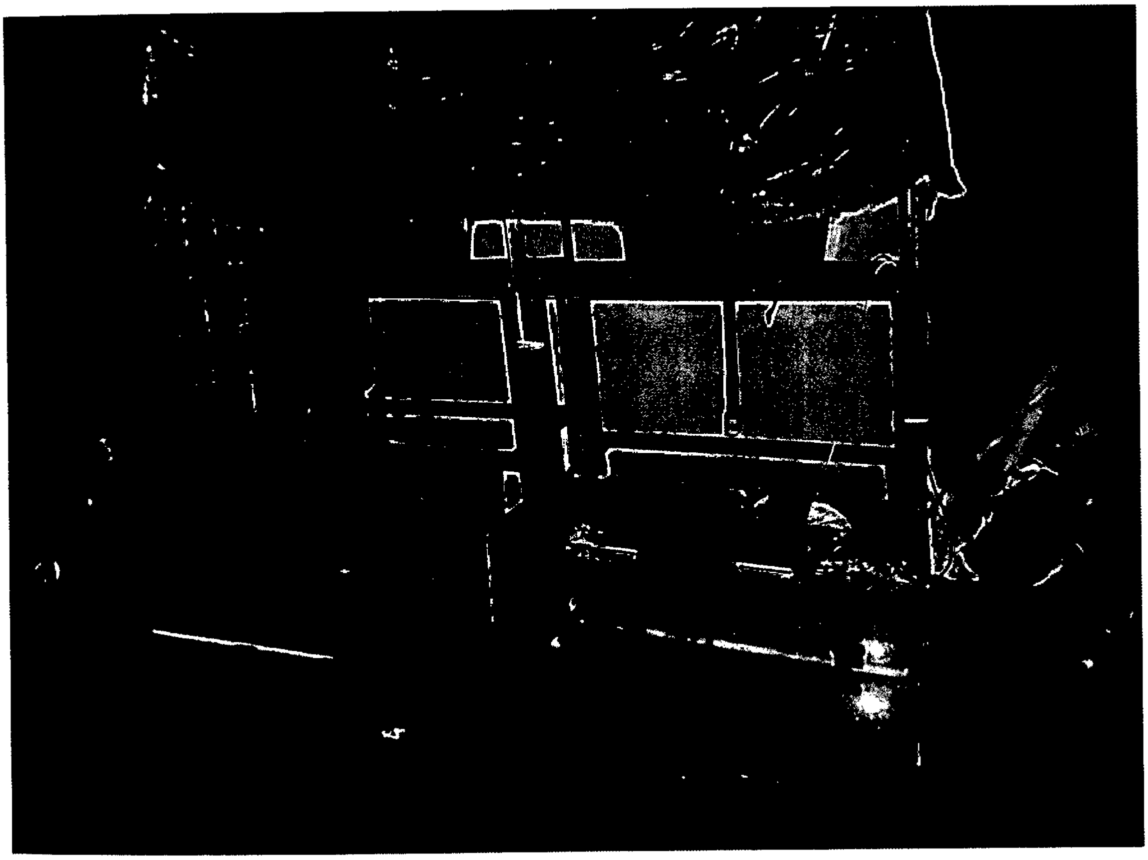

Figure 3.2: Prototype of Aquaponic System

Raw sample was collected from Abu Bakar Ikan Patin located in Pekan, Pahang. Fish wastewater was collect together with the fish and placed the raw sample in the system. Two bunches of water spinach was planted in the growth bed and another system is a water spinach-free which will act as a control. The influent of sample for both systems was collected and after 48 hours the effluent from growth bed was collect again to test the change in nutrients concentration. Sample collection from the systems was collect and test within 48 hours. Time taken for sampling processes is 6 days.

Environmental parameters to test the nutrient contents in the water were chemical oxygen demand (COD), biochemical oxygen demand (BOD), ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N). Procedure for every parameter was followed according to manual standard. The experiment was done in environmental laboratory lab.

Data analysis was made after finish the experiments of the research. The result is discussed and conclusion and recommendation can be made based on the obtained result. Report writing is the final step of the research.

3.3 Testing Instruments

Test was carried out in the environmental laboratory is to find out the level of nutrients contained in polluted water. Some of the equipment was used for reading the concentration of nutrients in the water. Among the tools used are as follows:

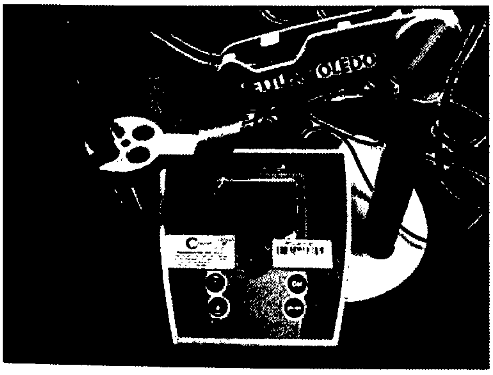

Figure 3.3: pH Meter

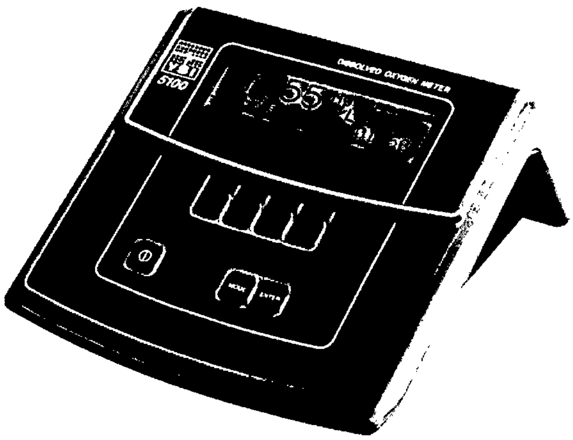

Figure 3.4: Dissolved Oxygen (DO) Meter

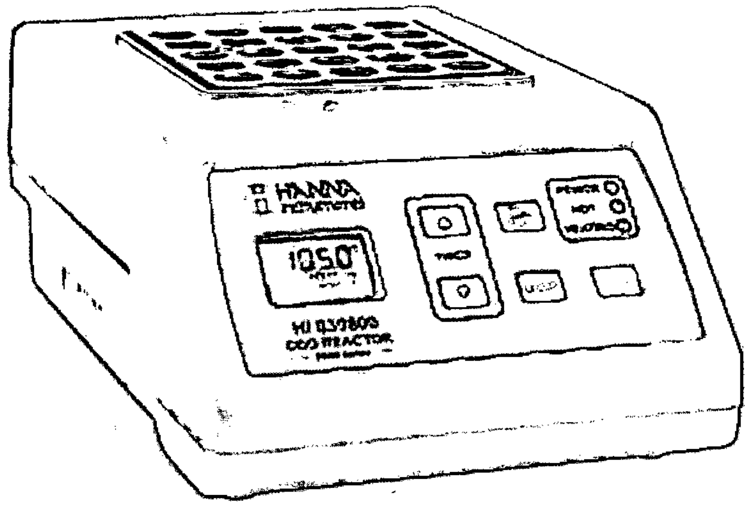

Figure 3.5: COD Reactor

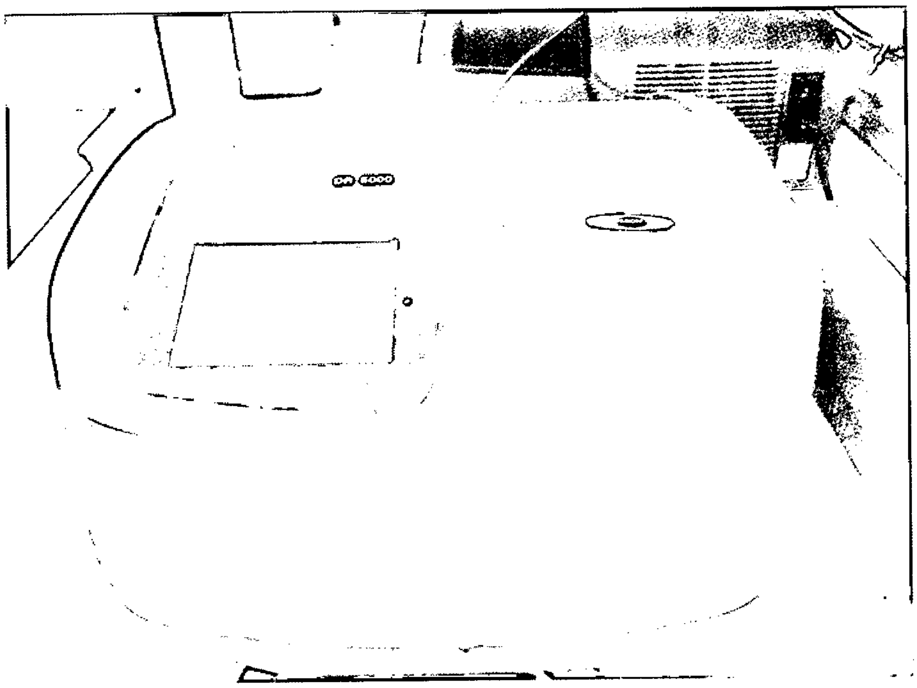

Figure 3.6: Spectrometer

CHAPTER 4

RESULT AND DISCUSSION

4.1 CHEMICAL OXYGEN DEMAND (COD)

The chemical oxygen demand (COD) concentration in the compartment increased with time during the root germination period due to the release of enzymes and other growth substances and was dependent on the hydraulic retention time and quantity of water spinach (I.Aquatica) used. Increasing the quantity of water spinach increased the concentration of COD in the compartment as well.

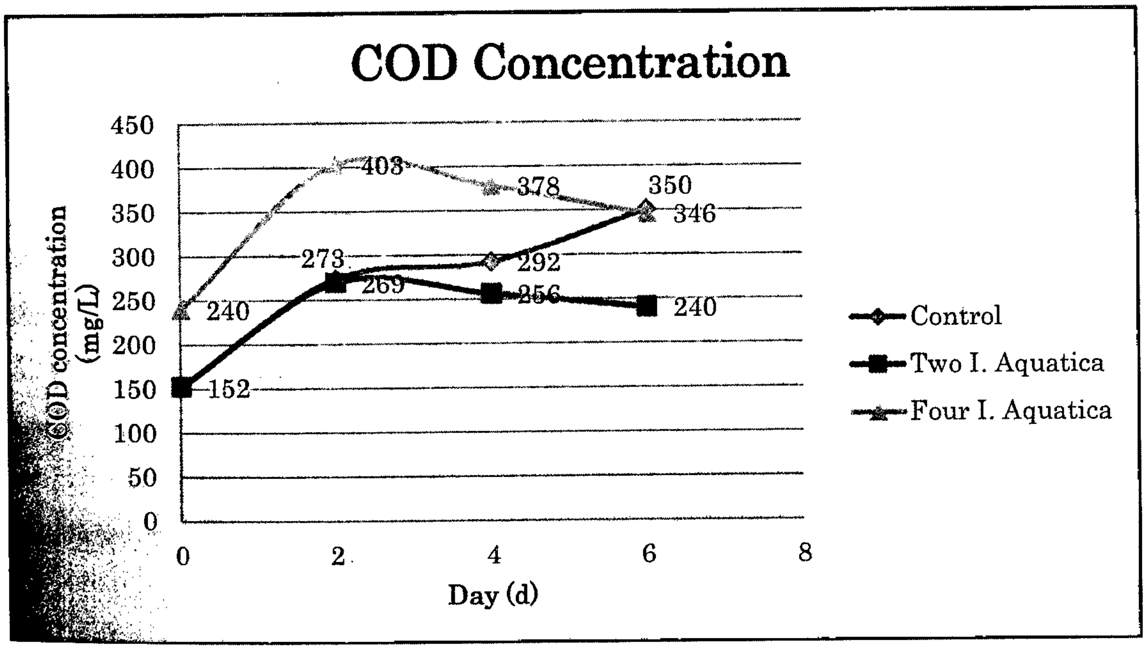

Figure 4.1: COD (mg/L) vs. Day (d)

From the graph of COD concentration in figure 4.1 above, it shows that the influent concentration for control and presence of two bunches water spinaches was 152mg/L while for four bunches of water spinach the concentration was initially