THE RELATIONSHIP BETWEEN DISSOLVED OXYGEN, NITRATE AND TEMPERATURE IN AQUACULTURE POND

by

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DECLARATION

I declare that this thesis entitled "The Relationship between Dissolved Oxygen, Nitrate and Temperature in Aquaculture Pond" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :________________________________

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
EC	Electrical Conductivity
EPA	Environmental Protection Agency
mg/ L	miligram/ litter
MPI	Metal Pollution Index
MYT	Malaysia Time
NWQS	National Water Quality Standard
pH	potential hydrogen
PHILMINAQ	Mitigating Impact of Aquaculture in the Philippines
PPMC	Person product-moment correlation
PSU	Prince of Songkla University
Sig.	Significance Value
SD	Standard Deviation
SPSS	Statistical Package for the Social Science
TA	Total Alkalinity
TH	Total Hardness
TSS	Total Suspended Solid
UK	United Kingdom
UMK	University Malaysia Kelantan
UTC	Universal Time Coordinated
US	United States
WQI	Water Quality Index
WHO	World Health Organization

LIST OF SYMBOLS

°*C*	Degree Celsius
r	Pearson's correlation coefficient
%	Percentage

The Relationship between Dissolved Oxygen, Nitrate and Temperature in Aquaculture Pond

ABSTRACT

Aquaculture is an important sector to food security, education and also to promote economy growth. In order to enhance the productivity, there is a need to understand the water physicochemical parameter. So, a study of water quality data analysis in aquaculture pond UMK Jeli had been carried out. This was to investigate Dissolved Oxygen (DO), Nitrate (NO_3^{2-}) and temperature of aquaculture pond collected from the data collecting sensor, Aquasense. Another objective was to correlate of DO, NO_3^{2-} and temperature. For a duration of forty-five days, every minute of data were sent for statistical analysis that include Independent T-test and Pearson Correlation, using SPSS version 20. Additionally, it was tabulated and analyzed daily and weekly. Moreover, the mean, standard deviation, minimum and maximum of each of the investigated parameters would be studied. Temperature reading obtain showed a relative divert result from the reality. Overall, the value of these three parameters were in an acceptable range and the water quality in this pond was considered good. Thus, it is suitable for the culture of living organisms in this pond. DO and NO_3^{2-} ($p<0.01$) showed a maximum and negative correlation with $r = -1$ along the forty-five crop rearing days. The major contributing factor to this trend was the introducing of new freshwater that lead to constant water exchange, water circulation and water mixing. This study had some inadequacies where there are some grey areas that the author did not include or justify since there is still have many uncertainties and unknown factors that would affect the variation of water quality parameter at different condition. Apart of that, the sensor's performance was good and yet there was still need some improvements. This study would be useful to any parties that used to monitor water quality by using new technology.

Hubungan antara Oksigen Terlarut, Nitrat dan Suhu di Kolam Akuakultur

ABSTRAK

Akuakultur adalah sektor penting untuk keselamatan makanan, pendidikan dan juga untuk mempromosikan pertumbuhan ekonomi. Untuk meningkatkan produktiviti, terdapat keperluan untuk memahami parameter fizikokimia air. Oleh itu, satu kajian analisis data kualiti air di kolam akuakultur UMK Jeli telah dijalankan. Ini adalah untuk menyiasat Oksigen terlarut (DO), Nitrat (NO_3^{2}-) dan suhu kolam akuakultur yang dikumpul dari sensor, Aquasense. Objektif kedua adalah untuk mengaitkan DO, NO_3^{2-} dan suhu. Bagi tempoh empat puluh lima hari, setiap minit data telah dihantar untuk analisis statistik yang merangkumi *Independent T-test* dan *Pearson Correlation*, dengan menggunakan SPSS versi 20. Selain itu, data tersebut telah ditabulasi dan dianalisis dalam bentuk harian dan mingguan. Di samping itu, purata, sisihan piawai, minimum dan maksimum bagi setiap parameter telah dikaji. Bacaan suhu telah menunjukkan hasil bacaan yang berlawanan dengan realiti. Secara keseluruhannya, nilai ketiga-tiga parameter tersebut masih berada dalam julat yang boleh diterima dan kualiti air di kolam ini dianggap baik. Oleh itu, kolam ini sesuai untuk pembiakan organisma hidup. DO dan NO_3^{2}- ($p < 0.01$) telah menunjukkan korelasi maksimum dan negatif dengan $r = -1$ sepanjang empat puluh lima hari pengkulturan ikan. Faktor utama yang menyumbang kepada trend ini adalah pengenalan air tawar baru yang membawa kepada pertukaran air yang berterusan, peredaran air dan pencampuran air. Kajian ini mempunyai beberapa kekurangan di mana terdapat beberapa 'kawasan kelabu' di mana ahli penyelidik tidak memasukkan serta menjustifikasikan. Ini adalah kerana masih terdapat banyak faktor ketidakpastian dan faktor yang tidak diketahui yang akan mempengaruhi variasi parameter kualiti air dalam keadaan yang berbeza. Selain itu, prestasi sensor dikira baik namun masih terdapat banyak ruang penambahbaikan. Hasil kajian ini dapat membantu mana-mana pihak dalam memantau kualiti air dengan menggunakan teknologi baru.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Aquaculture is the cultivation, nurturing and harvesting of fish, algae, plants and other organisms in any types of water surroundings or environment (National Oceanic and Atmospheric Administration, 2018). In the 1990s, the development of Malaysia aquaculture was constrained by the environmental problem such as water pollution and land pollution (Hanafi, 1995). Anthropogenic activities such as agricultural, domestic and industrialization had contributed to these problems. The main source of water pollution comes from agriculture such as the excess nitrate in the soil in the agricultural area (California Water Boards, 2013). Not only agricultural and industrialization, others human influences like urbanization and increased of human for water resources consumption also contributed to the water environmental quality issue. Natural factors that lead to water quality deterioration consist of weathering of crustal materials, changes in precipitation inputs as well as the soil erosion (Carpenter et al. 1998; Jarvie et al. 1998).

Water quality refers to the water characteristic in the aspect of chemical, biological and physical (Bisht, Ali & Rawat, 2013). In another word, water quality illustrates the condition of a water body and its interrelated appropriateness for various usage. Water quality also termed as environmental values (EPA South Australia, 2018). In order to achieve the best water quality, each country has its own water quality standards. Water quality standards are the provisions of authorized tribal, state, territorial or federal law that is permitted by Environmental Protection Agency (EPA), that depict the level of protection or the desired condition of water bodies or mandate how the desired condition will be expressed or established of this water for the future purpose (US Environmental Protection Agency, 2016).

Anthropogenic activities like unsustainable agriculture practice that used excessive fertilizers for the purpose of increasing crops productivity had contributed to the alteration of water quality. One of the reasons could be the excessive chemicals is not fully utilized or absorbed by the plantations hence whenever there is a rainfall or irrigation, all of the undissolved chemicals would be flushed or washed to the nearby streams such as rivers or lakes. Indirectly, the chemicals would be deposited in the river. As time passed by, the accumulation of chemicals would alter the original water condition. In another word, the relatively higher frequency or magnitude of used chemicals than the rate of plant utilization had contributed to the changes of water state in a stream.

In Malaysia, there are laws and regulations that link to aquaculture. There are Environmental Quality Act, 127 of 1974, Fisheries Act, 317 of 1985, Fisheries (Cockle Culture) regulations, 1964, Fisheries (Marine Culture System) regulations, 1990 and also National Land Code, 56 of 1965 (Hanafi, 1995). Basically, these laws share the same job scope of safeguarding the environmental qualities.

Thus, the study of water parameters relationship that includes dissolved oxygen (DO), nitrate (NO_3^{2-}) and temperature are relatively important. In this paper, the author would use the data collected from the sensor and so carry out the analysis. This paper also would discuss the correlation of few parameters with the aids of Statistical Package for the Social Science (SPSS). Under this, Pearson's Correlation Coefficient, a statistical method would be used to know the relationship of temperature with DO, temperature and

NO_3^{2-}. Plus, Independent Sample T-test were used to determine whether is there any significant difference between two groups of population means. This study was held in one of the aquaculture ponds in University Malaysia Kelantan (UMK).

1.2 Problem Statement

Aquaculture has become one of the sectors that contribute to the growth of the economy. Many fishermen rely on fisheries sectors to sustain their livelihoods (UK Essays, 2015; Yusoff, 2015). Since Malaysia government is focusing on promoting aquaculture, as a consequent, aquaculture is becoming one of the contributors to the environmental problem such as water pollution. The causing agents are the fertilizers, pesticides and many others (Abu Bakar et al., 2010; Ang, 2017).

However this sector contribute environmental issue, hence there is a great demand and pressure by different society level to make this industry become more economically, socially and environmentally sustainable (Berg et al., 1996; Funge-Smith & Briggs, 1998; Crab et al., 2007; Martins et al., 2010; Bjornsdottir et al., 2016). The environmental issues are habitat loss due to the conversion of mangrove to shrimp ponds, the spread of diseases, salinization of soil and water, alteration of water drainage pattern, contamination of groundwater aquifers as well as aquaculture waste (Páez-Osuna, 2001; Primavera, 2006; Cao et al., 2007). With sustainable aquaculture, it would create safe environment, save labour cost, cost of chemical test and so bring human prosperity where everyone is healthy.

Liebetrau (1979) had listed out four importance of having water quality monitoring. There are: to have an overview of the water quality, to monitor the long-term pattern of selected water quality variables and to detect the hidden or actual water issues. Last but not least was the facilitation of water quality monitoring in formulating law or enforcing the related standards. Many researches had been conducted to study the water but there were relatively little researches focus on the aquaculture pond water quality. Hence, this study was conducted on aquaculture pond by investigating only three parameters.

The water used alone for aquaculture pond would not give a satisfied production or result when all of the water quality parameters are not within the range of water quality standard. Good water quality management in pond aquaculture is one of the crucial parts to have a good aquaculture system. Water quality is mainly depending on the chemical and biological processes that include organism's photosynthesis and respiration in a pond. Thereby, the good relationship between water quality parameters and aquatic productivity is vital in achieving favourable cultivation and production (Bisht et al., 2013). These parameters include potential hydrogen (pH), total dissolved solids, turbidity, DO, temperature and NO_3^{2-}.

Temperature, DO and NO_3^{2-} level are relatively the most important parameters that affect the aquatic life. Without the measurement of these, the water quality cannot be monitored, evaluated and treated. In return, the contaminated water would cycle back to the consumer and it would cause a detrimental effect on human health by affecting the function of the human immune system.

Deep understanding of DO is required for the aquatic plant and aquatic animals to carry out photosynthesis and respiration. Sources of DO could be come from the direct diffusion from the atmosphere, photosynthesis, wind and also the action of wave (Svobodová, 1993; Moriarty, 1997). Without DO, organisms cannot carry out normal respiration, eventually they will die. Respiration specifically aerobic respiration is the process of breaking down food with oxygen to obtain energy. Plants also need oxygen to release energy for their own metabolic purpose. This is done by breaking down sugars and the used up of oxygen. Without oxygen, plants' cells cannot convert carbohydrates, proteins and fats into energy.

Nitrate is very important in water quality management too. Nitrate comes from the nitrogen-containing compounds. It acts as nutrient that is crucial for the water organisms and might come from many sources. Natural sources would include the soil and water that naturally contain organic matter. For anthropogenic source, it could be come from the addition of organic fertilizer to the water stream, runoff from the fertilized cropland and also from the animal manure.

Algae use NO_3^{2-} as their food source. Whenever there is a high amount of NO_3^{2-} then there would be unlimited growth of algae which eventually would lead to eutrophication (algae boom). Occurrence of eutrophication would indirectly cause the fluctuations of DO level in aquaculture. When there is high rate of algae decomposition then high levels of organic matter would deplete the availability of oxygen in the water. Subsequently, it would affect the consumption of other organisms in the water since the affected DO level does not meet these organisms' standard oxygen demand. Thus, it would create a hypoxia condition where there is low dissolved oxygen level in a habitat. As for inorganic (mineral) fertilizers, it is manufactured industrially to improve the crop yields.

Temperature is another important parameter in water quality. It is determined by the geographical and environmental conditions. It is vital as it would influence the water chemistry that indirectly affect the organisms' chemical and biological processes. It would have a direct effect on the organisms' growth, food requirement, food conversion and oxygen demand.

Thus, there is a need to know what is the relationship (trend) between the bivariate parameters, how close (strength) are these bivariate variables and what are the rationales of these parameters behave on such way. This study will focus on the main parameters that establish the relationship between temperature with DO and temperature with NO_3^{2-}.

Many people know that water is important. However, the awareness of the need to protect the water is still very low. There are many point sources and non-point sources contribute to the water pollution. In order to formulate measures to deal with water pollution, there is a need of urgent to study the correlation between these parameters.

T-test was conducted to know any significance difference between two groups of mean. This statistical test would give a relative clearer image on the relationship between two independent groups where sometimes some plotted graphical chart only gave a rough idea.

Correlation describes the relationship between two variables (Newsom, 2013). In this study, Pearson Correlation analysis would be carried out to know is there any significant linear relationship between temperature and DO as well as temperature with NO_3^{2-}. In addition, Pearson Correlation aids in determining the direction and the strength of these association (Kent State University, 2018a). Apart of identifying the cause and effect that contribute to the concentration of parameters, correlation analysis also helped in predicting the future trend of the parameters under certain situation.

1.3 Objectives

1. To investigate DO, NO_3^{2-} and temperature of aquaculture pond collected from the Aquasense
2. To correlate of DO, NO_3^{2-} and temperature

1.4 Scope of Study

In this research, primary data would be used for graphical method analysis and statistical analysis. Graphs also would be plotted and used in order to illustrate the relationship of DO (mg/L) with temperature (°C) and also temperature with NO_3^{2-} (mg/L).

Primary data is being used throughout this research as it is considered to be more reliable and they had more validity than the secondary data (Bradley, 2013). Since primary data is collected directly from the study site hence the data accuracy is increased. Plus, the direct obtained primary data would have processed by the researcher so the collected data would show unbiased characteristic.

In addition, Independent Sample T-test and Pearson's correlation would be carried out by SPSS on the parameters relationship of the temperature, DO and NO_3^{2-} (mg/L). In another word, this research only would focus on these three parameters which are temperature, DO and NO_3^{2-}. The analytical data would be 45 days data which is from 22th January 2018 to 7th March 2018.

Pearson's Correlation is used among all of the statistical tests because bivariate Pearson's Correlation is used to test the correlation between pairs of variables as well as the correlation within and between sets of variables (Janda, 2001; Kent State University, 2018; Malek, 2018b). From the result, it could be deduced on the relationship between these three mentioned parameters. The result would also include the r-value and Significance (Sig.) (2-tailed) value that shows the significance level.

1.5 Significance of Study

The study of the relationship of DO, NO_3^{2-} and temperature is vital as they are the parameters that help in determining the water quality level of water bodies. It is hoped that by the end of this research, the result could be contributed to the Department of Environment, Agriculture Department and any agriculture-related business company.

This study is focusing on the correlation among the main parameters: DO, temperature and NO_3^{2-}. Hence, with the statistical figure provided at the end of this study, the government could make it as a reference in developing policy or law. Department of Environment (DOE) and Environmental Impact Assessment consultants could work together to evaluate the necessities to construct buffer zone either riparian buffer or aquatic buffer whenever there was a need to develop a construction project.

Any relevant parties that include Agriculture Department could make good use of the sensor by utilizing the latest technology to monitor the water parameters and to solve some problems in agriculture. For long term aspects, it could help them to save the money.

In addition, this research study is also useful for the researchers to conduct their study that was related to water quality parameters. This could be a guide or reference for them to come out a more holistic research.

Moreover, the result of this research could act as the supporting or education materials in encouraging farmers to practice a more environmentally method of aquatic life cultivation. This was due to this sensor recorded data automatically so it is relatively convenient, save time and also do not have much labor work. Hence, there would be a maintain of good water quality in the aquaculture pond. Indirectly, it helped to alleviate the burden of environment system.

Plus, the outcome of this study could help in determining the performance of the sensor thus there is not need to manually collect the water quality data. As the energy costs rise, there is a concern on reducing the operating expenses in aquaculture pond. Automatic sensor system will help in detecting the water quality based on the time set up and it had greatly relatively reduced the labor work. In future, educators or researchers would only have to buy an automatic system to monitor water quality rather than purchasing apparatus or equipment that require labor to collect the data manually. On the other hand, it indirectly gives the author on the information on the long-term performance of sensor aid in finding out the difficulties or challenges on operating the sensor.

In a short conclusion, the author hopes that the findings of this research are able to become useful or helpful to any parties. The parties would be the students, producers or researchers that either directly or indirectly involved in this aquaculture industry. This research's outcome would become more favourable especially for people who always faced difficulties or issues regarding the water quality.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Aquaculture

Aquaculture sector is important as it provides business and investment opportunity, generate foreign exchange earnings, reduce unemployment rate as well as diversify the income for farmers and fishermen. Almost all of the aquaculture was used widely for the business purpose activities and some researchers were even involved in aquaculture sector in order to come out with a good technique that helped farmers to increase their crops or fisheries productivity (Boyd & Tucker, 2012).

2.1.1 Anthropogenic Activities on Aquaculture Pond

In 2010, Malaysia's aquaculture industry had produced 1.88 million metric tons of scheduled waste which had a rise of 0.17 million metric tons from 1.71 million metric tons in 2009 (DOE, 2010; Poon et al., 2016). It is also estimated that there is an increase of having more than 30,000 tonnes of waste generated daily by 2020 in Peninsular Malaysia (Jereme et al., 2015). Improper industrial practices would contaminate water quality, lead to the exposure of human to heavy metals by the food chain. Subsequently, it does not only give the effect on the safety and public health but also the social welfare in the society (Mokhtar et al., 2011; Sany et al., 2013; Poon et al., 2016).

2.1.1 (a) Impact on the Social Aspect

Along with the gaining popularity of aquaculture and fishery industry as one of the nation's economy, the potentially contaminated aqua products may bring detrimental effects on human health (Yusoff, 2015; Ang, 2017). This proven with the study of heavy metal contamination of collected Tilapia fish (*Oreochromis niloticus*) in Langat Basin, Malaysia had shown high Metal Pollution Index (MPI). Hazard Quotient had depicted there was an elevated human health risk which means that there would be an adverse health effect occur when nation consume this contaminated fish (Alam et al., 2015).

The persistence of chemicals in edible tissue also arose the public health concern. The chemicals of algicides, therapeutants, disinfectants, soil treatment and water treatment compound for the growth of shrimp culture could lead to the toxicity in non-target populations. The non- target populations would be human that act as consumers, other cultured species and also wild biota. Taking one of the victims - human as an example, high antibiotic consumptions would let them suffer from many illnesses like fatigue, slow down their immune system efficiency and many other relative less severe conditions (Primavera et al., 1993; Gräslund & Bengtsson, 2001; Holmström et al., 2003; Primavera, 2006).

2.1.1 (b) Impact on the Environmental Aspect

The pollution attributed by the industrial effluents, radioactive substances and high nutrient concentration had caused the decrease of the fish population which in term alter the marine environment. Majority of the world marine fish stocks dropped due to anthropogenic activities. Thereby reducing the aquatic habitat and so the arose the biodiversity issue (Ansari & Matondkar, 2014).

Moreover, the widespread use of chemicals in aquaculture sector for the construction, plants feeds, chemotherapeutants as well as disinfectants would deteriorate the environment quality. The examples of chemicals would be the antifoulants, stabilizers, pigments and also antimicrobial (Cao et al., 2007).

2.1.1 (c) Impact on the Economics Aspect

In 2005, Reddy & Behera had an economic analysis on the impact of the water pollution in India. Although the rapid development of many sectors aid in the economic growth, however at the same time it would result in the heavy losses in term of economic welfare. The impact of low irrigation water quality on agriculture was that it turned the productive land into barren land. Not only affect the productivity of the crops but also the replacement costs and repairing costs of agricultural machineries or equipment. Indirectly, all of these changes would lead to the loss of the national income. Besides that, it also would contribute to the stability of the paddy market price too (Reddy & Behera, 2005).

2.2 Physico-Chemical Parameters of Aquaculture

Parameters were being defined as guideline, limitation, specification or variable (Parameter, 2018). The common parameters of water aquaculture were temperature, turbidity, pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), DO and ammonium (NH_4).

2.2.1 Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is the available oxygen that dissolved in water that is important for the respiration process of aquatic organisms. To be more precise, it is referred to the oxygen gas but not the oxygen that is part of the water molecules. According to Boyd in 1982, 6 mg/L to 9 mg/L was the range of the optimum DO concentration in pond waters (Boyd, 1982). But these ranges might be changed because there are many factors could influence DO concentration just as the water temperature, water flow, photosynthesis activity, water depth and consumption of aquatic organisms (Sallam & Elsayed, 2014).

Sánchez, et al., (2007) had used the Water Quality Index (WQI) and DO deficit as simple mark or clue of watersheds pollution. Oxygen deficit was obtained by calculating the difference of the level of DO (measured by portable DO meter) at respective assigned sampling point and the saturation concentration of pure water at same pressure and temperature. YSI (2015) stated that the optimum fluctuation range of DO within 24 hours was 2mg/L to 3mg/L. PHILMINAQ (2015) added that there should be have at least 5mg/L of DO in the water.

The concentration of DO level could be increased by using paddle wheels or propeller from the motor machine (Ong et al., 2016). However, too high DO concentrations would cause gas bubble disease in aquatic animals. Similarly, too low DO concentration also would cause a problem. When a water body is overpopulated with fish, the rate of oxygen used-up is faster than its replenish rate, so reduced oxygen level leads to the mortality of aquatic life. Besides that, the higher rate of aerobic decomposition also could contribute to the high rate DO utilization (Rowan, 2012b; Fondriest Environmental Inc., 2013).

2.2.2 Nitrate (NO_3^{2-})

Nitrate (NO_3^{2-}) is an anion of the nitrogen chemical forms. It is tasteless, colourless and odourless. Under the aerobic system, NO_3^{2-} exist in a stable condition. Low concentration of NO_3^{2-} is harmless, however it can pollute groundwater when it exists in high amount (California Water Boards, 2013). Normally, it would exist naturally together with nitrite (NO_2^-). Both of them typically remain in highly water-soluble forms that always combine with other species such as potassium (K), ammonia (NH_3) and sodium (Na). In turn, it will form potassium nitrate (KNO_3), ammonium nitrate (NH_4NO_3) and sodium nitrate ($NaNO_3$).

In addition, NO_3^{2-} always coexists with other nitrogen forms in a complex nitrogen cycle. The existence of NH_3 from agricultural fertilizers, industrial, nitrogenous wastes from animals' excretion and nitrogen fixation would undergo aerobic conversion which is also termed as nitrification. Nitrification would convert NH_3 to nitrite and so nitrite to nitrate (Neospark Drugs and Chemicals Private Limited, 2014). After that, the nitrate nutrient would be taken by plants for their germination or cultivation and the formation of organic nitrogenous compounds (World Health Organization, 2011; Harper et al., 2017). Nitrification was identified by Theophile Schloesing and Achille Müntz in 1877.

When there was an increase in temperature, it would lead to an increase of decomposition rate and so the increase of nitrate production. This is due to there is much-accumulated NH_4 available from the organic matter decomposition rather than being used up by aquatic life (Joslin & Wolfe, 1993). In another word, the rate of nitrate production is higher than the rate of plant nitrate consumption. The condition becomes even worse whenever there is any chemical runoff occurred to the aquaculture from the agriculture nitrate addition (Chern, Kraft & Postle, 1999). Cao et al. (2007) also added that the excessive nitrate concentration together with the presence of other essential nutrient factors, it would lead serious environmental impacts like algae blooms or eutrophication. Subsequently, it would cause oxygen depletion for aquatic life in the aquaculture pond.

Normally, NO_3^{2-} would not cause an adverse health effect if people are not exposed to the highest dangerous level of NO_3^{2-} concentration. To support that, the sensitivity of each individual's immune system also would influence the effect of NO_3^{2-} towards the dose-response relationship of each individual (California Water Boards, 2013; Harper et al., 2017). Thus, there was a need to investigate NO_3^{2-} in order to know the cause and effect that contribute to the high or low NO_3^{2-} concentration.

2.2.2 (a) Nitrogen cycle

Nitrogen cycle was the conversion of different chemical forms of nitrogen through physical, biologic and geologic processes on Earth. Basically, there were four major process involved in this cycle which were nitrogen fixation, ammonification, nitrification and denitrification (Markov, 2012).

Nitrogen fixation also known as the reduction of nitrogen gas (N_2) to ammonia (NH_3) was the utilization of molecular nitrogen by specific bacteria like cyanobacteria, *Rhizobium* and cyanobacteria. The chemical reaction of this process was $N_2 + 8e + 8H^+ + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16P$. This was catalyzed by nitrogenase, bacterial enzyme. Ammonia was the product from this reaction. However, it would further being ionized to ammonium ions (NH_4^+) that would be exist in the form of nucleic acids (DNA), proteins or any other nitrogen – containing organic molecules. Agriculture relied on nitrogen fixation because it supported the nitrogen needs of many crops.

Ammonification was the production of NH_3 or NH_4^+ which is also named as mineralization. It is being defined as the breaking down of organic matter into inorganic matter by living organisms. NH_4^+ was normally exists as a waste by animals and also the decomposition of organic waste by bacteria.

Nitrification was defined as the oxidation of nitrogen compound. Nitrification involved two sequential process. It involved nitrosifyers (the ammonia-oxidising bacteria) like *Nitrosomonas* that convert NH_4^+ into nitrite (NO_2). The reaction is $NH_4^+ + O_2 \rightarrow NO_2^- + H_2O + H^+$. After that, nitrifying bacteria (nitrite-oxidizing bacteria) like *Nitrobacter* would oxidise NO_2^- into NO_3^{2-}. The equation was $NO_2^- + O_2 \rightarrow NO_3^{2-}$. On the other hand, nitrification aids in the nitrogen removal from the municipal of wastewater.

Denitrification (nitrate reduction) worked as the opposite way of nitrogen fixation, it was the reaction that convert NO_3^{2-} into gaseous nitrogen compounds by many groups of organism. The chain of this anaerobic reaction was $NO_3^{2-} \rightarrow NO_2^-$ (nitrite) $\rightarrow NO \rightarrow N_2O \rightarrow N_2$. It required the action from heterotrophic bacteria. The examples of microorganisms were *Thiobacillus denitrificans* and *Paracoccus denitrificans*. This denitrification had a negative impact on agriculture as it would remove the nutritional nitrogen from soil (Markov, 2012; Stein and Klotz, 2016).

Nitrogen cycle was important to organism's daily life, however the interference of human towards this cycle could cause massive impact on the cycles. Anthropogenic activities like the addition of excessive amounts of inorganic nitrogen into the water or water. Leaching of extra nitrogen from soils could be channeled into the waterways that eventually nitrogen enrichment lead to eutrophication. Apart of that, improper management of industrial and domestic wastes also would intense this problem. The imbalanced of nitrogen cycle would invite many inevitable problems.

2.2.3 Temperature

Temperature is described as the degree of coldness or hotness in the living organisms' body that is either live on land or in water. Since aquatic organisms are cold bolded or poikilotherm, therefore, their body temperature would change according to the changes in surrounding temperature (Lee & Wee, 2010). This is due to the surrounding environment temperature would affect their physiology, metabolism, feeding activity, health, the working of its internal process and eventually their production (Sarkar, 2010; Bhatnagar & Devi, 2013). For instance, high temperature would cause plant to experience plant shock or low rate of photosynthesis.

In 2010, Lee and Wee stated that Malaysia water temperature in aquaculture system should fall within the range of 25°C to 30°C. In addition, the temperature changes must less than 5°C within an hour, or else it would give pressure to the livestock (Lee & Wee, 2010). To further elaborate that, each species would only tolerate a comparatively narrow temperature range which depends on the climatic conditions in their natural habitat. It is unwise to let the temperature fall outside the range as fish will become sick easily and cannot grow properly. For certain cases, some still can survive but they could not live well (Sarkar, 2010).

The temperature value would only be altered for the purpose of inducing reproduction and to combat the diseases. For example, Catfish's spawning activity only started when the water temperature was 21.11°C – 29.44°C (Sarkar, 2010; Mittelmark &

Kapuscinski, 2013). It is difficult to control the temperature in a mixed environment that consists of plants, fishes and other aquatic organisms unless these inhabitants could live within the same temperature range (Sarkar, 2010).

Temperature controls the gases solubility, the toxicity of NH_3 and the chemical reaction rate. When the water temperature increased, the biochemical activities of organisms would increase which in turn causing a high demand for DO. Eventually, the DO level of the water bodies decreased (Bhatnagar & Devi, 2013). Rowan stated that in order to hatch Chinese carps, apart of the water temperature must lie within 25°C to 27°C, the DO also should not less than 4-5 mg/L (Rowan, 2012a). From Rowan (2012a), it was clearly proven the importance of maintaining the temperature at an optimum level.

2.3 Water

Water is the commonest fluid found in nature (Agarwal & Saxena, 2011). Water was very important for all of the creatures or living organisms in the world. It was widely used as recreational activities, food industry and also the source of water-drinking. The water quality would be modified or influence easily with the presence of radiological elements, toxic compound and also infectious agents. (World Health Organization, 2018).

2.3.1 Water quality monitoring

Water quality monitoring is also known as water quality assessment or water quality evaluation. There were many studies had been carried out to investigate water quality by assessing the water quality using water sampling method and from there compare it with National Water Quality Standard (NWQS) or WQI (Debels et al., 2005; Al-Badaii, Shuhaimi-Othman & Gasim, 2013). WQI served to give a simple and understandable picture of the water quality for layman like managers or any parties that was linked to the usage of the water body (Bordalo et al., 2001). These studies were more focused on the method that was more connected to model or scientific initiatives (Crabtree et al., 1986; Donia & Bahgat, 2016). Hence, it could be concluded that there was relatively fewer people chose the methods of using data analysis especially in terms of big data analytic method.

Debels et al. (2005) had stated that traditional approaches to assess water quality were relatively not providing adequate global vision on either temporal or spatial trends with the respect of the overall water quality. In another term, the lack of enough or holistic findings from this conventional approach could not represent the overall water quality. This traditional approach was done by having a comparison of experimentally collected parameter data with the existing local normative. Apart from its disadvantage, there was a rationale on why the researchers prefer to use this methodology. This was because it allowed for a good tracking or identification on the source of water contamination and also it might be important on the inspection of legal compliance.

From 1970s to 2000s, many authors or researchers had suggested on integrating WQI to get a numerical expression that facilitate on obtaining the general overview of water quality (Brown et al., 1970; Ott, 1978; Miller et al., 1986; Bordalo et al., 2001; Cude, 2001; Hallock, 2002; Debels et al., 2005). The using of WQI was considered better because one single value of WQI had made the findings more understandable instead of the long list of numerical values. Plus, WQI's value enables the researchers to compare the water quality of different sampling sites. Subsequently, WQI was deemed as a more advanced means of conveying information to the public. (Štambuk-Giljanović, 1999; Debels et al., 2005). Additionally, it aids in the water management and also the process of decision- making (Debels et al., 2005). The decision includes the suitably of using water for drinking purpose, fishing and also irrigation.

However, the disadvantage of using WQI was that it only evaluates on pH, total alkalinity (TA), electrical conductivity (EC), DO, total hardness (TH), BOD, sulphate (SO_4^{2-}) and also total suspended solids (TSS), this was supported by the studies of Bora & Goswami (2017). Thus, there is a lack of investigating the parameter of a temperature of water and also NO_3^{2-}.

2.3.1 (a) Method of monitoring water quality

There were relatively more people prefer to collect water data manually. Normally they will select water sampling sites, observed and collected the required data for a period and then performed WQI calculation. This was proven with the studies carried out by Bordalo et al. (2001), Debels et al. (2005) and Bora & Goswami (2017). As for the water quality assessment in Semenyih River, Selangor, Al-Badaii et al. (2013) used YSI meter to measure DO, temperature, pH and conductivity.

Next, there were also some studies do not practice the manual method of water sampling and transporting it for chemical laboratory analysis to investigate the water quality. This was due to on-site sampling were costly, require many labor works and also take times. Instead of in-person collecting data, people had made good use of the sensor and communication technology to remote the monitoring capabilities in water condition (Glasgow et al., 2004). Using real time monitoring would eliminate all of these weaknesses however, everything cuts both points it also associated together with other problems such as the high data vulnerability towards the recording and geo-referencing errors during the transcription. In addition, this methodology also was being influenced by oxygen depletion and also harmful algal blooms as claimed by Pettinger (1971) and Teillet et al., (2002).

2.4 Statistical Package for the Social Science (SPSS)

Boyacioglu & Boyacioglu (2008) had utilized the multivariate statistical methods in their water pollution sources assessment, which was conducted in the Tahtali Basin, Turkey. They argued that using this multivariate approach was the best method to prevent the occurrence of misunderstood of environmental monitoring data in terms of data categorisation and modelling (Reisenhofer et al., 1996). But, it might become a dispute because there is a need to take into consideration on the factor of the nature of the type of environmental monitoring data. If there was only one sampling point in a study then the utilizing of another statistical method like Pearson's correlation coefficient between two sets of variables would be the best option. In short, the using of any statistical method in SPSS had to be judged based on a case by case.

These two authors further explained on the advantageous using this multivariate method. The merit points were that this method reflected more precisely on the characteristic of natural ecological system and it also reduces the redundancy in handling many data sets with the existence of many numbers of variables (McGarigal et al., 2000).

Not only Boyacioglu & Boyacioglu (2008) investigated the water quality with the aid of multivariate statistical method, Zhang et al. (2009) also had carried out a study of water quality assessment at Xiang Jiang watershed, China by using the same method. To further elaborate that, the author used the mentioned technique to analyze the surface water quality in red soil hilly region. The methods involved in his study of multivariate were cluster analysis and principal component analysis (factor analysis). All of these methods were done by using SPSS (Zhang et al., 2009).

In Malaysia, Azrina et. al. (2006) studied the microbenthic data and physicochemical relationship with Pearson's Correlation Coefficient analysis and the analysis of multiple stepwise regression. But still, there was relatively less of the studies reported in the literature on the parameter relationship by just using Pearson's Correlation Coefficient solely. If there was a use of Pearson's Correlation Coefficient in an academic study then it was mainly integrated together with other analysis like multivariate analysis and chemical analysis (Zhang et al., 2009; Agarwal & Saxena, 2011).

2.4.1 Independent Samples T-test

Independent Sample T- test had been used by Kimathi (2013) in order to determine the concentration of heavy metals of parts of the tree (leaves and corms) in different type of plants (arrow root and taro) which was linked to the water quality. Azrina et. al. (2006) also practiced this statistical analysis technique to compare the means of water quality parameters value collected respectively in upstream station and downstream station in Langat River.

2.4.2 Pearson's correlation coefficient (r)

Pearson's correlation coefficient (r) was the measure of association strength between two variables. It was one of the statistical analysis methods.

Works by Agarwal & Saxena (2011) had integrated this Pearson's correlation coefficient in their studies of the physicochemical water parameters in India. However, the depicted result only illustrated in the form of scatter diagram where the Sig. and also the values of Pearson's correlation coefficient were not provided. Plus, the investigated parameters only focused on alkalinity (mg/ L) with COD (mg/ L) and alkalinity (mg/ L) with BOD (mg/ L). Temperature, NO_3^{2-} and DO were not included in their works. Hence, there was a gap or lack of adequate information in their study so there is a need to study the correlation between temperature and DO as well as temperature and NO_3^{2-}. To conclude that, they only focused on the analysis for BOD and COD using statistical analysis and chemical analysis.

Zhang, et al. (2009) conducted their studies of water quality in Han River by using Pearson's Correlation analysis, stepwise least squares multiple regression and principal components analysis. For Pearson's Correlation analysis, they had run the data with many sets of testing parameters variables. Each of its sets was both conducted in the rainy and dry season respectively. The tested variables include pH, EC, turbidity, DO, COD, nitrate-nitrogen (NO_3^{2-}-N), ammonium-nitrogen (NH^{4+}-N), chloride (Cl^-), SO_4^{2-}, K, calcium (Ca), magnesium (Mg) and also Na. However, it did not involve the parameter of temperature. So, there was a relative lack of adequate data to judge the water quality specifically by using this Pearson's Correlation method.

DO had showed positive relationship of Pearson's correlation coefficient with COD, Cl^-, and SO_4^{2-} which were r = 0.09, r = 0.10 and r = 0.18 respectively. On the contrary, DO had a negative relationship with more parameters as compared to positive relationship parameters. These parameters were NH_4^+-N, NO_3^{2-}-N, K, Ca, Na and Mg. The above results were conducted during the rainy season in Han River (Zhang, et al., 2009).

The opposite result was depicted during the dry season. There were relatively more positive correlation parameters connected with DO than negative correlation. There were only NH_4^+-N and COD had a negative value of r with DO. The former was r = -0.31 and the latter was r = -0.25 (Zhang, et al., 2009).

The findings of Zhang, et al. (2009) stated that NO_3^{2-} had shown a positive correlation of Pearson's Correlation Coefficient with Na parameters (r = 0.91), SO_4^{2-} (r = 0.87) and also Cl^- (r = 0.86) in the condition of the rainy season. As for the dry season, the parameters that showed had a positive relationship with NO_3^{2-} were Na which had the value of r = 0.92, followed with Mg parameters which were r = 0.87 and Cl with r = 0.76. Surprisingly, this author study did not reveal the relationship of DO with NO_3^-.

Similar to the studies of Zhang, et al. (2009), Bu, Zhang & Wan (2014) also did their studies during the period of the dry season and rainy seasons. The former investigated the relationship of one parameter responding to another parameter using correlation statistical method while the latter had related the correlation analysis with land use types and water quality chemistry. The demerit point for both of these two studies was that both of them did not involve the temperature parameter in their research.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

The study area is Jeli, Kelantan, Malaysia which is the southern part of Kelantan. 82% of Jeli is covered with forest, hills and rivers. The elevation of Jeli is from 90m to 500m above sea level (University Kebangsaan Malaysia, 2014). The population in this area is estimated to be around 40,637 since 2010 (City Population, 2017).

To be more specific, the data was collected in the aquaculture pond of UMK, Jeli Campus with a sensor located 10-15cm below the surface at the middle of the pond as shown in Figure 3.1 below. The coordinate is latitude: 5° 45' 6.85" N and longitude: 101° 51' 54.83 E. The fish reared in this pond was Tilapia (*Oreochromis niloticus*) fish and it took 8 to 10 months for them to grow from small to big (Amin, 2018a; Hafiz, 2018). There was no any aerator being placed. It was a fresh water open body surrounded with land.

Figure 3.1: Location of study area: Aquaculture Pond, UMK Jeli campus

Source: (Amin, 2018a)

The total acre of the investigated pond was 1 acre. It was the human made pond where the depth of the front was 1.5m and the depth toward the end was 2m. The pond was surrounded with bamboos and some wild, natural grasses.

During the pond preparation (water filling), 5 fishes per cubic meter would be reared and 50 kg of the fertilizers would be added. Fertilizer only be added once during this stage and there was no other adding in future. The water in the pond was not being changed throughout the period since the water was constantly flowing in and out all the time, there would be at least two or three days per week for water flowing. The water inflow and outflow were 100L/ min where the influent was from the dam while the outflow was to UMK river (Amin, 2018b).

3.2 Data Collection

In this study, the data used was a primary raw data. The data would be collected from the Aquasense for a period of forty-four days which is from 22th January 2018 to 7th March 2018. The collected data would be a one-minute data interval. At the same time, the data would be transferred to cloud data storage software. Subsequently, data could be extracted and collected by the researchers to do data analysis. Before this, the decided investigated period was from 30 November 2017 to 7th March 2018, sadly the beginning of about 53 days data were showing abnormal behavior like the data value go beyond or lie below the acceptable range so these data were eliminated.

There were sixty-four thousand and eight hundred (64, 800) data were being sent for analysis. The need of having many data because it was believed that when there were many data available for the analysis, the result would be more reliable and representable.

Hence, the result could give and serve as an overall picture of the water quality study (Malek, 2018a). As for this case, the strength of the correlation was the result. The weakness of using this equipment for data collection was that there would be a missing of three to four sets of minutes data within an hour. In addition, some of the data were not recorded consequently which means there were two data are loss subsequently. Some of the time data were duplicated consequently. In a short summary, the above-mentioned data was a primary data with some weak points.

Primary data was the collected data being treated as raw materials for research purpose. It was the original data that have not been processed (Abas, 2018). Primary data was the data collection method which was being utilized throughout this study. It was collected from the original resource. The original resource for this case was the aquaculture pond in UMK, Campus Jeli.

The strength of using primary data was that it was collected at first hands in regards to the specifications outlined problems or issues where appropriate procedures were practiced to fit the problem best. As for this study, primary data also revealed problems like the missing of sets of data and also the insensible temperature value, hence it allowed researchers to take further action to adjust and correct this value by identifying the causes, modify it with mathematical calculation and so eventually getting the correct value.

The limitations of using this primary data was that it only could represent the correlation of NO_3^{2-}, DO and temperature in UMK, Campus Jeli. This was due to the collected data was from one of the aquaculture ponds in UMK, Campus Jeli. So, it would be more representable in above mentioned location but not to be assumed as the whole picture of these parameters correlation in Kelantan or in Malaysia. In short, it was just an overview or general picture of parameter correlation in Kelantan, specifically in UMK, Campus Jeli.

3.3 Equipment

The equipment needed to conduct this study was Aquasense. Aquasense was a real-time monitoring device that can collect pH, DO, NH_4, NO_3^{2-} and temperature physico-chemical data from minute to minute (Amin, 2018b). All of the used parameters probes were from Vernier brand. However, only DO, NO_3^{2-} and temperature data were being extracted for this research. This Aquasense was also a system that comprised a floating sensor unit, transmitter, communications units that are linked to cloud data storage software. Hence, big data would be collected from this cloud data storage. Plus, Aquasense was a custom-made equipment, prototype tool that was still undergoing research and development, it was the first time being used to monitor the water quality of aquaculture pond. Before the sensor was being placed into the real aquaculture environment, it was calibrated or tested in the indoor environment which many controlled factors that is similar with the real experimental environment.

Aquasense was scheduled to be cleaned once in two weeks or whenever it was found out dirty. Sometimes, there might be some occurrence of weird or inaccuracy of the data. This might be due to the thunderstorms, unfavorable environmental conditions or the blockage by the algae (Amin, 2018b). Once there was a weird trend of parameter being detected, manually calibration would be carried out. For instance, if the DO value was fall outside the acceptable range then the value would be adjusted back by manually using DO meter to get back the real DO value (Amin, 2018b). In short, Aquasense was the equipment that helped in a research study.

3.4 Data Analysis

Statistical Package for the Social Science (SPSS) is an application or software that help in organizing data. With SPSS, it would automate the statistical tests instead of the researchers have to analyze the data manually, which is relatively tedious. The advantages of using SPSS software was that, it was comparatively very easy to use and it facilitated user to pick up easily as it is understandable. Besides that, it greatly reduced the risks of getting an error and improved efficiency when performing SPSS. Furthermore, it was accessible to all skill levels users (IBM Corporation, 2015a, 2015b).

In this research, IBM SPSS Statistic 20 software was used to tabulate, plot and analyze all of the data. It also helped in data storage and data documentation. From Aquasense, it provided the parameters values of DO, pH, temperature, NO_3^{2-} and NH_4. However, the author only analysis on the selected of these three parameters which were DO, NO_3^{2-} and temperature because these parameters were relatively more connected to each other as compared to others.

Readings of temperature, DO and nitrate was tabulated and plotted. Based on the plotted graphs, analysis of the change in these three parameters was done by observing the trend of DO and NO_3^{2-} level when the temperature value and minute-interval are changed accordingly. First of all, descriptive analysis was carried out to know the mean and standard deviation.

The comparison of mean was done by Independent Samples T-test in order to provide statistical evidence that the related population means are different significantly. Other name given to this test is Independent Measures *t* Test, Student *t* Test and so Two-Sample *t* Test (Kent State University, 2018b). Independent- Samples T-test was chosen as the primary data could be classified as independent variables and also having continuous dependent variable that were the parameters of temperature, DO and NO_3^{2-}.

There was one part from the result section that compare the means of first day (one independent variable) and last day (one independent variable) for three investigated parameters and also there would be another group that compare the first week and last week parameters' mean throughout the investigated period. The first day is 22th January 2018 and 7 March 2018 would be the last day. From 22th January 2018 to 28th January 2018 would be the first week investigated period and the last week duration is the 1st March 2018 until 7th March 2018. Mean temperature and concentrations of both DO and NO_3^{2-} were expressed as mean ±SD (min- max). After that, significant differences were determined by t-tests with a 95% confidence level.

Pearson's correlation coefficient (r) was a measure of the association strength between two variables. It was also known as Person product-moment correlation (PPMC) or Pearson Correlation. Normally, a scatter plot would be carried out first in order to check the linearity. Linearity characteristic was the pre-requisite in conducting Pearson's Correlation Coefficient.

The range of value r is $-1 \leq r \leq 1$. A correlation that was close to zero shows that there is no linear relationship between the two variables. For instance, when $r = 0.8$, it gave the meaning of a strong and positive association between two variables, meanwhile when r = -0.43 showed a weak and negative relationship (University of Tasmania, 2015; University of the West of England, 2018). The difference of each correlation relation was shown in Figure 3.2 below.

'Sig.' (2-tailed) is referred as the p-value. It is the probability of how unlikely a given r value occurs with no relationship in the population. The smaller the p-value it is, the more significant is the correlation (Stephanie, 2017).

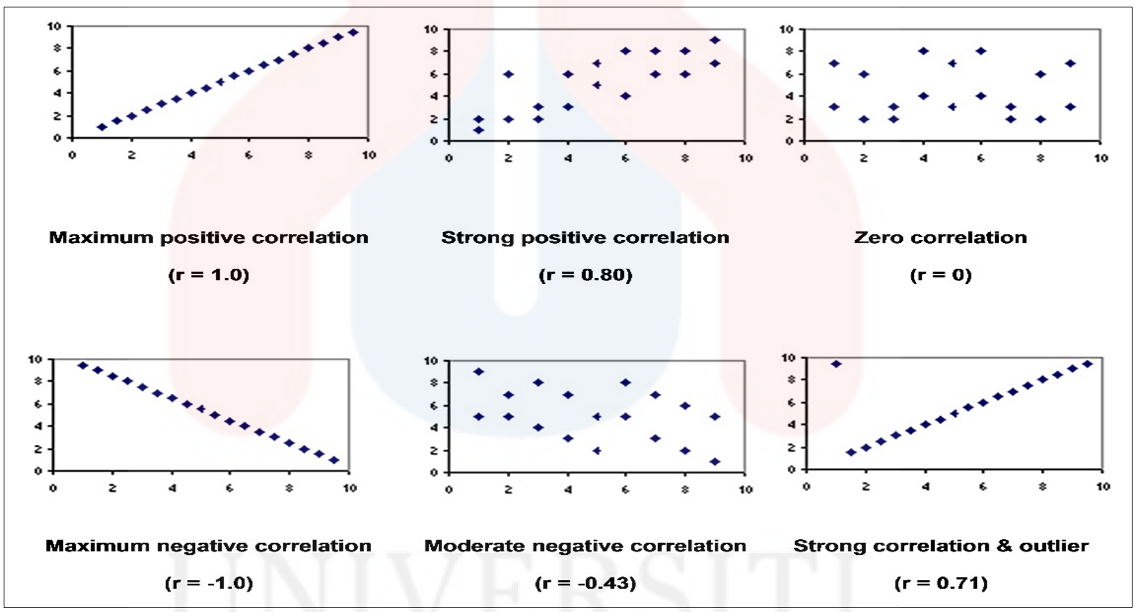

Figure 3.2: Scatter plot of each Pearson Correlation Coefficient

Sources: (University of Tasmania, 2015)

Pearson Correlation analysis was used as well throughout this research. From the Person Correlation values, it was judgeable on whether these two parameters of DO and NO_3^{2-} have a strong or weak relationship with temperature. Plus, the Sig. 2-tailed level would tell the significance level of temperature with DO and temperature with NO_3^{2-}. The lower the value of Sig. 2-tailed, the more significant it was of the relationship between two parameters.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This section discussed the results after the process conducted as mentioned in the previous Chapter 3. This was carried out in order to achieve the objectives of this paper. This discussion includes the general overview of three parameters along the crop rearing period, discussion on the temperature, dissolved oxygen and also nitrate. Lastly, there was a part to explain the relationship between DO and NO_3^{2-}.

4.2 The general overview of three parameters along the crop rearing period

Figure 4.1 below showed the overview of the three parameters which were temperature, DO and NO_3^{2-} from the first week to the seventh week. Basically, the values of these parameters were fluctuating steadily all the time since the water movement in the aquaculture pond were not static plus there was constant daily water inflow and outflow. All of the parameters' ups and downs range were within the acceptable range. Forty-five days of recorded temperature readings in Figure 4.1 showed that it fluctuated constantly from 19°C to 32.5°C. For DO, the recorded lowest value was from 6.21mg/L to the highest 8.99 mg/L whereas NO_3^{2-} was 5.14mg/L up to 5.33mg/L.

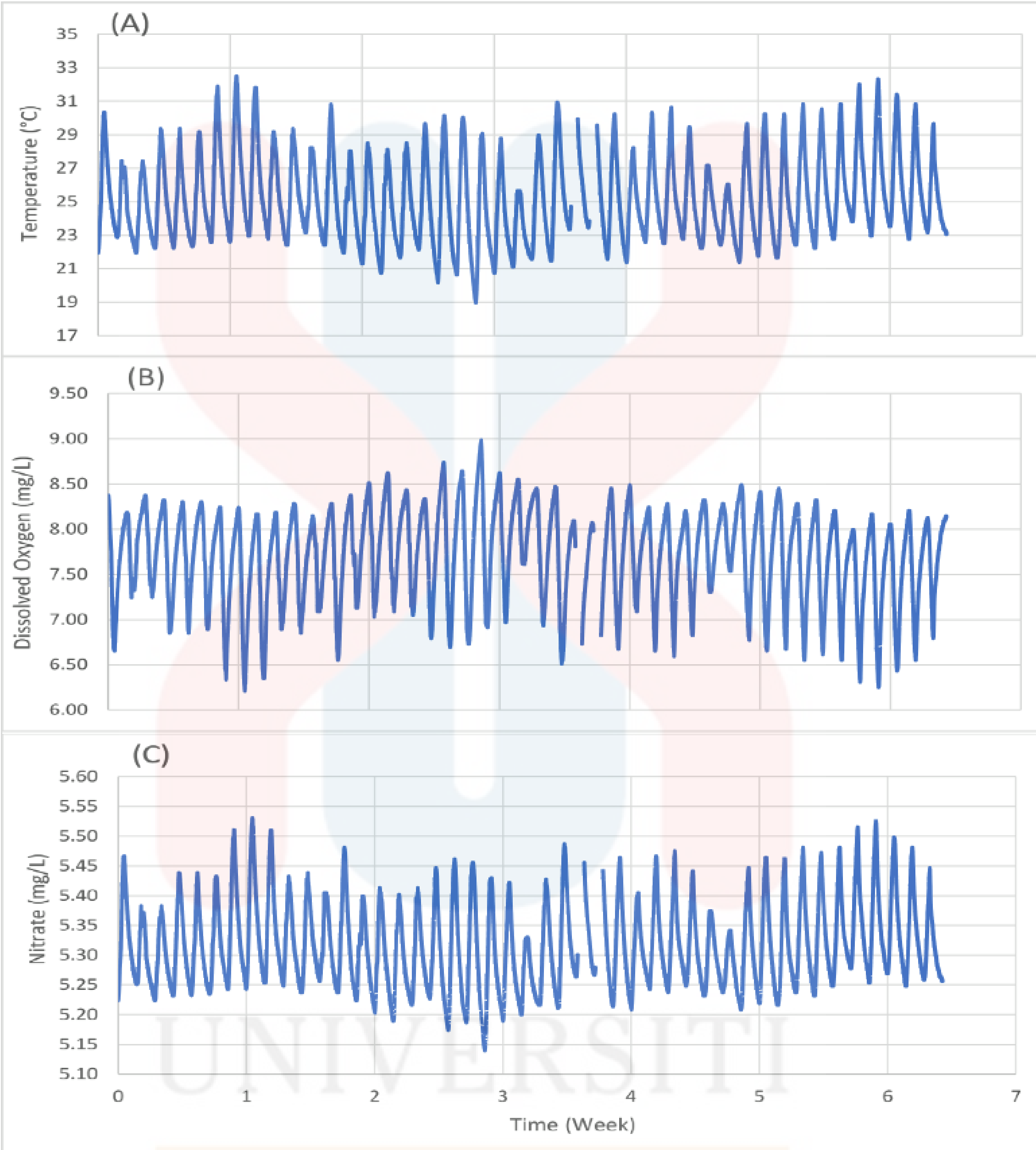

Figure 4.1: The trend of the graphs for each parameter along the investigated crop rearing term which is from the first day to the last day (22th January 2018 to 7th March 2018), (A) Temperature (°C), (B) Dissolved Oxygen (mg/L) and (C) Nitrate concentration (mg/L)

Figure 4.2 (A) and Figure 4.2 (B) below showed the graph that had big gap interval for the three parameters from around 0100am to 1100am on both of the 26th and 27th day in this study. These also could be observed from Figure 4.1 which there was two intervals of missing data from Week 3 to Week 4. This was due to there was a need to recalibrate the system on these two days throughout the experimental period. Therefore, there was lack of some minutes- data within these two days (Amin, 2018b).

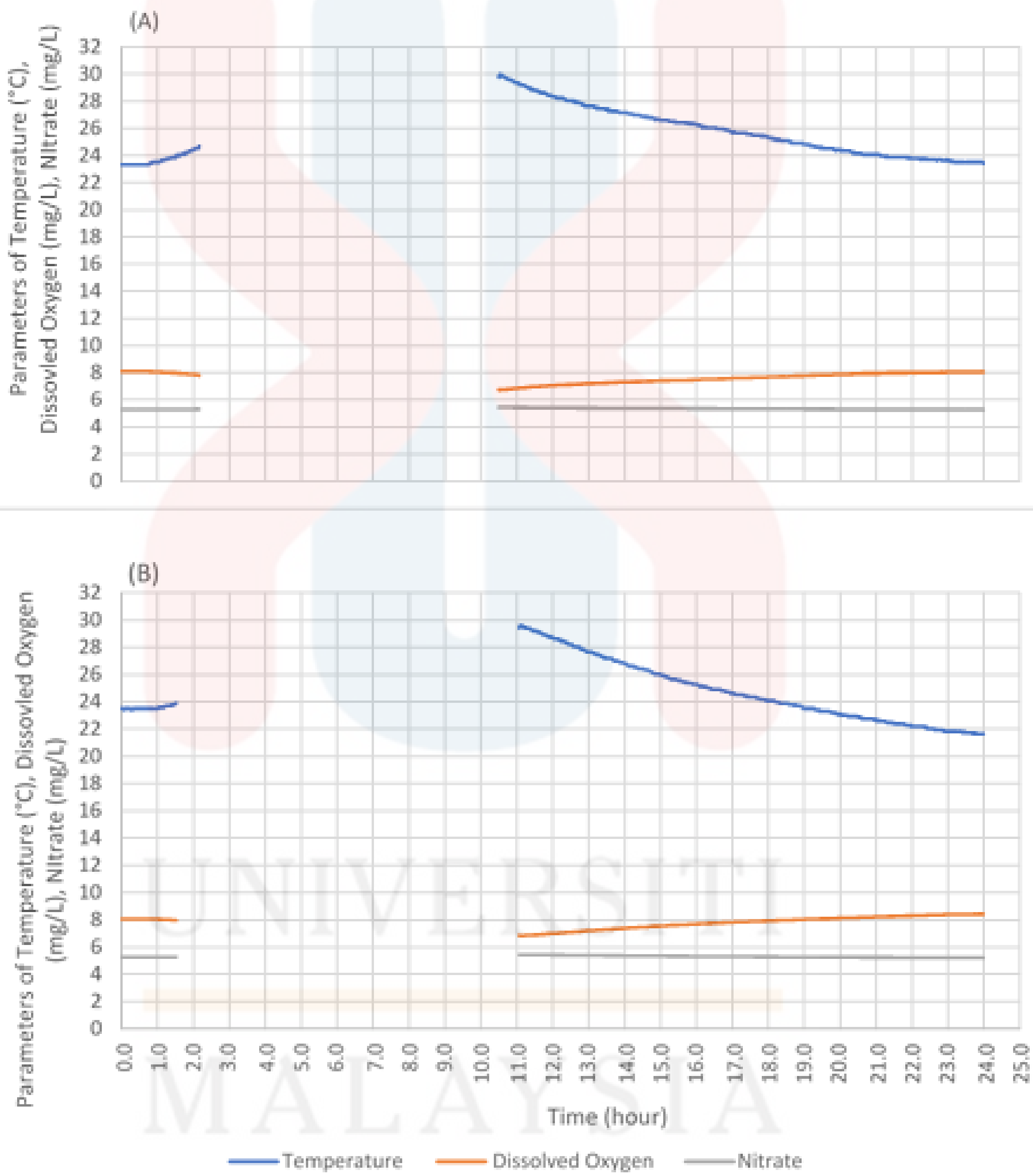

Figure 4.2: Daily data of the temperature, dissolved oxygen and nitrate (A) on 26th day (16th February 2018) and (B) on 27th day (17th February 2018)

Table 4.1 informed the brief summary of the two parameters that represent in a way of the first and last duration, starting from unit of day, week and lastly the whole 45 days interval. Each of them was recorded along with the smallest and biggest value. Next, Figure 4.3 and Figure 4.4 would give graphical view which would aid in comparing two different parameters over the same mentioned period.

Table 4.1: The summary of the mean with standard deviation (SD) and summary data of the water qualities parameters that were measured by Aquasense (water quality sensor) during crop Tilapia production

Time range	The mean ± SD and range of detection by water quality sensor, Aquasense	
	Dissolved Oxygen (mg/L)	Nitrate (mg/L)
First day (22th January 2018)	7.60±0.50 (6.65-8.38)	5.33±0.07 (5.22-5.47)
Last day (7 March 2018)	7.69±0.39 (6.79-8.15)	5.32±0.06 (5.26-5.45)
First week (22th January 2018 - 28th January 2018)	7.70±0.47 (6.33-8.38)	5.32±0.07 (5.22-5.51)
Last week (1st March 2018 – 7th March 2018)	7.51±0.52 (6.25-8.32)	5.35±0.07 (5.23-5.53)
Along crop rearing (45days)	7.70±0.53 (6.21-8.99)	5.32±0.07 (5.14-5.53)

From both Table 4.1 and Figure 4.3, NO_3^{2-} showed a mean of 5.33mg/L on the first day which was opposite with the theory. Theoretically, the sensor should depict reading that was less than 5.33mg/L since it was the first day and there should be relatively lower NO_3^{2-} concentration naturally. This could be explained which the first day stated in this experiment was not the first day Aquasense being placed onto the aquaculture pond. There was about one-month data being eliminated before this study period since the data showed abnormal behavior. The term of abnormal behavior referred to the values of these three parameters had exceeded the optimum range. Surprisingly, there were no result of temperature parameters included in Table 1, Figure 4.3 and Figure 4.4. The justification would be given in the following subtopic.

The standard deviation shown in Table 1 and Figure 4.3 illustrated that the last day of nitrate had a lower value than the first day. The same observation also goes to nitrate that had the lowest dispersion for the first week and last week data analysis found in Figure 4.4. This mean that fluctuation of nitrate throughout these days did not experience much difference. This was probably due to the concentration of NO_3^{2-} had been constantly being accumulated and diluted, thus it was balanced with the income new freshwater whenever there was some accumulation of NO_3^{2-}.

Generally, the narrower standard deviation observed from both Figure 4.3 and Figure 4.4 informed that the data collected by the sensor was stable and it was relatively less disturbed by other unknown factors since the variation was relatively small.

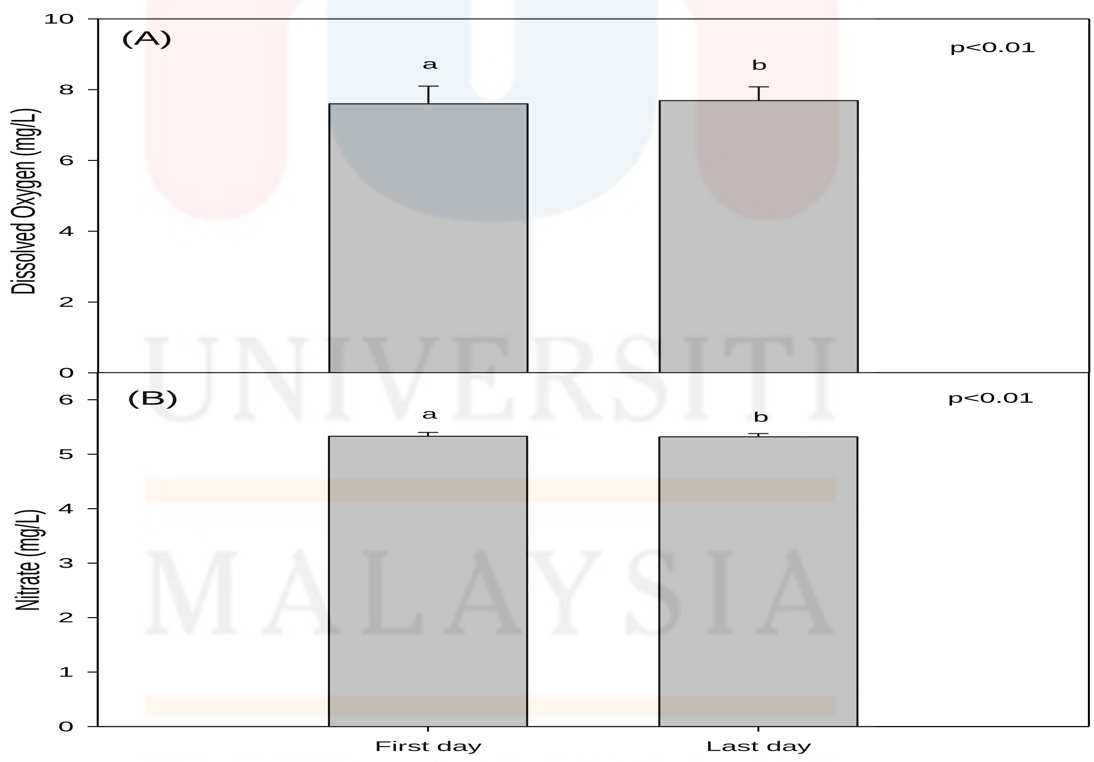

Figure 4.3: The standard deviation and the mean on the first day and last day for each investigated parameter against first day and last day (A) Dissolved Oxygen and (B) Nitrate

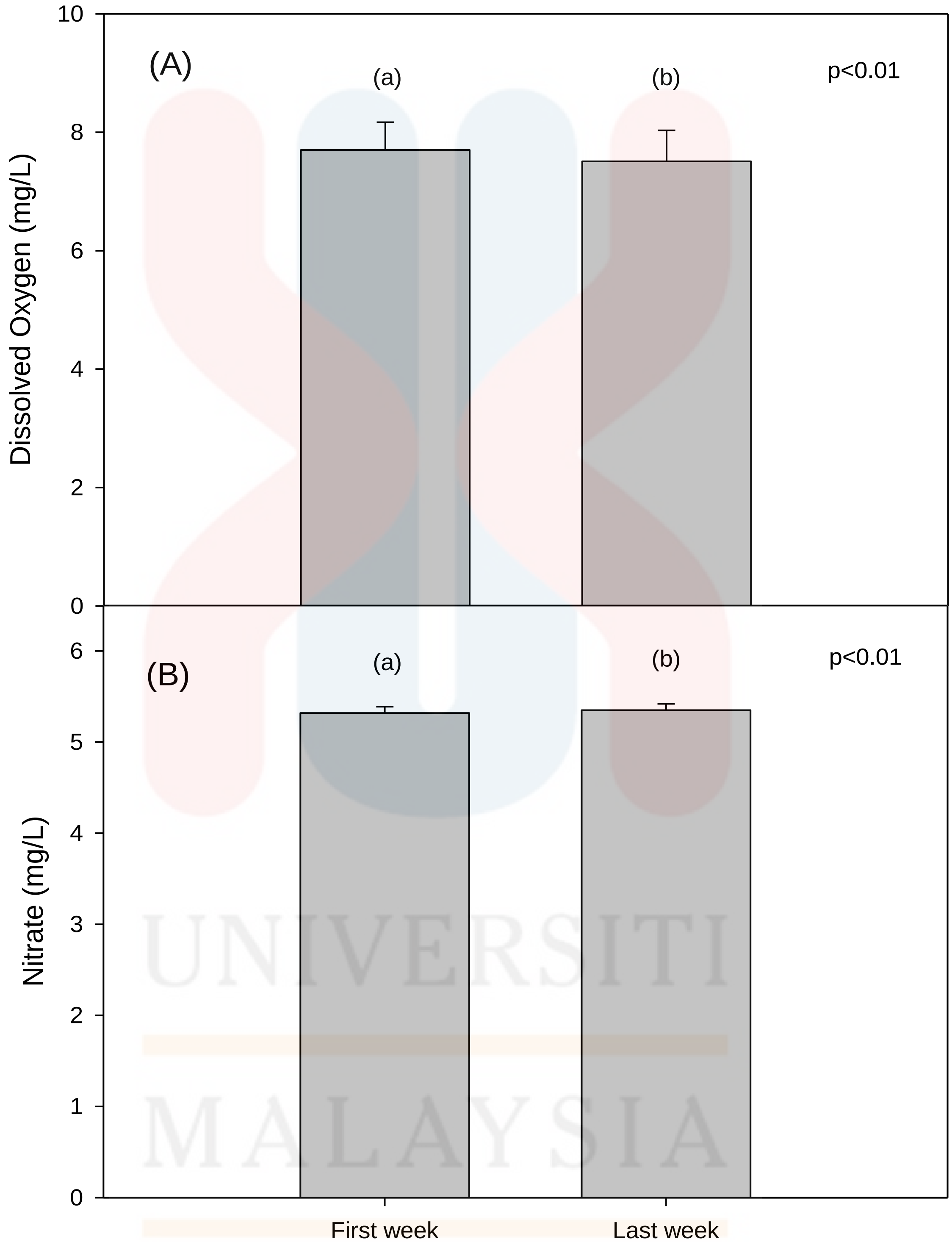

Figure 4.4: The standard deviation and the mean on the first week and last week for each investigated parameter (A) Dissolved Oxygen and (B) Nitrate

4.3 Temperature

Figure 4.5(A) below showed that the temperature was fluctuated from 22°C till 30.5°C, this range was a little bit wider than the suggested range (25°*C* to 30°*C)* by Lee and Wee in 2010. Nevertheless, it was still in an acceptable fluctuation range since Lee and Wee (2010) further mentioned that the temperature changes must not more than 5°*C* within an hour. Figure 4.5 illustrated that the temperature had a difference of only 5°C to 8.5°C within a day. Hereby, it was estimated that the temperature had an increase of almost 1°C for every hour. In short, the pattern of the temperature reading was still good and coincide with the statement outlined by Lee and Wee in 2010.

As everyone knows that pond water would warm when the sun shines on it, on the contrary when the sun did not shine on it, the pond would cool down which would be supported with a lower temperature reading. Unfortunately, the trend showed in this graph were opposite of the reality. During night time, the value should exist in a lower value as compared to the day time because the surrounding environment at night was cold. Unfortunately, the trend graph of Figure 4.5(A), Figure 4.5(B) and Figure 4.5(C) revealed that the mid- night temperature reading from 0000am to 0600am was increasing where it supposed exist in a much lower reading by showing falling or going down trend. This was because it was at the late midnight and the surrounding temperature was getting cooler and cooler than the night interval. Thus, the correct temperature trend was declining instead of increasing.

In addition, it was an abnormal decreasing trend from 0800am to 1600pm, this was because in the real-life situation, the sun was shining brightly at that durations and water would absorb many heats. Hence, the temperature should rise instead of fall. During daylight hours, waters absorbed the heat from the sun and the reverse happened where heat would be lost to the surrounding (cooler atmosphere) when it was approaching night (Simbeye & Yang, 2014). This observation was further proved by plotting graphs on the first day of the investigated period revealed from Figure 4.5(A), the middle stage (the 24th day) which was from the Figure 4.5 (B) and also the last day on Figure 4.5 (C). The correct shape of a twenty-four-hour temperature graph was that it should start with a V- shaped from 0000am to 1600pm, followed with an inverted second half V-shaped start from 1601pm onwards. Of course, the suggested trend of the shape should increase constantly and steadily. All of these errors occurred probably due to the malfunction of the sensor such as no Internet connection (Amin, 2018b). There might be also some algae organisms tend to block the sensor which in turn affect the readings.

Vernier (2016) had suggested that the probe should be washed every time after the usage however in this study the probe was scheduled to wash only once in two weeks or when it was dirty. There were also some other unknown reasons since there were many unpredicted events when dealing with environment live, real time recording system (Amin, 2018b). The influenced factors could be the adverse weather condition like thunderstorms that might affect the water conditions such as water temperature. Plus, the malfunction on the electrical signal of temperature sensor could be one of the contributing factors.

The suggested measure to be taken for the temperature parameter was that the obtained values were substituted into some equation or formula to correct the temperature back to normal. So, parameter of temperature's reading from Aquasense would not be discussed further in this chapter since it had been identified that the value showed the opposite trend from the realities.

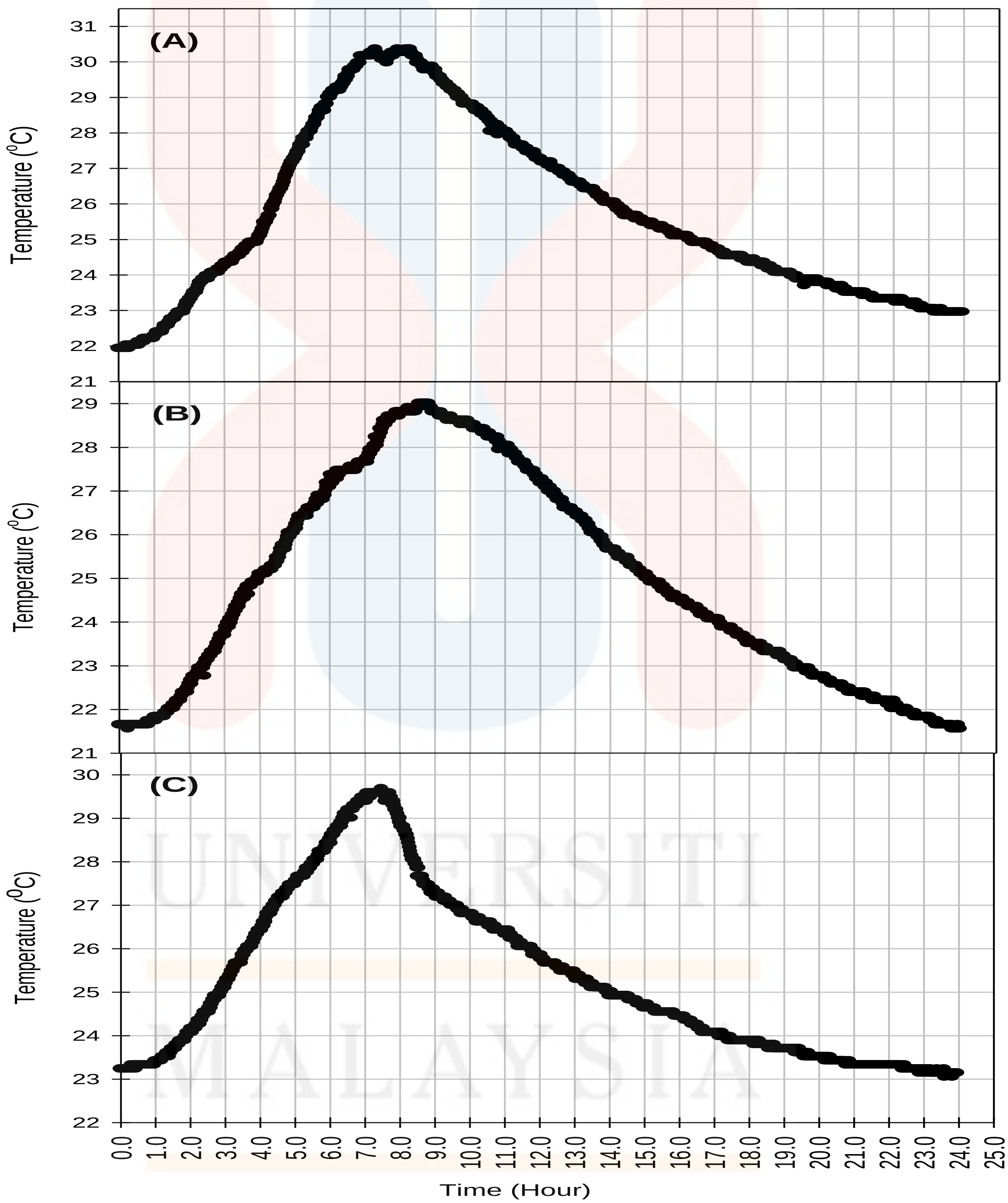

Figure 4.5: Temperature against time for three different term which is the initial. middle and the final. (A) on first day (22th January 2018), (B) on the mid of the experimental period (14th February 2018) and (C) on last day (7th March 2018)

4.4 Dissolved Oxygen (DO)

Graph from Figure 4.6 showed a similar V-shaped trend for both of the first day and last day of DO concentration. This figure displayed the DO level in 24 hours basis for both of the first and last day.

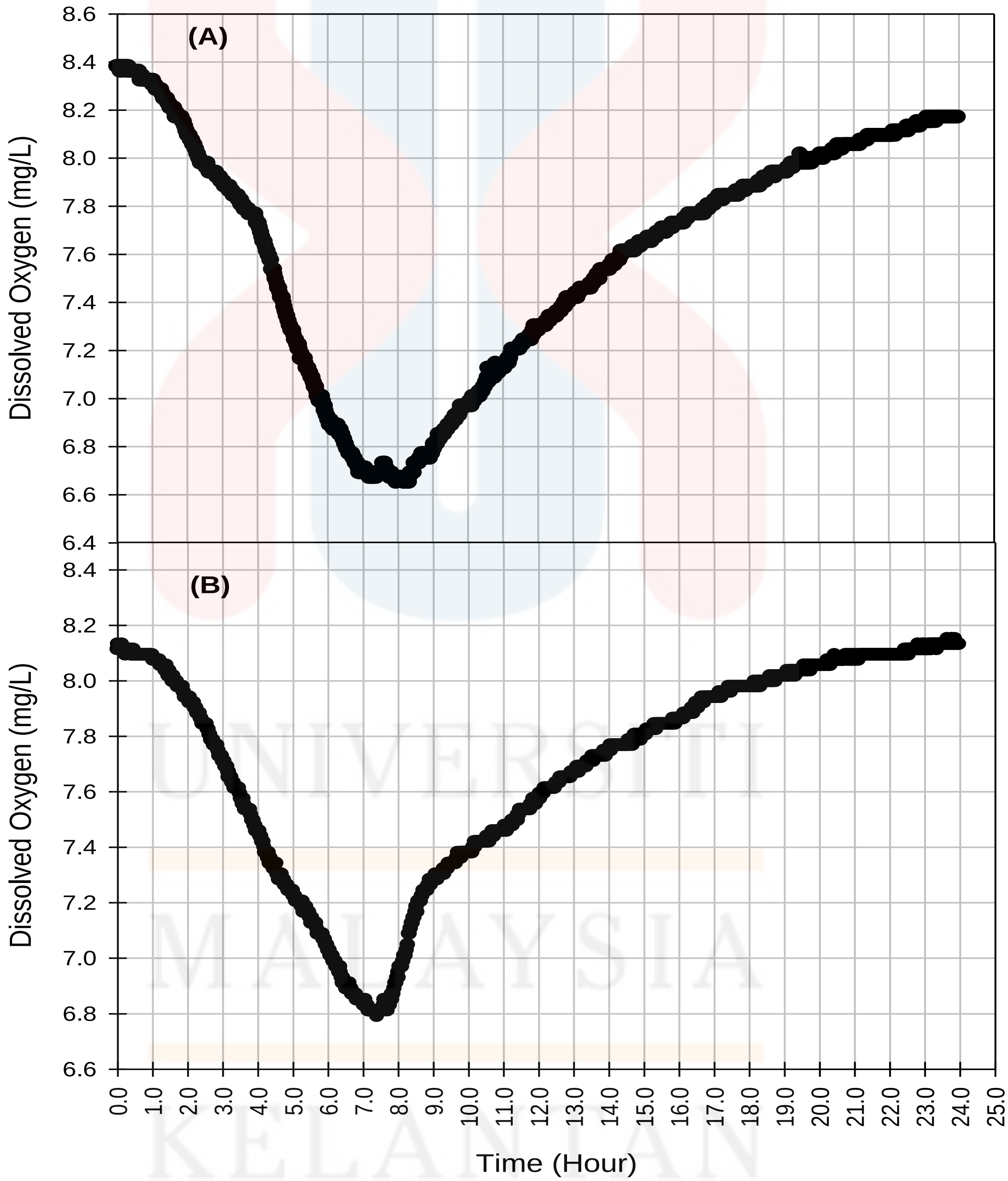

Figure 4.6: Level of Dissolved Oxygen against time (hour) on the (A) first day (22th January 2018) and (B) last day 7 March 2018

During daytime, algae plants would absorb carbon dioxide (CO_2) for the purpose of photosynthesis, thereby oxygen was produced and released into the water. (Svobodová, 1993; Moriarty, 1997). Hence, DO level was increasing during daytime from 0800 am till 1800 pm as shown on the Figure 4.6. It was the period of sunrise and so shining brightly. Nevertheless, biological respiration process was carried out at the same time. Air and water would go through natural gas exchange process where fish used oxygen to breathe and the byproducts of carbon dioxide would be released to the surrounding.

Plus, new freshwater was introduced during this period that contribute to the increment of DO level. This was supported by Sanares et al., (1986) that pond water circulation would promote the growth of phytoplankton. From there, Boyd (1998) commented that this would raise the DO level since there were a growth of phyto -living organisms that would carry out photosynthesis. Observed from Figure 4.6(B), there was an obvious of relative sharp increase of DO occurred from 0800am to 0900am. This might be due to there was some precipitation happened at that interval.

Starting 1801 pm onwards, the line graph was about to level off because the major process that had been carried out on this period was just respiration. Living organisms including plants need oxygen for aerobic respiration and release carbon dioxide as byproduct. It might be argued that on 1900pm, the sensor not only showed the amount of DO was still very high, but it also showed in an increasing trend of DO from 1900pm to 2400am, although it was ranged with a little amount of ±0.10mg/L. This might be there was some water flowed in at this time. Little of the water inflow would lead to water exchange, water mixing as well as water circulation. Fast et al. (1983) stated that DO level of a pond could be increased by water mixing.

At night especially during the midnight, DO level fall because probably there was only organisms respiration occurred throughout this period. This was attributed by the absence of sunlight penetrate to the pond so there was no photosynthesis activity being carried out. Thus, there was only little of gaseous exchanged. Apart of the reason oxygen level declined due to the respiration process carried out by any of the living organism in the water, there was also due to the decomposition process done by microorganisms (Svobodová, 1993).

From Figure 4.3 and Figure 4.6 and Table 4.1, the fluctuations of DO on the first day (mean = 7.60 mg/L) and last day (mean = 7.69 mg/L) were just 1.73mg/L and 1.36 mg/L respectively, it was relatively low as compared to the suggested fluctuation range (2 mg/L to 3 mg/L) as stated by YSI (2015) for a 24-hour period. However, the overall fluctuation range throughout the experimental period was same as the range as mentioned by YSI (2015), which was 2.78 mg/L that fall within the interval. In addition, the lowest oxygen level which was 6.6 mg/L shown in this graph was in an acceptable range. Figure 4.3(A) had depicted that both the mean of the DO on the first day and the last day had no different but the T- test as shown in Appendix A had revealed that the significance level. was significant (.000) which mean that there was something different of DO on the first day and the last day.

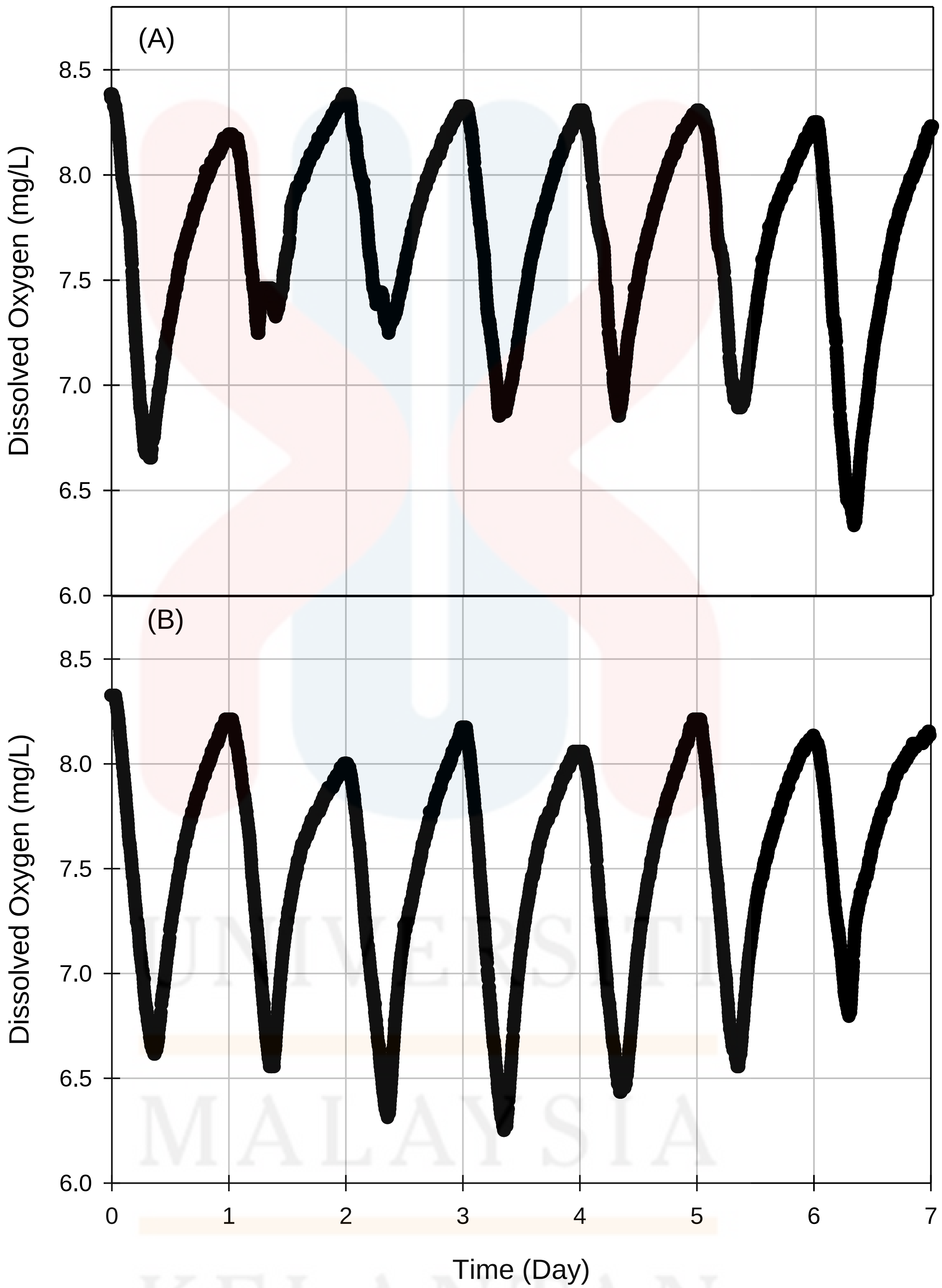

Figure 4.7: Level of Dissolved Oxygen against time (day) on the, (A) first week (22th January 2018 to 28th January 2018) and (B) last week (1st March 2018 to 7th March 2018)

As shown in Figure 4.7, there would be a one-day period for every one V-shaped DO curve. The trough of one V-shaped in day was between 0700am to 0800am. Generally, the wave of both Figure 4.7(A) and Figure 4.7(B) were the same, however by comparing the six peaks, Figure 4.7(A) had more highest peaks than Figure 4.7(B). The peaks of Figure 4.7(A) had higher values that were fluctuated from 8.2mg/L to 8.5mg/L whereas Figure 4.7(B) had lower values ranged from 8.0mg/L to 8.3mg/L.

This was because January was relatively still in a less warm season (29°C) as compared to March which was 30°C (AccuWeather, 2018; Season of the year, 2018). Hence in a much lower water temperature, more oxygen would dissolve in the water and this explained why there was a higher oxygen level for the first week than the last week which was in the spring season. In a relative hot period, there was relative less water movement, low water flow rate and so the water level dropped when the sun shines so comparatively less oxygen would mix with the water as a result there would be low DO (Murphy, 2007). Dallas (2008) stated that higher temperature would affect dissolved oxygen level by decreasing the concentration and so the availability to aquatic life. In short, warmer temperature would decrease the oxygen solubility. In another word, both water temperature and DO concentration at saturation were in a reverse relationship (Boyd, 1998). This reason also supported with the values presented in Table 4.1, Figure 4.4 and Appendix B which stated that Figure 4.4 showed no mean difference but the significance value showed there was a difference.

Looking from day one to day three on Figure 4.7(B), the trough of each one was getting lower than the previous troughs. Next, starting day three onwards the trend of every new trough was becoming higher than the troughs before that. The ups and downs of Figure 4.7(B) was relative stable than Figure 4.7(A), this was due to the weather conditions which include the rainfall frequency and the surrounding temperature.

Along the crop rearing duration, DO was ranged from 6.21mg/L to 8.99mg/L, with a mean value of 7.70±0.53mg/L (Table 4.1). It was considered exist in an optimum level since PHILMINAQ (2015) stated that there was a need to have a minimum level of 5mg/L DO. This result was also stay within the safe region where National Water Quality Standards, Malaysia (NWQS) classified it from Class 1 (>7mg/L) to Class II (5mg/L – 7mg/L) (DOE, 2007). YSI (2015) also highlighted that 5-12mg/L was the concentration level that suitable for most of the fish species to stay alive and grow. A study done by Lloyd (1992) also highlighted that specifically Tilapia species should stay at an environment that surrounded with DO level that exceed 5mg/L. The optimum range of DO in this study also agreed by Boyd (1982) that mentioned 6 to 9 mg/L was the optimum range for DO concentration.

The difference along the crop rearing period for DO parameter was just 2.78 mg/L, which was from 6.21mg/L to 8.99mg/L. Readings of DO value does not fluctuate much because this pond had a relative steady and constant water movement. Moreover, this pond did not equip with aerator so there would be relatively less splashing or bubbling over other objects. Hence, the reading of DO was relatively low. Study of monthly collected data from Center for Environmental Monitoring of Hunan Province in Zhang et al. (2009) showed 3.4mg/L for minimum and 9.5mg/L for maximum. It was a huge difference (6.1mg/L) as compared to this study. This was due to the study of Zhang et al. (2009)

focused on thirty-four river and tributaries sampling sites and probably there were many oxygen sources channeled to it plus the disclosed DO mean was 6.23mg/L with a relatively small standard deviation of 0.89mg/L. So, the outlined minimum and maximum value for both studies was correct respectively.

4.5 Nitrate (NO_3^{2-})

Nitrate was influenced by relative more factors than temperature and DO parameters. In this study, NO_3^{2-} mainly depend on DO production and sometimes also depend on source of nitrogen. Some of the other minerals or vitamins would have subtle or slight effect on the NO_3^{2-} concentration level too. In short, the concentration of NO_3^{2-} did not influence by daytime or nighttime.

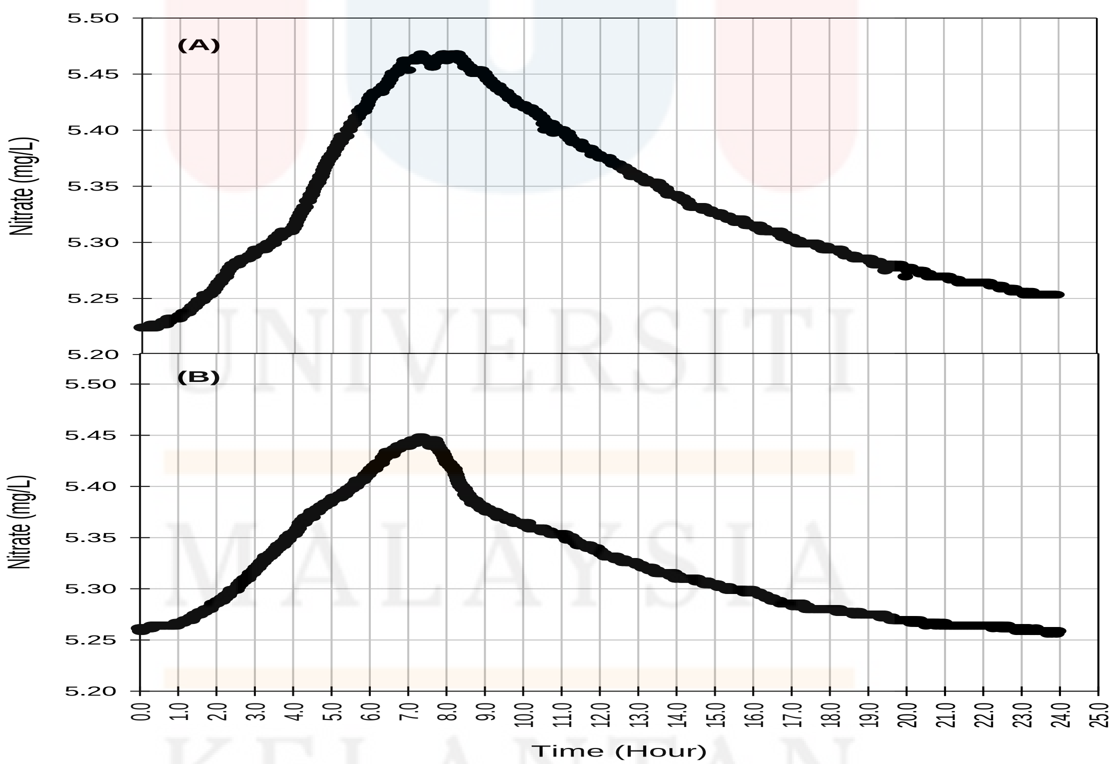

Figure 4.8: Level of Nitrate against time on the (A) first day (22th January 2018) and (B) last day (7 March 2018)

In this study, NO_3^{2-} level was in a tolerable region highlighted by NWQS which was 7mg/L (DOE, 2007). Normally there was certain amount of NO_3^{2-} that naturally existed in the pond. Throughout the investigated period, NO_3^{2-} recorded a mean value of 5.32±0.07mg/L, with a minimum of 5.14mg/L and a maximum of 5.53mg/L. Zhang et. al had showed the mean (0.83mg/L) with a standard deviation of 0.04mg/L, minimum (0.04mg/L) and maximum (1.97mg/L). This scholar's founding on NO_3^{2-} was relatively low as compared to this study, this might be attributed by the NO_3^{2-} concentration of each type of water surface or catchment that had been balanced and diluted by each other with the aid of different sources of oxygen passed to it. Low NO_3^{2-} concentration would have lower probability in posing threat to any living life (Al-Badaii, Shuhaimi-Othman & Gasim., 2013).

At 0000am, NO_3^{2-} started to rise constantly till 0800am. This goes-up trend probably this was the period where aquatic life carried out their excretory process. Of course, excretion of living organisms not only done by during this period, but also other period. From 0801am onward, it started to fall continuously because the oxygen level throughout this period was high. Oxygen level was high because of the relative higher rate of water exchange on this period since there was incoming water mixes with the pond water. This new introduced freshwater would help in diluting the concentration of dissolved compound in the pond. One of the examples could be ammonia. Thus, there would be low ammonia compound available for nitrifying bacteria to convert into nitrite and so NO_3^{2-} (McGee and Boyd, 1983; Boyd, 1998). Furthermore, apart of diluting nutrients, water exchange also would flush the phytoplankton and nutrients away from the ponds (Boyd, 1998).

Nitrate concentration was primarily coming from the waste of fish excretion and the decomposition of excess unconsumed fish foods (Lin & Wu, 1996). Both of these fish excreta and feed residues that existed in urea or ammonia form would be convert by micro life to NO_3^{2-}. Large amount of nitrate was potential to pollute the surface waters and groundwaters. Thus, it was essential to keep on moderate and control the concentration of NO_3^{2-}.

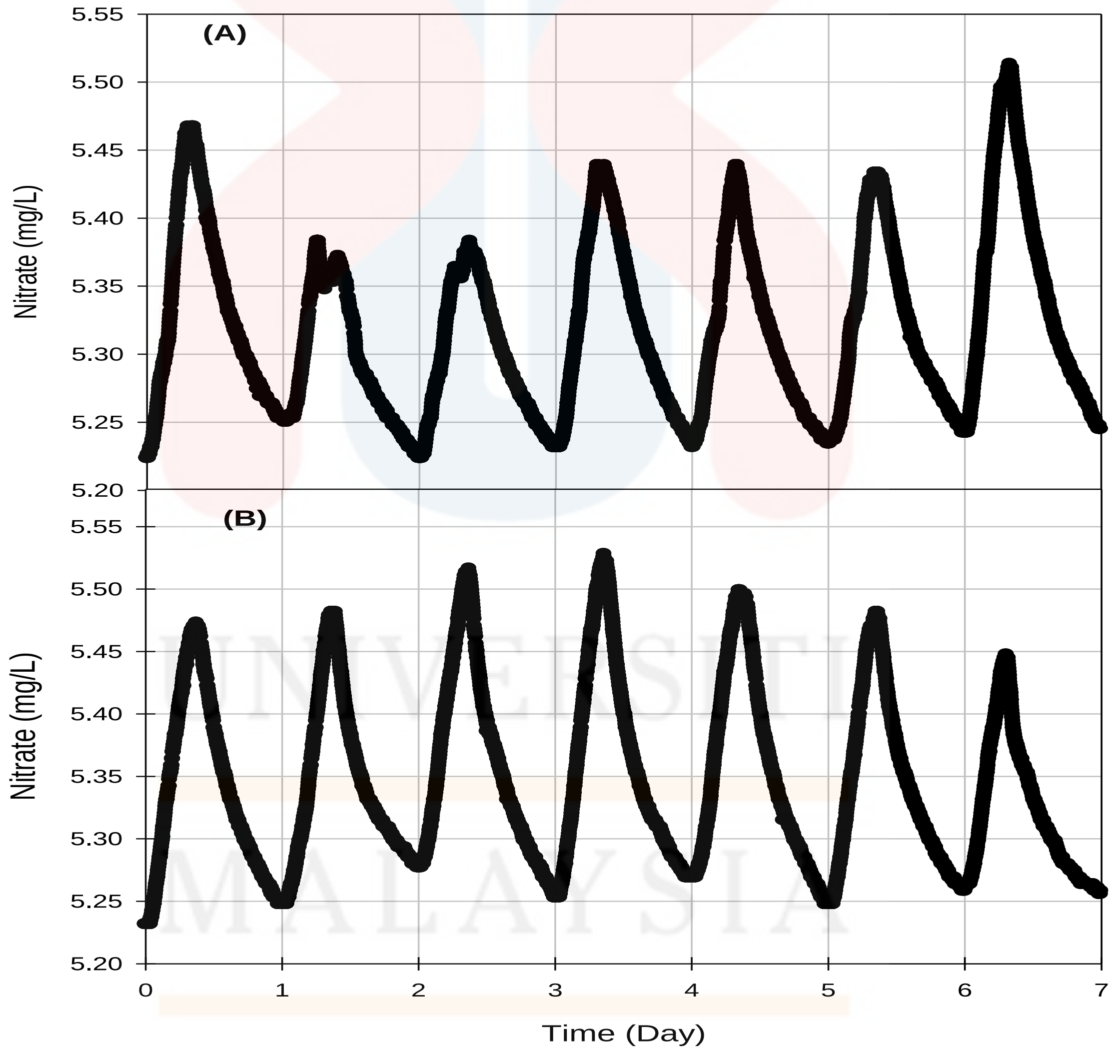

Figure 4.9: Level of nitrate against time (day) on the (A) first week (22th January 2018 to 28th January 2018) and (B) last week (1st March 2018 – 7th March 2018)

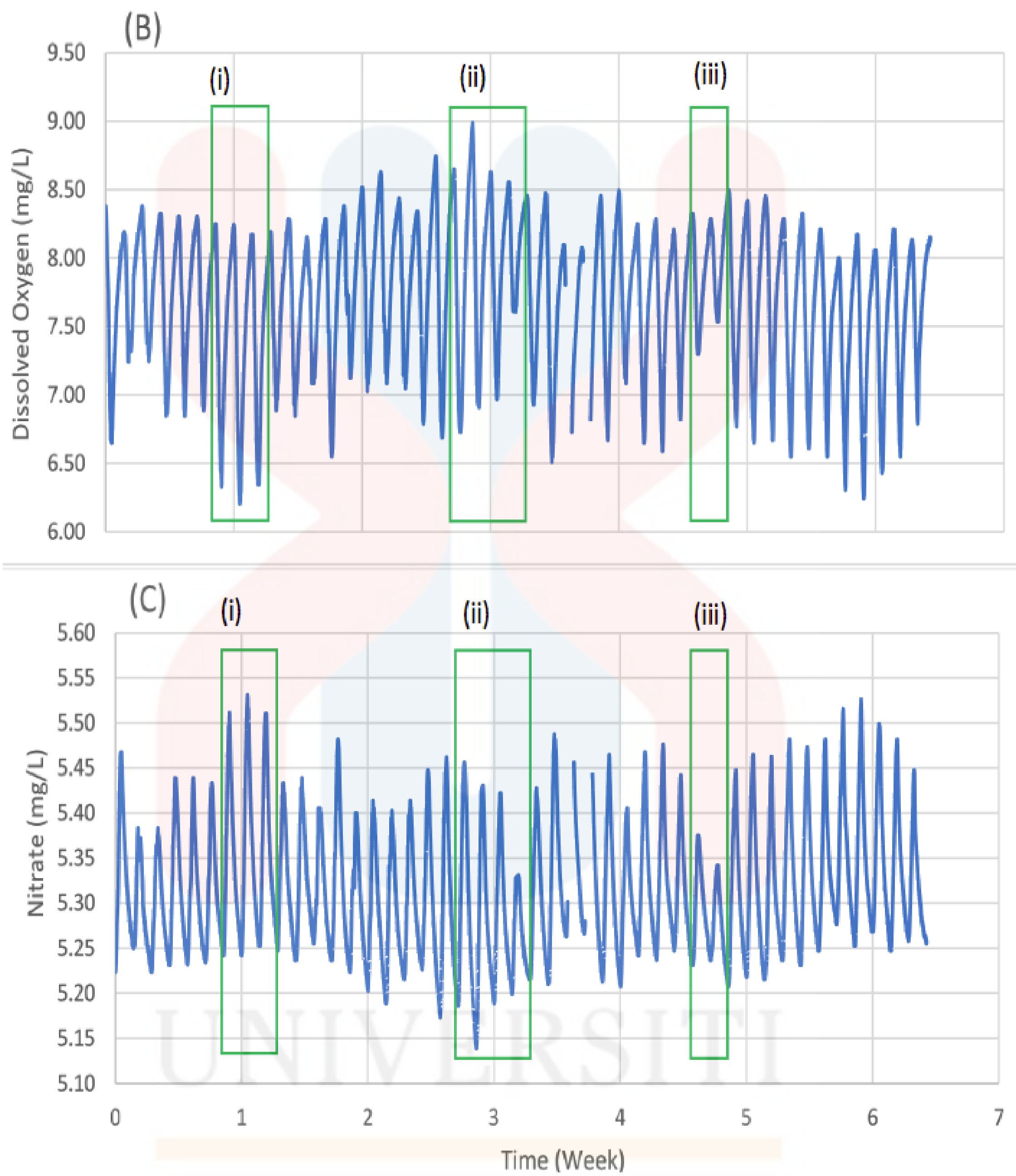

Figure 4.10: The extracted data of DO and NO_3^{2-} from Figure 4.1(B) and Figure 4.1(C)

As Figure 4.10 showed, there were three parts that the author had emphasized to find out the reasons that causing both of these parameters behave that way. As mentioned before, every one V-shaped of DO equal to one day data. At the same time, every one inverted V-shaped represent one day of NO_3^{2-} data.

For both of the first highlighted part in Figure 4.10(Ai) and Figure 4.10(Bi), lowest DO occurred in Week 1 and Week 2 for the first part probably due to the amount of nitrogen, potassium and phosphorus (Rhoades, 2018). Since there were chicken manure added to this pond that act as fertilizer so there was a high chance of occurring algae growth or algae blooms especially when there were excess nutrients that were not fast enough being consumed by the living organisms (Cao et al., 2007). Thereby, the process of algae decomposition would consume a lot of DO or creating a high oxygen demand environment (Minnesota Pollution Control Agency, 2009). Consequently, high concentration of nutrient would cause the drop of DO. Additionally, nutrient would be converted into nitrate continuously during nitrification, this created a relative high nitrate concentration and the rapid used up of available oxygen. In another meaning, when the nitrate production rate was higher than the plant nitrate consumption, DO level would fall.

For both of the second rectangle as stated in Figure 4.10(Aii) and Figure 4.10(Bii), these were the duration that recorded the highest reading of DO (8.99mg/L) and the lowest reading of NO_3^{2-} (5.14mg/L) at the end of 20th day along with the beginning of the 21th day. Major sources of oxygen in this study was from the photosynthesis and newly freshwater that flow in so throughout these four days, there might be relative low nutrients present in the pond and so there was comparatively low microbial activities that used up oxygen. This explained why level of DO was high and NO_3^{2-} was low. Another possibility was that there was rainfall throughout these periods so new water was added to the pond that make the pond saturated with oxygen and so there was more rapid dilution process being carried out to remove the presence nutrient level. Besides that, raining would make the surrounding temperature cooler so a relative cool water could hold more DO. To further extend that, relative cooler temperature would not speed up the biochemical activities of organisms consequently there would be low demand of oxygen (Bhatnagar & Devi, 2013). So, concentration of DO was high.

Lastly, there was relatively small fluctuation within one V-shaped of DO and one inverted V-shaped of NO_3^{2-} for the third highlighted part in Figure 4.10(Aiii) and Figure 4.10(Biii). In another word, the peak-to-trough (amplitude) of a V and an inverted V was small. On 34th day, DO's trough (second V in the third rectangle) was about 7.55mg/L and the peak was 8.50mg/L with just a little difference of 0.95mg/L. It was the smallest change as compared to the others one day DO. The peak of NO_3^{2-} at 34th day was 5.34 mg/L and the trough was 5.21mg/L, there was slight difference of 0.13mg/L.

Moving to March, the temperature was hot. This high temperature could yield more oxygen level in the water due to the plant photosynthesis. In addition, higher temperature also would weaken the capability of the water's capacity to hold the oxygen and the gases solubility (Bhatnagar & Devi, 2013). At the same time, some water would loss to the surrounding due to evaporation process. Higher temperature also would lead to the higher rate of organic matter's oxidation activities. This process would be referring to the nitrification. Simultaneously, quantity of oxygen also would reduce to carry out nitrification when there was not enough of oxygen (Munawar, 1970). All of these processes that probably carried out at the same time could explain why DO and NO_3^{2-} had a small fluctuation rate at the end of Week 4.

4.6 Relationship of Dissolved Oxygen (DO) and Nitrate (NO_3^{2-})

Table 4.2 listed the r value of each aspect from first day, last day, first week, last week and as well as the whole researches duration. On the whole, all of the values were negative and the p- values were significant which the value was less than 0.01 respectively. Apart of first week (r = -0.680) and last week (r = -0.72), the others variable showed the maximum negative correlation (r = -1.0). This strong relationship explained both DO and NO_3^{2-} were highly correlate. Scatter diagram illustrated in Figure 4.11 revealed the strong negative linear relationship of these two physicochemical water parameters. Whereas, Figure 4.12 showed the relationship of both of these two parameters on the first day.

Table 4.2: The Pearson Correlation of Dissolved Oxygen vs Nitrate along 45 days

	Pearson Correlation, r	Significant Level
First day	-1	** (p<0.01)
Last day	-1	** (p<0.01)
First week	-0.68	** (p<0.01)
Last week	-0.72	** (p<0.01)
Along crop rearing	-1	** (p<0.01)

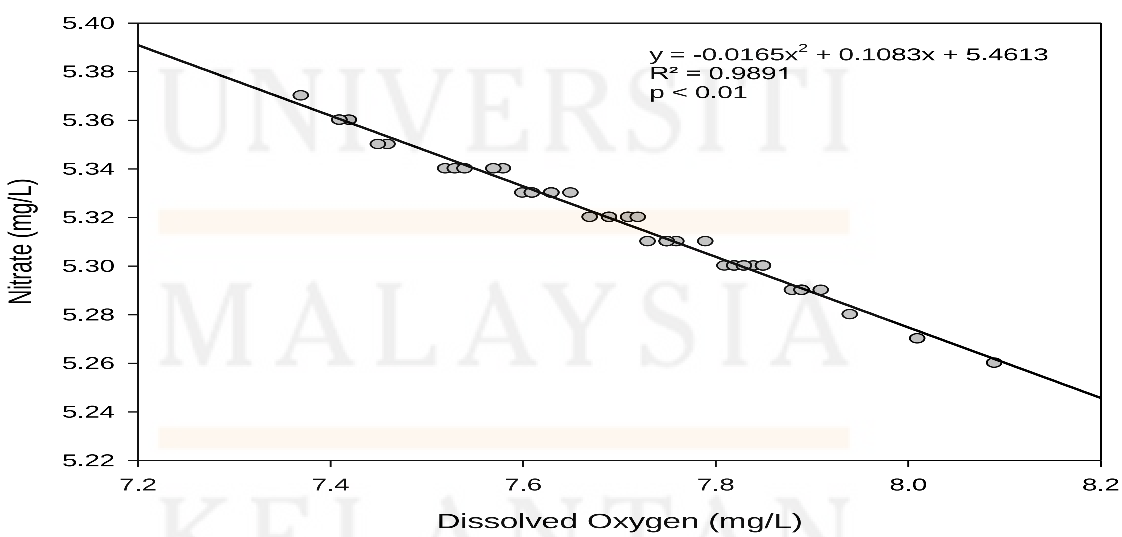

Figure 4.11: Scatter plot of daily average Nitrate reading (mg/L) vs daily average Dissolved Oxygen reading (mg/L) throughout the 45 days of crop rearing

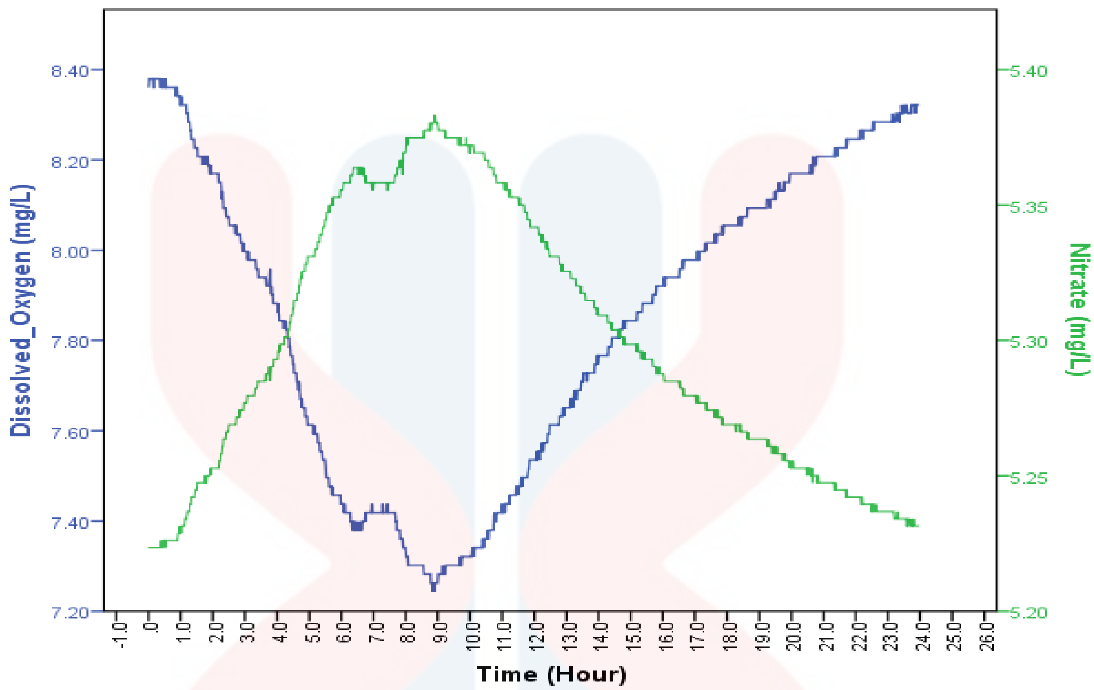

Figure 4.12: Dissolved Oxygen and Nitrate against Time on the first day (22th January 2018)

Normally, nitrification was carried out on daytime since there were abundant of oxygen available due to the plant photosynthesis process. In another word, it was done in an aerobic condition. Thereby, theoretically the NO_3^{2-} level suppose rise up in the morning from 0800am onwards (Markov, 2012; Stein and Klotz, 2016). This was because increased in oxygen level would also increase the rate of nitrification process. Unfortunately, the graph for both Figure 4.8 and Figure 4.12 showed that the value of NO_3^{2-} was declining. This was due to the opening of water flow valve in the morning that lead to the flow in of new freshwater from the dam and subsequently the happened of NO_3^{2-} dilution.

During midnight and early morning, level of NO_3^{2-} built up with about 0.23mg/L and at the same time oxygen level decreased (Figure 4.12). At night, there was relatively less oxygen available supplied for the organisms to carry out respiration since there was no sunlight, no production of oxygen from photosynthesis and so living organisms would try any length to look for oxygen. Hence, they would use up the oxygen atom from NO_3^{2-} so it was clearly seen that NO_3^{2-} level was decreasing especially during the midnight from 2000 pm to 0000 am. In the morning, the oxygen level increased due to the opening of water flow valve, so there were many freshwaters flowed from the dam to the pond. All of these were supported by the T-test done by SPSS (Appendix A), both of the parameters were significant. This was due to both of them were related to each other. When one of the parameter values fluctuate, another one parameter also would be affected.

In daytime around 0900am, NO_3^{2-} content reached to a peak that might be linked to the adding of chicken manure fertilizer as it consists of high level of nitrogen so high formation of NO_3^{2-} (Rhoades, 2018). This negative linear relationship was further proved with Table 4.2 and Figure 4.11.

Basically, both Figure 4.8(A) and Figure 4.8(B) showed the similar trend and this was the same with Figure 4.9(A) and Figure 4.9(B). Figure 4.9(B) had a relative constant value trend compared to Figure 4.9(A). Similar to the daily data of DO in Figure 4.7 to determine a one-day data, the differ point was the inverted V-shaped represented one day data. This was caused by the negative relationship of NO_3^{2-} and DO.

The peak of last week Figure 4.9 (B) began fluctuate from 5.47mg/L to 5.53mg/L but peak of NO_3^{2-} on first week began with 5.37mg/L to 5.52mg/L. This probably due to the environmental condition surrounded this aquaculture pond had settled down or became relatively stable to the surrounding after a few months of ‘adapting’.

Significant negative relationships were observed among the relationship of DO and NO_3^{2-} from the above Figure 4.8, Figure 4.9, Figure 4.10 and Table 4.2. This indicated that both of these parameters were significantly interrelated than each other. When DO increased, NO_3^{2-} would decrease. Moreover, the scattered plot as shown in the Figure 4.10 suggested that DO and NO_3^{2-} existed in a nearly negative linear relationship.

As mentioned before there was new freshwater discharged from the dam to the aquaculture pond daily and definitely the water in the pond was not 100% static. There was a continuous slow water flow. Along the pathway to transfer water to the aquaculture pond, the new freshwater came out from the water pipeline would indirectly 'interact' with the surrounding air above the aquaculture pond as well as the water surface. The 'interacting' part could be observed with the relatively small water splashing like the water of the waterfall falling down. This would lead to the formation of air bubbles or water drops (Minnesota Rural Water Association, 2017). Once it had 'penetrated' into the water of the aquaculture pond, these new discharged freshwaters would act as a dilutor that would dilute the ammonia concentration in a unit area of the aquaculture pond. Subsequently, the reading of NO_3^{2-} would decrease and the DO level would increase (comparatively higher). Once the rate of replenishing new water was higher than the NO_3^{2-} production, the total DO content would be at a higher level and so show a going up trend. This explained the negative strong correlation (r = -1) between DO and NO_3^{2-} in this study (Figure 4.11).

There was another evidence that support negative correlation. In nitrification, micro living things would obtain the free oxygen atom from the water molecules to convert ammonia into NO_3^{2-}. The abundant or the high level of available oxygen atom in the water because there were aquatic plants carried out photosynthesis on the daytime (Neospark Drugs and Chemicals Private Limited, 2014). They would produce oxygen that would turn to DO in water. It could be concluded that the negative correlation was contributed by the daily freshly introduced water, photosynthesis and the removal of oxygen atom from the water molecules.

Here, it might be argued that DO and NO_3^{2-} should positively correlated. Microorganisms need oxygen to carry out decomposition process of organic waste all the time. However, at night, there was already relative less oxygen available in the water since there was no sunlight and so no photosynthesis carried out which would help in producing oxygen. In the condition of anaerobic, NO_3^{2-} compound would be used by microorganism since they were in need of oxygen and in turn would convert NO_3^{2-} into NO_2^{-} and so nitrogen. This process was known as denitrification. This situation explained that when oxygen decrease, NO_3^{2-} also would decline too (World Health Organization, 2011; Harper et al., 2017).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the author had lost one parameter which was temperature due to the depicted result was the opposite of the reality temperature reading. For instance, water temperature was high from 0600am to 0800am but started to decrease from 0900am onwards. Further temperature analysis such as mathematical substitution had to be carried out to correct back the readings.

Apart of both DO and NO_3^{2-} concentration level were stay within a safety NWQS desirable limit, DO and NO_3^{2} ($p<0.01$) showed a maximum and negative correlation with $r = -1$ along the forty-five crop rearing days. This mean that they had inverse relationship. The major contributing factor to this trend was the introducing of new freshwater that lead to constant water exchange, water circulation and also water mixing.

On the whole, the range of fluctuation of these three parameters were acceptable. Thus, it could be concluded that the water quality of this aquaculture pond was suitable for fish cultivation. Hopefully that this study could aid any relevant parties to make the most suitable, acceptable social and ecological decisions. Apart of that, the sensor's performance was good and yet there was still need some improvements and need of relatively close monitor. The limitation of this study is that it does not include other significant factors such as soil, topography, land use change that could contribute to the changes in these three water quality parameters.

5.2 Recommendations

Temperature sensor was identified on displaying relative less accurate data so it is recommended to formulate mathematical equation, calibrate or modify the probe. Any back up system like manually collecting data is required as sometimes there might be some environment factors causing Internet disconnection. Alternative system or monitoring is needed when Aquasense had to be send for calibration or maintenance. Hence, it indirectly helps in improving the consistency and so smoothing the data-analysis working process. Although nothing is perfect in this world but there is a need to make the obtained data as accurate as the researchers can.

Moreover, the author also should daily check the sensor reading. This could be done by using each respective parameter equipment to obtain data manually, probably two sessions in a day, the suggested time is 0800am and 1800pm. This suggestion was similar to the research done by Soderberg et al. (1983) which DO readings were collected at dawn and dusk. This is to ensure that the recorded sensor readings are within the correct range, probably with ±0.50 unit, depend on the acceptable tolerable range. Plus, it also helps in increasing confidence on the data reliability and the data accuracy.

In addition, this study should go in parallel with chemical laboratory test or analysis test so that it could serve as the evidence to proof the performance of the sensor along with the observed manual collecting data that would be undergone many chemical tests. Štambuk-Giljanović (1999) emphasized that there was a need to note down the current conditions during the manual data processing of the big analytical data. So, constant and regular on-site surveillance is needed to get the data that is close to the real-life result. The purpose of doing this was to reduce the error of making quick and misleading interpretation.

Using an automatic data recording sensor is relative costly however it is not expensive by looking on the long-term duration as it is cost effective. The cost could be reduced by modifying the system of sensor. For example, the electricity needed by the sensor to operate or to send the data could be generated by the renewable energy like solar energy, water energy or wind energy. Of course, there is a need of having extensive planning and research beforehand to produce a relative sustainable, environmental friendly and cost-friendly sensor.

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APPENDICES

APPENDIX A

INDEPENDENT SAMPLE T- TEST RESULT

Table 1: Independent Sample T-Test analysis data of the two parameters on the first day and last day

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Dissolved_Oxygen	Equal variances assumed	134.299	.000	-5.190	2809	.000	-.08831	.01702	-.12167	-.05495
	Equal variances not assumed			-5.195	2659.472	.000	-.08831	.01700	-.12164	-.05498
Nitrate	Equal variances assumed	135.031	.000	5.198	2809	.000	.01247	.00240	.00777	.01718
	Equal variances not assumed			5.203	2658.587	.000	.01247	.00240	.00777	.01717

Table 2: Independent Sample T-Test analysis data of the two parameters on the first week and last week

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Dissolved_Oxygen	Equal variances assumed	119.979	.000	26.867	19750	.000	.18936	.00705	.17554	.20317
	Equal variances not assumed			26.855	19557.740	.000	.18936	.00705	.17554	.20318
Nitrate	Equal variances assumed	124.963	.000	-26.921	19750	.000	-.02677	.00099	-.02872	-.02482
	Equal variances not assumed			-26.908	19549.900	.000	-.02677	.00100	-.02872	-.02482

APPENDIX B

PEARSON'S CORRELATION TEST RESULT

Table 1: Correlations of Dissolved Oxygen vs Nitrate on the first day

		First_day_Dissolved_Oxygen	First_day_Nitrate
First_day_ Dissolved_ Oxygen	Pearson Correlation	1	-1.000**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	356.730	-50.314
	Covariance	.253	-.036
	N	1411	1411
First_day_ Nitrate	Pearson Correlation	-1.000**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	-50.314	7.099
	Covariance	-.036	.005
	N	1411	1411

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2: Correlations of Dissolved Oxygen vs Nitrate on the last day

		Last_day_Dissolved_Oxygen	Last_day_Nitrate
Last_day_Dissolved_Oxygen	Pearson Correlation	1	-1.000**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	214.776	-30.267
	Covariance	.154	-.022
	N	1400	1400
Last_day_Nitrate	Pearson Correlation	-1.000**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	-30.267	4.267
	Covariance	-.022	.003
	N	1400	1400

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3: Correlations of Dissolved Oxygen vs Nitrate on the first week

		First_week_Dissolved_Oxygen	First_week_Nitrate
First_week_Dissolved_Oxygen	Pearson Correlation	1	-.680**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	2273.199	-274.451
	Covariance	.229	-.028
	N	9930	9930
First_week_Nitrate	Pearson Correlation	-.680**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	-274.451	71.671
	Covariance	-.028	.007
	N	9930	9930

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4: Correlations of Dissolved Oxygen vs Nitrate on the last week

		Last_week_Dissolved_Oxygen	Last_week_Nitrate
Last_week_Dissolved_Oxygen	Pearson Correlation	1	-.720**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	2676.794	-333.634
	Covariance	.272	-.034
	N	9830	9830
Last_week_Nitrate	Pearson Correlation	-.720**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	-333.634	80.258
	Covariance	-.034	.008
	N	9830	9830

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5: Correlations of Dissolved Oxygen vs Nitrate along the crop rearing

		Along_crop_rearing _Dissolved_Oxygen	Along_crop_rearing_Nitrate
Along_crop_rearing _Dissolved_Oxygen	Pearson Correlation	1	-1.000**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	17249.523	-2429.581
	Covariance	.276	-.039
	N	62508	62507
Along_crop_rearing _Nitrate	Pearson Correlation	-1.000**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	-2429.581	342.302
	Covariance	-.039	.005
	N	62507	62507

**. Correlation is significant at the 0.01 level (2-tailed).