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UNRAVELLING SENSITIVE PHYSICOCHEMICAL DYNAMICS IN COMMERCIAL AQUACULTURE EARTHEN PONDS ACROSS SOUTHERN SARAWAK

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Graphical abstract

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Abstract

Aquaculture activities in Sarawak is currently undergoing great expansion and advancement by the government to provide sustainable food source for the local people. With the changing environment, climate change and increases in nutrients this could disrupt the water quality for the fish production. Hence, this study was conducted to assess the water quality in commercialize aquaculture ponds in Southern Sarawak. This study was carried out between June 2023 to November 2023. The temperature, dissolved oxygen, turbidity, pH, conductivity, total dissolved solids, ammonia, phosphate, nitrate, and nitrite which are deemed as the most sensitive and pertinent for the fish production were evaluated. The YSI multiparameter was used to measure the physical variables and the nutrients variables were measured using the HACH spectrophotometer. The results obtained for the temperature (28±0.00-32±0.00 °C), dissolved oxygen (1.10±0.01-12.99±0.01 mg/L), pH (3.72±0.03-8.39±0.06 mg/L), conductivity (0.03±0.00- 215.10±0.35 µS/cm), total dissolved solids (10.45±0.01-10137.17±0.02 mg/L), turbidity (6.77±0.16-483.22±40.41 NTU), ammonia (0-3.5 mg/L), phosphate (0.06±0.03-4.52±0.04 mg/L), nitrate (0.01±0.00-3.5 mg/L) and nitrite (0.003±0.002-3.5 mg/L) denoted that the physicochemical parameters of water quality in the aquaculture ponds, if found within normal levels considered tolerable. Some of the physicochemical parameters examined this study did not fall within the recommended range for optimal fish production, suggesting that some physicochemical parameters in these aquaculture ponds does not provide conducive conditions for the fish survival and growth. Thus, vigilant monitoring and stricter management of water quality in aquaculture ponds is needed to protect the health of aquaculture industry as well as the public health that consume them.

Keywords: Aquaculture, Physicochemical, Water quality, Fish, Commercial

Abstrak

Aktiviti akuakultur di Sarawak sedang mengalami perkembangan dan kemajuan besar oleh kerajaan supaya dapat membekalkan sumber makanan yang mampan untuk penduduk tempatan. Dengan perubahan persekitaran, perubahan iklim dan peningkatan kandungan nutrien ini boleh mengganggu kualiti air kolam akuakultur untuk pengeluaran ikan. Kajian ini dijalankan untuk menilai kualiti air dalam kolam akuakultur komersial di Selatan Sarawak. Kajian ini dijalankan antara Jun 2023 hingga November 2023. Suhu, oksigen terlarut, kekeruhan, pH, kekonduksian, jumlah pepejal terlarut, ammonia, fosfat, nitrat dan nitrit yang dianggap paling sensitif dan relevan dalam penternakan ikan telah dinilai. Multiparameter YSI digunakan untuk mengukur pembolehubah fizikal dan pembolehubah nutrien diukur menggunakan spektrofotometer HACH. Keputusan yang diperolehi untuk suhu (28 ± 0.00 - 32 ± 0.00 °C), oksigen terlarut (1.10 ± 0.01-12.99 ± 0.01 mg/L), pH (3.72 ± 0.03 - 8.39 ± 0.06), kekonduksian (0.03 ± 0.06). 215.10 ± 0.35 µS/cm), jumlah pepejal terlarut (10.45 ± 0.01 - 10137.17 ± 0.02 mg/L), kekeruhan (6.77 ± 0.16 - 483.22 ± 40.41 mg/L), ammonia (0.0.61 mg/L) ± 0.03 - 4.52 ± 0.04 mg/L), nitrat (0.01 ± 0.00 - > 3.5 mg/L) dan nitrit (0.003 ± 0.002 - > 3.5 mg/L) menandakan jika parameter fizikokimia kualiti air dalam kolam akuakultur didapati dalam paras normal, ianya boleh diterima. Beberapa parameter fizikokimia yang dinilai dalam kajian ini tidak berada dalam julat sesuai yang disyorkan untuk penternakan ikan dan ini menunjukkan bahawa beberapa parameter fizikokimia dalam kolam akuakultur ini tidak menyediakan keadaan yang kondusif untuk kemandirian dan pertumbuhan ikan. Maka, kawalan kualiti air yang kerap bagi kolam akuakultur diperlukan untuk melindungi kesihatan industri akuakultur serta kesihatan awam yang memakannya.

Kata kunci: Akuakultur, Fisikokimia, Kualiti air, Ikan, Komersial

1.0 INTRODUCTION

Aquaculture involves the breeding, nurturing, and harvesting of aquatic life, usually for human consumption. This globally important industry plays a pivotal part in tackling upcoming food supply issues [1]. Depending on the type of organism being cultivated, specific names are assigned to indicate the nature of the culture, such as algaculture, malacoculture, carciniculture, fish farming or pisciculture. Pisciculture is the specialised field within aquaculture that focuses on dedicated to the fish cultivation. Aquaculture has been practiced globally for more than 2000 years B.C [2] and continues to emerge as a reliable means for meeting food demands and fostering economic development in various developing nations worldwide. Aquaculture is one of the industries that experienced remarkable global growth with approximately 60 million tonnes of farmed aquatic organisms exported annually, marking a 245% increase over the last 40 years. With an average annual growth rate of 7% during this period, aquaculture distinguishes itself as one of the fastest-expanding industries worldwide, exceeding other sectors in animal food production.

The aquaculture sector has provided millions of people across the globe with opportunities for income and livelihood. In aquaculture industry, fish, shellfish, and aquatic plants are raised and breed in freshwater, saltwater, and brackish waters [3]. The pond bed typically consists of sediment containing sand, decomposing organic material, and microorganisms. Pond water tends to be still and harbour a diverse range of microbial life. Nutrients enter the pond through streams, rain runoff and human activities [4]. The decomposition of water in soil, animal waste, and rotting plant matter power up the pond ecosystem. Assessing the quality of pond water through physicochemical and microbial analyses helps inform its suitability for various purposes [5].

Water quality refers to the attributes of water, including its chemical, physical, biological, and radiological characteristic. It defines the state of water in relation to its suitability for specific purposes like drinking, swimming, or determining its suitability for artificial fish culture in ponds [6]. Physical elements that are essential in domestic fish farming are the concentration of dissolved oxygen, bacteria levels, salinity, and turbidity [5]. In aquaculture, water quality pertains to the physical, chemical, and biological factors indicating the water's capacity to sustain the health of cultivated organisms [7]. Therefore, maintaining recommended level of these parameters within acceptable limits is crucial for achieving optimal productivity [7]. The most critical physicochemical parameters for fish production are temperature, pH, dissolved oxygen, turbidity, conductivity, ammonia, nitrate, nitrite, and phosphate [7]. Inadequate understanding of aquaculture nutrition, feed formulation, and effective feeding practice may result in poor water quality in aquaculture facilities due to the buildup of undigested feed [3]. In fish farming environments, nutrients from organism excretions and leftover foods can lead to eutrophication in the surrounding ecosystem where aquaculture is conducted [8]. Just 13.9% of the nitrogen and 25.4% of the phosphorus from the fish food is utilized, while the remainder accumulates in the water and sediment.

The quality of water in the aquaculture facilities plays a crucial role in determining the success of fish production [7]. Feeds and feeding, fish health, disease management, and adherence to good aquaculture practices can greatly influence farm productivity and quality [3]. The use of poor-quality water could result in reduced fish growth, prolonged production cycles, increased susceptibility to diseases causing potential mortality, low product quality, decrease production, and reduced economic returns, causing the fish cultivation activity economically unfeasible [7]. Poor disease management and subsequent improper use of drugs can result in the accumulation of chemical residues in fish tissue [3]. This not only poses a potential health risk to consumers but also leads to the release of fish wastes containing these residues into the nearby water, contributing to the gradual development of antibiotic or drug resistance in both farmed goods and the surrounding environment [3].

Currently, aquaculture activities in Sarawak are undergoing great expansion and advancement by the government to provide sustainable food source for the local people. In 2020, Sarawak shipped 4,345 metric tonnes of shrimp to big destinations including Australia, New Zealand, Japan, China, Singapore, Middle Eastern countries, and the European Union. Sarawak is actively producing a huge number of fishes through aquaculture system, so with the changing environment and climate change happening along with the increases in nutrients, this could further affect the water quality in the aquaculture ponds. To successful expansion up of aquatic farming requires effective management of water quality which is a vital factor of fisheries management [3]. Because poor water quality that is in use for aquaculture could reduce fish production and produce poor quality fish product. This will not only negatively affect the aquaculture industry but would also pose health risk to human through the consumption of the cultured fish. Therefore, extensive research on environmental factors and nutrient management in fish aquaculture ponds is crucial to mitigate their adverse impact on both aquaculture and human health. This to ensure the delivery of safe fish products to consumers. Thus, this study was conducted to evaluate the main sensitive physicochemical parameters in commercialize aquaculture earthen ponds in southern Sarawak and assessing its suitability for the development of the fish farming activity.

2.0 METHODOLOGY

2.1 The Study Area

The samples were obtained from the aquaculture farms in the Southern part of Sarawak which were Kuching, Bau and Samarahan (Figure 1).

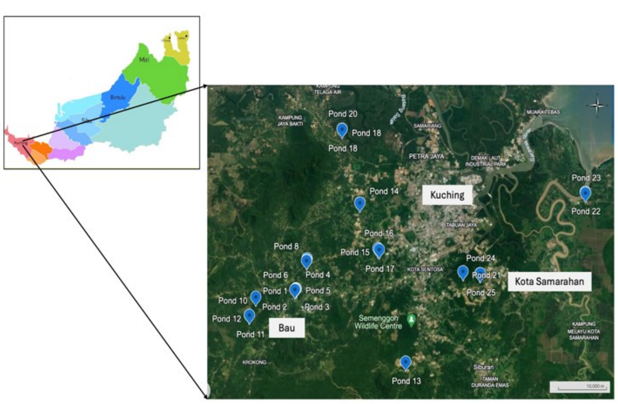

Figure 1 The location of the selected aquaculture ponds in Kuching, Samarahan and Bau in Sarawak, Malaysia

Samplings and evaluations were done in 25 ponds from June 2023 to November 2023. All of the selected aquaculture ponds were earthen ponds, dedicated for fish production business. As pond size greatly influences production, management and the fish quality and size, this study concentrate on pond sizes measuring at least 100 m^2 as recommended by the previous studies [9].

2.2 Sample Collection and Environmental Data Collection

2.2.1 Temperature

This test was conducted to assess water temperature in the pond. The temperature was determined using YSI multiparameter (EXO2 Multiparameter Sonde). The temperature probe was washed using distilled water. The YSI was thrown in to the water at the depth of 0.5 m. The reading was recorded once the temperature displays a constant value. Then, after each insertion, the probe was washed using distilled water and dried with tissue paper.

2.2.2 Potential of Hydrogen (pH)

This test was conducted to assess the hydrogen ion level in the pond water. The pH was examined using YSI multiparameter (EXO2 Multiparameter Sonde). The probe of the pH meter was washed with distilled water. The YSI was thrown into the water at the depth of 0.5 m. The reading was recorded once the pH displays a constant value. After each insertion, the probe was washed using distilled water and dried with tissue paper.

2.2.3 Turbidity

This test was aimed to quantify the reduction in water transparency caused by suspended solid particles. The value of turbidity was obtained using a YSI multiparameter (EXO2 Multiparameter Sonde). The YSI was immersed to a depth of 0.5 m. Readings were recorded once the turbidity displays a constant value. After each insertion, the probe was washed using distilled water and dried with tissue paper. Readings were recorded in units known as Nephelometric Turbidity Unit (NTU).

2.2.4 Conductivity

This test aimed to ascertain the level of the dissolved mineral salt and to assess the ionic effect in the water. The value of conductivity was obtained using a YSI multiparameter (EXO2 Multiparameter Sonde). The YSI was immersed to a depth of 0.5 m. Readings were recorded once the conductivity displays a constant value. After each insertion, the probe was washed using distilled water and dried with tissue paper. Readings were recorded in units known as µs/cm (micro Siemens per cm).

2.2.5 Total Dissolved Solids (TDS)

The total dissolved solid (TDS) encompass ions like potassium, sodium, chloride, carbonate, sulphate, calcium, and magnesium, which make up the dissolved solids present in water. The value of TDS was obtained using a YSI multiparameter (EXO2 Multiparameter Sonde). The YSI was immersed to a depth of 0.5 m. Readings were recorded once the TDS reading showed a steady value. After each insertion, the probe was washed using distilled water and dried with tissue paper.

2.2.6 Dissolved Oxygen (DO)

This was conducted to assess oxygen content in the water. The DO meter probe was washed using distilled water. The YSI was thrown in to the water at the depth of 0.5 m. Readings were recorded once the DO reading showed a steady value. After each insertion, the probe was washed using distilled water and dried with tissue paper.

2.2.7 Ammonia, Phosphate, Nitrate, Nitrite

For the nutrient's analysis, 500 mL water sample were collected in replicates at 0.5 m depth using a Van Dorn water sampler (Wildco, USA) and stored immediately into acid washed sample bottle. Before analysis, water samples undergone pre-filtration using a 0.45 µm membrane filter (Millipore, USA) before analysis. Then, the determination of phosphate, nitrate, nitrite, and ammonia levels were done using the HACH 3900 spectrophotometer (HACH, USA) according to the manufacturer's protocols (Hua and Yaacob, 2019). Ammonia was determined using the Nessler Method where Mineral Stabiliser, Polyvinyl Alcohol Dispersing Agent and Nessler Reagent were poured into 25 mL of samples and measured using HACH DR3900. Nitrate was determined using cadmium reduction method. Nitraver 6 Powder Pillows and Nitriver 3 Powder Pillows were added into 15 mL of samples. A pink color shows if nitrate is present in the sample and measured using HACH DR3900. Orthophosphate was determined using PhosVer 3 (Ascorbic Acid) Method. PhosVer 3 Reagent Powder Pillows was added into a sample cell with 10 mL of sample. A blue colour will develops if phosphorus is present in the sample. Nitrite was determined using Diazotization Method. NitriVer 3 Reagent Powder Pillows was added into a sample cell with 10 mL of sample. A pink color will develop if nitrite is present in the sample.

2.2.8 Statistical Analysis

The analysis of data was done using Statistical Package for Science Social (SPSS) software for ANOVA to determine the significance of the results. Pearson's correlation was employed to assess the degree of correlation between temperature, DO, pH, turbidity, conductivity, TDS and nutrients (ammonia, phosphate, nitrate and nitrite). The graphs were generated using GraphPad Prism.

3.0 RESULTS AND DISCUSSION

Temperature values were significantly different across the 25 earthen ponds ($p < 0.05$) where the lowest temperature (28 ± 0.00 °C) was recorded in Pond 13, while the highest temperature (32 ± 0.00 °C) was recorded in Pond 19 (Figure 2).

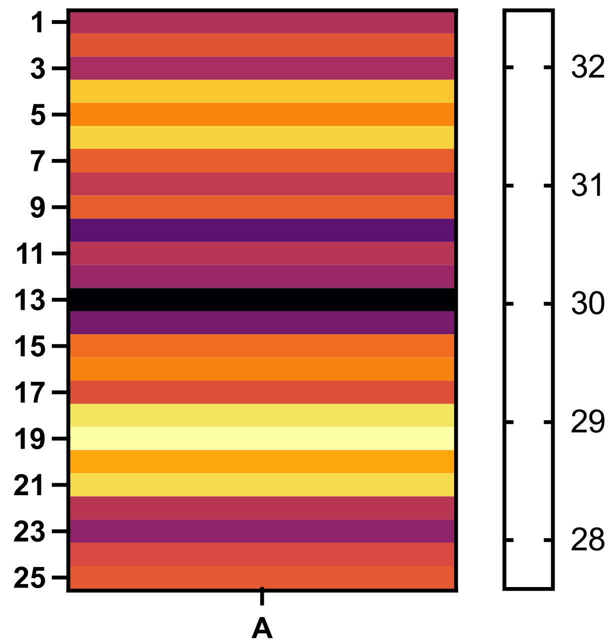

Figure 2 The temperature values (°C) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

The temperature obtained from this study were within the range of 25 °C - 32 °C as stated by National Water Quality Standard (NWQS). The pond temperatures identified in this research were found to be suitable for fish production, indicating favourable conditions for the fish in those ponds. Temperature plays a crucial role in controlling physiological functions and significantly impacts the digestive system of aquatic organisms [10]. Variations in temperature can impact the water density, salinity and DO. Global climate drivers such as increasing air temperature can contribute to the rising of surface water temperatures globally [11]. Temperature variations can impact oxygen consumption by biota and the solubility of oxygen in water which can influence the fish metabolism and feeding rates. The temperature within a pond is beyond control, so aquatic species possess the ability to adjust their body temperature according to the surrounding environment. However, they are highly susceptible to abrupt temperature fluctuation [12]. Different species will have different range of temperature. Fish behaviour such as migrating to surface water in warm conditions and seeking deeper water in cold weather with harsh temperatures, show their adaptive response to the temperature changes [13]. Fluctuations in temperature can affect the metabolism, physiology and productivity of fish, thus optimal temperature is crucial for their growth and sustenance [10], [14].

The dissolved oxygen (DO) levels obtained in this study were significantly different across the 25 earthen ponds ($p < 0.05$) and ranged between 1.10 ± 0.01 mg/L to 12.99 ± 0.01 mg/L (Figure 3).

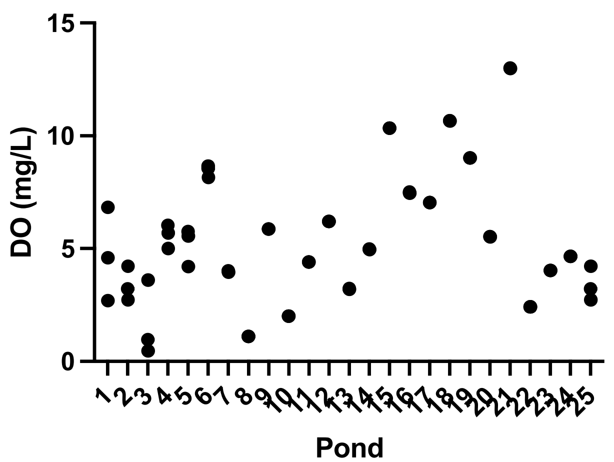

Figure 3 The concentration of DO (mg/L) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

However, Pond 3, 8, 10, and 22 recorded DO levels below the NWQS acceptable limit. Meanwhile, Ponds 6, 15, 16, 17, 18, 19 and 21 were above the NWQS acceptable limit. Although the lowest recorded level 1.10 mg/L falls within the alert range, it had no significant negative impact because the exposure of fish to this level was short, primarily during the transitions of evening and morning. The DO recorded in this study were lower than the DO recorded from [13] which were ranged between 41.67 mg/L to 62.77 mg/L. The DO levels in aquaculture ponds are affected by factors such as temperature. Cold temperatures generally support higher DO concentrations. Organisms' respiration and the photosynthesis process play significant roles in determining maximum and minimum oxygen levels. During periods of increased solar radiation, the reverse process occurs as phytoplankton decrease the photosynthesis process and lead to decreases oxygen released and subsequently lowering oxygen levels in the ponds [7]. The decrease in DO resulting from low water levels in the ponds, caused by seepage and evaporation, can be addressed by extending the hydraulic retention time. This can be achieved by replenishing the ponds with additional water to maintain the high-water level. This ensured stability in ecosystem, lowering stress due to crowding and favouring fish productivity [12]. High DO levels in Pond 6, 15, 16, 17, 18, 19 and 21 might be ascribed to higher temperature, increased microbial and metabolic activity and elevated organic loads. DO is a metric assessing the level of DO in the aquatic environment which is crucial for the sustenance, growth, mental health, behaviour, and productivity of aquatic organisms. Changes in DO influence microbial decomposition of organic matter and are used up in the process [10]. High fluctuations in oxygen concentration and pH, often associated with massive phytoplankton blooms, can be detrimental to fish populations. Fish face suffocation in the absence of oxygen. Adequate oxygen levels are critical for the well-being of aquatic organisms, and levels below 4 mg/L may result in low fish feeding, starvation, and stunted growth stress, reproduction issues and diseases [13][15]. The oxygen requirement varies depending on the fish species in the pond, as certain species exhibit greater tolerance to lower oxygen level compared to others. Oxygen-rich waters can accommodate a diverse array of aquatic organisms while environments with lower DO levels can only sustain limited numbers and variation of aquatic life [13]. In ponds, oxygen production primarily comes from aquatic plants and phytoplankton thus, oxygen cycle in ponds is influenced by the photosynthesis and respiration of phytoplankton, leading to higher dissolved oxygen (D.O) levels during the day [16]. Natural water bodies are saturated with DO at a level that is in balance with the air. However, this saturation concentration tends to diminish due to factors such as rising temperatures, heightened salinity, reduced atmospheric pressure, elevated humidity and a dense population of submerged plant and blooming of planktons [14]. The presence of DO significantly influences the growth, survival, distribution, behaviour, feed intake, disease resistance, metabolism, physiology of fish and other aquatic organisms thus ensuring adequate DO levels in the water is important for ideal fish production [12]. According to [15], DO level above 5 mg/L is crucial for supporting optimal fish production. Preventing the overuse of fertilizers or organic manure is beneficial in regulating DO levels in fish ponds. Fish farmers can also employ strategies such as water recycling, controlling aquatic weeds and phytoplankton, and using aerators to regulate DO concentration in the earthen ponds [17].

The pH levels in this study were significantly different across the 25 earthen ponds ($p < 0.05$) and with the highest pH (8.39 ± 0.06) was recorded at Pond 6 and the lowest pH (3.72 ± 0.03) was recorded at Pond 18 (Figure 4). The pH levels for Ponds 14, 15, 18, 19, 21, 22, 24 and 25 were lower than the NWQS standard. The pH values obtained from the other ponds were ranged within the NWQS standard, which is between pH 5.0 to 9.0, creating favourable conditions and requirements for fish production [18] pH is a critical factor influencing the microorganism's growth, and its measurement assists in assessing the water suitability for fish, plants and algae [5]. [10] stated that the ideal water pH range for fish production typically falls between 6.5 and 9.

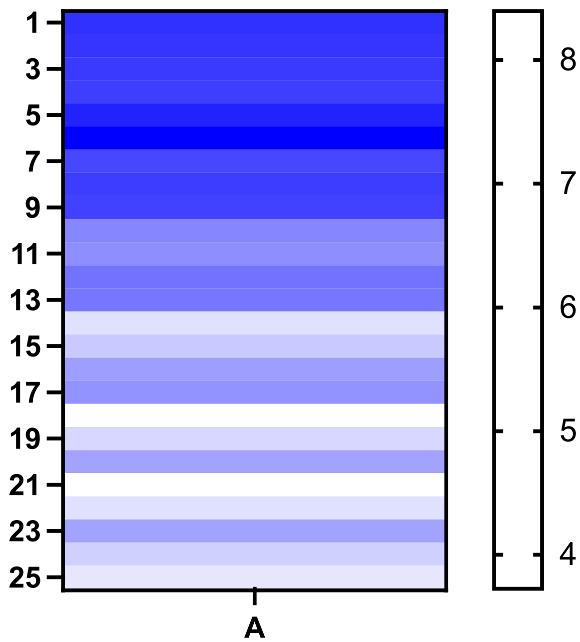

Figure 4 The pH values obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

However, differences in pH, such as pH 4 to pH 6 or pH 9 to pH 10 can reduce fish growth rates, though the majority may still survive. Fish can experience stress when exposed to water with pH levels between 4 and 6.5, as well as between 9 and 11. The likelihood of death significantly increases when pH falls below 4 or exceeds 11 [19]. [15] stated that acidic water that has pH below 5.5, can hinder fish growth and reproduction thus maintaining pH levels between 6.5 and 7.0 is crucial in freshwater aquaculture to support fish survival and reproduction. According to [20] suggest that fish thrive best in ponds with a pH near 7.0, and ponds with pH levels below 6.0 may lead to growth inhibition or decreased production of fish. pH serves as a key factor for microorganisms' growth and aids in assessing whether the water provides a suitable environment for fish, plants and algae [5]. The average blood pH of fish is 7.4 and generally between 7.0 to 8.5 are optimal for fish life [15]. Methods such as adding gypsum or organic matter can lower elevated pH levels, while low level of pH can be fixed by applying quick lime [17]. The pH level of natural water is influences by the presence of carbon dioxide, an acidic gas that can lead to higher acidity and can affect fish culture [14]. Other studies conducted in other locations showed that fish mortality occurs at pH levels of 2 and 11 [13]. The lowest values obtained in the study was 3.72 ± 0.03 and a possible explanation for this phenomenon is the regular rainfall is gradually acidic because of industrial air pollutants in various global regions as stated by [13]. Other than that, when chlorine dissolved in water, it creates a weak acid that could potentially alter the water's pH. Overall, the pH levels recorded in this study did not appear to negatively affect the health of the fish. Although the pH of 6 is generally deemed safe for fish habitats, certain species may experience reduced productivity, as fish growth rates is preferred in moderately alkaline environments. Algae activity is also influenced by pH, with higher productivity observed in the range of pH 7.5-9 and this clarifies why productivity of fish is more conducive within this pH range compared to values lower than 6 [13]. The fluctuations in photosynthesis rate due to the daily photoperiod can cause daily pH fluctuations and the carbon dioxide accumulation during the night can cause the pH to fall [15]. The process might account for the low pH values in certain ponds investigated in this study. Signs of low pH include fish exhibiting excessive mucus on their gills, abnormal swimming patterns, fin deterioration, eye lens damage, and poor growth of phytoplankton and zooplankton [12].

It was found that the turbidity values in this study were significantly different across the 25 earthen ponds ($p < 0.05$) and ranged from 6.77 ± 0.16 NTU at Pond 22 to 483.22 ± 40.41 NTU at Pond 1 (Figure 5).

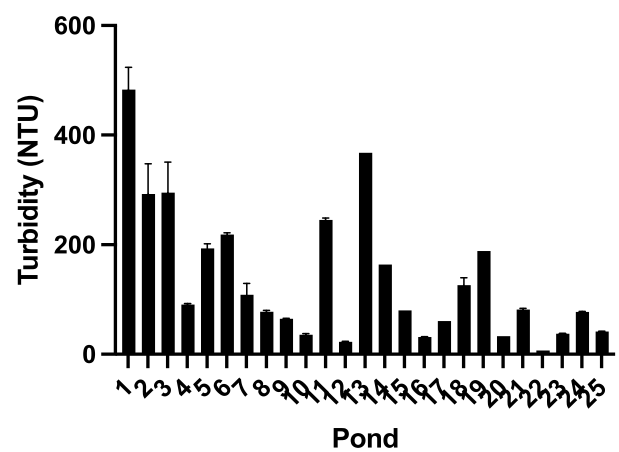

Figure 5 The turbidity values (NTU) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

The turbidity in this study was within the acceptable limit set by NWQS (5-5000 NTU). Turbidity is the cloudiness intensity of water due to suspended particles [10] which can hinder the sunlight penetration in the pond. This problem makes it challenging for the aquatic habitats, particularly algae which rely on light for photosynthesis to gain the advantageous light effects [22]. The turbidity findings from this study resembled those of [4] who documented turbidity values ranging from 5 NTU to 170 NTU in their studies. [23] reported a lower turbidity value which range from 20 to 72 NTU compared to this study. Excessive turbidity can lead to a reduction in sunlight absorption in the pond which then will potentially causing fish mortality. High turbidity levels might be attributed to inadequate management of facilities, leading to the accumulation of unwanted debris in the fish pond and irregular replacement of the pond's water source could contribute to the accumulation of fish waste. Turbidity resulting from effluent discharge into water bodies may also inhibit the photosynthesis of organisms that involved in the phytoremediation of contaminated water [10].

The conductivity in this study were significantly different across the 25 earthen ponds ($p < 0.05$) and were ranged from 0.03 ± 0.00 µS/cm (Pond 13) to 215.10 ± 0.35 µS/cm (Pond 5) (Figure 6).

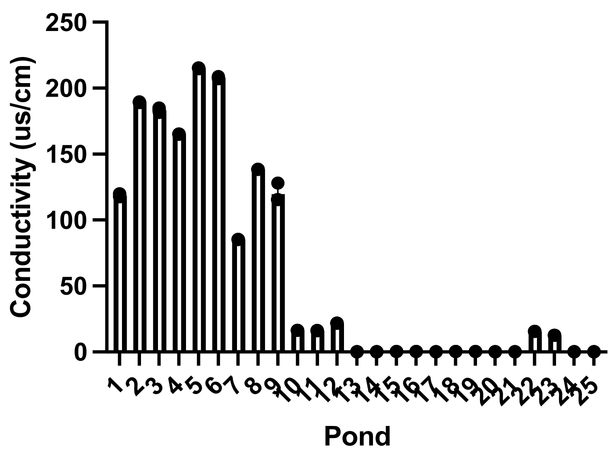

Figure 6 The conductivity values (µS/cm) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

Based on the NWQS standard for fishery, the conductivity in this study were all in the range which means that the conductivity in the ponds is suitable for fish production. Conductivity is a parameter for assessing electrical conductivity which involves measuring the capacity of water ions to conduct electricity, offers valuable information about the mineral composition of the water [24]. The evaluation depends on the cations and anions abilities to conduct the electric current within the water sample, serving as an indicator where higher electrical conductivity values correspond to increased cation and anion abilities. The conductivity relies on both the quantity and mobility of dissolved ions. The higher temperature signifies a higher mineral content in the water, contributing to an increased ability to conduct electricity. According to [24], the usual conductivity in freshwater aquaculture is 0–5000 µS/cm. Higher conductivity value might be because of discharge of pollutants into the pond [5]. This indicates the presence of minerals from fish and feed waste, thereby impacting dissolved particles and elevating pond conductivity. Conductivity in aquatic environments is affected by soil composition or the underlying bedrock of a river [25]. The variation in conductivity readings among the 25 ponds may come from the underlying bedrock material beneath the ponds, influenced by a combination of natural factors and human activities. Before constructing a fish pond, it is important to take into account the rock type and soil composition of the location, as optimum conductivity levels differ among fish species [15]. Conductivity values exceeding 100 µS/cm indicate human activity. [25] proposed an ideal water conductivity range between 150 to 500 µS/cm for fish culture, while [26] broadened the acceptable range to 100 to 2000 µS/cm. Water conductivity is influenced by its ionic concentration, temperature, and dissolved solids. Elevated conductivity levels typically signify pollution [14].

The TDS in this study were significantly different across the 25 earthen ponds ($p < 0.05$) and were ranged between 10.45 ± 0.01 mg/L (Pond 11) to 10137.17 ± 0.02 mg/L (Pond 22) (Figure 7) where most of the reading were below the range and only two ponds (Pond 22 and Pond 23) were above the acceptable limit. The values of the TDS in this study were outside of the NWQS range (500-1000 mg/L) which shows a tendency to increase as the fish harvesting progresses. TDS serves as a measure of dissolved organic and inorganic substances in a given water sample, encompassing all solids, mainly mineral salts, dissolved in water [27]. The elevated conductivity and TDS levels in the Pond 22 and 23 may be attributed to groundwater serving as the water source for the ponds, the absence of phytoplankton and aquatic vegetation to absorb mineral salts and the influence of residual feed in the water. The decomposition of residual feed likely contributed additional mineral salts to the water, particularly in the intensive culture system implemented in the two ponds. Conversely, the existence of algae and macrophytes in the ponds, which utilize salts and rainwater as their water sources, might elucidate the marginally lower levels of conductivity and TDS in the other earthen ponds [27].

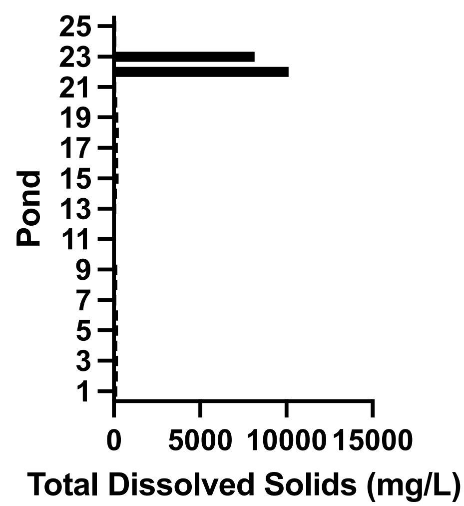

Figure 7 The concentration of TDS (mg/L) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

Ammonia levels in this study were ranged between 0 mg/L (Pond 16 and 24) to greater than 3.5

mg/L (Pond 18) (Figure 8) and the differences were statistically significant ($p < 0.05$).

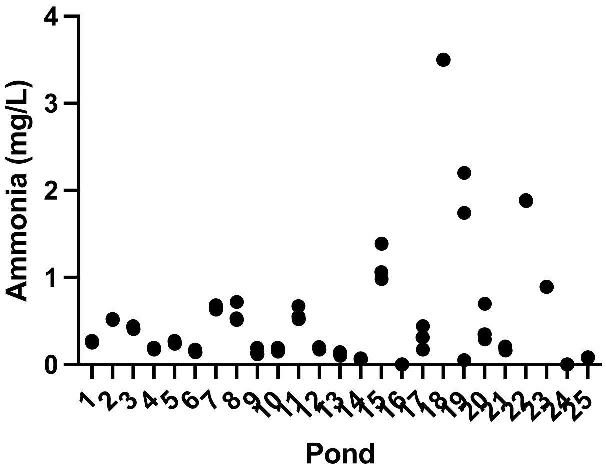

Figure 8 The concentration of ammonia (mg/L) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

The values recorded in Ponds 15, 18, 19 and 22 were above the limit while Ponds 16, 24 and 25 were below the limit as stated by NWQS (0.1-0.9 mg/L). The ammonia level was visibly increase corresponding to the intensification of production. A study conducted by [7] recorded average value of ammonia 1.55 mg/L and this were considered critical and lethal and are unsuitable for production due to potential toxicity to the species, leading to intoxication and mortality issues. A study done by [28] in tilapia pond recorded an average of 2.07 mg/L, categorizing it as ideal for tilapia production in ponds and emphasized that prolonged exposure of tilapia to fluctuating ammonia levels can cause high fish death rates or increased susceptibility to diseases. Ammonia enters the ponds as by-product of fish protein metabolism and through the bacterial breakdown of organic matter, such as leftover food, feces and dead plankton [31] [10]. Ammonia level greater than 0.1 mg/L could cause damage to fish gills, weakened immune system, poor coloration change, reduced growth, and compromised mucous membrane production [10]. However, [29] observed that a value of 0.6 mg/L of unionized ammonia can prove lethal to fish, even with brief exposure, while long exposure to concentration as low as 0.06 mg/L can lead to gill and kidney damage and hinder growth. Concentrations of ammonia exceeding 0.1 mg/L can lead to gill damage, harm mucous-producing membranes, poor growth, inefficient feed conversion and weakened resistant to disease [31]. Other researchers suggested the maximum recommended limit for ammonia level in aquatic organisms is 0.1 mg/L [30] while [31] stated that ammonia concentration below 0.2 mg/L for pond fishery. Ammonia in fish pond can be managed by improving pond aeration, conducting frequent water changes and incorporating quicklime [15].

In the present study, phosphate values were significantly different across the 25 earthen ponds ($p < 0.05$) and were ranged from 0.06 ± 0.03 mg/L (Pond 21) to 4.52 ± 0.04 mg/L (Pond 4) (Figure 9).

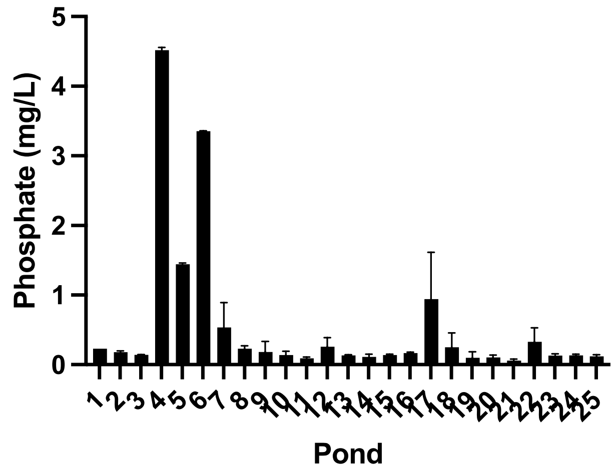

Figure 9 The concentration of phosphate (mg/L) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

The phosphate values in this study were all in the range of 0.10 to 0.20 mg/L as stated by NWQS except for Pond 1, 4, 5, 6, 7, 8, 12, 17, 18 and 22 that were above the NWQS limit. These high phosphate levels might come from the specific type of fish feed used in the pond or from surface run off. Phosphorus is among the 20 inorganic minerals that constitute approximately 1.0% - 2.5% of the fish diet [32]. This study revealed similar findings with study conducted by [4] who recorded phosphate levels ranging from 1.40 mg/L to 4.51 mg/L in their study. The lower phosphate values in this study may be attributed to factors such as the type of fish feed added to the pond, surface runoff, or the materials used in constructing the ponds [5]). Elevated phosphate concentrations could induce algal blooms, leading to fish mortality in the pond. Fish could accumulate phosphate in their organs and upon death, they discharge the phosphate into the water, fostering the proliferation of new algae which then lead to algal blooms or eutrophication [5]. Ponds with high phosphate levels often experience issues like green water and blanket weed. [33] stated that phosphate concentrations need to be controlled to restrict algae growth to prevent eutrophication in ponds. According to [12], phosphate levels exceeding 0.4 mg/L and exceeding 1.5 mg/L in fish pond did not helping in enhancing fish pond productivity.

The values of nitrate obtained in this study were significantly different across the 25 earthen ponds ($p < 0.05$) and were ranged from 0.01 ± 0.00 mg/L (Pond 13, 22 and 24) to greater than 3.5 mg/L (Pond 18 and

19) (Figure 10), consistently below the maximum acceptable limit of 7 mg/L stated by NWQS. The lower level of nitrate might be because of no eutrophication [13]. These findings were similar to study by [4], who recorded nitrate levels of 2.21 mg/L to 4.91 mg/L. Nitrate identified as a skin irritant and can induce symptoms of irritability in fish, including rubbing their bodies, jumping, and gliding over the pond's surface. Elevated nitrate concentrations trigger the bloom of algae, while nitrate deficiency enhances the lipid content in algae, consequently impacting the water ecosystem [13]. [5] highlighted that high nitrate concentrations hinder the oxygen absorption from water by the blood cells, resulting in a dull brown coloration of blood, a phenomenon commonly known as nitrite poisoning. Ingested nitrate diminishes haemoglobin's oxygen-carrying capacity [34]. Although the nitrate levels in the pond waters were in the range of permissible range for aquaculture, it is crucial to note that this range may still exceed and lead to eutrophication due to the influence of other contributing factors.

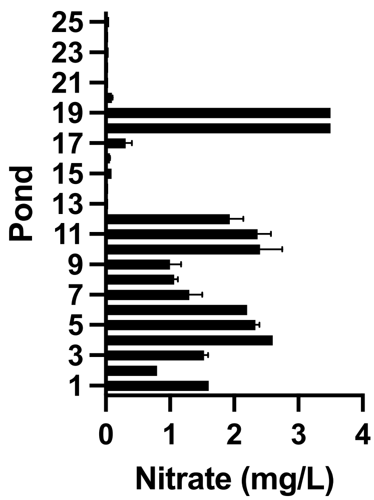

Figure 10 The concentration of nitrate (mg/L) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

The values of nitrite in this study were significantly different across the 25 earthen ponds ($p < 0.05$) and were ranged between 0.003 ± 0.002 mg/L (Pond 14) to 3.5 mg/L (Pond 18 and 19) (Figure 11). All the ponds were within the acceptable limit for fish production except for Pond 18 and 19. Nitrite a nitrogenous compound and intermediary product resulting from feeding and the conversion of ammonia into nitrate through bacterial activity, can pose risks to aquatic organisms [12]. Elevated carbon dioxide levels may decrease the pH below 6.5, causing nitrite toxicity due to the formation of nitrous acid. Nitrites have been found to be harmful or lethal to aquatic organisms at concentrations of 2 mg/L and above [12]. In aquaculture water, nitrite is typically an intermediate product in the nitrification process [35]. In pond, significant quantity of nitrogen enters the water via fish feeds, as majority of fish feed contain 32% to 45% protein [36]. However, nitrite tends not to accumulate in water bodies as it is rapidly converted into nitrate. Furthermore, ammonia assimilation by phytoplankton and other aquatic plants restricts the availability of ammonia for nitrification, thereby reducing nitrite production. The nitrite level in aquaculture pond is typically low, with an acceptable range below 0.1 mg/L [15]. Considering the specificity of certain parameters for the fish growth, it is crucial to maintain optimal physicochemical levels throughout the entire fish culture process in pond.

Analysing water quality is an essential aspect of environmental monitoring to maintain the overall health and sustainability of the planet. Poor water quality not only impacts aquatic organisms but also affects the surrounding ecosystem. As urban development, agricultural, aquaculture and various alterations to the natural environment are made, water quality monitoring becomes very crucial.

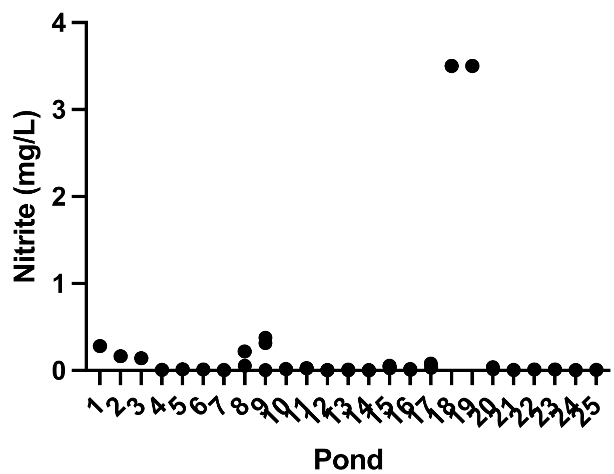

Figure 11 The concentration of nitrite (mg/L) obtained in the aquaculture commercial ponds at Kuching, Bau and Samarahan

4.0 CONCLUSION

The assessment of sensitive physicochemical water parameters in aquaculture ponds in Southern Sarawak revealed that majority of the parameters were within acceptable levels and were considered tolerable in fish production, even though they have tendency to increase as the production progresses.

Parameters such as DO, pH, TDS, ammonia, phosphate and nitrite levels exceeded the acceptable limit in certain pond, indicating a need for more cautious management to maintain them at optimal levels during the whole process of fish farming in ponds. It is also advisable for farmers to equipped themselves with standard practices related to waste reduction management of pond, feeding and environmental conservation. The results of this research highlight that consistent monitoring of water parameters offers valuable insights into the health of aquatic ecosystems, providing crucial knowledge for effective management and monitoring strategies in aquaculture ponds. This is to increase fish quality, productivity and to guarantee the great wellbeing of the aquatic ecosystem as well as the human itself.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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