



EVALUATION OF PHYSICOCHEMICAL PARAMETERS IN FISH FARMS IN NSUKKA LOCAL GOVERNMENT AREA, ENUGU STATE

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Abstract

This study evaluated the physicochemical parameters in fish farms in Nsukka Local Government Area of Enugu state. The study adopted a descriptive survey design while multistage sampling techniques was used. The study locations were from the three zones of Nsukka Local Government namely; Nsukka East, Nsukka Central and Nsukka West. Water samples for physicochemical parameters were collected six times each from the eighteen fish farms across the three zones of Nsukka Local Government Area and three autonomous communities in an interval of one month. Seven physicochemical parameters namely ammonia, dissolved oxygen, turbidity, nitrate, nitrite, temperature and hydrogen ion concentrations were studied using standards laboratory procedures. The water sample for physicochemical parameters were collected at a depth of about 5-10 cm from the pond with 250 ml and 500 ml sample bottles at the various ponds monthly for six months. Data were analyzed using t-test and ANOVA. Results showed that there were no significant ($p > 0.05$) differences in the physicochemical parameters monthly variations, except for dissolved oxygen and temperature that varied significantly ($p < 0.05$) in some months. The level of dissolved oxygen in October (6.64 ± 0.93 ppm) was significantly ($p < 0.05$) higher than the levels observed in March (5.46 ± 1.34 ppm). The temperature level recorded in December (27.00 ± 0.62 °C) was significantly ($p < 0.05$) lower than what was recorded in October (27.95 ± 0.74 °C), February (28.03 ± 0.61 °C) and March (28.40 ± 0.48 °C). Also, there were no significant ($p > 0.05$) differences in their monthly variations of ammonia, dissolved oxygen, turbidity, nitrite, pH; however, the variations of nitrate and temperature showed significant difference ($p < 0.05$). Whereas, nitrate level was significantly ($p < 0.05$) higher in Nsukka West (0.37 ± 0.20 mg/L), temperature was significantly ($p < 0.05$) higher in Nsukka East (28.23 ± 0.79 °C). Temperature, pH, dissolved oxygen and turbidity have high level of association with pond water change ($r = 0.676^{**}$). It is recommended that regular monitoring of physicochemical parameters should be adopted in order to ensure water quality.

Keywords: Parameter, Physicochemical Parameters, Fish Farms

INTRODUCTION

The word Physicochemical parameters means physical and chemical parameters. Water physicochemical parameters are indices used in determining water quality. These parameters encompass a wide range of physical and chemical characteristics, including temperature, pH, dissolved oxygen (DO), turbidity, ammonia, nitrate, nitrite etc. Water quality includes all physical, chemical and biological factors that influence the beneficial use of water. A good water conditions is a necessity for the survival and growth of the fish, since the entire life process of the fish wholly dependent of the quality of its environment.

The sun is the primary energy source on earth; the sunlight brings solar energy to ponds, which is absorbed, warming up the water mass. The low thermal conductivity of water restricts the heat to the upper water layers. Evaporation of water and diffusion of gases in solution in the water cause heat losses (Kasim, 2017). Temperature is known to affects the behavior, feeding growth and production of fish in general. It has pronounced effects on chemical and biological process. The rate of chemical and biological reaction of every 10 °C increase in temperature, Fishes are known to have poor tolerance to sudden changes in temperature (Body and Lichtkoppler, 1979). Therefore, fish farmers, should not suddenly thrust them into a water of appreciably higher or lower temperature (Kasim, 2017).

Fish readily tolerate gradual changes in temperature. For example, fish farmer could raise the temperature from 25°C to 32°C over several hours without harming the fish, Badiru (2005) as cited by Kasim, 2017. Laboratory mercury in glass thermometer can be used to detect the temperature of the fishpond water, so that action can be taken to reduce or increase the water temperature as the case may be. The optimal temperature range of 25 - 32°C should be maintained at all time. Temperature is a factor of great importance for aquatic ecosystems, as it affects the organisms as well as the chemical and physical characteristic of water. For example, the metabolism of cold-blooded organisms is dependent on temperature, as are the solubility of dissolved oxygen, and the density and viscosity of water. Therefore, there is a need to keep pond water within some range, avoiding temperature which is either too high or too low, and agreement with the temperature requirements of cultured organisms (Kasim, 2017).

pH is a measure of the hydrogen-ion concentration and indicates whether the water is acidic or basic in reaction. pH meter is used to determine the pH level of water. The pH-scale ranges from 0 to 14, with pH 7 the neutral point. Thus, a water of pH 7 is neither acidic nor basic, while water with pH below 7 is acidic and one with a pH above 7 is basic. The greater the departure from pH 7, the more acidic or basic of the water (Boyd, 1979). pH is important as a measure of the acidity of the fish pond water. pH affects many chemical and biological processes in the water. It is known to influence the toxicity of certain chemicals like ammonia, sulfides and cyanide in water (Kasim, 2017). Many aquaculture research scientists agreed that fresh waters with alkaline pH have potential to be productive and suitable for fish culture (Kasim, 2017). Acid waters (pH below 6.5) will not have good plankton growth and so will not be productive. Generally, fresh water fish cannot survive in waters below pH 4 and above pH 11 for long period. The optimum pH for fish is between 6.5 and 9 (Boyd, 1979).

Dissolved oxygen is one of the key factors of life. Oxygen is much more important to aquatic than terrestrial life (Badiru, 2005). As oxygen has low solubility in water and is often a limiting factor for life in water (Boyd, 1979). Some species are able to breathe the atmospheric oxygen, by surfacing and gulping air, and do not rely entirely on oxygen dissolved in water. However, oxygen is also needed for all oxidation, nitrification, and decomposition processes. Its presence in good quality in fish pond will improve the water quality in fish pond by oxidizing poisonous gases such as ammonia, carbon dioxide, etc into their non-poisonous forms like ammonium salt, carbonate, and bicarbonate. Low dissolved oxygen level can be deadly, resulting in acute fish anoxia and reduces fecundity, thereby, preventing spawning and egg hatchability. It also retards growth of embryo, juveniles and lead to eventual mortality (Kasim, 2017).

There are three major factors that influence level of dissolved oxygen in fish pond (Boyd et al, 1978) as cited by (Kasim, 2017). These are: Temperature: Oxygen solubility in fish pond water decrease with increasing temperature and increasing salinity. Photosynthesis: The magnitude of daily changes in oxygen concentration in fish pond water influenced by phytoplankton density. Oxygen is lowest at sunrise, before photosynthesis becomes active, increase during the daylight hours to peak in late afternoon or early evening, and declines at night and Respiration by Zooplankton: Fish and benthic organisms and decomposition of organic matter.

The term turbidity indicates that a water contains suspended materials which intense with the passage of light. In fish pond, turbidity which results from planktonic organism is a desirable trait, whereas that cause by suspended clay particles is undesirable. Even with the latter condition, the clay particles are seldom abundant enough in water to directly harm fish (Boyd, 1979). The clay particles which remain in suspension restrict light penetration and limit the growth of plants in the pond. Turbidity is also an important water quality, which a fish farmer has to control. Turbid water has many particles suspended in it. These may also be plankton or suspended solid (Silt, clay/mud). It is therefore a measure of water transparency. Turbidity caused by plankton is not harmful to fish as and so beneficial to fish growth. Turbidity caused by suspended soil particles has direct effects on fish, but it restricts the amount of light penetrating the water and limit the photosynthesis and production of dissolved oxygen (Kasim, 2017). The best practical technique for measuring turbidity in fish pond water is the Secchi-disk. This is the depth at which a disc 20 cm in diameter with alternate black and white quadrants disappears from view. A Secchi-dish transparency in the 30 cm to 60 cm range is generally adequate for good fish production (Kasim, 2017).

Ammonia is a toxic compound produced by aquatic organisms' metabolic processes, decomposing organic matter and nitrogen-rich waste. Ammonia is measured in milligram per liter (mg/L). Ammonia reaches pond water as a product of fish metabolism and decomposition of organic matter by bacteria, in water, ammonia nitrogen occurs in two forms; un-ionized ammonia (NH_3) and ammonium ion (NH_4^+). Un-ionized ammonia is toxic to fish, but the ammonium ion is harmless except at extremely high concentration. The acceptable value of ammonia in aquaculture ranges from 0.00-0.01. The level above 0.2 mg/L will indicate harmful conditions for the fish. The toxic level of unionized ammonia for short term exposure usually lies between 0.6 and 2.0 mg/liter for pond fish. The greatest concentration of total ammonia nitrogen usually occurs after phytoplankton die off at which time pH is low because of the high concentration of CO_2 (Kasim, 2017).

Nitrates (NO_3) are form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. It is commonly byproduct of ammonia oxidation and organic matter decomposition. Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems that can lead to corrosion of the ponds. The acceptance values of Nitrate in water range from 0.10-0.50 mg/L. The level of nitrate above 0.10 mg/L will indicate excessive nutrient which will harm the fish and affect water quality (Kasim, 2017). Nitrate affect nitrate levels which reflect nitrogen cycle efficiency, promote algae growth, reduced growth and influence biofilm formation. There is need to monitor nitrate levels regularly, maintain optimal biological filtration, reduce nitrogen-rich waste and implement water circulation (Kasim, 2017).

Nitrite are toxic compound formed during the nitrogen cycle. Spectrophotometer will be used to determine the nitrite of the water. The level of nitrite above 0.03 mg/L will indicate harmful condition which will affect the fish. The effects of nitrite in Aquaculture reduces oxygen availability and damage kidneys, live and gills of aquatic organism (fish).

The physicochemical parameters of fish farm environments are essential for maintaining optimal conditions for fish growth and health. Factors such as water temperature, pH, dissolved oxygen levels, ammonia, turbidity, nitrate and nitrite directly influence the well-being of the fish. In evaluating these parameters within fish farms in Nsukka, a researcher identified differences

from ideal conditions and recommend management strategies to mitigate potential risks to fish health and productivity.

OBJECTIVES

The objectives of the study are:

1. to determine the physicochemical parameters (temperature, pH, dissolved oxygen, turbidity, ammonia, nitrate, nitrite) of fish ponds in Nsukka Local Government Area of Enugu state.
2. to investigate the relationship between the physicochemical parameters in Nsukka Local Government Area of Enugu state.
3. to explore potential mitigation strategies for addressing the challenges associated with physicochemical parameters in fish farming in Nsukka Local Government Area of Enugu state.

MATERIALS AND METHOD

Nsukka Local Government Area is one of the seventeen local government areas (L.G.A.) that make up Enugu State, South-East Nigeria. Nsukka Local Government Area lies approximately between Latitude 6.86'N, and 7.39'E with an area of 1,820 km². Towns and villages that make up Nsukka Local Government Area include; Ede-Oballa, Nsukka (Nkpunanor, Ihe-owerre, Nru, Echara, Umakashi, Nguru, Isi-Akpu), Lejja, Opi, Eha –Alumona, ALor Uno, Obukpa, Ibagwa Ani, Okpuje, Okutu and Anuka. The study adopted a descriptive survey design and multistage sampling techniques was used. Water samples for physicochemical parameters were collected six times each from the eighteen fish farms across the three zones of Nsukka Local Government Area and three autonomous communities in an interval of one month. The water sample for physicochemical parameters were collected at a depth of about 5-10cm from the pond with 250ml and 500ml sample bottles at the various ponds monthly for six months. Data resulting from the tests of physicochemical parameters of the sampled fish ponds was analyzed using t-test, one-way Analysis of Variance (ANOVA).

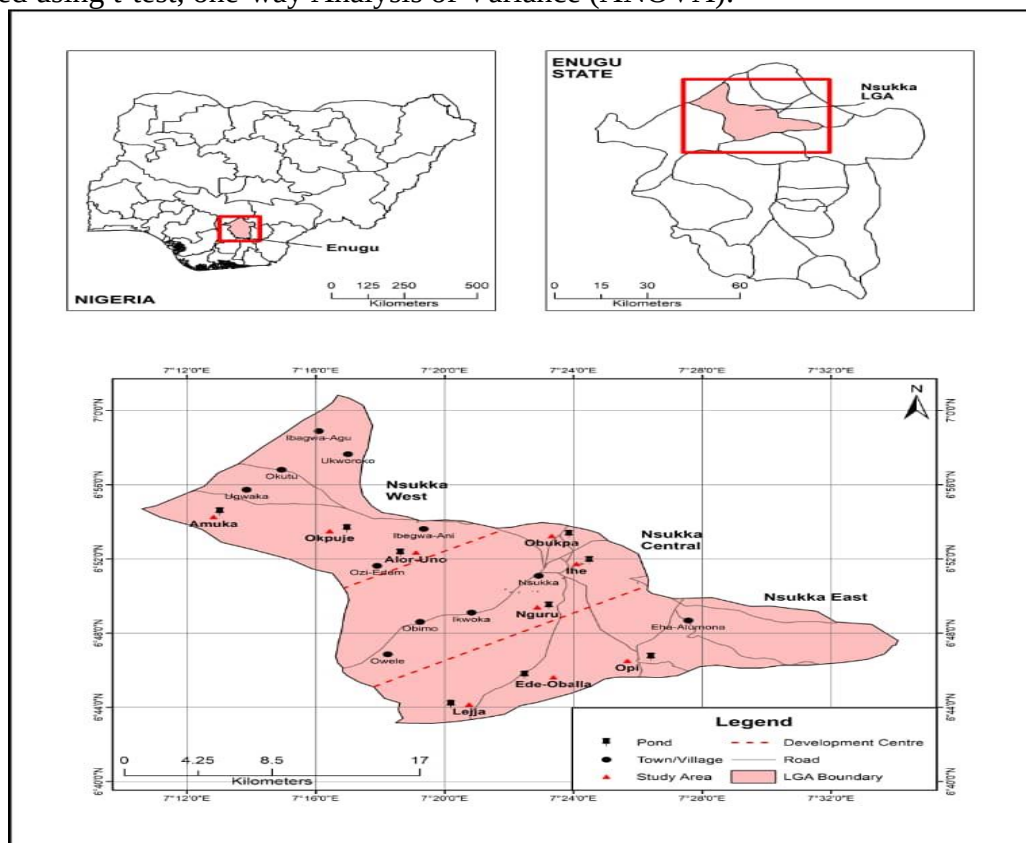


Figure 4: Map of Nsukka Local Government Area showing the Sample Communities

Determination of water pH

Hannah digital field meter was used to take the pH of the water at the site of the sampling. The electrode of the meter was thoroughly rinsed with the river water before dipping into the pond water to read the pH. The reading was taken after stabilization within 1-3 minutes. The pH value displayed was recorded after the reading was stable; (APHA, 1999). pH level includes: Acidity: 0-6.9, Neutral: 7.0 and Basic/Alkaline 7.1-14.

Determination of water temperature

The measurement of the Temperature was done *in situ* of the sampling with the aid of a Digital Thermometer. The probe of the instrument was dipped into the water and allowed in the water undisturbed for about 2 to 3 minutes in other for the equilibration of the temperature. Reading was taken as steady temperature was attained. The temperature value displayed was recorded after the reading was stable (APHA, 1999).

Determination of dissolved oxygen (DO)

The Dissolved Oxygen Metre (Hanna) was used for the determination of Dissolved Oxygen. The probe of the DO metre was dipped into the pond water and a steady value read out was recorded as the dissolved oxygen in the sample (APHA, 1999).

Determination of ammonia

Spectrophotometer was used to determine the Ammonia of water pond with Nessler's reagent. Sample water was collected from the pond using glass sample bottle 125ml. The sample bottle was dipped into the pond for about 10 to 15cm below the water surface and allow water flows inside the sample bottle. The sample was taken to laboratory for experiments and tested to assess the Ammonia level of the water. Level above 0.2 mg/L indicated harmful conditions for the fish (APHA, 1999).

Determination of turbidity

Secchi was used to determine the transparency of the water. The disc was lowered slowly into the water until it disappears from the view and the depth at which it occurs was taken and recorded. The mean value between the point of disappearance and appearance was recorded as the turbidity (APHA, 1999).

Determination of water nitrate

Sample water was collected from the pond using glass sample botte 125 ml. The sample bottle was dipped into the pond water below the water surface and allow water flows inside the sample bottle. The sample was taken to laboratory for analysis using spectrophotometer at 520-540 nm wavelength (APHA, 1999).

Determination of nitrite

Sample water was collected from the pond using glass sample botte 125ml. The sample bottle was dipped into the pond water below the water surface and allow water flows inside the sample bottle. The sample was taken to laboratory for analysis using spectrophotometer at 540mm wavelength (APHA, 1999).

RESULTS

Physicochemical Parameters of the Ponds

Results for physicochemical parameters were collected and analyzed from the eighteen communities for six months while production practices among fish farmers in the zones were analyzed using questionnaire. Six from each of the three zones; Nsukka Central, Nsukka East and Nsukka West.

Table 1 below showed the variations in the physicochemical parameters of ponds in the studied area according to months studied. The parameters measured included ammonia, dissolved oxygen, turbidity, nitrate, nitrite, temperature and pH. There were no significant ($p > 0.05$) differences in their monthly variations except for dissolved oxygen and temperature that varied significantly ($p < 0.05$) in some months. The level of dissolved oxygen in October (6.64 ± 0.93 ppm) was significantly ($p < 0.05$) higher than the levels observed in March (5.46 ± 1.34 ppm). The temperature level recorded in December (27.00 ± 0.62 °C) was significantly ($p < 0.05$)

lower than was recorded in October (27.95 ± 0.74 °C), February (28.03 ± 0.61 °C) and March (28.40 ± 0.48 °C).

Table 1: Variations in the physicochemical parameters of ponds in the studied area according to months

Month	Physicochemical parameters						
	Ammonia (mg/L)	DO (ppm)	Turbidity (NTU)	Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)	pH
October	0.37 ± 0.21^a (0.11 – 0.83)	6.64 ± 0.93^b (4.21 – 7.83)	22.49 ± 5.40^a (14.00 – 30.00)	0.32 ± 0.14^a (0.11 – 0.52)	0.32 ± 0.15^a (0.12 – 0.61)	27.95 ± 0.74^b (26.25 – 29.00)	5.93 ± 0.80^a (4.82 – 7.00)
November	0.40 ± 0.23^a (0.11 – 0.73)	6.29 ± 1.07^{ab} (4.10 – 7.43)	20.73 ± 4.95^a (12.00 – 26.00)	0.34 ± 0.15^a (0.13 – 0.59)	0.28 ± 0.13^a (0.12 – 0.49)	27.67 ± 1.11^{ab} (25.90 – 29.50)	5.99 ± 0.83^a (4.80 – 7.20)
December	0.30 ± 0.13^a (0.11 – 0.48)	6.29 ± 0.90^{ab} (4.83 – 7.32)	21.14 ± 5.26^a (12.00 – 27.00)	0.26 ± 0.10^a (0.12 – 0.42)	0.30 ± 0.07^a (0.21 – 0.40)	27.00 ± 0.62^a (25.70 – 28.00)	6.06 ± 0.78^a (4.92 – 7.00)
January	0.44 ± 0.29^a (0.12 – 0.99)	6.30 ± 1.09^{ab} (4.21 – 7.35)	21.54 ± 6.04^a (10.00 – 28.10)	0.38 ± 0.22^a (0.10 – 0.80)	0.31 ± 0.19^a (0.11 – 0.63)	27.69 ± 0.76^{ab} (26.63 – 29.35)	6.06 ± 0.62^a (4.95 – 6.95)
February	0.38 ± 0.26^a (0.13 – 0.91)	6.16 ± 1.33^{ab} (3.86 – 7.63)	20.76 ± 6.62^a (10.00 – 28.00)	0.24 ± 0.18^a (0.00 – 0.63)	0.26 ± 0.15^a (0.10 – 0.60)	28.03 ± 0.61^b (26.95 – 29.00)	5.94 ± 0.65^a (4.95 – 6.95)
March	0.47 ± 0.25^a (0.16 – 0.95)	5.46 ± 1.34^a (3.50 – 7.00)	18.54 ± 7.81^a (8.00 – 27.00)	0.35 ± 0.21^a (0.10 – 0.82)	0.36 ± 0.29^a (0.12 – 1.33)	28.40 ± 0.48^b (27.65 – 29.23)	6.11 ± 0.66^a (4.90 – 6.95)

DO: dissolved oxygen; Values expressed as Mean $\pm$ SD; Different superscript letter indicates significant ($p < 0.05$) difference in mean variations of each parameter across months using Tukey B test.

Table 2 below showed the variations in the physicochemical parameters of ponds in the studied area according to zones. There were no significant ($p > 0.05$) differences in their monthly variations of ammonia, dissolved oxygen, turbidity, nitrite, pH; however, the variations of nitrate and temperature showed significant difference ($p < 0.05$). Whereas, nitrate level was significantly ($p < 0.05$) higher in Nsukka West (0.37 ± 0.20 mg/L), temperature was significantly ($p < 0.05$) higher in Nsukka East (28.23 ± 0.79 °C).

Table 2: Variations in the physicochemical parameters of ponds in the studied area according to zones

Nsukka Zone	Physicochemical parameters						
	Ammonia (mg/L)	DO (ppm)	Turbidity (NTU)	Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)	pH
East	0.34 ± 0.24^a (0.11 – 0.90)	6.42 ± 1.04^a (3.91 – 7.63)	22.22 ± 4.83^a (9.00 – 27.00)	0.25 ± 0.17^a (0.00 – 0.66)	0.26 ± 0.21^a (0.10 – 1.33)	28.23 ± 0.79^b (26.50 – 29.50)	6.07 ± 0.76^a (4.80 – 7.20)
Central	0.39 ± 0.18^a (0.13 – 0.80)	6.16 ± 1.09^a (3.82 – 7.51)	20.88 ± 6.41^a (8.00 – 30.00)	0.34 ± 0.15^{ab} (0.11 – 0.70)	0.32 ± 0.12^a (0.11 – 0.61)	27.45 ± 0.80^a (25.70 – 29.00)	5.92 ± 0.71^a (4.83 – 7.00)

West	0.46 ± 0.29^a (0.13 – 0.99)	5.92 ± 1.37^a (3.50 – 7.83)	18.92 ± 6.77^a (8.00 – 28.00)	0.37 ± 0.20^b (0.11 – 0.82)	0.35 ± 0.18^a (0.11 – 0.63)	27.71 ± 0.74^a (26.25 – 29.23)	6.10 ± 0.66^a (4.95 – 7.00)
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DO: dissolved oxygen; Values expressed as Mean $\pm$ SD; Different superscript letter indicates significant ($p < 0.05$) difference in mean variations of each parameter across zones using Tukey B test.

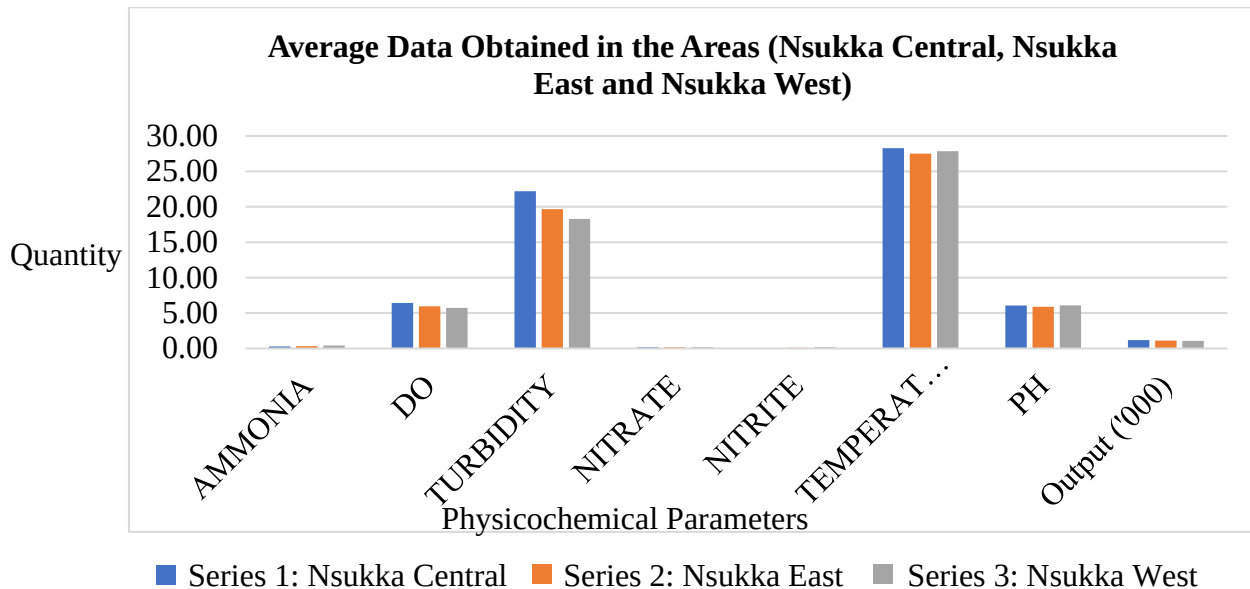


Figure 1: Average Data Obtained in the Areas (Nsukka Central, Nsukka East and Nsukka West)

Table 3 below showed the monthly variations in the physicochemical parameters of ponds in the studied area according to zones. There were no significant ($p > 0.05$) differences in their monthly variations, except for temperature level that showed significantly higher ($p < 0.05$) value in Nsukka East in October (28.17 ± 0.47 °C), November (28.74 ± 0.76 °C), January (28.36 ± 0.69 °C) and March (28.66 ± 0.39 °C) when compared to other zones. Nsukka Central had a significantly ($p < 0.05$) lower dissolved oxygen in March (4.86 ± 1.02 mg/L) than other months. Temperature level in Nsukka West was significantly ($p < 0.05$) higher in March (28.62 ± 0.56 °C) than other months. Similarly, the temperature level was significantly ($p < 0.05$) lower in Nsukka East (26.99 ± 0.39 °C) and Nsukka Central (26.68 ± 0.69 °C) in December, when compared to levels observed in other months.

DO: dissolved oxygen; Values expressed as Mean $\pm$ SD; Different superscript letter indicates significant ($p < 0.05$) difference in mean variations of each parameter across zones for each month, while different superscript number indicate significant ($p < 0.05$) difference in mean variations of each parameter months for each zone using Tukey B test.

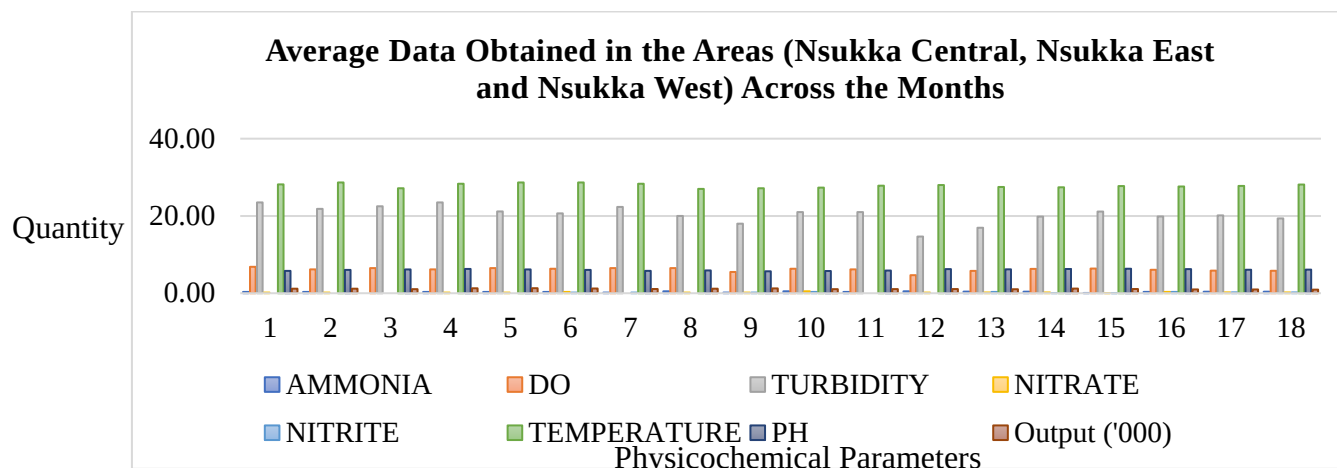


Figure 2: Average Data Obtained in the Areas
(Nsukka Central, Nsukka East and Nsukka West) Across the Months

Relationship Between Physicochemical Conditions

The results in the Table 4 show that there are strong positive correlations which indicate that high levels of ammonia are associated with high levels of nitrate, indicating a potential nitrogen cycle imbalance ($r = 0.873^{**}$). Also, the results indicate that high levels of ammonia are associated with high levels of nitrite, suggesting a possible link to nitrogenous waste production ($r = 0.779^{**}$). In addition, the results show that high levels of nitrate are associated with high levels of nitrite, indicating as well a potential nitrogen cycle imbalance ($r = 0.779^{**}$). The results show that the Dissolved Oxygen (DO) has high level of association with turbidity ($r = 0.676^{**}$) and the pH ($r = 0.514^{**}$) respectively suggesting a possible link to phytoplankton growth and photosynthesis and respiration processes across the concerned fish ponds. The results also reveal that high levels of dissolved oxygen are associated with high pH levels, indicating a potential link to photosynthesis and respiration processes across the examined fish ponds at Nsukka central, Nsukka east and Nsukka west ($r = 0.514^{**}$). And that high levels of turbidity are associated with high pH levels, suggesting a possible link to phytoplankton growth and photosynthesis ($r = 0.519^{**}$). The possible practical implications of these associations indicate that high levels of ammonia association with low levels of dissolved oxygen (DO) and high levels of nitrite can lead to ammonia toxicity, which can cause stress, reduced growth rates, and increased mortality in fish. Too, that extreme pH fluctuations can also cause stress, reduced growth rates, and increased mortality in fish.

Table 3: Monthly variations in the physicochemical parameters of ponds in the studied area according to zones

Month	Nsukka Zone	Physicochemical parameters						
		Ammonia (mg/L)	DO (ppm)	Turbidity (NTU)	Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)	pH
October	East	0.34 ± 0.26 ^{a1}	6.85 ± 0.53 ^{a1}	23.53 ± 4.20 ^{a1}	0.24 ± 0.18 ^{a1}	0.25 ± 0.18 ^{a1}	28.17 ± 0.47 ^{b2}	5.78 ± 0.80 ^{a1}
	Central	0.35 ± 0.13 ^{a1}	6.72 ± 0.84 ^{a2}	23.14 ± 6.18 ^{a1}	0.35 ± 0.10 ^{a1}	0.31 ± 0.13 ^{a1}	28.22 ± 0.70 ^{b4}	5.95 ± 0.94 ^{a1}
	West	0.47 ± 0.27 ^{a1}	6.17 ± 1.54 ^{a1}	19.78 ± 6.05 ^{a1}	0.38 ± 0.12 ^{a1}	0.44 ± 0.16 ^{a1}	27.16 ± 0.71 ^{a1}	6.10 ± 0.68 ^{a1}
November	East	0.34 ± 0.25 ^{a1}	6.30 ± 1.09 ^{a1}	21.87 ± 4.16 ^{a1}	0.27 ± 0.15 ^{a1}	0.19 ± 0.08 ^{a1}	28.74 ± 0.76 ^{b2}	6.03 ± 0.96 ^{a1}
	Central	0.45 ± 0.20 ^{a1}	6.47 ± 0.95 ^{a2}	20.57 ± 5.04 ^{a1}	0.41 ± 0.13 ^{a1}	0.35 ± 0.09 ^{a1}	26.87 ± 0.84 ^{a12}	5.75 ± 0.83 ^{a1}
	West	0.41 ± 0.27 ^{a1}	6.00 ± 1.41 ^{a1}	19.25 ± 6.75 ^{a1}	0.33 ± 0.19 ^{a1}	0.32 ± 0.18 ^{a1}	27.25 ± 0.50 ^{a1}	6.37 ± 0.69 ^{a1}
December	East	0.25 ± 0.15 ^{a1}	6.56 ± 0.96 ^{a1}	22.55 ± 4.72 ^{a1}	0.21 ± 0.10 ^{a1}	0.26 ± 0.05 ^{a1}	26.99 ± 0.39 ^{a1}	6.15 ± 0.96 ^{a1}
	Central	0.36 ± 0.12 ^{a1}	5.94 ± 1.04 ^{a12}	20.17 ± 5.85 ^{a1}	0.28 ± 0.10 ^{a1}	0.35 ± 0.04 ^{a1}	26.68 ± 0.69 ^{a1}	5.85 ± 0.73 ^{a1}
	West	0.27 ± 0.11 ^{a1}	6.40 ± 0.56 ^{a1}	20.50 ± 6.14 ^{a1}	0.31 ± 0.07 ^{a1}	0.29 ± 0.09 ^{a1}	27.50 ± 0.58 ^{a12}	6.27 ± 0.70 ^{a1}
January	East	0.31 ± 0.24 ^{a1}	6.24 ± 1.17 ^{a1}	23.58 ± 3.51 ^{a1}	0.25 ± 0.18 ^{a1}	0.22 ± 0.11 ^{a1}	28.36 ± 0.69 ^{b2}	6.28 ± 0.72 ^{a1}
	Central	0.48 ± 0.21 ^{a1}	6.45 ± 1.02 ^{a2}	21.67 ± 6.33 ^{a1}	0.44 ± 0.19 ^{a1}	0.34 ± 0.20 ^{a1}	27.18 ± 0.44 ^{a123}	5.85 ± 0.35 ^{a1}
	West	0.57 ± 0.45 ^{a1}	6.12 ± 1.35 ^{a1}	18.25 ± 8.42 ^{a1}	0.46 ± 0.29 ^{a1}	0.39 ± 0.26 ^{a1}	27.73 ± 0.72 ^{ab12}	6.10 ± 0.86 ^{a1}
February	East	0.38 ± 0.30 ^{a1}	6.39 ± 1.50 ^{a1}	21.08 ± 6.41 ^{a1}	0.22 ± 0.25 ^{a1}	0.20 ± 0.13 ^{a1}	28.45 ± 0.58 ^{a2}	6.16 ± 0.48 ^{a1}
	Central	0.32 ± 0.18 ^{a1}	6.33 ± 0.96 ^{a12}	21.67 ± 6.15 ^{a1}	0.22 ± 0.07 ^{a1}	0.29 ± 0.12 ^{a1}	27.67 ± 0.48 ^{a234}	5.83 ± 0.75 ^{a1}
	West	0.49 ± 0.33 ^{a1}	5.53 ± 1.78 ^{a1}	18.75 ± 9.07 ^{a1}	0.31 ± 0.23 ^{a1}	0.31 ± 0.23 ^{a1}	28.01 ± 0.53 ^{a12}	5.84 ± 0.77 ^{a1}
March	East	0.44 ± 0.29 ^{a1}	6.16 ± 1.07 ^{a1}	20.68 ± 6.61 ^{a1}	0.33 ± 0.22 ^{a1}	0.46 ± 0.45 ^{a1}	28.66 ± 0.39 ^{b2}	6.04 ± 0.80 ^{a1}
	Central	0.42 ± 0.21 ^{a1}	4.86 ± 1.02 ^{a1}	17.42 ± 9.45 ^{a1}	0.32 ± 0.19 ^{a1}	0.27 ± 0.09 ^{a1}	28.00 ± 0.22 ^{a34}	6.30 ± 0.63 ^{a1}
	West	0.57 ± 0.29 ^{a1}	5.32 ± 1.89 ^{a1}	17.00 ± 8.29 ^{a1}	0.44 ± 0.26 ^{a1}	0.35 ± 0.21 ^{a1}	28.62 ± 0.56 ^{b2}	5.91 ± 0.55 ^{a1}

Table 4: Correlation Matrix

	Ammonia	Do	Turbidity	Nitrate	Nitrite	Temperature	pH	Live Weight of Matured Fish
Ammonia	1	-0.776**	-0.717**	0.873**	0.779**	0.294**	-0.641**	-0.217*
Do	-0.776**	1	0.676**	-0.666**	-0.593**	-0.315**	0.514**	0.209*
Turbidity	-0.717**	0.676**	1	-0.629**	-0.643**	-0.327**	0.519**	0.134
Nitrate	0.873**	-0.666**	-0.629**	1	0.783**	0.19	-0.502**	-0.211*
Nitrite	0.779**	-0.593**	-0.643**	0.783**	1	0.132	-0.453**	-0.171
Temperature	0.294**	-0.315**	-0.327**	0.19	0.132	1	-0.279**	-0.029
pH	-0.641**	0.514**	0.519**	-0.502**	-0.453**	-0.279**	1	0.322**
Live Weight of Matured Fish	-0.217*	0.209*	0.134	-0.211*	-0.171	-0.029	0.322**	1

Author's Data Results 2025

*p=>0.1 **p=>0.05 ***probability>0.00

The Table 4 above showed the physicochemical parameters at its natural states (normal, moderate and worst-case scenario with the likely effects on the fish production output. At normal state of ponds parameters, fish output is 150 – 250 g increase per month which give rise to an average live weight of 1.5 kg of a matured fish at of 6 months.

Figure 7 represents the three variables (mean values of Cost Benefit Analysis, Cost and Revenue) across the areas (Nsukka East, Nsukka Central and Nsukka West). The chart reveals that we move geographically from Nsukka East to Nsukka West, the variables figures continue to decrease. The graph also shows that the revenue is above the cost indicating profitability. In addition, the gap between the revenue and cost chart lines narrow as we move towards Nsukka West, indicating declining. The declining trend could be attributed to differences in market access, production efficiency, and or operational costs across the locations. In summary, Nsukka East appears to have the highest profitability, while Nsukka West has the lowest profitability. The declining in the output is evidenced, where the average outputs: Nsukka Central (1,168 gms), Nsukka East (1,168.50 gms) and Nsukka West (1,047.67 gms) fall down to Nsukka Central (979.68 gms), Nsukka East (970.11 gms) and Nsukka West (925.02 gms) across the six months periods.

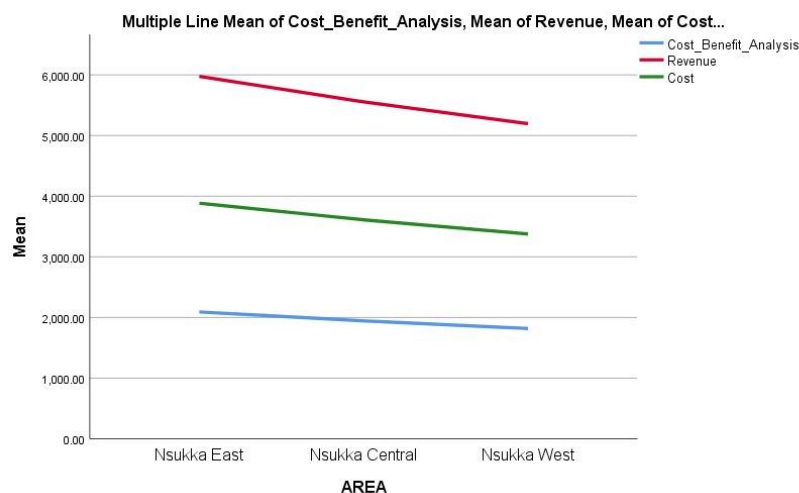


Figure 3: Multiple line mean of cost benefit analysis, mean of revenue and mean of cost Discussion

DISCUSSION

Physicochemical properties of water across the different ponds

Water quality variables have been known to impact greatly on the yield of fish. Fei (1989) pointed out that water quality variables such as temperature, transparency, oxygen content, pH, hardness, alkalinity and nutrient availability could affect the health, survival, growth, reproduction, production or management of fish. Physicochemical parameters such as temperature, turbidity, nitrate, nitrite, dissolved oxygen, pH and ammonia have been used as reliable indicators of the quality of waters and for providing correlations. The physicochemical properties of water across the different ponds in the three zones; Nsukka Central, Nsukka East and Nsukka West for six months indicated that ammonia levels peaking in November, January and March. Dissolved Oxygen levels were highest in October while turbidity levels also highest in October. Nitrate and nitrite level peaked in January which indicated that there are changes in the water quality management practices. The results correlated with the findings by Boyd (2015) which highlighted the importance of regular water quality monitoring in fish farming. The results also suggested that water quality parameters can vary significantly over time emphasizing the need for adaptive management strategies. The results show consistent levels of temperature and pH across the six months which that parameter may be less influenced by seasonal changes.

The ammonia levels were highest in Nsukka West while Dissolved Oxygen (DO) levels highest in Nsukka Central. Turbidity levels were also highest in Nsukka Central which indicated the higher levels of suspended solids in the water. The results correlated with the study by Boyd (2015) which suggested the importance of regular water quality monitoring in fish farming. Also, the result suggested that water quality management practices may vary across locations, leading to differences in water quality practices. The levels of nitrate, temperature and pH across the three zones suggested that parameters may be less influenced by local management practices.

Table 3 shows the significant spatial and temporal variations in water quality parameters across the three zones (Nsukka Central, Nsukka East and Nsukka West) and the six months. Ammonia levels peaked in Nsukka West in January while Dissolved Oxygen levels were highest in Nsukka Central during October. Turbidity levels were also highest in Nsukka Central in October which indicated potentials changes in water quality management practices. The findings show water quality parameters can vary significantly across the different locations and time which emphasize the need for adaptive management strategies.

Table 4 shows the correlations between water quality parameters in fish ponds across the three zones. High levels of ammonia were associated with high levels of nitrate and nitrite which indicated the potential nitrogen cycle imbalance ($r = 0.873^*$, $r = 0.779$). Dissolved Oxygen (DO) levels were also correlated with turbidity and pH levels which suggested, there is a link to phytoplankton growth, photosynthesis and respiration processes ($r = 0.676$, $r = 0.514^*$). The findings correlated with Boyd (2015) which highlighted the importance of monitoring water quality parameters to prevent nitrogen cycle imbalance and ammonia toxicity in fish farming. The results suggested that pH fluctuations can also cause stress, reduced growth rates, and increased mortality in fish which emphasized the need for proper water quality management. The correlations between water quality parameters highlighted the importance of integrated water quality management strategies in fish farming.

Figure 5 shows the geographical variations in profitability and output among the fish farmers in Nsukka Central, Nsukka East and Nsukka West. The data showed a declining trend in revenue and output as one moves from Nsukka East to Nsukka West which indicated the differences in market access, production efficiency and operational costs. The highest profitability was observed in Nsukka East while Nsukka West had the lowest profitability. The findings correlated with Adeogun *et al.* (2017) which highlighted the importance of location specific factors in determining the profitability of fish farming operations. Also, the results suggested the production efficiency and market access which play an important role in determining the output and profitability of fish farming operations (Olaleye *et al.*, 2018). Therefore, farmers need to adopt more efficient production practices in order to maintain profitability.

The physicochemical properties of water across the different ponds indicated no significant relationship in the different analyte measured. Also, the analyte unsteadily increased by concentration in the different farms of the different zones measured. An analyte such as ammonia occurs due to digested protein in fish feed. The fish in turn excrete ammonia through their gills and in their feces (Ogbonna and Chinomso, 2010). In the present study, the least ammonia concentration level when compared with zone 3 which had the highest concentration level; however, these values were below the values that was suggested to harm the fish (i.e., 0.20 mg/L) (Ogbonna and Chinomso, 2010). On the other hand, the unsteady increase in the concentration of analyte measured in this study could be attributable to the different fish feed types fed to fish in their various ponds or there was the possibility that the ammonia concentration of the pond was caused by bacterial activities such as decomposition of organic matter (such as uneaten feed or dead algae and aquatic plants), (Ogbonna and Chinomso, 2010).

The fluctuation in dissolved oxygen values could have been caused by diffusion and aeration, photosynthesis, respiration or the decomposition of the various ponds (Langland and Cronin, 2003). More likely, dissolved oxygen have been found to also fluctuate with temperature, salinity and pressure changes of the pond (Langland and Cronin, 2003). Thus, the present study values for dissolved oxygen were not below the values found in the study of Akinwale and Adeola (2012). The pond turbidity also fluctuated and it is suggested that whether mineral or humic, turbidity usually reduce the amount of light penetrating the pond. This can affect fish directly through damaging their vital organs (Cumming and Herbert, 2016). Although the highest and lowest turbidity level of ponds recorded in the locations, the values were below the one recorded in the study conducted by Ehiagbonare and Ogunrinde (2010). In nitrate concentration of this study was lower than the values of the study of Umeh *et al.*, (2020) and lower than the desirable limit of 0 - 2 mg/L and acceptable limit less than 4 mg/L (DWAMD, 1994). A higher value of nitrate indicates the presence of pollutants like pesticides and bacteria (Umeh *et al.*, 2020). suggesting that ponds of this were not largely polluted. Temperature and pH are other factors that could alter the chemistry of a pond. A study shows that Akinwale and Adeola (2012) found a relationship existing among water quality parameters. Among the parameters assessed, temperature had a higher correlation with pH. According to Delince (1992) 30-35 °c is tolerable to fish, however, the present study found that temperature range levels in the pond were lower than the said values suggested above, thus, indicating a variation in results.

CONCLUSION

The water quality showed significant temporal and spatial variations in the physico-chemical parameters studied. Variations in physico-chemical parameters such as temperature, pH, dissolved oxygen, and turbidity were observed among the fish farms. Water quality monitoring has a high priority for the determination of current conditions and long-term trends for effective management.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made:

1. Regular monitoring of physicochemical parameters should be adopted in order to optimize production.
2. Regular training and workshops for fish farmers should be organized to enhance their knowledge and skills in aquacultural activities.
3. There is need for the fish farmers to improve water quality by reducing ammonia accumulation through better waste management and filtration systems.
4. There is need for the fish farmers to improve water clarity by reducing sediment runoff and controlling algal blooms.
5. There is need for the farmers to maintain optimal temperature ranges and provide shading during excessive heat. Enhance water filtration and waste management to reduce ammonia and nitrite.
6. There is need to implement sediment control measures to reduce turbidity by the fish farmers.

7. There is need for the farmers to monitor water temperature fluctuations to maintain stable conditions.

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