# Evaluation of Physicochemical Parameters of Selected Aquaculture Ponds' Water in Bhimavaram Mandal, W.G. District, A.P. State, India.

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**Abstract:**
Fish production is highly dependent on water's physical, chemical, and biological properties. To ensure successful fish pond management, it is important to understand the water's quality. In this study, different physiochemical parameters were analyzed from water samples taken from fish ponds located at five different places in Bhimavaram mandal of West Godavari district, Andhra Pradesh. Total twenty physiochemical parameters are taken for analysis. These parameters included water temperature, pH value, salinity value, total hardness value, electrical conductivity value, chemical oxygen demand value, and biological oxygen demand value. For the analysis of the physicochemical parameters different types of analytical methods are adopted. This study will provide fish culturists with useful information to improve the environmental conditions needed for fish species to grow in their ponds. Additionally, this information could be useful for determining the growth rates and productivity of fish.

**Keywords:** Aquaculture, Physicochemical parameters, Chemical oxygen demand, Biochemical oxygen demand, Fish ponds.

## INTRODUCTION

Water is a useful natural resource and fundamental need of all organisms, flora, animals and human beings. It is also the most vital solvent for agriculture, industry, tourism and aquaculture (1). Aquaculture depends predominantly on water and everyday monitoring of water best is a necessity. Fish cultivation additionally known as aquaculture consists of herbal and synthetic fish farming achieved in ponds (2). Further to the use of ponds, fishes are also cultured in various water keeping facilities including pens, happas, tanks, cages, raceways and so on. Water is ht environment for fishes and its excellent determines its health to be used and potential to maintain the health of farmed aquatic organisms. Environmental pollutants is a primary burden of aquaculture as poor water fine in fish ponds will result to deteriorated fish fitness and in the end low manufacturing. The upkeep of healthy aquatic atmosphere is depending on the homes of water (3). The popularity of numerous water parameters like turbidity, pH, alkalinity, hardness, ammonia, nitrite, nitrate, biochemical oxygen demand and so forth, can't be over searched for keeping a wholesome aquatic surroundings (4). The circumstances of pond water quality as it imparts its physiochemical homes is fundamental to the practical nation of the pond and productiveness of the fish, that is a very key problem for this take a look at specifically because the end result will offer valuable records to fish farmers in elevating fishes successfully.

In recent years, shrimp farming has been carried out intensively in many regions. With the rapid growth of fish and shrimp trade, a number of ancillary units such as ice-making plants have come up on a large scale in Bhimavaram Mandal. It is not only an agricultural Mandal but also aquaculture producing Mandal in our country and it is next to Cochin in exporting aquaculture products. A large area of fertile land in Bhimavaram Mandal, West Godavari District, which has rich potential in terms of flora and fauna, has been converted into fish ponds. As a result, the region had some negative impacts on the natural environment and economic society.

Water quality is characterized by many physical and chemical factors. These measurements include ground water, type of pollution, seasonal changes etc. It varies greatly depending on many factors such as urban lakes are affected by many external factors that can change the structure and function of this ecosystem.
The literature Survey data showed that no study has been carried out on fish pond management in the BhimavaramMandal. Thus five fish ponds were prepared and conducted for this study. The selected sited are from different parts of Bhimavaram Mandal.

## MATERIALS AND METHODS

### Study area

Laboures Society, Bhimavaram Mandal, AndhraPradesh shown in Figure 1 and Table 1.

**Figure 1:** Study area

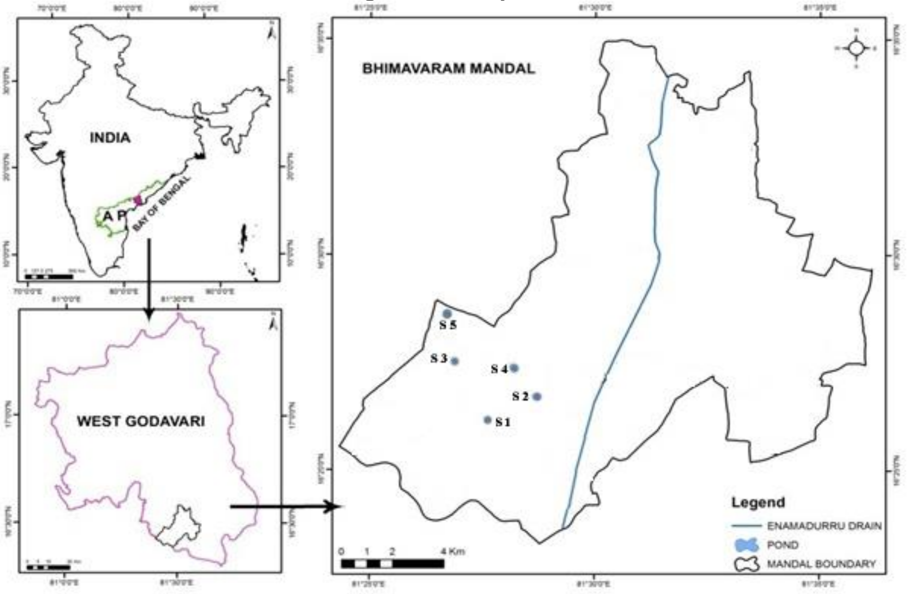


**Table 1: Sampling stations with number, name, description of their surroundings, area and geographical coordinates**

| .Sampling Stations | Village Name | Description of the study area | Area (Hectares) | Latitude | Longitude |
|---|---|---|---|---|---|
| S1 | Kotta Pusalamuru | Located nearby an aquaculture ponds | 7.69 | $16^0$ 26’ 10.380” N | $81^0$ 27’ 37.044” E |
| S2 | PataPusalamuru | Located beside Lossari main channel | 0.55 | $16^0$ 26’ 43.306” N | $81^0$ 28’ 39.478” E |
| S3 | Upputeru Reserved Forest | Located nearby an aquaculture ponds | 6.21 | $16^0$ 27’ 33.540” N | $81^0$ 26’ 52.660” E |
| S4 | Laboures Society | Located adjacent to Ennamadur drain | 2.22 | $16^0$ 27’ 24.078” N | $81^0$ 28’ 10.447” E |
| S5 | Laboures Society | Located nearby an aquaculture ponds | 2.38 | $16^0$ 28’ 35.300” N | $81^0$ 26’ 42.577” E |

Fish pond water samples were accrued from five ponds located in the village Laboures Society in the morning hours between 7am and 9am two times a month during July 2014 to June 2015. Water becomes gathered in polyethylene bottles labelled with pattern code and transported to the laboratory in an ice box. They had been stored cool, preferably among $4^0$C to $10^0$C, however not frozen. The temperatures of water, pH, dissolved oxygen, EC and total dissolved solids have been analyzed without delay at on site, whilst the ultimate parameters have been analyzed at once in Environmental Laboratory, Andhra University, Visakhapatnam. The samples were processed and analyzed carefully following the appropriate methods.

### Methods of sampling for physico–chemical analysis

### Accuracy of the analytical data:

The errors in the estimation of the chemical parameters involving gravimetric estimations are less than 1.0% and the estimations involving volumetric methods may be up to 2.0%. GC, Ion selective electrode meter and flame photometer, the errors are in the range of 1.0-5.0%.

| **Water analyses procedure:** | | |
|---|---|---|
| **S. NO.** | **Physic-chemical parameters** | **Method** |
| 1. | Temperature | Measured with calibrated thermometer |
| 2. | Salinity | Gravimetric method |
| 3. | Turbidity | Turbidity metric method |
| 4. | Total Dissolved Solids | Gravimetric method |
| 5. | Electrical Conductivity | Electronic method |
| 6. | pH | Electrometric method |
| 7. | Total alkalinity | Titration with standard acid using indicator |
| 8. | Dissolved Oxygen | Winkler method with the azide modifications |
| 9. | Biochemical Oxygen Demand | Wet oxidation procedure |
| 10. | Ammonia | Tested with Nessler's reagent |
| 11. | Nitrate | Ultraviolet screening / cadmium reduction method |
| 12. | Phosphate | Colorimetric – Molybdophosphoric acid method |
| 13. | Sulphate | Turbidity metric method- precipitation with barium Chloride and measured the turbidity photometrically at 420 nm using Spectrophotometer. |
| 14. | Calcium | Calculation followed by complexometric method With EDTA |
| 15. | Magnesium | Calculation followed by complexometric method With EDTA |
| 16. | Carbonate | Titrimetric method |
| 17. | Bicarbonate | Titrimetric method |
| 18. | Total Hardness | Complexometric titration using EDTA and Eriochrome Black T (EBT) as indicator |
| 19. | Fluoride | SPADNS method- Ion selective electrode |
| 20. | Chloride | Argentometric titration with chromate ions as indicator |

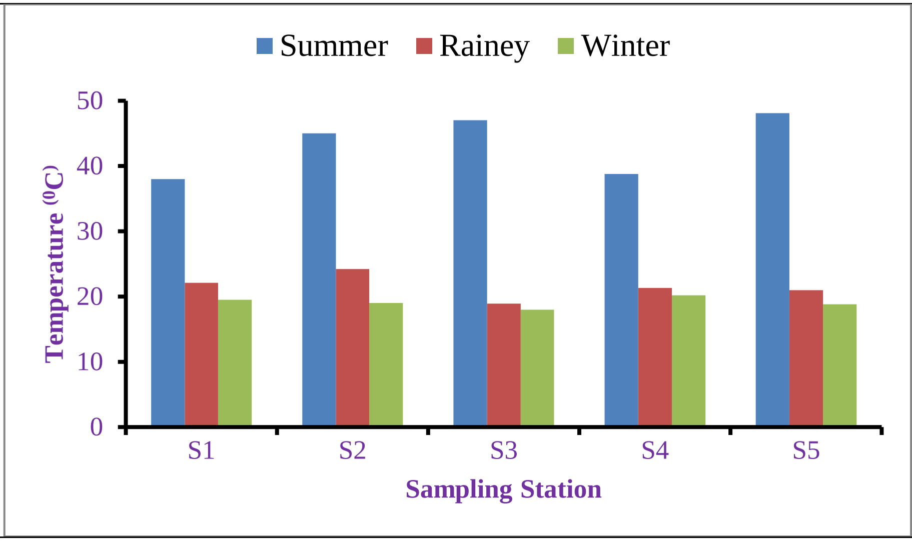


**Fig: 2** Temperature

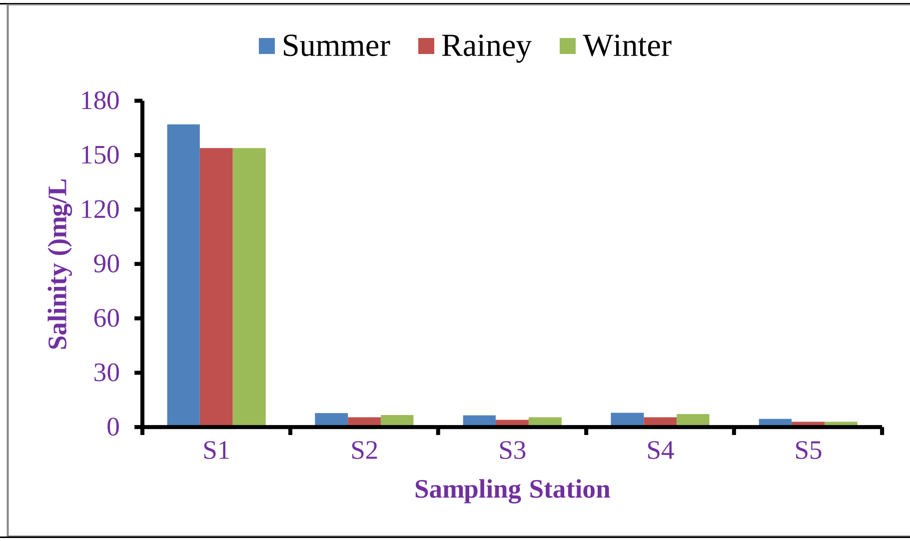


**Fig: 3** Salinity

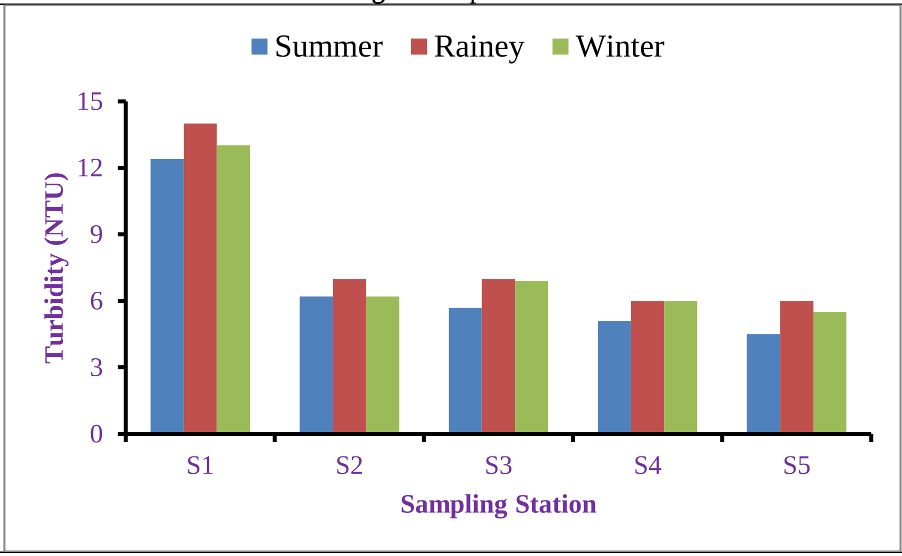


**Fig: 4** Turbidity

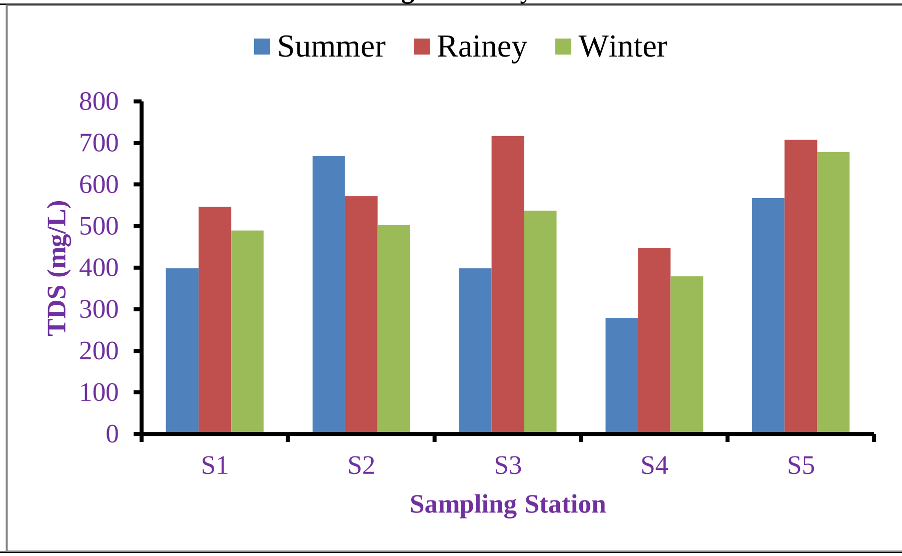


**Fig: 5**Total Dissolved Solids

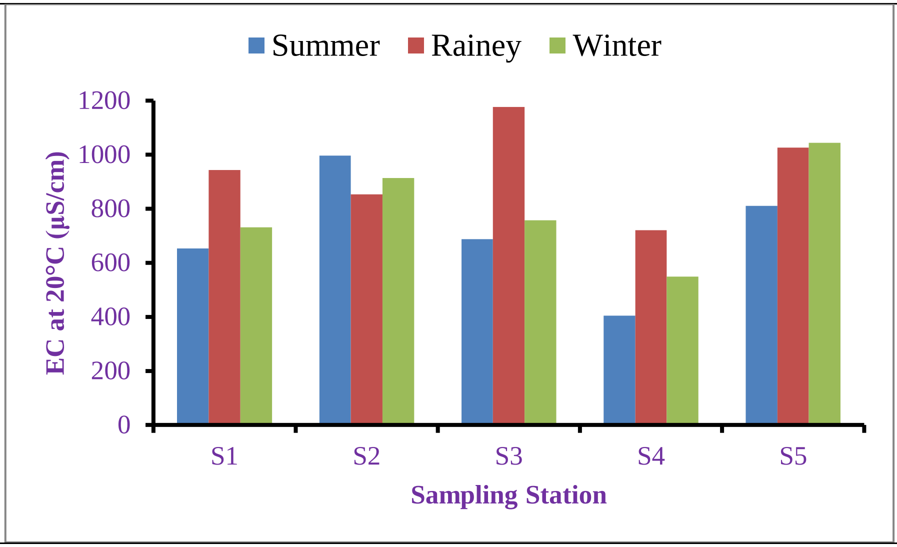


**Fig: 6**Electrical Conductivity (EC)

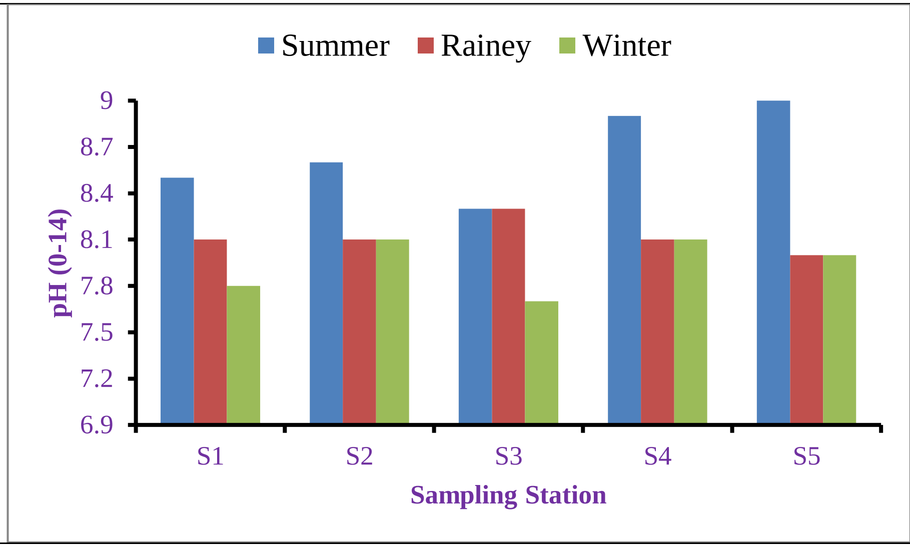


**Fig: 7**pH

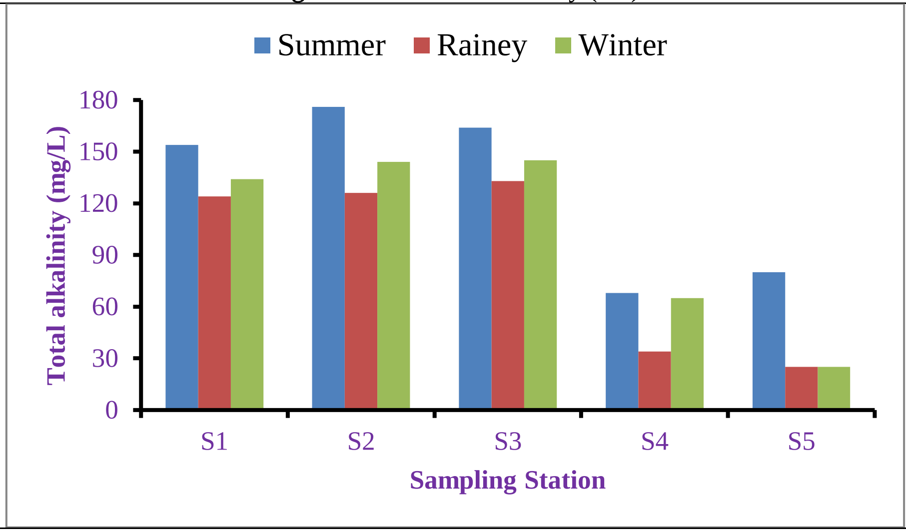


**Fig: 8**Total alkalinity

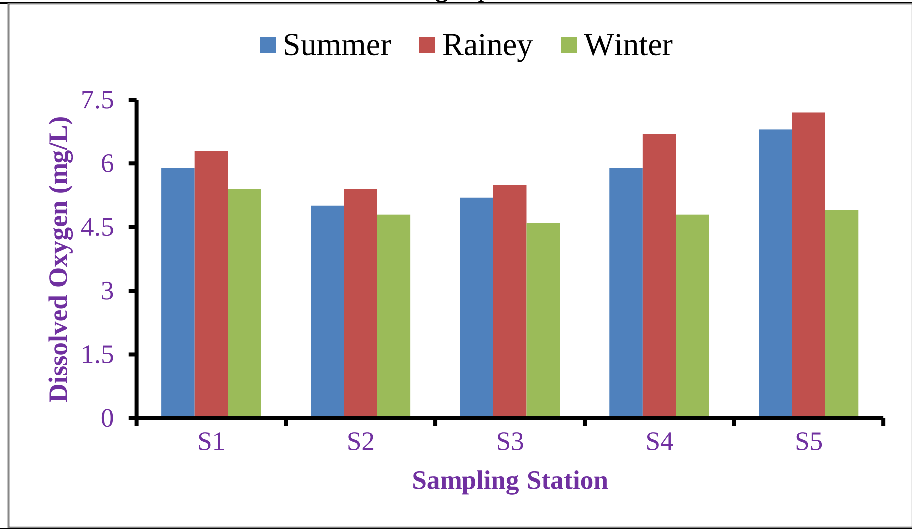


**Fig: 9**Dissolved Oxygen

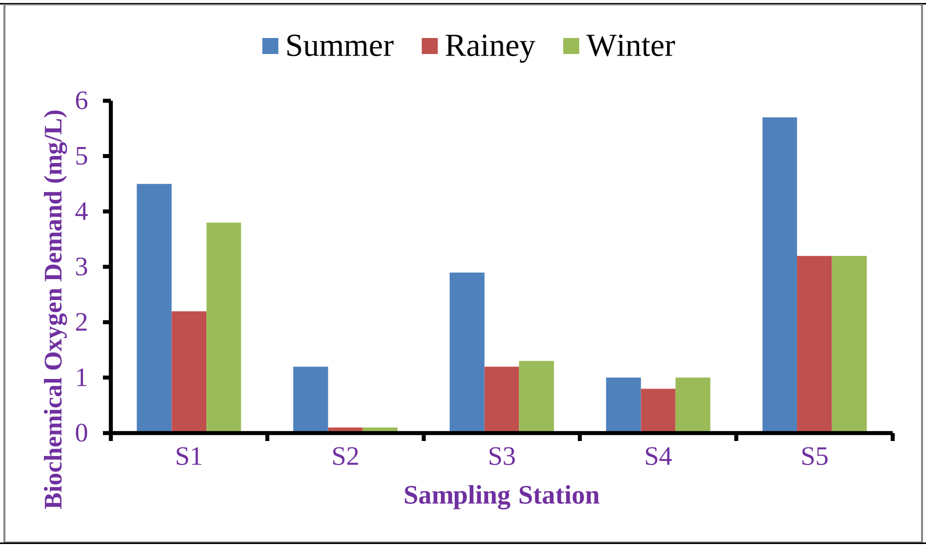


**Fig: 10**Biochemical Oxygen Demand

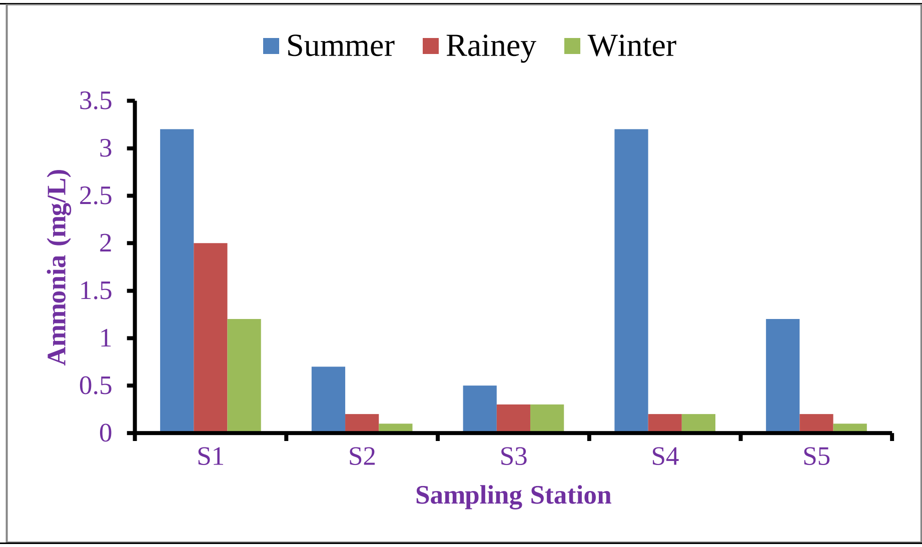


**Fig: 11**Ammonia

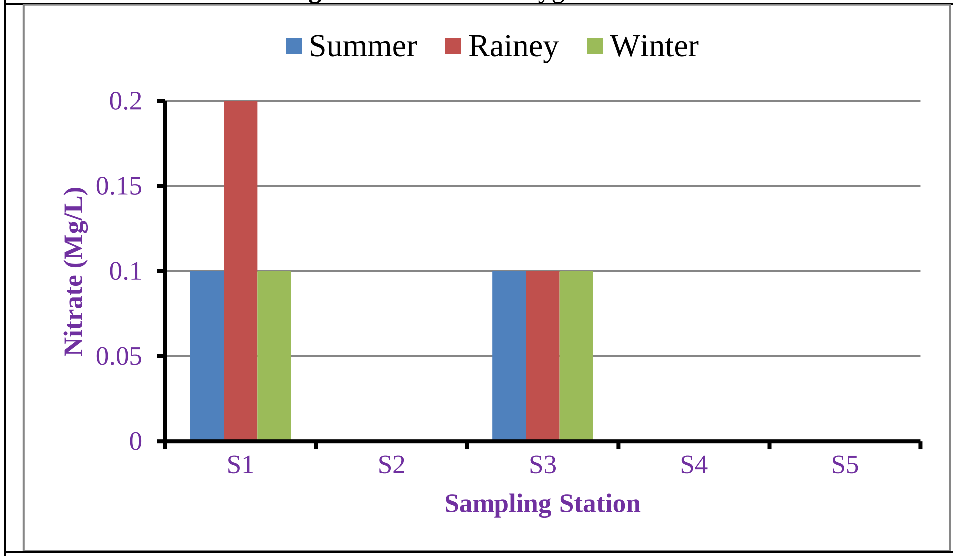


**Fig: 12**Nitrate

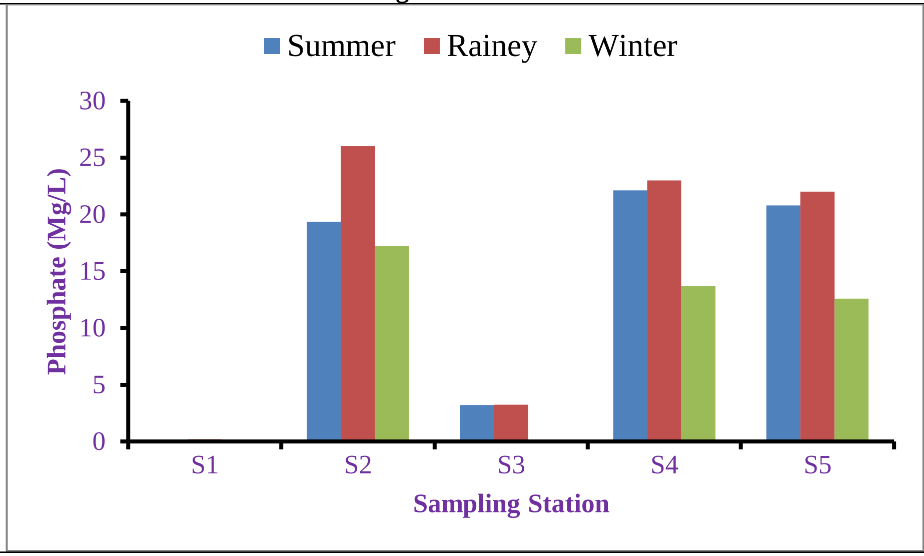


**Fig: 13**Phosphate

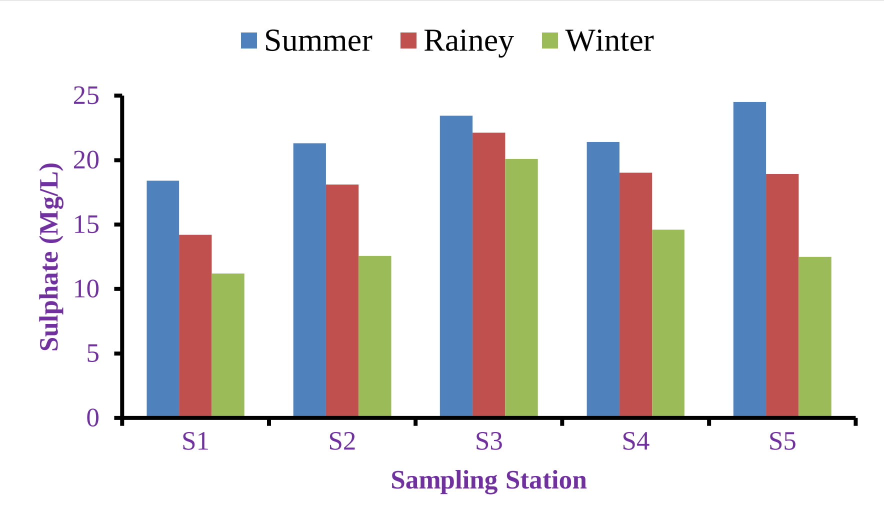


**Fig: 14**Sulphate

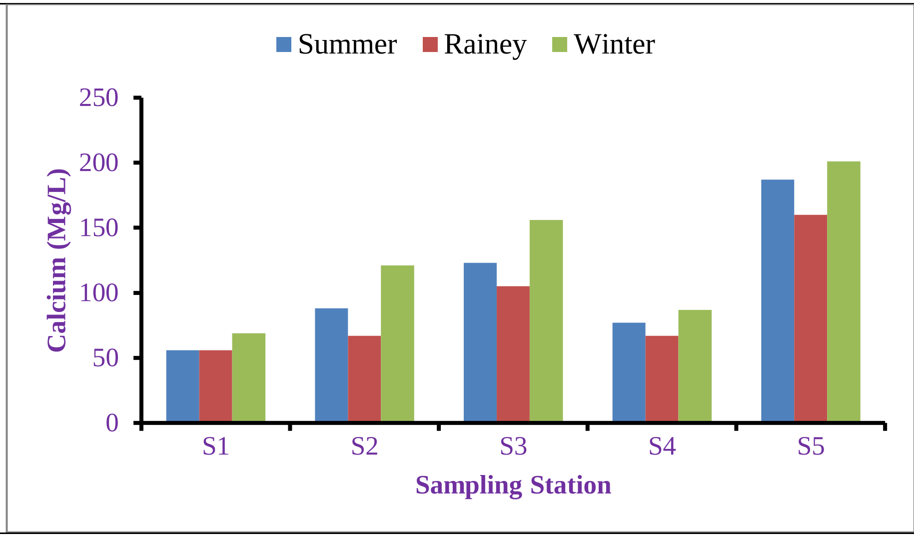


**Fig: 15**Calcium

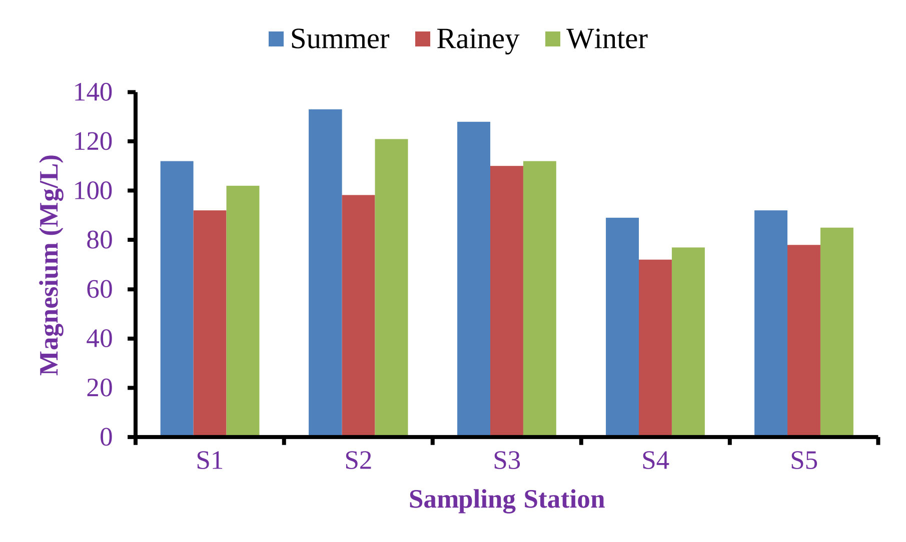


**Fig: 16** Magnesium

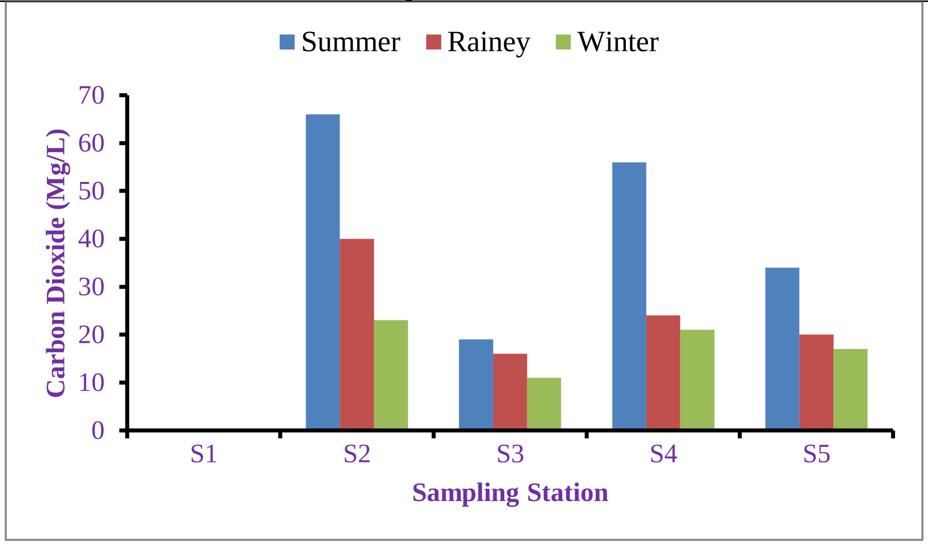


**Fig: 17**Carbon Dioxide

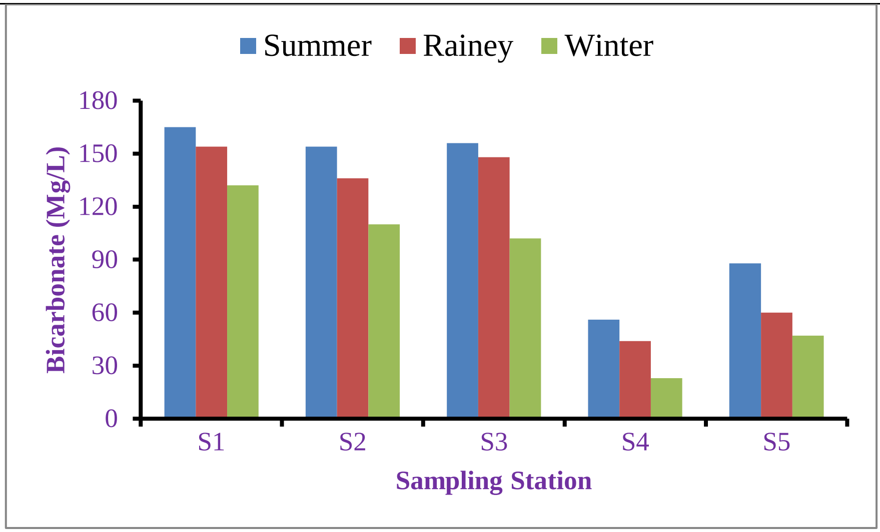


**Fig: 18**Bicarbonate

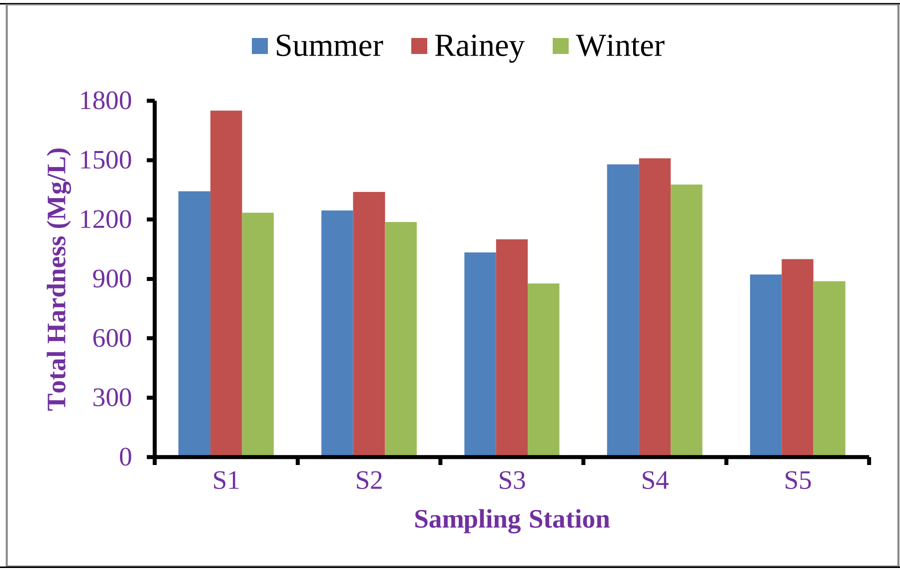


**Fig: 19**Total Hardness

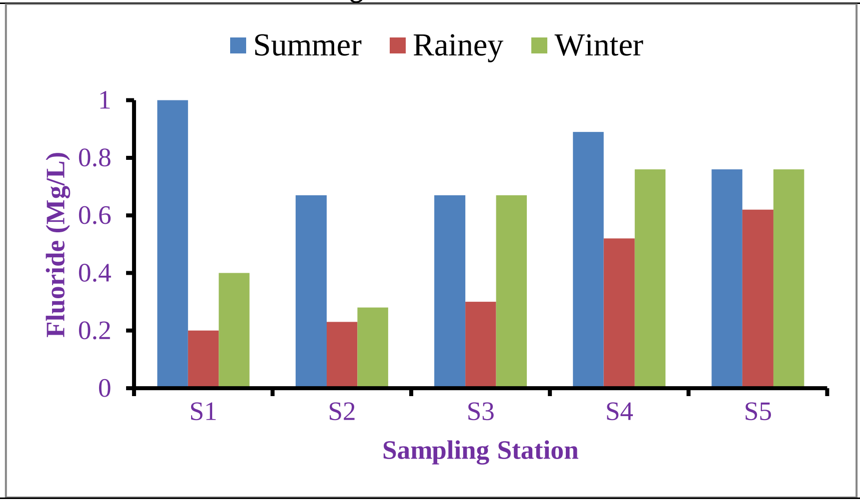


**Fig: 20**Fluoride

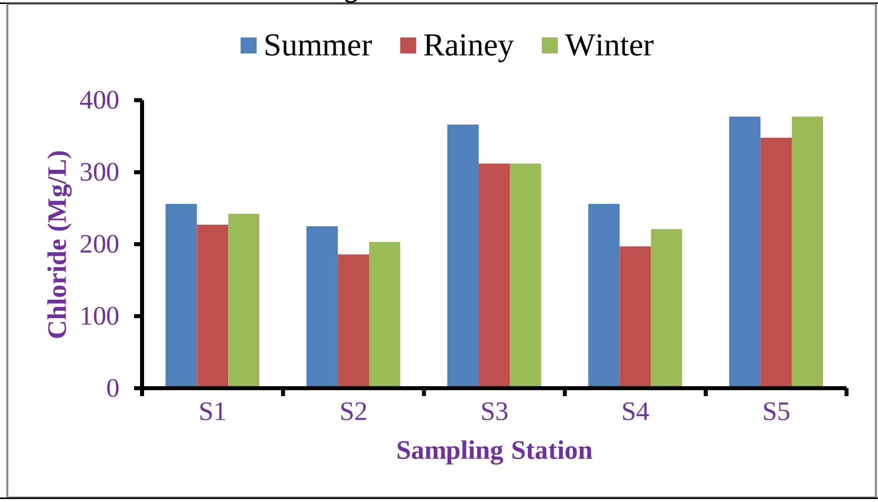


**Fig: 21**Chloride

## RESULTS AND DISCUSSION

### Physico-chemical parameter analysis

The following physico-chemical parameters are discussed as follows.

**Temperature**

The most important physical variable of aquatic ecology is temperature. Since fish are cold-blooded animals, their body temperature will change with changes in the environment, affecting their metabolism and body and ultimately affecting fish production. During the study period, the highest temperature of sample S5 was recorded in summer ($48.1^0$C), while the lowest temperature of sample S3 was recorded in winter ($18^0$C) (Fig 2). Higher temperature increases the biochemical activity rate of the micro biota, the plant'srespiration rate, improves protein degradation and increase oxygen demand. It continues to reduce oxygen solubility and increase ammonia levels in the water, causing fish deaths.

**Salinity**

Salinity is defined as the total concentration of charged ions. Salinity plays an important role in the growth of culture through osmotic control of nutrients in the surrounding water. Salinity is an important driver of aquatic population and growth (5). During the study, the highest salinity rate was recorded in the S1 sample in the summer season (167 mg/L), and the lowest salinity was recorded in the S5 sample in the winter season (3.0 mg/L) (Fig 3).

**Turbidity**

Turbidity is an important property for understanding the physical properties of water. The increased turbidity during the rainy season is due to the decomposition of organic matter, the growth of algae, and massive soil erosion from the nearby pond tank bunds (lake) (6, 7, 8). During the study period, the highest turbidity was recorded in the rainy season (14 NTU) for sample S1, while the lowest turbidity was recorded in the summer season (4.5 NTU) for sample S5 (Fig 4).

**Total Dissolved Solids (TDS)**

The amount of total dissolved solids indicates the quality of the water. The observed changes may be due to the dilution effect due to the rainy season and high water evaporation in summer. During the study period, the highest total total dissolved solids were recorded in sample S3 (717.06 mg/L), while the lower total dissolved were recorded in sample S4 (287.7 mg/L) (Fig 5).

**Electrical Conductivity (EC)**

Electrical conductivity (EC) is a measure of how well a solution conducts electricity regarding salt content. The higher the salt content, the higher is the EC. During the study, sample S1 recorded the highest conductivity (14μS/cm) during the rainy season, while sample S5 recorded the lowest conductivity (4.5μS/cm) during the summer months (Fig 6)

**pH**

pH is an important factor in the growth of aquatic plants because it affects the metabolism and other physiological processes of the culture. In this research, a sample S5 has the highest PH (9.0) in summer, while sample S3 has the lowest pH (7.7) in winter (Fig 7). This may be due to the strong photosynthesis of underwater algae in the lake, which decreases during winter

**Total Alkalinity**

Alkalinity of lake water samples may result from dissolved carbonates, bicarbonates and hydroxides in some metal ions such as calcium and magnesium (9, 10). The alkalinity of water in the lake is increasing, possibly due to a combination of chemicals, increased evaporation and changes in alkalinity as weathering increase. During the study, the high alkalinity of the S2 sample was recorded in the summer season (176 mg/L), and the lowest total alkalinity of the sample S5 was recorded in the rainy season and winter season (25 mg/L) (Fig 8). Due to the high rate of photosynthesis, the bicarbonate and carbonate content in the pond increases.

**Dissolved Oxygen (DO)**

Dissolved oxygen (DO) represents physical, chemical and biological activity in water; it is an important indicator of water quality. Higher oxygen levels during the monsoon season may be due to conditions during this period being more conductive to high photosynthesis. During the study, sample S5 recorded the highest oxygen concentration (7.2 mg/L) during the rainy season, while sample S3 recorded the lowest oxygen concentration (4.6 mg/L) during the winter season (Fig 9). Low oxygen levels, especially when algal blooms die and blooms are disrupted, can reduce growth, feeding and molt frequency and cause stress or death of fish in the lake.

**Biochemical Oxygen Demand (BOD)**

BOD is a measure of the total amount of oxygen used by the biodegradation of organic matter such as food or sewage. BOD level of 3.0-6.0 ppm is most suitable for normal fish; 6.0-12.0 ppm is not lethal to fish and > 12.0 ppm is generally lethal to fish (11). During the study period, the highest BOD of sample S5 occurred in summer (5.7 mg/L), while the lowest BOD of sample S2 occurred in the rainy season winter season (0.1 mg/L) (Fig 10). This may be due to higher organic loading in these lakes, resulting in higher BOD.

**Ammonia**

Ammonia is a product of protein metabolism produced by fish and the decomposition of organic matter (food waste, dead plankton, sewage etc). The maximum ammonia demand of samples S1 and S4 occurred in summer (3.2 mg/L), while the minimum value (0.1 mg/L) for samples S2 and S5 during the study period occurred in winter (Fig 11). The reason for the increase in ammonia nitrogen content in the summer months is that rainfall erodes the soil containing fertilizer, turbulence renews and releases all the phosphorus in the bottom mud of the water, water accumulated in aquaculture enters the channel and soluble alkali metal phosphate mixtures enter the channel. Water flow was taken to ht estuary.

**Nitrate**

Nitrates are not toxic to fish and do not pose a health hazard unless present at very high levels. During this research, it was determined that nitrate values were higher in the summer months than in other seasons and there were no samples exceeding the maximum allowed value. The highest nitrate demand of sample S1 was recorded in the rainy season (0.2 mg/L) and the lowest (0.0 mg/L) in all seasons i.e., Zero nitrogen was observed for samples S2, S4 and S5 throughout the study period (Fig 12).

**Phosphates**

Phosphorus is necessary for the growth of plants and animals. During the study period, the highest phosphate requirement for sample S1 is occurred in the rainy season (26 mg/L), while the lowest phosphate requirement for sample S3 occurred in the winter season (0.0 mg/L) (Fig 13). The reason for the increase in phosphate content during the monsoon season is that rainfall fertilizes the soil, turbulence renews and releases all the phosphorus in the bottom mid of the water, and soluble alkali metal phosphates are mixed from the upper part and taken into the estuary.

**Sulphate**

Sulphates are often found in natural water samples. During the study period, the highest sulphate demand for sample S5 occurred during the summer months (24.5 mg/L), while the lowest sulphate demand for sample S1 occurred during the winter months (11.2 mg/L) (Fig 14). The high sulphate rate may be due to the scarcity of water in the summer months and the anaerobic production of hydrogen sulphate.

**Calcium**

Calcium is an important element of fish and the calcium content in aquaculture water supports the osmoregulation of fish during stress. As we mentioned above, calcium is very important for the development of eggs and larvae. Calcium plays an important role in the biological processes of fish. It is necessary for bone formation, blood clotting and other metabolic reactions. Calcium is generally found in the soil as carbonates and most importantly in the environment as divalent salts in fish farming water. Gish can absorb calcium from water or food. During the study, the highest calcium value in the S5 sample was recorded in winter (201 mg/L) and lowest calcium value in the S1 sample recorded in rainy season (56 mg/L) (Fig 15).

**Magnesium**

Magnesium is necessary for the growth of fish. During the study period, the highest magnesium requirement for the S2 sample occurred in the summer season (133 mg/L), while the lowest magnesium requirement for the S4 sample occurred in the rainy season (72 mg/L) (Fig 16). Higher values in summer may result from higher organic matter decomposition, higher evaporation rates and other human activities.

**Carbondioxide ($CO_2$)**

When $CO_2$ dissolves in water, it produces carbonic acid, which lowers the pH of any system. The results showed that the lowest carbon dioxide level was recorded in the winter months and the highest carbon dioxide level was recorded in the summer months. This may be due to the accumulation of free carbon dioxide during the decomposition of deeper sediment during the summer months, leading to the conversion of insoluble carbonate into soluble bicarbonate. Sample S2 has the highest $CO_2$ demand (66 mg/L) in summer, while sample S1 has lowest $CO_2$ demand (0.0 mg/L) in all three seasons (Fig 17).

**Bicarbonate**

Bicarbonate concentration in the lake tends to be highest in summer and lowest in winter. This may be because water evaporates and the pH of the water increases during the summer months. Therefore, the S1 sample saw the highest demand in the summer months (165 mg/L) and the S4 sample saw the lowest demand in the winter months (23 mg/L) (Fig 18)

**Total Hardness (TH)**

Water hardness is important for fish farming and is an indicator of water quality. Hardness is a measure of the amount of alkaline earth elements (such as calcium and magnesium) and other ions (such as lead, iron, manganese, strontium, zinc and hydrogen ions) in a body of water. Calcium and magnesium are necessary for metabolic processes such as bone and scale formation in fish. During the study, the total hardness requirement of the S1 sample was recorded highest in the rainy season (1750 mg/L), while the total hardness requirement of the S3 model was lowest in the winter season (877 mg/L) (Fig 19).

**Fluoride**

Fluoride is a trace element that has been reported to cause losses in some fish species at concentrations of 3 mg/liter and above, depending on the quality of the water. During this study, we found that the fluoride value was high in summer than in other seasons; none of the sampling locations exceeds the maximum allowed. During the study, the fluoride demand of sample S1 was recorded in the summer season (1.0 mg/L), while the fluoride demand was lowest (0.2 mg/L) in the rainy season (Fig 20).

**Chloride**

Chlorine is a very effective chemical used as a disinfectant. Chloride is the only element in salt form. Although chlorine kills fish, chloride is a common component of water and is important in helping fish maintain osmotic balance. During the study, the chloride ion demand of the S5 sample was recorded as (377 mg/L) in summer and winter, while the S2 sample recorded the lowest chloride ion demand (186 mg/L) during rain driving (Fig 21).

| **Table 2: (S1) Results of water quality parameters tested in 3 different seasons** | | | | | **Water quality Standards** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Physico-chemical parameters** | | **Summer** | **Rainy** | **Winter** | **BIS 10500 : 2012** | | **WHO** | **EU** | **US EPA** | **Boyd (1998) Water Quality for Pond Aquaculture** |
| | | | | | **Acceptable limit** | **Permissible limit** | | | | |
| Temperature | ºC | 38 | 22.1 | 19.5 | - | - | - | - | 24-32 | - |
| Salinity | mg/L | 167 | 154 | 154 | - | - | - | - | - | - |
| Turbidity | NTU | 12.4 | 14 | 13.02 | 1 | 5 | 5 | < 5 | - | < 4 |
| Total Dissolved Solids(TDS) | mg/L | 398.2 | 546.8 | 489.6 | 500 | 2000 | 2000 | 500 | 1000 | - |
| Electrical Conductivity (EC) at 20°C | (µS/cm) | 653 | 943 | 731 | 500 | 2000 | 2000 | 2500 | - | 2500 |
| pH | 0 -14 | 8.5 | 8.1 | 7.8 | 6.5-8.5 | - | - | 6.5-8.5 | 6.5- 9.0 | 6.5-9.5 |
| Total alkalinity (as $CaCO_3$) | mg/L | 154 | 124 | 134 | 200 | 600 | 600 | 50-200 | - | 20-200 |
| Dissolved Oxygen (DO) | mg/L | 5.9 | 6.3 | 5.4 | > 5 | - | - | > 5 | > 5 | > 5 |
| Biochemical Oxygen Demand (BOD) | mg/L | 4.5 | 2.2 | 3.8 | - | - | - | - | - | - |
| Ammonia (as total $NH_3$-N) | mg/L | 3.2 | 2 | 1.2 | 0.5 | - | - | 1.5 | - | - |
| Nitrate (as $NO_3$-N) | mg/L | 0.1 | 0.2 | 0.1 | 45 | - | - | 50 | 10 | 10 |
| Phosphate (as $PO_4$-P) | mg/L | 0.12 | 0.2 | 0.11 | - | - | - | 0.1 | - | - |
| Sulphate (as $SO_4$) | mg/L | 18.4 | 14.2 | 11.2 | 200 | 400 | 400 | 250 | 250 | 250 |
| Calcium (as Ca) | mg/L | 56 | 56 | 69 | 75 | 200 | 200 | 200 | - | - |
| Magnesium (as Mg) | mg/L | 112 | 92 | 102 | 30 | 100 | 100 | 150 | - | - |
| Carbon Dioxide ($CO_2$) | mg/L | 0 | 0 | 0 | - | - | - | - | - | - |
| Bicarbonate ($HCO_3$) | mg/L | 165 | 154 | 132 | - | - | - | - | - | - |
| Total Hardness (as $CaCO_3$) | mg/L | 1343 | 1750 | 1234 | 200 | 600 | 600 | 500 | - | 100-500 |
| Fluoride (as F) | mg/L | 1 | 0.2 | 0.4 | 1.0 | 1.5 | 1.5 | 1.5 | 4 | 1.5 |
| Chloride (as Cl) | mg/L | 256 | 227 | 242 | 250 | 1000 | 1000 | 250 | 250 | 250 |

**Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007);Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).**

**Remarks:** Out of 20 parameters studied 5 exceeded the permissible limits of different standards compared and 2 parameters (Temperature in rainy and winter and Turbidity) are below the optimum range of Boyd (1998) water quality standards for pond aquaculture.

**Note:** 1. Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.
2.Parameters which exceed the permissible limits and which fall below the optimum range are highlighted with red colour.

| **Table 3: (S2) Results of water quality parameters tested in 3 different seasons** | | | | | **Water quality Standards** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Physico-chemical parameters** | | **Summer** | **Rainy** | **Winter** | **BIS 10500 : 2012** | | **WHO** | **EU** | **US EPA** | **Boyd (1998) Water Quality for Pond Aquaculture** |
| | | | | | **Acceptable limit** | **Permissible limit** | | | | |
| Temperature | ºC | 45 | 24.2 | 19 | - | - | - | 24-32 | - | 25-30 |
| Salinity | mg/L | 7.8 | 5.5 | 6.6 | - | - | - | - | - | 1-250 |
| Turbidity | NTU | 6.2 | 7 | 6.2 | 1 | 5 | < 5 | - | < 4 | 20-35 |
| Total Dissolved Solids(TDS) | mg/L | 667.8 | 571.74 | 502.7 | 500 | 2000 | 500 | 1000 | - | 500-1200 |
| Electrical Conductivity (EC) at 20°C | (µS/cm) | 997 | 853 | 914 | 500 | 2000 | 2500 | - | 2500 | - |
| pH | 0 -14 | 8.6 | 8.1 | 8.1 | 6.5-8.5 | - | 6.5-8.5 | 6.5- 9.0 | 6.5-9.5 | 6.5 - 9.0 |
| Total alkalinity (as $CaCO_3$) | mg/L | 176 | 126 | 144 | 200 | 600 | 50-200 | - | 20-200 | 50-300 |
| Dissolved Oxygen (DO) | mg/L | 5.01 | 5.4 | 4.8 | > 5 | - | > 5 | > 5 | > 5 | > 5 |
| Biochemical Oxygen Demand (BOD) | mg/L | 1.2 | 0.1 | 0.1 | - | - | - | - | - | < 10 |
| Ammonia (as total $NH_3$-N) | mg/L | 0.7 | 0.2 | 0.1 | 0.5 | - | 1.5 | - | - | 0.05-0.2 |
| Nitrate (as $NO_3$-N) | mg/L | 0 | 0 | 0 | 45 | - | 50 | 10 | 10 | < 5 |
| Phosphate (as $PO_4$-P) | mg/L | 19.34 | 26 | 17.2 | - | - | 0.1 | - | - | 0.005-0.2 |
| Sulphate (as $SO_4$) | mg/L | 21.3 | 18.11 | 12.56 | 200 | 400 | 250 | 250 | 250 | 5-100 |
| Calcium (as Ca) | mg/L | 88 | 67 | 121 | 75 | 200 | 200 | - | - | 75-150 |
| Magnesium (as Mg) | mg/L | 133 | 98.2 | 121 | 30 | 100 | 150 | - | - | 5-100 |
| Carbon Dioxide ($CO_2$) | mg/L | 66 | 40 | 23 | - | - | - | - | - | <10 |
| Bicarbonate ($HCO_3$) | mg/L | 154 | 136 | 110 | - | - | - | - | - | 50-300 |
| Total Hardness (as $CaCO_3$) | mg/L | 1246 | 1340 | 1187 | 200 | 600 | 500 | - | 100-500 | 5-200 |
| Fluoride (as F) | mg/L | 0.67 | 0.23 | 0.28 | 1.0 | 1.5 | 1.5 | 4 | 1.5 | - |
| Chloride (as Cl) | mg/L | 225 | 186 | 203 | 250 | 1000 | 250 | 250 | 250 | 1-100 |

**Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007);Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).**

**Remarks:** Out of 20 parameters studied 7 exceeded the permissible limits of different standards compared and 3 parameters (Temperature in rainy and winter, DO in winter and Turbidity) are below the optimum range of Boyd (1998) water quality standards for pond aquaculture.

**Note:** 1. Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.
2.Parameters which exceed the permissible limits and which fall below the optimum range are highlighted with red colour.

| Table 4: (S3) Results of water quality parameters tested in 3 different seasons | | | | | Water quality Standards | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Physico-chemical parameters | | Summer | Rainy | Winter | BIS 10500 : 2012 | | WHO | EU | US EPA | Boyd (1998) Water Quality for Pond Aquaculture |
| | | | | | Acceptable limit | Permissible limit | | | | |
| Temperature | ºC | 47 | 18.9 | 18 | - | - | - | 24-32 | - | 25-30 |
| Salinity | mg/L | 6.4 | 4 | 5.5 | - | - | - | - | - | 1-250 |
| Turbidity | NTU | 5.7 | 7 | 6.9 | 1 | 5 | < 5 | - | < 4 | 20-35 |
| Total Dissolved Solids(TDS) | mg/L | 398.6 | 717.06 | 537.3 | 500 | 2000 | 500 | 1000 | - | 500-1200 |
| Electrical Conductivity (EC) at 20°C | (µS/cm) | 687 | 1176 | 757 | 500 | 2000 | 2500 | - | 2500 | - |
| pH | 0 -14 | 8.3 | 8.3 | 7.7 | 6.5-8.5 | - | 6.5-8.5 | 6.5- 9.0 | 6.5-9.5 | 6.5 - 9.0 |
| Total alkalinity (as $CaCO_3$) | mg/L | 164 | 133 | 145 | 200 | 600 | 50-200 | - | 20-200 | 50-300 |
| Dissolved Oxygen (DO) | mg/L | 5.2 | 5.5 | 4.6 | > 5 | - | > 5 | > 5 | > 5 | > 5 |
| Biochemical Oxygen Demand (BOD) | mg/L | 2.9 | 1.2 | 1.3 | - | - | - | - | - | < 10 |
| Ammonia (as total $NH_3$-N) | mg/L | 0.5 | 0.3 | 0.3 | 0.5 | - | 1.5 | - | - | 0.05-0.2 |
| Nitrate (as $NO_3$-N) | mg/L | 0.1 | 0.1 | 0.1 | 45 | - | 50 | 10 | 10 | < 5 |
| Phosphate (as $PO_4$-P) | mg/L | 3.2 | 3.23 | 2,13 | - | - | 0.1 | - | - | 0.005-0.2 |
| Sulphate (as $SO_4$) | mg/L | 23.45 | 22.13 | 20.1 | 200 | 400 | 250 | 250 | 250 | 5-100 |
| Calcium (as Ca) | mg/L | 123 | 105 | 156 | 75 | 200 | 200 | - | - | 75-150 |
| Magnesium (as Mg) | mg/L | 128 | 110 | 112 | 30 | 100 | 150 | - | - | 5-100 |
| Carbon Dioxide ($CO_2$) | mg/L | 19 | 16 | 11 | - | - | - | - | - | <10 |
| Bicarbonate ($HCO_3$) | mg/L | 156 | 148 | 102 | - | - | - | - | - | 50-300 |
| Total Hardness (as $CaCO_3$) | mg/L | 1034 | 1100 | 877 | 200 | 600 | 500 | - | 100-500 | 5-200 |
| Fluoride (as F) | mg/L | 0.67 | 0.3 | 0.67 | 1.0 | 1.5 | 1.5 | 4 | 1.5 | - |
| Chloride (as Cl) | mg/L | 366 | 312 | 312 | 250 | 1000 | 250 | 250 | 250 | 1-100 |

**Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007);Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).**

**Remarks:** Out of 20 parameters studied 8 exceeded the permissible limits of different standards compared and 3 parameters (Temperature in rainy and winter, DO in winter and Turbidity) are below the optimum range of Boyd (1998) water quality standards for pond aquaculture.

**Note:** 1. Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.
2.Parameters which exceed the permissible limits and which fall below the optimum range are highlighted with red colour.

| **Table 5: (S4) Results of water quality parameters tested in 3 different seasons** | | | | | **Water quality Standards** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Physico-chemical parameters** | | **Summer** | **Rainy** | **Winter** | **BIS 10500 : 2012** | | **WHO** | **EU** | **US EPA** | **Boyd (1998) Water Quality for Pond Aquaculture** |
| | | | | | **Acceptable limit** | **Permissible limit** | | | | |
| Temperature | ºC | 38.8 | 21.3 | 20,2 | - | - | - | 24-32 | - | 25-30 |
| Salinity | mg/L | 7.9 | 5.5 | 7.1 | - | - | - | - | - | 1-250 |
| Turbidity | NTU | 5.1 | 6 | 6 | 1 | 5 | < 5 | - | < 4 | 20-35 |
| Total Dissolved Solids(TDS) | mg/L | 278.7 | 446.73 | 378.9 | 500 | 2000 | 500 | 1000 | - | 500-1200 |
| Electrical Conductivity (EC) at 20°C | (µS/cm) | 404 | 721 | 549 | 500 | 2000 | 2500 | - | 2500 | - |
| pH | 0 -14 | 8.9 | 8.1 | 8.1 | 6.5-8.5 | - | 6.5-8.5 | 6.5- 9.0 | 6.5-9.5 | 6.5 - 9.0 |
| Total alkalinity (as $CaCO_3$) | mg/L | 68 | 34 | 65 | 200 | 600 | 50-200 | - | 20-200 | 50-300 |
| Dissolved Oxygen (DO) | mg/L | 5.9 | 6.7 | 4.8 | > 5 | - | > 5 | > 5 | > 5 | > 5 |
| Biochemical Oxygen Demand (BOD) | mg/L | 1 | 0.8 | 1 | - | - | - | - | - | < 10 |
| Ammonia (as total $NH_3$-N) | mg/L | 3.2 | 0.2 | 0.2 | 0.5 | - | 1.5 | - | - | 0.05-0.2 |
| Nitrate (as $NO_3$-N) | mg/L | 0 | 0 | 0 | 45 | - | 50 | 10 | 10 | < 5 |
| Phosphate (as $PO_4$-P) | mg/L | 22.12 | 23 | 13.67 | - | - | 0.1 | - | - | 0.005-0.2 |
| Sulphate (as $SO_4$) | mg/L | 21.4 | 19.01 | 14.6 | 200 | 400 | 250 | 250 | 250 | 5-100 |
| Calcium (as Ca) | mg/L | 77 | 67 | 87 | 75 | 200 | 200 | - | - | 75-150 |
| Magnesium (as Mg) | mg/L | 89 | 72 | 77 | 30 | 100 | 150 | - | - | 5-100 |
| Carbon Dioxide ($CO_2$) | mg/L | 56 | 24 | 21 | - | - | - | - | - | <10 |
| Bicarbonate ($HCO_3$) | mg/L | 56 | 44 | 23 | - | - | - | - | - | 50-300 |
| Total Hardness (as $CaCO_3$) | mg/L | 1478 | 1510 | 1376 | 200 | 600 | 500 | - | 100-500 | 5-200 |
| Fluoride (as F) | mg/L | 0.89 | 0.52 | 0.76 | 1.0 | 1.5 | 1.5 | 4 | 1.5 | - |
| Chloride (as Cl) | mg/L | 256 | 197 | 221 | 250 | 1000 | 250 | 250 | 250 | 1-100 |

**Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007);Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).**

**Remarks:** Out of 20 parameters studied 6 exceeded the permissible limits of different standards compared and 3 parameters (Temperature in rainy and winter, DO in winter and Turbidity) are below the optimum range of Boyd (1998) water quality standards for pond aquaculture.

**Note:** 1. Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.
2.Parameters which exceed the permissible limits and which fall below the optimum range are highlighted with red colour.

| Table 6: (S5) Results of water quality parameters tested in 3 different seasons | | | | | Water quality Standards | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Physico-chemical parameters | | Summer | Rainy | Winter | BIS 10500 : 2012 Acceptable limit | BIS 10500 : 2012 Permissible limit | WHO | EU | US EPA | Boyd (1998) Water Quality for Pond Aquaculture |
| Temperature | °C | 48.1 | 21 | 18.8 | - | - | - | 24-32 | - | 25-30 |
| Salinity | mg/L | 4.5 | 3 | 3 | - | - | - | - | - | 1-250 |
| Turbidity | NTU | 4.5 | 6 | 5.5 | 1 | 5 | < 5 | - | < 4 | 20-35 |
| Total Dissolved Solids(TDS) | mg/L | 567.2 | 707.74 | 678.3 | 500 | 2000 | 500 | 1000 | - | 500-1200 |
| Electrical Conductivity (EC) at 20°C | (µS/cm) | 810 | 1026 | 1044 | 500 | 2000 | 2500 | - | 2500 | - |
| pH | 0 -14 | 9 | 8 | 8 | 6.5-8.5 | - | 6.5-8.5 | 6.5- 9.0 | 6.5-9.5 | 6.5 - 9.0 |
| Total alkalinity (as $CaCO_3$) | mg/L | 80 | 25 | 25 | 200 | 600 | 50-200 | - | 20-200 | 50-300 |
| Dissolved Oxygen (DO) | mg/L | 6.8 | 7.2 | 4.9 | > 5 | - | > 5 | > 5 | > 5 | > 5 |
| Biochemical Oxygen Demand (BOD) | mg/L | 5.7 | 3.2 | 3.2 | - | - | - | - | - | < 10 |
| Ammonia (as total $NH_3$-N) | mg/L | 1.2 | 0.2 | 0.1 | 0.5 | - | 1.5 | - | - | 0.05-0.2 |
| Nitrate (as $NO_3$-N) | mg/L | 0 | 0 | 0 | 45 | - | 50 | 10 | 10 | < 5 |
| Phosphate (as $PO_4$-P) | mg/L | 20.8 | 22 | 12.57 | - | - | 0.1 | - | - | 0.005-0.2 |
| Sulphate (as $SO_4$) | mg/L | 24.5 | 18.92 | 12.5 | 200 | 400 | 250 | 250 | 250 | 5-100 |
| Calcium (as Ca) | mg/L | 187 | 160 | 201 | 75 | 200 | 200 | - | - | 75-150 |
| Magnesium (as Mg) | mg/L | 92 | 78 | 85 | 30 | 100 | 150 | - | - | 5-100 |
| Carbon Dioxide ($CO_2$) | mg/L | 34 | 20 | 17 | - | - | - | - | - | <10 |
| Bicarbonate ($HCO_3$) | mg/L | 88 | 60 | 47 | - | - | - | - | - | 50-300 |
| Total Hardness (as $CaCO_3$) | mg/L | 923 | 1000 | 889 | 200 | 600 | 500 | - | 100-500 | 5-200 |
| Fluoride (as F) | mg/L | 0.76 | 0.62 | 0.76 | 1.0 | 1.5 | 1.5 | 4 | 1.5 | - |
| Chloride (as Cl) | mg/L | 377 | 348 | 377 | 250 | 1000 | 250 | 250 | 250 | 1-100 |

**Bureau of Indian Standards IS 10500 : 2012; WHO Guidelines for Drinking-Water Quality (2011);US EPA Primary Drinking Water Standards; E.U: European Union /European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. 278 of 2007);Water Quality for Pond Aquaculture-Acceptable Concentration Ranges in Aquaculture Pond Waters" Boyd (1998).**

**Remarks:** Out of 20 parameters studied 7 exceeded the permissible limits of different standards compared and 3 parameters (Temperature in rainy and winter, DO in winter and Turbidity) are below the optimum range of Boyd (1998) water quality standards for pond aquaculture.

**Note:** 1. Season wise data primarily compared with Boyd (1998) water quality standards for pond aquaculture.
2.Parameters which exceed the permissible limits and which fall below the optimum range are highlighted with red colour.

**Suggestions and Conclusions**

Based on the results of the present research work, the analysis of the significance of the data and the relationship between the data and the state of fish culture in and around Bhimavaram, we arrive at the following recommendations.

At present aquaculture now becoming a popular rural activity, it is recommende that water be checked regularly to monitor water quality and that water be returned to ponds before being used for aquaculture. Good water is essential for production. Aquaculture farmers use too much feed and do not use pesticides and herbicides, which is the main reason for poor water quality in fish ponds. Water can be protected from pollution by smart regulations.

When well implemented the following measures and tips not only increase productivity and economic benefits, but also help farmers protect aquatic fish in the environment, which is essential for the development of aquaculture.

1. Regularly physico-chemical tests should be carried out to protect the fishes from the waterborne disease.
2. Green technologies such as planting shady trees on tank bunds of fish ponds or making artificial shades during summer's thermal stratification can protect fishes in fishponds. That should be implemented with immediate effect.
3. Clear water indicates very low or absence of biological production- not fertile.
4. Use bio-fertilizers in the place of organic fertilizers enough to reduce pollution and then fish will grow well in it.
5. Pond recirculation system technology is relatively new. Potential designs of pond systems have significantly greater fish production over traditional open pond aquaculture.
6. Adopt eco-friendly technologies in fish culture ponds (upon use of harmful feed, antibiotics, effluent treatment facility etc.).
7. Abrupt addition of large quantities of water in small ponds may result in sudden environment change, which subsequently can stress in culture of fishes.

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