

**AN INVESTIGATION OF THE TRANSITIONAL PHYSICO-CHEMICAL REGIME OF
AVIS DAM WINDHOEK, NAMIBIA FROM WINTER TO SUMMER**



BY

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**A Report in the Department of Fisheries and Aquatic Sciences, Faculty of Agriculture and
Natural Resources**

**Submitted to the Department of Fisheries and Aquatic Sciences, Faculty of Agriculture and
Natural Resources, University of Namibia, in partial fulfillment of the requirements for the
award of the degree of Bachelor of Science in Fisheries and Aquatic Sciences of the
University of Namibia.**

NOVEMBER 2010

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DECLARATION

I hereby declare that this work is the product of my own research effort, undertaken under the supervision of Professor E. Omoregie and has not been presented elsewhere for the award of a degree or certificate. All other sources of information used in compiling this paper have been appropriately acknowledged.

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CERTIFICATION

This is to certify that this report has been examined and approved for the award of a Bachelors Degree in Fisheries and Aquatic Sciences offered at the University of Namibia.

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ACKNOWLEDGEMENTS

Acknowledgements are due to my supervisor, Professor E. Omoregie, Mrs. B. Kachigunda (Lecturer) and Mr. P. Nashima (Lecturer) for their support and comments throughout the research period. I thank the entire management and staff of the department of Fisheries and Aquatic Sciences as well as Department of Biology for the material support made available to me. My sincere thanks go to Mr. Akawa (Technologist) and Ms L. Ekanjo (Assistant Technologist) for a commendable work in the field and laboratory during data collection and analysis. I also humbly thank my sampling partners (Dan Ng'uni, L. Malela and Henry Mapwesera) for the job well done, all my friend and classmates for their support and encouragement. Finally, I thank the Royal Norwegian Embassy for providing financial support and my employers, Bunda College of Agriculture for giving me a study leave to enable me pursue my studies at the University of Namibia.

DEDICATION

I would like to dedicate this report to my mum (Dyna Kaliati), my sister Florence and my aunt Lexa Mwalemba for their timely and tireless advice rendered to me during the entire period of study in Namibia.

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ABSTRACT

This study investigated the physicochemical regimes of water parameters of Avis Dam in Windhoek, Namibia from 31st July to 4th September, 2010 representing transitional months between winter and summer. It aimed at finding the variations in values that may occur in dissolved oxygen, water temperatures, conductivity, pH, secchi disc visibility (water transparency), total dissolved solids, alkalinity, salinity and nutrients like phosphorus, nitrate and nitrite during these transitional months. The results obtained revealed that there were significant ($P < 0.05$) physicochemical variations in water parameters like DO, temperature, conductivity, pH, TDS, alkalinity, phosphorus and nitrite an indication that the waters in the Dam were not homogeneous from winter to summer months. No significant differences were observed in water transparency, salinity and nitrate ($P > 0.05$). Though there were changes in physicochemical regime of Avis Dam waters, the quality remained within the required range of acceptable standards (ICMR, 1975; ISI, 1991) for domestic use.

Key words: physicochemical, transitional, regime.

CHAPTER ONE

1.0. INTRODUCTION AND LITERATURE REVIEW

1.1. Background Information

Avis Dam constructed in 1933 is situated at the edge of Windhoek four kilometers to the Eastern side in Namibia and has a potential for education purposes and ecotourism destination. It is located at Latitude 22.27°S and Longitude 17.07°S (Fig.1). A 2 km² Avis Dam occupies a catchment area of at least 230 – 290ha with an average daily maximum and minimum temperatures of 31°C and 2 -3°C registered in December and July respectively (Harper and Maritz, 1998). The Dam with water capacity ranging from 5000m³ to 1,510,000m³ depending on the amount of rainfall in a given period plus runoff waters from River Klein Windhoek and Rivers Avis. Avis dam is said to be a valuable habitat for reptiles (30 species of lizards and 40 species of snakes), mammals (mice, gerbils, hares, antelopes, etc) and invertebrates. The presence of fish species like Common Carp and Bream attracts the avifauna of the dam. There are 180 bird species of which 28% are aquatic birds and 17 species were observed to breed in the area (Harper and Maritz, 1998).

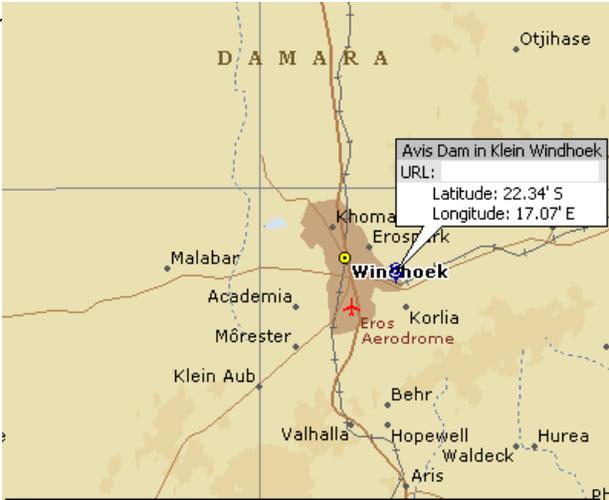


Figure 1: Map of Windhoek showing location of Avis Dam

1.2. Problem Statement

The physicochemical regime of water bodies vary with seasons as reported by (Hart, 2001) on the isothermal values of water column temperatures that increased significantly from winter towards the end of July (below 11°C) to mid September (above 13°C). Knowing the physicochemical parameters of a water body helps to understand the biological status of different organisms and their interactions with the environment. However, there is little or no information regarding to the transitional physicochemical regime of Avis Dam from winter months to summer months.

This paper presents and discusses the findings of physicochemical regimes occurring in Avis Dam and their state of change from winter to summer. The results from the study will act as baseline information of physicochemical regimes specifically occurring in Avis Dam from 31st July to 4th October and used for further studies about the Dam.

As a natural resource, water is important for every living organism on Earth including mankind therefore it is being overexploited and seriously degraded due to anthropogenic activities like disposal of pollutants in water bodies. Macintyre (2008) indicated that inappropriate levels of water physicochemical parameters affect growth rates, efficiency and physiology causing pathological changes, damage organs and in extreme cases cause mortality.

However, the physicochemical changes of water might be due to pollutants like activities from urban and agriculture farms, industrial and mine drains, chemical and oil spills, thermal and acid precipitation, dumping of solid wastes, etc. Ramachandra and Solanki (2007) reported that pollution of any form first affects the physicochemical regimes of the water and then systematically destroy living communities and disrupts delicate food webs in aquatic ecosystems.

1.3. Literature Review

In aquatic ecosystems, biota differs greatly with changes in physicochemical conditions. Barreira (2004) reported that changes in physicochemical condition alter the fauna and primary productivity of associated ecosystem. A study by George, Abowei and Daka (2009) revealed the existence of a direct relationship between physicochemical quality of water and the organisms in aquatic ecosystems. As such, physicochemical parameters can be used as indicator of organisms' ability to adapt, survive or migrate to favorable environmental conditions hence the distribution of organisms. In a related study Ayoade, Agarwal and Chandola (2009) found that changes in physicochemical parameters of Tehri Dam in India led to an increase in plankton density, fauna diversity, and presence of some immigrant species. Higher pH and total alkalinity were recorded in winter and these were attributed to the fluctuation of biogenic activities occurring in Tehri Dam at the time of data collection.

Research outcome by Ayoade *et al.* (2009) showed a maximum alkalinity during winter months in Bhilangana. Higher conductivity and hardness of the water was considered to be productive for Tehri Dam in winter whereas a total alkalinity of >50mg/L was regarded to be productive during winter and monsoon periods (Ayoade *et al.*, 2009). Poor water quality parameters are associated with the development of a variety of facultative (e.g. *Saprolegnia*) and obligate fungal, bacterial and viral diseases. Macintyre (2008) reported that non-infectious diseases are specific to particular water quality parameters like gas bubble disease (supersaturation of O₂), methaemoglobinaemia (nitrite), and fin erosion (low DO and alkalinity).

Dissolved Oxygen (DO) is one of the prime parameters important for water quality considerations among other physicochemical characteristics and its content vary widely in natural water bodies depending on the physical, chemical and biological processes in the water. Major sources of DO are diffusion due to surface water agitation by wave action or turbulence and photosynthesis by phytoplankton, higher plants and photosynthetic bacteria. DO gets reduced from a water body through flora and fauna respiration, decomposition of organic matters and reduction oxidation due to presence of other gases like N₂, H₂S and CO₂. Kutty (1987) reported that DO changes influences fish stock densities in water bodies and that fluctuating DO reduces growth rate almost close to that caused by low DO itself at 1mg/L. Kutty (1987) also indicated that oxygen in excess inhibit the activities of respiratory enzyme, succinic dehydrogenase.

Temperature is also one of the most important physical parameters as it regulates most chemical processes occurring in any water body like DO, photosynthesis and respiration rate among many others. However Macintyre (2008) reported that increased temperatures has a negative impact as it also increases infectious pathogens, toxicity of many dissolved contaminants as well as causing a reduction in dissolved oxygen like a rise in water temperature from 9 - 15°C lead to a reduction of water holding capacity to oxygen by 12.8%.

Water conductivity is the ability of water to allow electric current to passing through it due to the presence of inorganic dissolved solids like chloride, nitrate sulfate and phosphate anions or iron, calcium, aluminum, sodium and magnesium cations. Kutty (1987) indicated that at higher

temperatures, the conductivity of water is higher than at low temperatures and also that sewage system would raise the conductivity of a water body while oil spills lower the conductivity. Macintyre (2008) reported that the conductivity of fresh water bodies is usually in the range of 20 - 1500 μ S/cm. However, Kutty (1987) recommended a conductivity range of 150 – 500 μ S/cm in fresh water and any value outside this range is described as unsuitable for macro invertebrates and some species of fish.

The pH is also very important due to hydrogen ion concentration which is important to nearly all reactions associated with water quality. pH affects aquatic life for example, at low pH, gills in fish gets damaged or malfunctions due to mucus secreted in an effort to protect the gills against low pH situation. This follows a series of other disorders like respiratory stress, decreased sodium chloride concentration in blood (Boyd, 2000). The primary productivity of aquatic habitat can be estimated by studying pH changes.

Phosphate concentrations in nature occur at low values and limit the growth of phytoplankton though considered to be a primary cause of eutrophication in aquatic ecosystem (Boyd, 2000; Cole, 1994). The major sources of phosphate are the phosphate-bearing minerals like iron, aluminum and calcium phosphates as well as domestic sewage and animal manures as revealed by guano accumulated on dry cliffs. However, Cole (1994) reported that the original source of phosphate was igneous rock. There is always a balance between phosphate input and output in unpolluted ecosystem and any excess to natural waters are considered undesirable and a form of pollution (Boyd, 2000). Boyd (2000) reported that certain species of phytoplankton demonstrate a luxury consumption of phosphorus in excess. He further explained that Phosphorus is not toxic

but high concentrations of 0.005 - 0.05mg/L can cause phytoplankton bloom and cause eutrophication. Heavy nutrients loads exceeding thresholds in an ecosystem cause profound impacts on the food web. A Washington University (2004) research discovered that higher levels of phosphorus and nitrogen cause deformities in frogs by missing, having extra or deformed limbs.

Nitrite (NO₂-N) availability in water bodies poses a danger to living organisms as it is toxic. Kutty (1987) indicated that NO₂-N combines with hemoglobin and forms methaemoglobin causing a brown coloration of blood. It was also reported that NO₂-N toxicity increases at lower pH values and occurs at low concentrations in natural water bodies as it gets neutralized by chloride and calcium ions. Kutty (1987) suggested that NO₂-N concentration in fresh water pond in fish culture should not exceed 0.1mg/L NO₂-N, and in seawater be 1.0mg/L NO₂-N.

Nitrate (NO₃-N) as indicated by Kutty (1987) is a major form of nitrogen and recommended that waters with values ranging from 1.4 - 100 mg/L NO₃-N have no toxic effect on primary productivity and fish. However, Macintyre (2008) reported that exposure of eggs to NO₃-N result in egg developmental problems posing threats to egg hatchability hence impact on the aquatic fauna.

Total Alkalinity also known as titratable base, buffer capacity, excess base or acid-combining strength (Cole, 1994) is an index of the total concentration of titratable bases of equivalent calcium carbonate (CaCO₃) with a main source being dissolution of limestone. However the presence of free carbon dioxide results to more solution of calcium carbonate and greater

alkalinity and vice versa (Boyd, 2000). The other source of bicarbonate in water is the reaction between hydrogen ions (H^+) and basic ions like magnesium, sodium and potassium in sediments. Alkalinity in natural water bodies normally ranges from 0 - 500mg $CaCO_3/L$ with a moderate range of 50 – 150mg $CaCO_3/L$ (Boyd, 2000). A study by Boyd (2000) also showed that areas with semi-arid or arid climate have moderate to high alkaline values of 50 - 300mg $CaCO_3/L$. Alkalinity is said to have a positive relationship to pH that is an increase in pH leads to an increase in the alkalinity of water. However, Cole (1994) indicated that waters with higher alkalinity values are more effective in resisting pH changes. The daily fluctuation of alkalinity are said to be negligible despite changes in bicarbonate and carbonate proportions throughout the day. Respiration and photosynthesis have effects on carbonic acid only which change the pH of water thus CO_2 lowers pH without much change in total alkalinity (Cole, 1994).

Alkalinity is of great significance to the aquatic system as it is an important variable for productivity due to its relationship with carbon availability. Macintyre (2008) indicated that alkalinity values greater than 20mg $CaCO_3/L$ have potential to providing an ecosystem protection by buffering it against large and sudden changes in pH. Boyd (2000) reported that waters with total alkalinity values from 0 - 50mg $CaCO_3/L$ are usually less productive than those with total alkalinity concentration from 50 - 200mg $CaCO_3/L$. Kutty (1987) indicated that waters in arid regions are highly alkaline as it is also associated with higher phosphorus levels.

1.4. STUDY OBJECTIVES

1.4.1. Overall Objective

- To evaluate the transitional status of the physicochemical regimes of Avis Dam water parameters from winter to summer months.

1.4.2. Specific Objectives

- To assess the transitional states of DO, pH, temperature, phosphate, nitrate, alkalinity, turbidity, conductivity and total dissolved solids (TDS) concentrations in Avis Dam from winter to summer months.

1.5. HYPOTHESIS

- **H₀₁**: There is no significant difference in the mean physicochemical regimes of Avis Dam water parameters in winter and summer.
- **H₁₁**: There is a significant difference in the mean physicochemical regimes of Avis Dam water parameters in winter and summer.

CHAPTER TWO

MATERIALS AND METHODS

The study was conducted in Avis Dam, located at the urban vicinity of Windhoek, Namibia (Figure 1) where water samples were collected at a week interval from July, 2010 to October, 2010. Three sampling stations (Figure 2) were selected randomly based on the layout of the dam being at the inlet, center and outlet sections almost 50m apart for the horizontal data collection and the vertical positions established as surface, middle and bottom waters.



Fig.2. Map showing main sampling stations (A=Inlet, B=Center and C=Outlet)

2.1 DATA COLLECTION

Water samples for chemical analysis; total phosphate, nitrite, nitrate and alkalinity were collected in three replicates of 250mL plastic bottles (Plate 2) which were well labeled from 11:30am to 14:30pm. Before sampling, sampling bottles were cleaned with tap water, rinsed with distilled water and dried to remove all possible contaminants. Another material also used was a balloon boat which assisted the crew to move from one sampling station to another during water sample collection.

Collection of surface water samples were done by just filling in the sampling bottles held in hands directly. Waters samples from middle and bottom water column were collected using a Niskin water sampler. The water sampler was first set at a specific depth and then a messenger was sent to close the trapped water and hauled to the surface for determination of water parameters.

Water samples were analyzed systematically for physical and chemical water parameters using both volumetric and instrumental techniques. Water temperature, pH and dissolved oxygen (DO) readings were recorded at the sampling site using pH/ORP/Ion/DO meter-SG68 (Plate 4). Similarly, HACH-CO150 conductivity-meter was used to measure conductivity, total dissolved

solids and salinity. Turbidity readings were also determined in the field using a 20cm diameter secchi disc (Plate 3) by dipping it thrice and average value reported.



Plate1. Researcher recording DO & pH

Plate2. Researcher collecting water samples
from Niskin bottle



Plate3. Researcher launching a secchi disc



Plate4. Researcher recording water temperature

2.2. LABORATORY DATA ANALYSIS

Water samples collected were then taken to the laboratory at UNAM for determination of water chemical parameters like phosphate, nitrate, nitrite and alkalinity (Plate 5). These chemical components of water samples were analyzed following standard methods described by APHA (1985).

2.2.1. Phosphate PO₄-P Determination

5mL of sample water, blank (distilled water) and standard were prepared in test tubes placed in a rack and a 0.5mL of mixed reagent added to each test tube using a pipette. The absorbances for each sample were recorded within a minimum period of 5 minutes and maximum period of 2-3 hours at 885nm using HACH-DR2700 spectrophotometer with 450 cells (Appendix 1.1). The absorbances of each sample were read three times and the mean absorbance used to calculate the amount of phosphate (PO₄-P) in the water using the formula below;

$$\text{PO}_4 - \text{P} = \left[\frac{\text{Corrected Sample Absorbance}}{\text{Corrected Standard Absorbance}} \right] \times 3\mu\text{g/L}$$

Where,

Corrected Sample Absorbance = Sample Absorbance - Blank Absorbance

&: Corrected Standard Absorbance = Standard Absorbance - Blank Absorbance

2.2.2. Nitrate (NO₃-N) Determination

The reagents for NO₃-N determination were prepared that is concentrated ammonium chloride solution, dilute ammonium chloride, column of copperized cadmium, sulfanilimide solution, N-(1-naphthyl)-ethylenediamine dihydrochloride solution (NEDI), Nitrite Standard (10μg/L) and Cadmium Reduction Column (Appendix 1.2).

The test tubes containing 5mL of distilled water (blank) and nitrite standard (10μg/L) were prepared. Two rows of test tubes, one for NO₂-N analysis and one for NO₃-N analysis were also prepared where 5mL of sample water was put in each test tube for NO₂-N analysis in row 1 and

approximately 25mL of sample water was put into a beaker and 0.5mL of concentrated NH₄Cl added to each beaker. This sample water was made to pass through a reduction column of copperized cadmium and then 5mL of the reduced water sample was collected into test tubes in row 2 for NO₃-N analysis.

To each test tube (blank, standard and NO₂-N samples and NO₃-N samples), 0.1mL of sulfanilimide was added and mixed using Heidolph Vortex No: 541.10000.00.0. After the samples were allowed to react for 2-8 minutes, 0.1mL NEDI was added and mixed again. After a minimum period of 10 minutes and a maximum of 2 hours, the absorbances were read using HACH-DR2700 Spectrophotometer with 450 cells at a wavelength of 543nm.

The concentration of NO₂-N was calculated using the following formula:

$$\text{NO}_2 - \text{N} = \left[\frac{\text{Corrected Sample Absorbance}}{\text{Corrected Standard Absorbance}} \right] \times 10 \mu\text{g/L}$$

Where: Corrected Sample Absorbance = Sample Absorbance – Blank Absorbance

&: Corrected Standard Absorbance = Standard Absorbance – Blank Absorbance

The values for NO₃-N were obtained after subtracting Row 1 readings from Row 2 readings for each sample.



Plate5. Researcher analyzing water samples for Phosphate ($\text{PO}_4\text{-P}$), Nitrate ($\text{NO}_3\text{-N}$) and Nitrite ($\text{NO}_2\text{-N}$) determination.

2.2.3. Alkalinity Determination

Water samples of 50mL were measured using a measuring cylinder and put in Erlenmeyer flask then 0.1mL of phenolphthalein indicator was added but samples remain colourless. Immediately 0.1mL of methyl orange was added to samples in which the phenolphthalein was added since the pH of water samples were below 8.3 (Appendix 1.3). The water samples were titrated with 0.02N acid sulphuric thus a drop by drop of the acid added while stirring until the colour changed to pink. The final volume of acid added to water samples from the burette were recorded and alkalinity of water calculated using the following formulae.

$$\text{Alkalinity (mg CaCO}_3\text{/L)} = \left[\frac{\text{mL of Acid added} \times \text{Normality of Acid} \times 50,000}{\text{mL of Water Sample}} \right]$$

2.3. STATISTICAL DATA ANALYSIS

The data will be computed into Excel and imported in GENSTAT statistical package for analysis in which two-way analysis of variance (ANOVA) will be used. Least Significant Difference (LSD) will be used to separate the treatment means at 0.05 alpha levels of significance. The results from this research project will be presented using tables and graphs.

CHAPTER THREE

3.0. RESULTS

It was observed that DO, temperature, nitrite, nitrate and alkalinity values were higher in summer compared to those values collected in winter for the same water parameters. The situation for water parameter like conductivity, pH, phosphorus, TDS, salinity and transparency showed an opposite trend having higher values in winter than in summers. The means for the overall physicochemical results of water parameters for winter and summer months are given in Table 1. The ANOVA tables for field data and results for all statistical data (genstat output) are presented in Appendix 3.

Table 1. Overall summary of physicochemical water parameter mean values' results

PARAMETER	SUMMER	WINTER	MINIMUM	MAXIMUM	MEAN \pm SE
Dissolved Oxygen (mg/L)	2.71 ^b \pm 0.281	4.11 ^a \pm 0.278	1.00	9.30	3.40 \pm 0.28
Temperature ($^{\circ}$ C)	20.28 ^b \pm 0.272	15.89 ^a \pm 0.275	13.70	25.30	18.11 \pm 0.27
Conductivity (μ S/cm)	788.80 ^b \pm 5.01	803.50 ^a \pm 4.95	736.00	1013.00	796.10 \pm 4.98
pH	7.36 ^b \pm 0.106	7.94 ^a \pm 0.105	4.70	8.81	7.64 \pm 0.11
Phosphorus (mg/L)	1.82 ^b \pm 0.194	3.04 ^a \pm 0.191	0.05	8.70	2.42 \pm 0.19
Nitrite (mg/L)	0.37 ^b \pm 0.069	0.13 ^a \pm 0.070	0.01	3.30	0.25 \pm 0.07
Nitrate (mg/L)	0.19 ^a \pm 0.025	0.13 ^a \pm 0.025	0.00	0.88	0.16 \pm 0.02
Total Alkalinity (mgCaCO ₃ /L)	138.40 ^b \pm 1.90	110.90 ^a \pm 1.93	21.00	220.00	124.80 \pm 12.04
Total Dissolved Solids (mg/L)	379.20 ^a \pm 2.12	386.50 ^a \pm 2.10	352.00	461.00	382.80 \pm 2.11
Salinity (ppt)	0.40 ^a \pm 0.00255	0.41 ^a \pm 0.00252	0.40	0.50	0.40 \pm 0.002
Secchi Disc Visibility (m)	0.66 ^a \pm 0.0095	0.67 ^a \pm 0.0094	0.40	1.12	0.66 \pm 0.009

The values obtained for DO during sampling range from 1.0 - 9.3mg/L as shown in Table1. The lowest mean DO value of 1.89mg/L was recorded in summer during the fourth sampling and the highest mean value of 5.56mg/L in winter during the 5th sampling as shown in Appendix 2. These fluctuations in DO values indicate that the means were significantly different in winter and summer as well as among different sampling days ($P<0.05$, $F_1<0.001$ and $F_8=0.019$) as shown in Appendix 3.1.

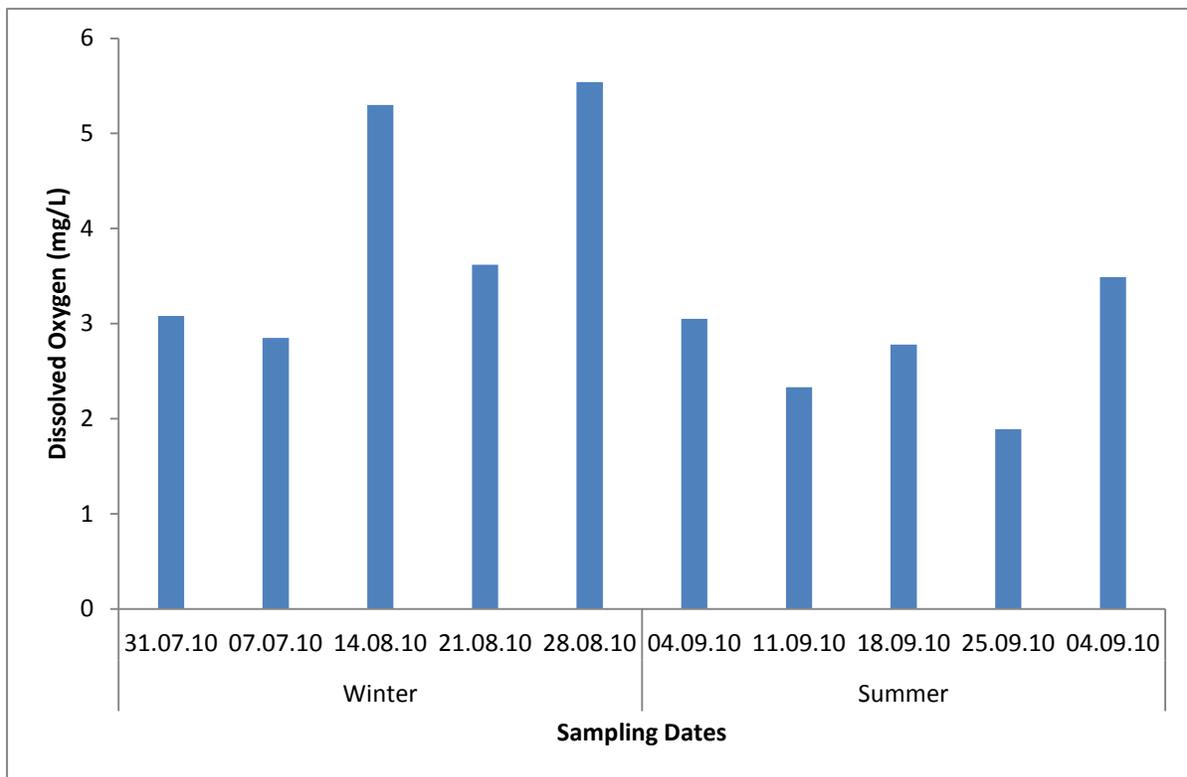


Fig.3. Variations in mean values of Dissolved Oxygen in Avis Dam from 31st July to 4th September, 2010.

Temperature recordings during sampling period were in the range of 13.7 °C - 25.3 °C as shown in Table 1. However, the lowest mean temperature value of 14.69 °C was obtained during the third sampling in winter and the highest value of 22.25 °C in summer (Appendix 2). The analysis shows that the means among temperature values were significantly different from winter to summer period as well as among different days at the time of data collection ($P < 0.05$, $F_{1,8} = 0.001$) as indicated in Appendix 3.2.

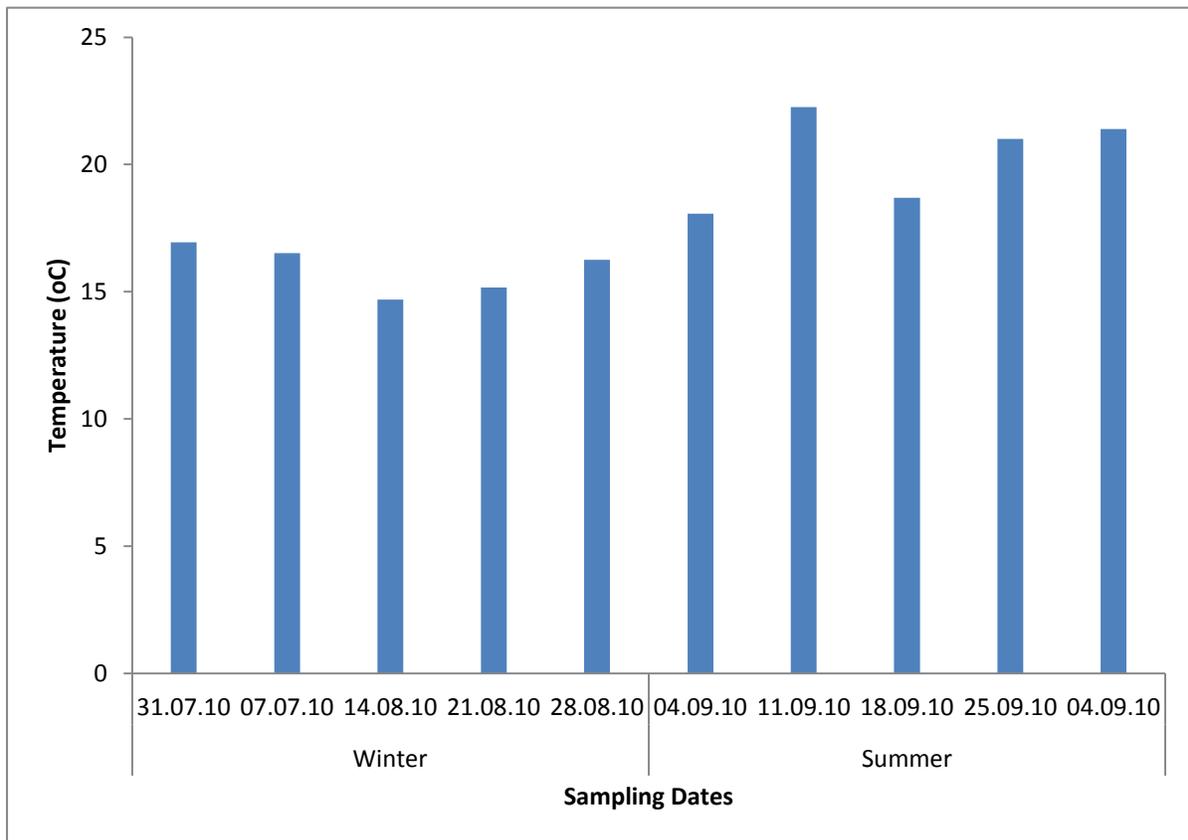


Fig.4. Variations in mean values of Temperature in Avis Dam from 31st July to 4th September, 2010

Conductivity values collected during sampling range from 736 μ S/cm to 1013 μ S/cm as shown in Table 1. The lowest mean value of 755.2 μ S/cm was registered during second sampling and the highest mean value of 858.9 μ S/cm during fourth sampling both in winter (Table 1). The values indicate a significant difference in the mean conductivity between winter and summer as well as among different sampling days ($P < 0.05$, $F_1 = 0.04$ and $F_8 < 0.001$) as presented in Appendix 3.3.

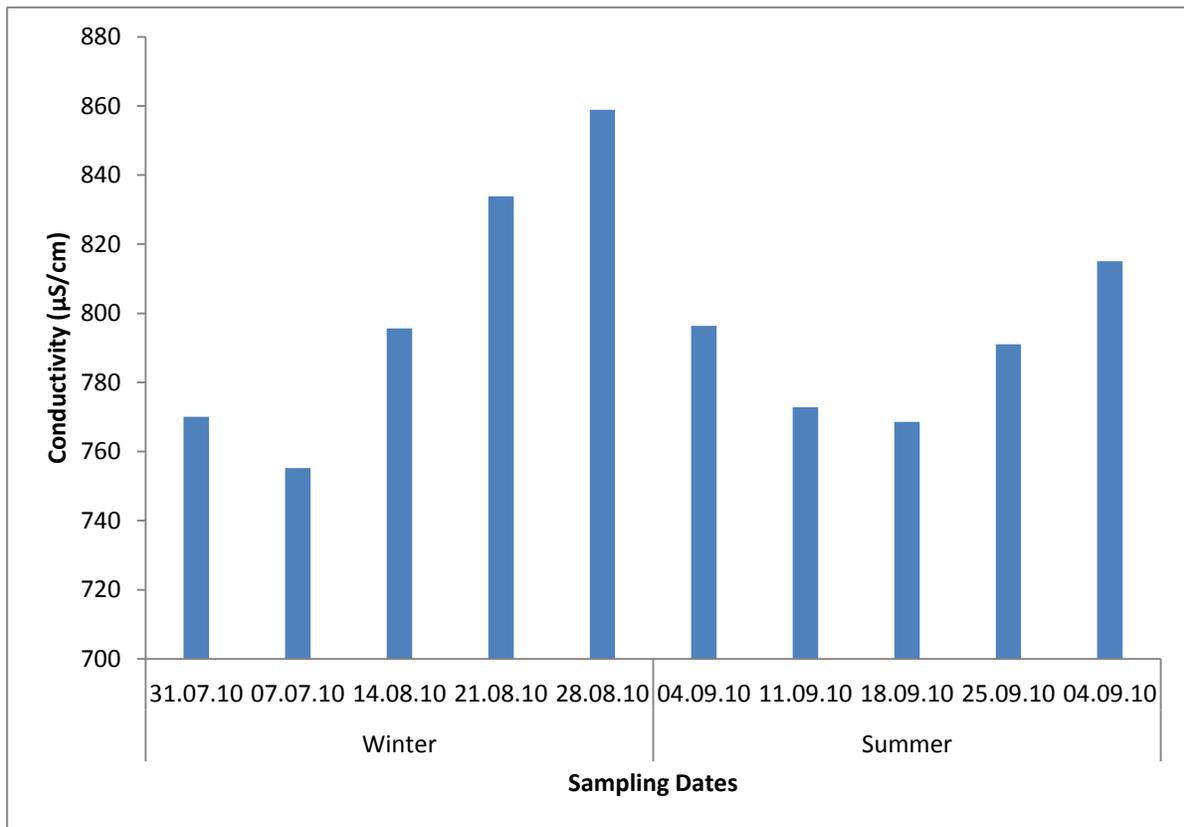


Fig.5. Variations in mean values of Conductivity in Avis Dam from 31st July to 4th September, 2010

The pH values obtained during sampling ranged from 4.7 to 8.81 with an overall mean of 7.64 ± 0.11 as shown in Table 1. Both lower and high pH values (6.512 and 8.434) were registered in summer and the mean pH value was higher (7.935) in winter than summer (7.355). These values were significantly different from winter to summer as well as among different sampling day ($P < 0.05$, $F_{1,8} = 0.001$) as indicated in Appendix 3.4.

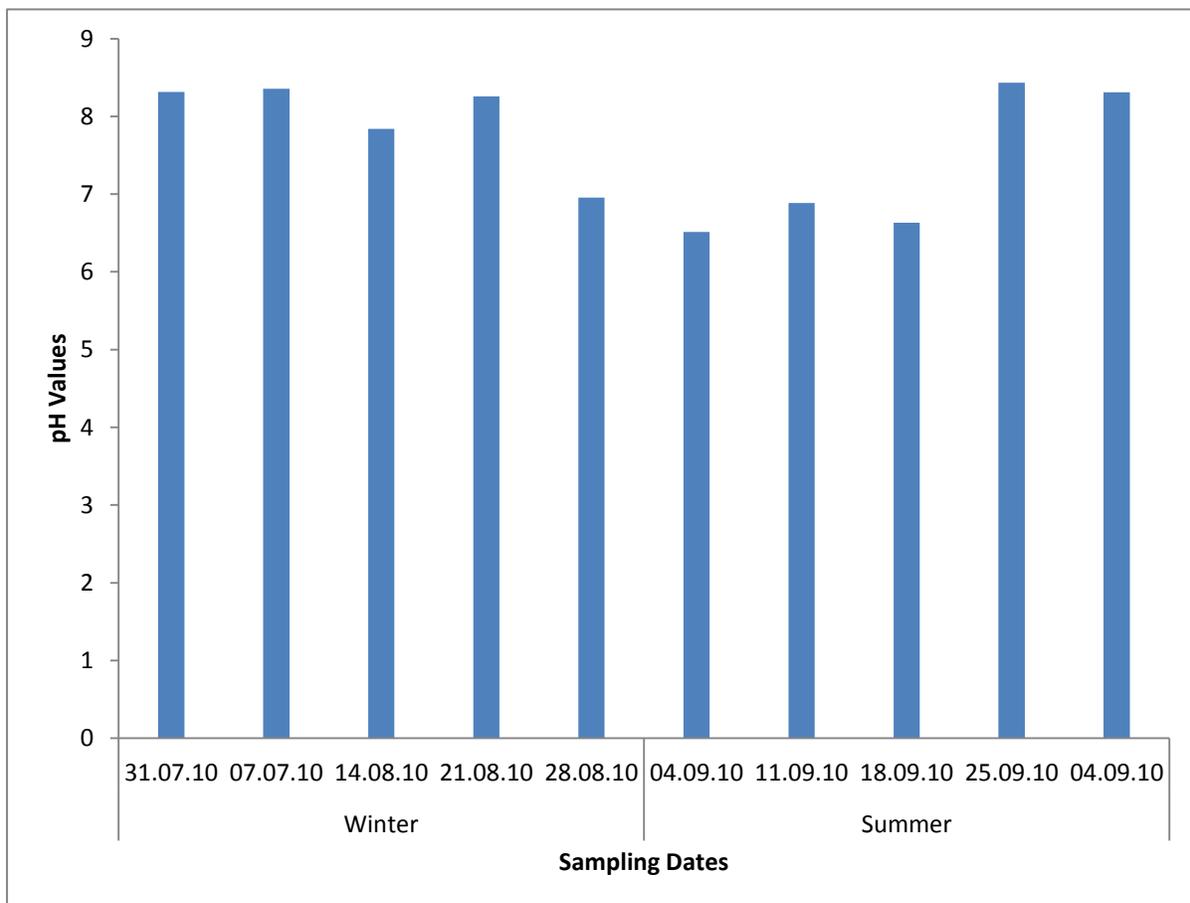


Fig.6. Variations in mean values of pH values in Avis Dam from 31st July to 4th September, 2010

Transparency values of water during sampling were in the range of 0.40 - 1.12m as observed by secchi disc visibility (Table 1). The minimum and maximum values were both obtained during the summer period. The mean visibility values were not significantly different between winter and summer months ($P>0.05$, $F_1=0.448$) there however significant differences in the mean visibility values obtained among the different sampling days ($P<0.05$, $F_7<0.001$) as presented in Appendix 3.11.

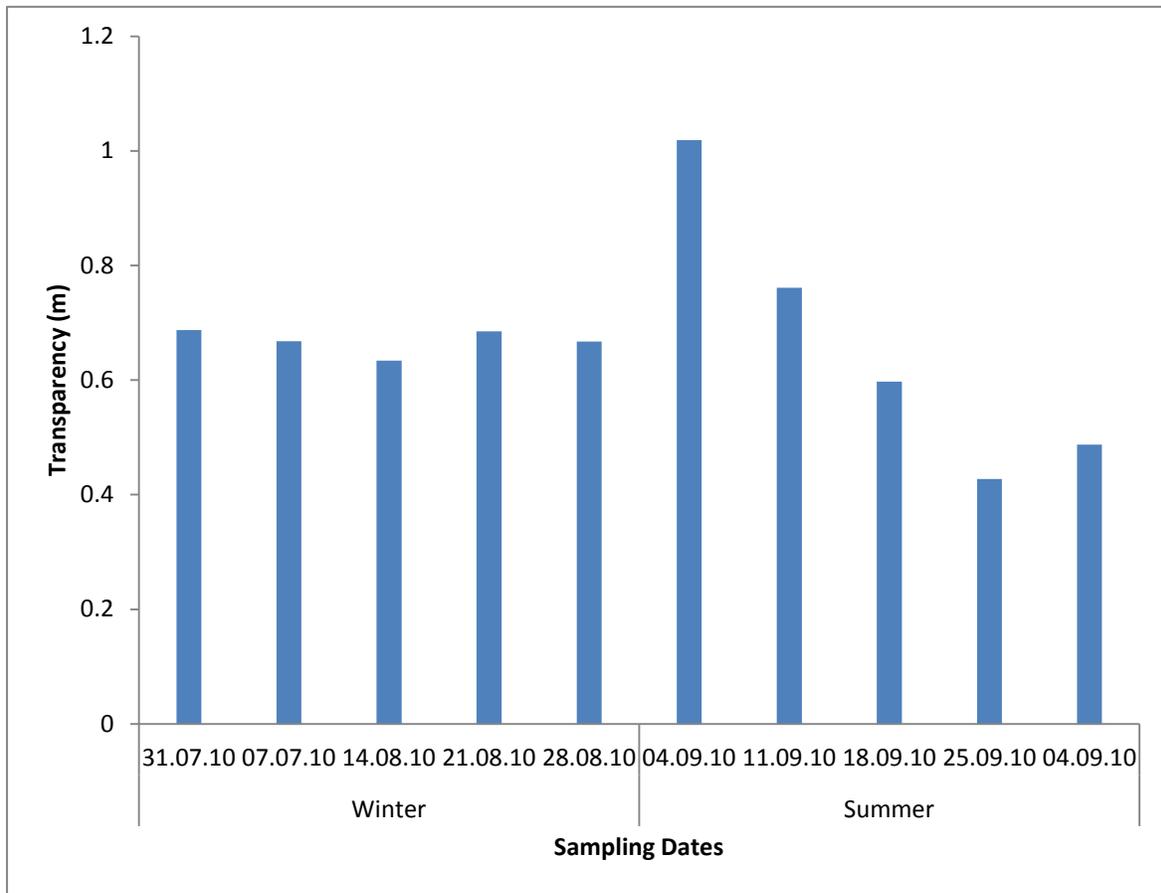


Fig.7. Variations in mean values of Secchi Disc Depth in Avis Dam from 31st July to 4th September, 2010

Phosphorus values ranged from 0.05 - 8.70mg/L with a mean value of 2.42 ± 1.21 mg/L as indicated in Table 1. It was also observed that the highest value of phosphorus was recorded at the 1st sampling on 04/09/10 in winter while the lowest value in summer at the 4th sampling on 25/09/10 (Appendix 2). Analysis also showed that water samples were significantly different in the mean PO₄-P among seasons as well as among different sampling days from winter to summer ($P < 0.05$, $F_{1,1} = 0.05$) as shown in Appendix 3.5.

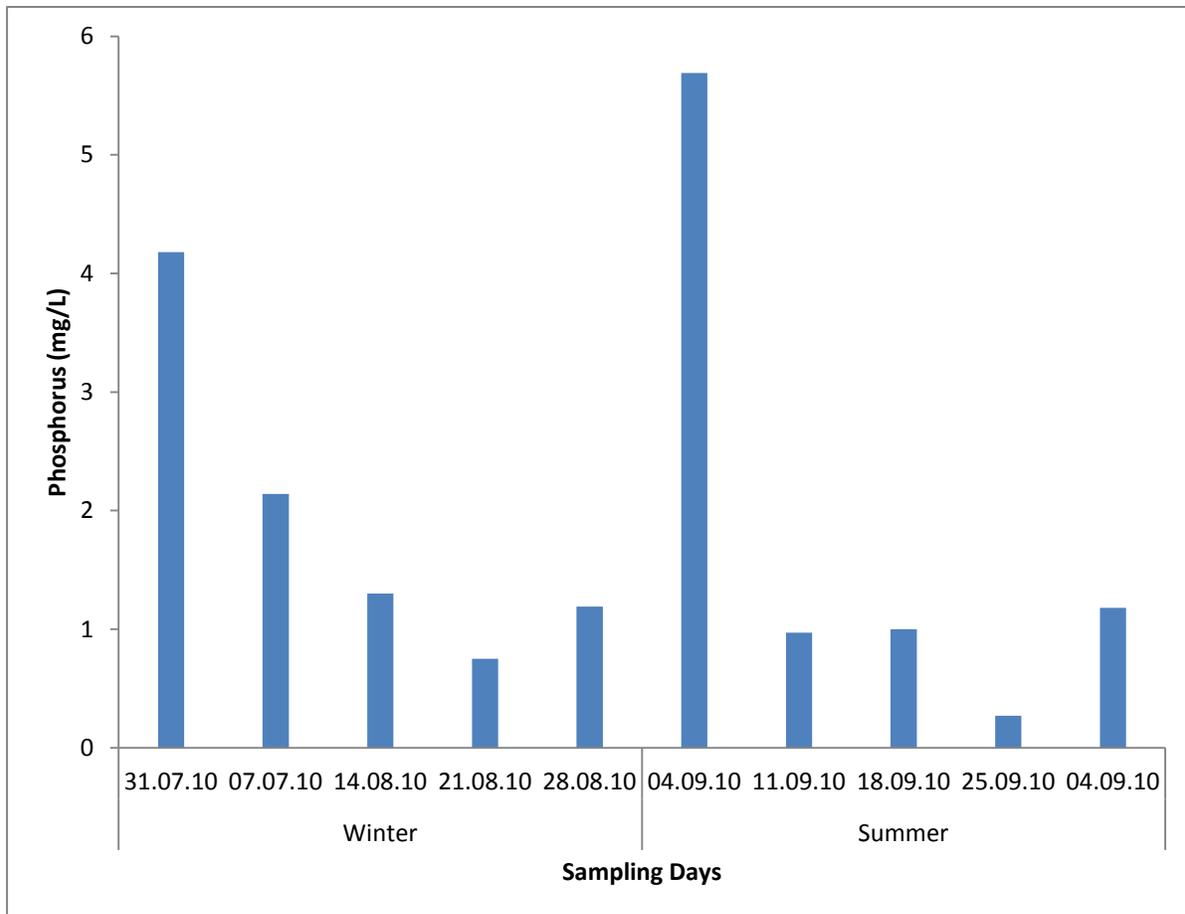


Fig.8. Variations in mean values of Phosphate ($\text{PO}_4\text{-P}$) in Avis Dam from 31st July to 4th September, 2010

Values of nitrite concentrations during the study varied from 0.01 - 3.3mg/L and mean value of 0.25 ± 0.44 mg/L was obtained (Table 1). Analysis indicated that there was a significant difference in the mean nitrite concentrations between seasons ($P < 0.05$, $F_1 = 0.019$) and the trend was also similar to the mean values for different sampling days ($P < 0.05$, $F_8 = 0.019$) as shown in Appendix 3.6.

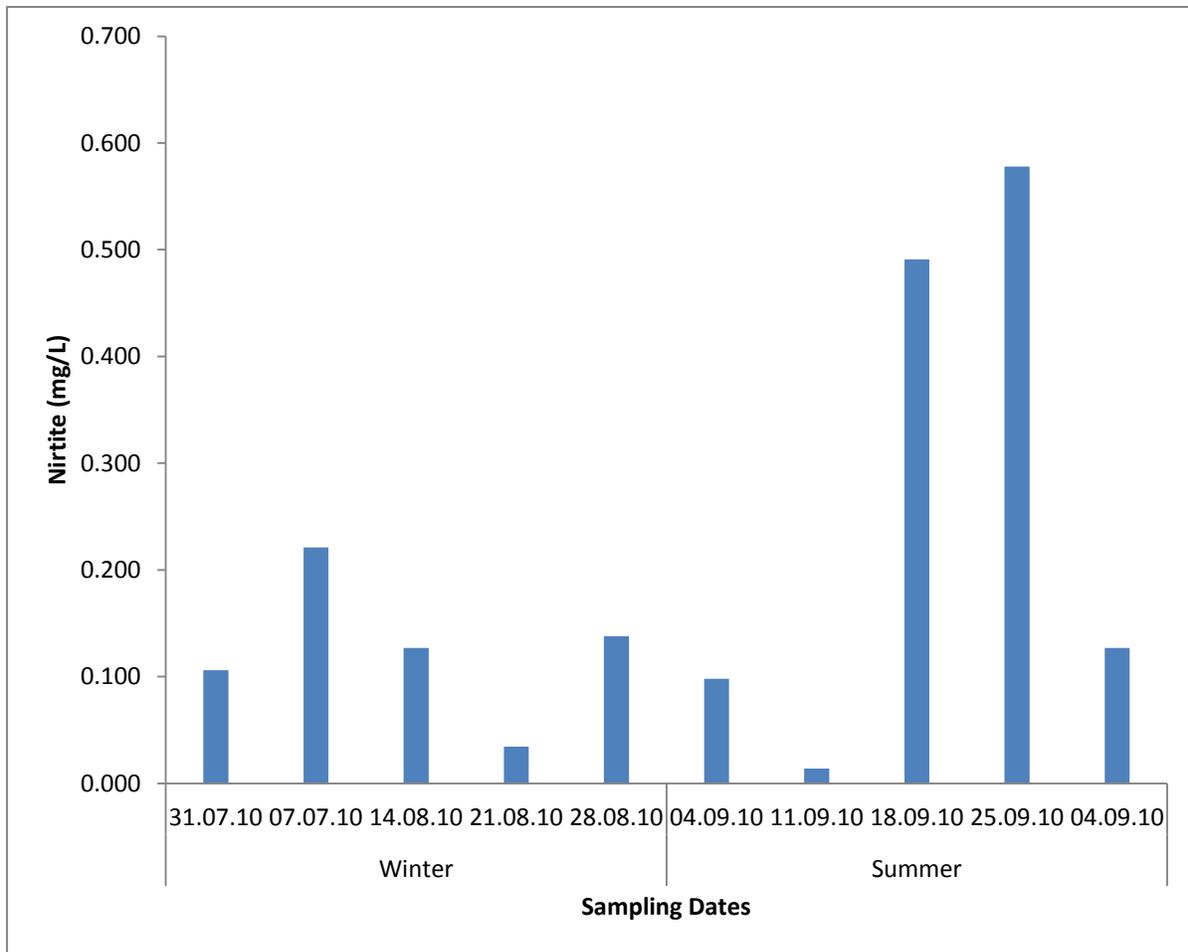


Fig.9. Variations in mean values of Nitrite (NO₂-N) in Avis Dam from 31st July to 4th September, 2010

Higher and lower values for nitrate were both recorded in summer (0.00 and 0.88mg/L) respectively, with a mean value of 0.16 ± 0.16 mg/L (Table 1). Results from data analysis indicated that there were no significant differences in mean nitrate concentrations ($P > 0.05$, $F_1 = 0.112$) between the two seasons, while significant differences in the mean nitrate values were observed for different sampling days ($P < 0.05$, $F_8 = 0.009$) as shown in Appendix 3.7.

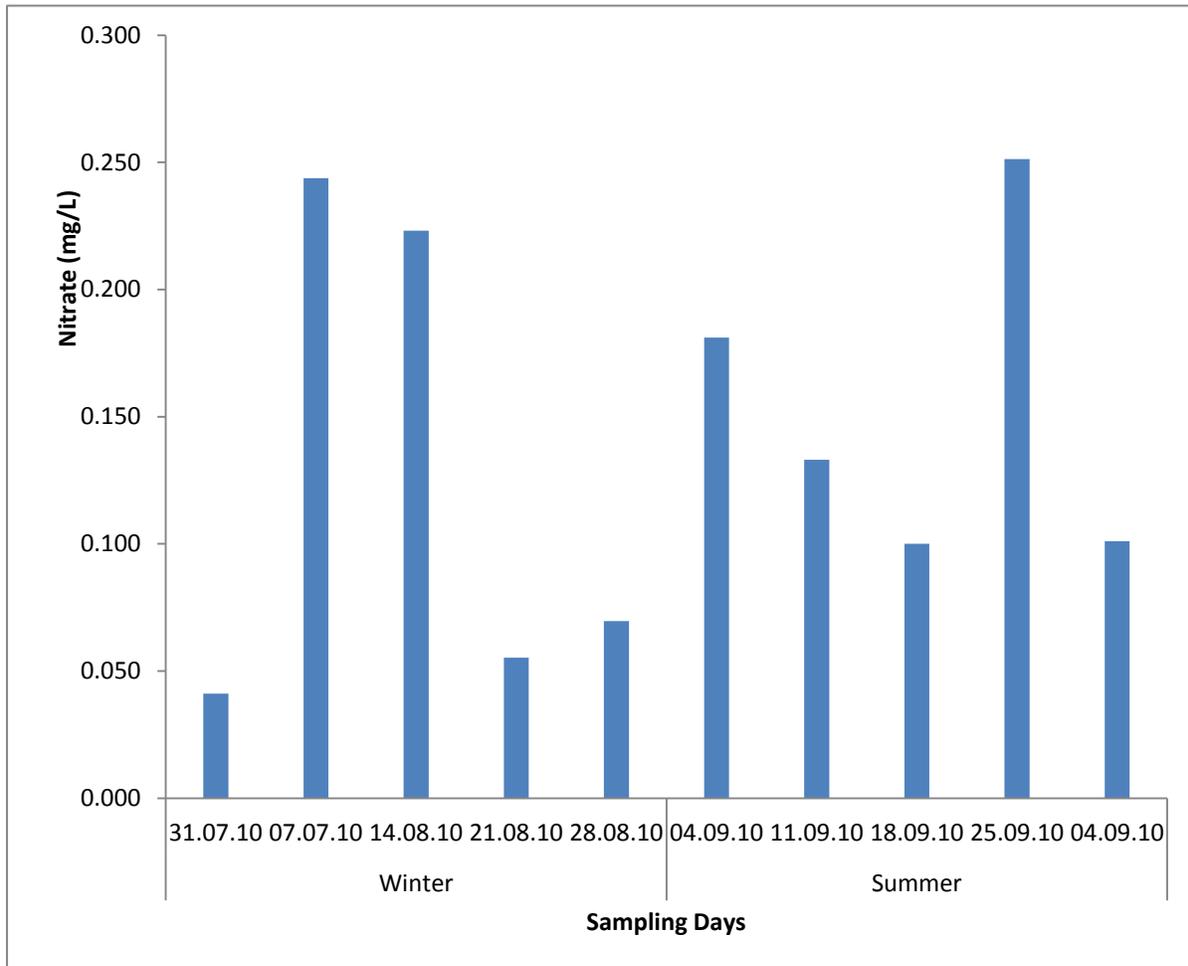


Fig.10. Variations in mean values of Nitrate ($\text{NO}_3\text{-N}$) in Avis Dam from 31st July to 4th September, 2010

The values obtained for total dissolved solids (TDS) indicated minor variations ranging from 352 - 461mg/L as shown in Table 1. However both lower and higher values were obtained in winter as indicated. These TDS results indicated that there were significant differences in the mean TDS values between winter and summer months as well as for the means among different

sampling days ($P < 0.05$, $F_{1,8} = 0.001$) as shown in Appendix 3.9. The highest mean values of TDS were also recorded in winter than those collected in summer (Table 1)

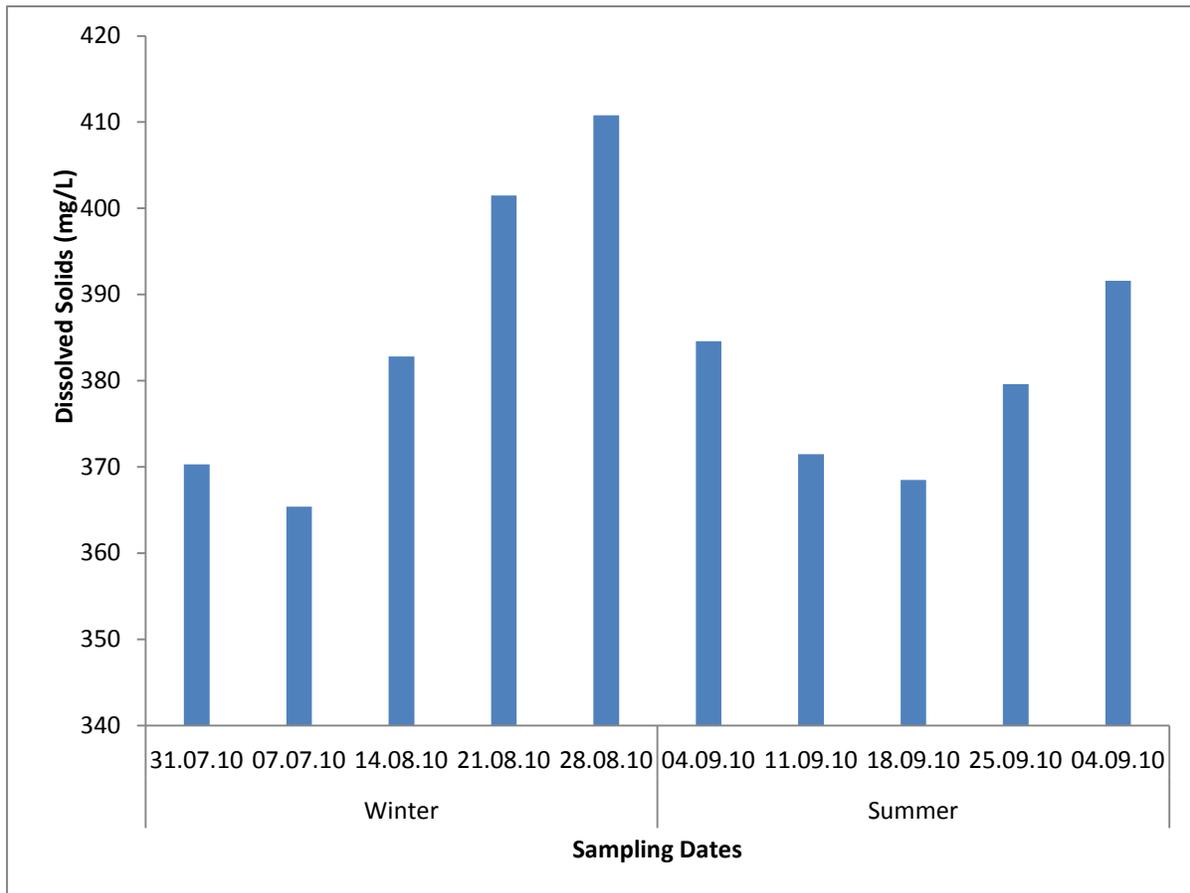


Fig.11. Variations in mean values of Total Dissolved Solids in Avis Dam from 31st July to 4th September, 2010

Results from this investigation indicated that alkalinity values varied greatly within sampling period during the winter months when compared to values obtained during the summer months. During sampling, alkalinity values ranged from 21 - 220mgCaCO₃/L (Table1). Summer values had small variations with a positive relationship to time series. Winter had both maximum and

minimum alkalinity values of 28.8 and 171.1mgCaCO₃/L (Appendix 2). Analysis of results indicated that there were significant differences among the means of alkalinity values with season and different sampling days ($P < 0.05$, $F_{1,3} = 0.001$) as in shown Appendix 3.8.

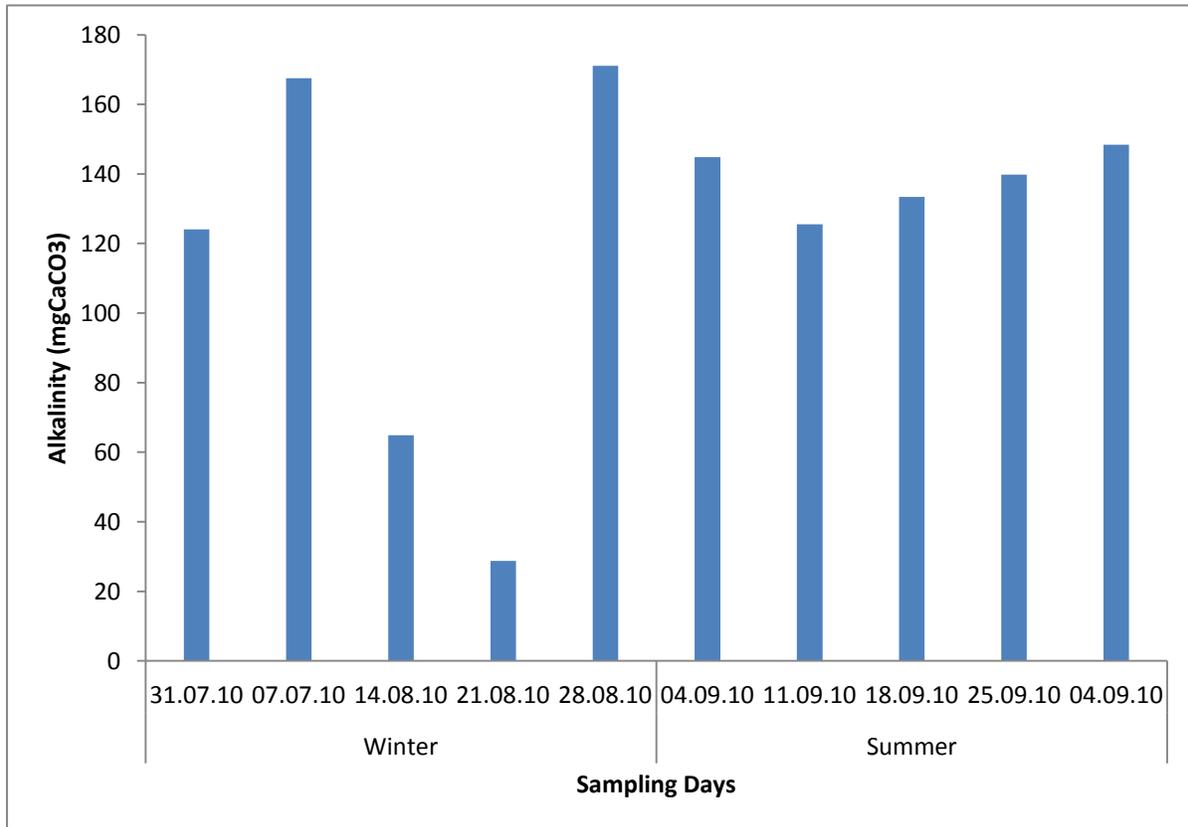


Fig.12. Variations in mean values of Total Alkalinity in Avis Dam from 31st July to 4th September, 2010

During sampling, it was observed that salinity values were almost constant both in winter and summer period. However slight changes were noted on 21 and 28/08/10 during sampling period and varied slightly from 0.4 - 0.5ppt as shown in Table 1. The salinity values showed that there

were no significant differences in the mean salinity values between winter and summer as well as among different sampling days ($P>0.05$, $F_1=0.157$ and $F_8=0.667$) as shown in Appendix 3.10.

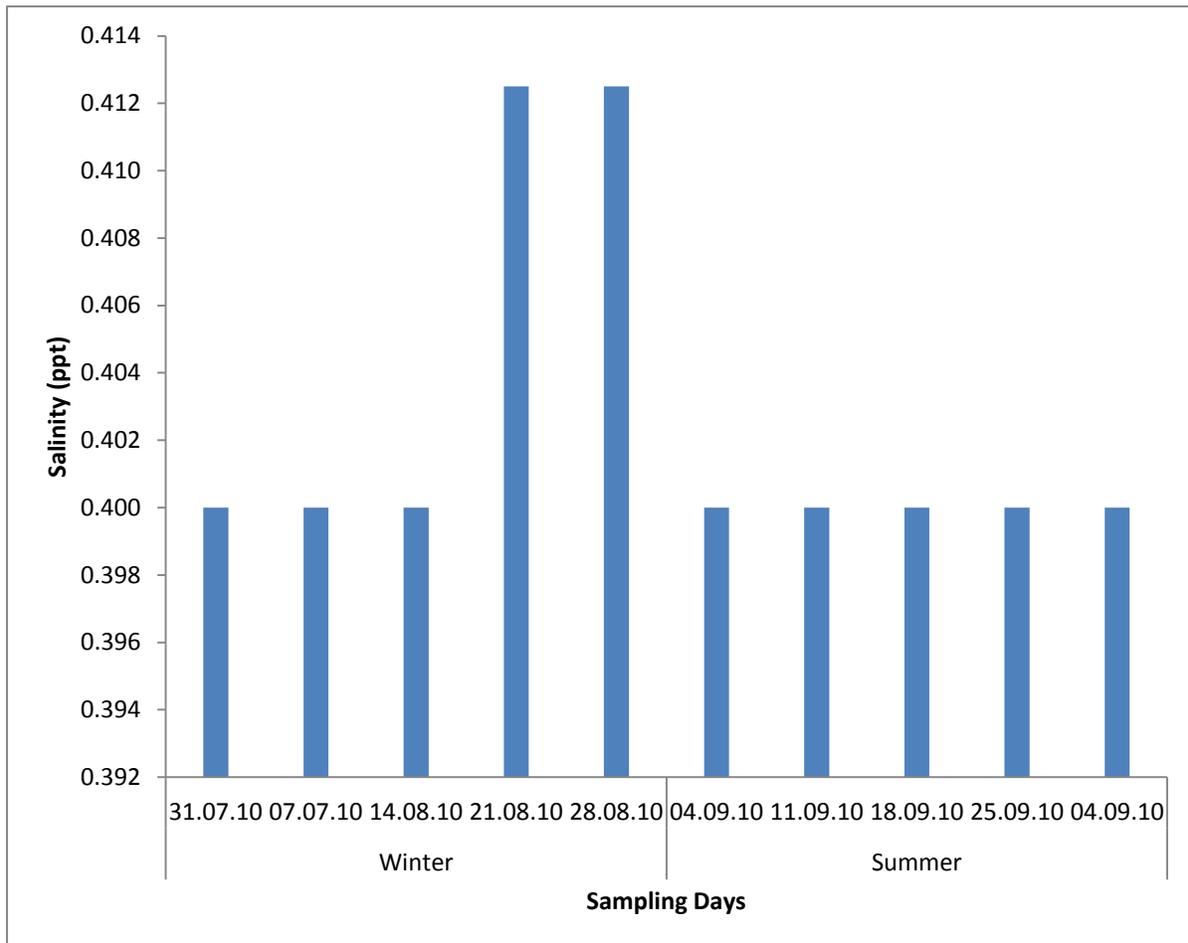


Fig.13. Variations in mean values of Salinity of Avis Dam from 31st July to 4th September, 2010

CHAPTER FOUR

4.0. DISCUSSION AND CONCLUSION

4.1. DISCUSSION

The lentic nature of water in Avis Dam has led to some changes in the physicochemical parameters of the dam. Physicochemical water parameters like dissolved oxygen, temperature, conductivity, pH, phosphorus, nitrite, alkalinity and total dissolved solids were observed to be significantly different among the transitional months between winter and summer. There were no significant differences in parameters like nitrite, salinity and secchi disc visibility within this period. However, all parameters except for salinity showed that there were significant differences in their mean values within the various sampling days.

Variations in physicochemical water parameters of the Dam during the study might be attributed to adverse fluctuations in the atmospheric weather conditions afflicting on a small water body with a capacity of $<1,510,000\text{m}^3$ (Harper and Maritz, 1998) such as Avis Dam. These changes are uncertain as might either illustrate deterioration or a compromise of the ecological status of the Dam thus either undesirable or desirable to the inhabiting aquatic biota. A study by Ayoade *et al.* (2009) in Tehri Dam in India revealed that the changes in the physicochemical water parameters had an overall effect on aquatic biota like an increase in plankton density, fauna diversity and presence of some migrant species.

The higher overall mean of dissolved oxygen recorded in winter months might be due to lower water temperature as compared to summer months. Ayoade *et al.* (2009) observed an inverse relationship between DO and temperature in the lentic part of Rivers Bhagirathi and Bhilangana in India. The daily variation of DO values were as a result of atmospheric weather condition being high on a clear/windy day as observed on the third sampling day and low on a partly cloudy/calm day during the eighth sampling day.

Depletion in dissolved oxygen could also be attributed to increased microbial activities and high temperature (Mahadev, Hosamani and Ahmed, 2010) within the system. In a related study, Otieno (2008) noted lower DO values as a result of organic discharges which require oxygen for decomposition. However, in the case of Avis Dam discharges were not released into it, therefore the rate of oxygen depletion by organic decomposition could be very minimal. Dissolved oxygen results during the investigation showed a minimum value of 1mg/L (Table 1) less than the required standard of 5 - 6mg/L for fresh waters as per ICMR (1975) and ISI (1991). This could be as a result of calibration errors of the DO meter used. Olele and Ekelemu (2008) explained that a decrease in dissolved oxygen concentration during rainy season was due to high turbidity, impeded light penetration and high decomposition. During the study DO range from 1 - 9.0mg/L and tally with the results of 0.9 – 9.83mg/L (Singh and Rai, 1999) obtained in River Ganga at Varanasi. Higher value of DO recorded might correspond to cold air-masses from the Benguela current system affecting the water body.

Water temperature is of greater significance as it regulates various abiotic characteristics and also biotic activities within the aquatic ecosystem as reported by Sharma & Sarang (2004), Radhika *et al.* (2004). Lower values of water temperature in winter and higher values in summer

obtained during this study indicated a sharp variation between the two seasons. These seasonal variations in water temperature were partly as a result of intensified heat radiation on the water body. Temperature variations also correspond with cold and dry South Easterly trade winds in the Benguela current system. The system generate a cold air-mass affecting weather patterns on the mainland and other smaller water bodies therein hence fluctuation of water temperature in Avis dam among sampling days. This finding is also supported by Kaul, Handoo and Raina, (1980) who reported that the surface water temperatures normally have similar readings to that of the atmospheric air temperature.

Water conductivity is described as an index of fertility and productivity (Olele and Ekelemu, 2008). However, Ayoade *et al.* (2009) reported of higher conductivity values recorded in winter during a study of Tehri Dam reservoir and suggested that an aquatic system could be more productive at a particular season. In this study, conductivity values varied considerably with season (higher in winter than summer) agreeing with the findings of Olele and Ekelemu, (2008) being attributed to carbon-iv-oxide release from non-reached substratum and connecting river systems. The variations in conductivity values in Avis Dam might be dependent on nutrient circulation within the Dam, increased evaporation and water currents as it does not continuously receive ions from its ephemeral river systems. During the study, conductivity values ranged from 736- 1013 μ S/cm higher than the values (91.2 - 320 μ S/cm) reported in Lake Vallayani by Radhika *et al.*, (2004). The higher values obtained might either be due to high chemical weathering in the catchment area of the Dam. Taheruzzaman and Kushari, (1995) and Sarojini,

(1996) had respectively documented similar results when they did similar studies in different aquatic systems being as a result of evaporation and concentration of soluble salts.

The mean of pH value of 7.935 in winter months and pH value 7.355 recorded in summer months indicated that Avis Dam ecosystem was within a safe range 6.5-7.5 (ISI, 1991) for aquatic life. The pH limits recorded in this study indicate that the waters were slightly alkaline. The higher values of $\text{pH} > 7$ observed might be as a result of decreased biogenic activities in the Dam. Otieno (2008) reported that increase in pH was among other factors attributed to organic pollution and at lower pH most metals tend to be more toxic (Ramachandra and Solanki, 2007) a situation not applicable to Avis Dam. Olele and Ekelemu (2008) reported that lower pH values in Lake Onah in Nigeria are normally observed during rainy season as a result of influx of acidic ions from the surrounding forest where heavy decomposition of organic matter occur and this situation might also be true for Avis dam as it receives water from the arid soils characterized by low pH. Values for water pH were within the recommended range of 6.5 – 8.5 for aesthetic quality for a national watercourse standards set by W.H.O (Otieno, 2008).

Nutrients like phosphorus and nitrate are profound elements responsible for primary productivity in aquatic system. It was observed that values for phosphorus varied significantly from winter to summer months. Higher values were recorded in winter than in summer and it could be as a result of phosphorus load during the previous rainy season. With time the phosphorus gets reduced by grazing animals like fish being assimilated into the animal's body. The nutrients get

further drained from the ecosystem by anglers who take some of the fish out of water with no replacement from outside sources, a situation that was commonly observed during this investigation. However, a considerable amount of nutrients might also possibly be introduced by fecal matters from terrestrial wild animals coming to drink water at the dam. Olele and Ekelemu (2008) reported of a higher concentration of nutrients during dry season as a result of cow droppings at the time when animals go to available water bodies to drink water and its concentration became pronounced as a result of evaporation.

The lower values of nitrate during the study might also be due to sedimentation especially when the weather was calm and there was no mixing of bottom and surface waters. Olele and Ekelemu (2008) explained that reduced nitrate values were attributed to low pH which was responsible for the reduction of nitrate to nitrite.

Higher values of total alkalinity were recorded in winter when compared to the summer months. These results are similar to the findings by Agarwal and Thapliyal (2005) conducted in River Bhilangana in India. (Ayoade *et al.*, 2009) explained that alkalinity values $>50\text{mgCaCO}_3/\text{L}$ can be considered productive following their results obtained during the study in Tehri Dam. These observations are similar to those observed during an investigation period (winter and summer months) of the transition physicochemical regimes of Avis Dam in Namibia hence the Dam can also be described productive both during winter and summer months. Otieno (2008) obtained the mean alkalinity value of 350mg/L and described this as customary to the alkalinity requirements for water quality in Kenya.

The mean total dissolved solid (TDS) recorded during the study was 382.2mg/L and could be described as normal since it meets the natural watercourse standard value of 500mg/L recommended by many countries (EPA, 1991). Increased value of TDS indicated pollution by exogenous sources (Mahadev *et al.*, 2010).

Salinity values from data collected during this investigation was very low (0.4ppt) and that there was no significant difference between winter and summer months as well as among different sampling dates. This implied that the waters in Avis dam could be characterized as fresh water having salinity of less than 0.5ppt. According to Herbst and Bromley (1984) increase in salinity is due to high rate of evaporation from a water body. During the investigation, it was observed that the volume of water got reduced but was not certain if such a reduction was due to evaporation or other sources. In a similar study Baumann (1987) reported that spatial and temporal salinity pattern in Barataria Estuary were attributed to seasonal evapotranspiration, precipitation regime and seasonal water level cycle. The fresh water characteristic feature of Avis Dam implies that it had a rainfall surplus (precipitation exceeds evaporation) in a previous season as explained by (Ward, 1980).

The mean secchi disc visibility obtained during this investigation was 0.66 ± 0.009 m described as less turbid. However, a minimum visibility of 0.4m was recorded but statistically analyzed as not significantly different from the higher value of 1.12m obtained (Table 1). During the investigation, lower transparency (secchi disc visibility of 0.4m) observed during summer months could be attributed to dust carried by wind as well as the underlying bedrock. Olele and

Ekelemu, (2008) also explained that increased turbidity of water might be as a result of infiltration and evaporation of waters, a situation experienced in most water bodies.

This study was also conducted in dry period characterized by settling effects of suspended particles and non organic/detrital transport hence an investigated low turbidity. Olele and Ekelemu (2008) described the settling effects of suspended particles which gave rise to lower photosynthetic activities and decreased food abundance as one of the contributing factors to lower turbidity values in water bodies. (Ovie, Adepoju and Adayi (2000) explained that suspended materials were responsible for low secchi disc visibility as they absorb blue-green light spectrum while allowing the red part of the spectrum penetration to greater depth.

4.2. CONCLUSION

A general examination of different physicochemical parameters obtained during this investigation suggested that waters in Avis Dam were not homogeneous from winter to summer months. This has been deduced from the values obtained that apart from water transparency, salinity and nitrate which were not significantly different ($P < 0.05$) all other parameters were significantly different ($P > 0.05$). Physicochemical regimes of the Dam during the study indicated that the waters were not polluted as very high levels of nutrients like phosphorus and nitrite were not recorded. However, it can easily be predicted that pollution of any kind might sooner or later be registered if recreation activities expand with the expansion of urban settlement close to the Dam which might bring some pollutant chemicals like oils. Higher conductivity values signified a long period of standing waters which might continue if there will be insufficient flushing of the waters due to low rainfall amount in future. Water from the Dam remained stable with minimal

fluctuation except for alkalinity which needed more periodic studies to establish scientific reasons as to why such variations.

It can therefore be suggested that further studies be encouraged for the physicochemical information of the Dam, as it might be essential for precautionary management measures to all resource users, better understanding of the ecological trend (structure and function) for sustainable maintenance of the natural biological systems available in Avis dam.

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APPENDICES

Appendix1. Laboratory Analysis Procedures

1.1. Phosphate (PO₄-P) Determination

Reagents and Equipment

Ammonium molybdate solution: 7.5g of analytical grade ammonium paramolybdate (NH₄)₆Mo₇O₂₄·4H₂O in 250mL of distilled water and stored in plastic bottle away from direct sunlight.

Sulfuric acid solution: Add 70mL of concentrated (sp.gr.1.82) analytical reagent quality sulfuric acid to 450ml of distilled water. Allow the solution to cool and store it in a glass bottle.

Ascorbic acid solution: Dissolve 13.5g of ascorbic acid in 250mL of distilled water. Store the solution in a plastic bottle frozen solid in the freezer. Solution is stable but should be kept for a week at room temperature.

Potassium antimonyl-tartrate solution: Dissolve 0.34g of potassium antimonyl-tartrate (tartar emetic) in 250mL of distilled water. Store in glass or plastic bottle. Solution is stable for many months.

Mixed reagents

10mL of ammonium molybdate

25mL of sulfuric acid

10mL of ascorbic acid

5mL of potassium antimonyl-tartrate

Phosphate Standard: Dissolve 0.816g of anhydrous potassium dihydrogen phosphate (KH_2PO_4) in 1 litre of distilled water. Store in dark bottle with 1mL of chloroform. This is the concentrate and is stable for many months. Take 0.1mL of concentrated standard and make up to 200mL. This is the phosphate standard and has a concentration of $3.00\mu\text{g/L}$.

Procedure:

In the test tube rack prepare a distilled water blank and standard (5mL).

Fill a test tube for each sample with 5mL of water sample.

Pipette 0.5mL of mixed reagents into the blank, standard and samples then mix and leave for a minimum of 5 minutes and a maximum of 2-3 hours.

Read the absorbances at 885nm on the spectrophotometer.

Subtract the blank absorbance from the standard and sample absorbances

Concentration of phosphate in samples

1.2. Nitrate (NO₃-N) Determination

Reagents and Equipment:

Concentrated ammonium chloride solution: Dissolve 25g of NH₄Cl in 100mL of distilled water and store in glass or plastic bottle.

Dilute ammonium chloride: Dilute 10mL of concentrated NH₄Cl in 400mL of distilled water and store in glass or plastic bottle.

Column of copperized cadmium: when not in use, keep the column in dilute NH₄Cl solution.

Sulfanilimide solution: Dissolve 1g of sulfanilimide in a mixture of 10mL of concentrated HCl and about 60mL of distilled water. Dilute to 100mL with distilled water. This solution is stable for many months.

N-(1-naphthyl)-ethylenediamine dihydrochloride solution (NEDI): Dissolve 0.1g of NEDI in 100mL of distilled water. Store the solution in a dark bottle. And be renewed after a month or when a strong brown colour develops.

Nitrite Standard (10µg/L): Anhydrous, analytical grade sodium nitrate should be dried at 110°C for an hour and 0.345g dissolved in 1000mL of distilled water, store in a dark bottle with 1mL of chloroform as a preservative. Solution is stable. 1mL of this solution contains 5µg/L of N. Dilute

0.2mL of this solution to 100mL with distilled water. This has a concentration of 10µg/L and can be used as the Standard in Nitrate / Nitrite determination.

Preparation of Cadmium Reduction Column

Wash cadmium granules with acetone and then deionised water.

Clean cadmium granules with HCl (dilute concentrated HCl with deionised water in the ratio 1:5 and then wash with deionised water).

Treat the cadmium granules with .08M copper sulphate.5H₂O

160g made up to 1 litre = 1M

12.8g made up to 1 litre = 0.08M

1.28g made up to 100mL = 0.08M

Use dilute ammonium chloride to pack the column and then store in the same medium

Procedure:

In a test tube rack, prepare a distilled water blank, and a 10µg/L standard (5mL in each).

In the same rack, prepare two rows of test tubes, one for NO₂-N analysis and one for NO₃-N analysis.

Row 1: NO₂-N analysis: Place 5mL of sample water in the row of tubes for NO₃-N analysis.

Row 2: NO₃-N analysis: For each sample, take approximately 25mL and add 0.5mL of concentrated NH₄Cl solution. Pass sufficient water sample through the reduction column to clear the column of previous water and then collect 5mL of reduced water sample in each of the tubes for NO₃-N analysis.

Repeat the process for each of the water samples.

To each test tube (blank, standard and $\text{NO}_2\text{-N}$ samples and $\text{NO}_3\text{-N}$ samples) add 0.1mL of sulfanilimide. Mix and allow reacting for 2-8 minutes. Then add 0.1mL NEDI and mix again. After a minimum period of 10 minutes and a maximum of 2hours, read the absorbance on the spectrophotometer at a wavelength of 543nm.

1.3. Alkalinity Determination

Laboratory Procedure

Take 50mL of water sample and add 0.1mL of phenolphthalein indicator. The sample should remain colourless.

If sample turns pink, proceed to step 4.

Titrate with 0.02N acid to the equivalent endpoint of 8.3 (sample turns pink at pH 8.3). This titration measures the fraction of the buffering capacity of the water since most waters have pH's below 8.3.

NOTE: If your sample pH is below 8.3 you do not need to do this step.

Add 0.1mL of methyl orange to sample in which the phenolphthalein alkalinity was determined and titrate with 0.02N acid (sulphuric or hydrochloric acid). Add the acid drop by drop when you begin to see a colour change. Make sure you record the initial and final volume in the burette so that you can calculate the volume of acid added

Appendix 2. Raw Data Collection Form from winter to summer months

2.1. VARIATE: Dissolved Oxygen (mg/L)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	3.33	3.55	3.51	*	1.22	3.21	5.71	1.05
Winter	07.08.10	3.29	3.50	2.81	3.56	1.00	2.55	5.06	1.07
Winter	14.08.10	5.56	7.14	6.00	5.40	6.23	4.80	6.28	1.03
Winter	21.08.10	3.07	3.20	3.63	3.83	2.20	3.69	6.13	3.22
Winter	28.08.10	6.10	6.00	8.00	9.30	2.00	7.00	1.54	4.40
Summer	04.09.10	3.00	1.62	3.83	2.30	2.92	3.81	2.00	4.91
Summer	11.09.10	2.21	1.50	1.80	1.00	1.31	1.82	6.96	2.02
Summer	18.09.10	3.49	2.75	2.72	2.55	6.01	1.03	1.06	2.66
Summer	25.09.10	1.00	1.83	1.62	2.33	1.45	2.48	2.81	1.62
Summer	04.09.10	2.85	8.57	1.80	2.03	2.20	1.92	6.41	2.10

2.2. VATIATE: Water Temperature (°C)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	25.30	16.30	16.10	*	14.30	15.20	16.10	15.30
Winter	07.08.10	18.30	18.30	16.00	15.50	14.80	17.40	16.70	15.20
Winter	14.08.10	14.80	13.90	14.50	14.90	14.40	16.60	14.70	13.70
Winter	21.08.10	16.00	16.00	15.30	15.50	14.20	15.20	14.70	14.40
Winter	28.08.10	16.70	16.00	16.60	16.70	16.10	16.50	16.00	15.40
Summer	04.09.10	19.40	17.80	19.00	18.70	18.20	18.20	16.80	16.40
Summer	11.09.10	20.20	20.90	21.50	25.00	18.60	25.00	25.00	21.80
Summer	18.09.10	19.20	18.70	18.20	18.50	18.10	19.80	18.80	18.20
Summer	25.09.10	25.00	22.30	22.30	21.90	18.10	20.20	19.40	18.90

Summer	04.09.10	22.90	20.90	22.50	22.30	20.60	20.30	20.90	20.70
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2.3. VATIATE: Conductivity ($\mu\text{S}/\text{cm}$)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	805	788	772	*	760	754	755	756
Winter	07.08.10	762	741	757	759	773	736	758	756
Winter	14.08.10	910	788	780	791	776	769	756	795
Winter	21.08.10	804	818	834	815	838	838	836	887
Winter	28.08.10	1013	846	845	842	850	830	829	816
Summer	04.09.10	816	802	780	795	828	752	768	830
Summer	11.09.10	772	775	743	742	817	760	740	833
Summer	18.09.10	775	775	751	769	768	764	770	777
Summer	25.09.10	796	782	791	798	792	777	781	811
Summer	04.09.10	812	819	808	812	824	806	816	824

2.4. VATIATE: pH

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	8.48	8.48	8.49	*	7.98	8.52	8.27	7.97
Winter	07.08.10	8.50	8.47	8.57	8.47	7.97	8.61	8.29	7.97
Winter	14.08.10	5.30	8.16	8.28	8.26	8.21	8.36	8.15	8.00
Winter	21.08.10	8.53	8.51	8.46	8.43	7.68	8.45	8.22	7.78
Winter	28.08.10	7.30	7.13	7.10	7.00	6.75	7.10	6.83	6.45
Summer	04.09.10	6.60	8.81	6.42	6.80	6.51	6.50	5.76	4.70
Summer	11.09.10	6.72	5.80	7.80	7.00	4.89	7.65	7.58	7.65
Summer	18.09.10	6.24	6.54	6.44	6.68	6.35	7.22	7.00	6.58

Summer	25.09.10	8.50	8.74	8.64	7.79	8.78	8.70	8.54	7.78
Summer	04.09.10	8.70	8.10	8.78	8.72	7.50	8.77	8.20	7.72

2.5. VATIATE: Phosphate (mg/L)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	3.53	3.87	7.40	*	1.11	8.18	4.11	1.07
Winter	07.08.10	1.41	3.00	1.94	2.82	2.82	1.59	2.29	1.24
Winter	14.08.10	6.90	6.90	6.90	6.90	5.40	8.70	6.90	8.10
Winter	21.08.10	0.09	0.35	0.59	0.33	1.34	2.92	0.23	0.18
Winter	28.08.10	0.74	0.77	0.56	0.93	0.96	0.74	1.02	3.77
Summer	04.09.10	6.00	8.00	5.50	5.50	7.50	4.50	4.00	4.50
Summer	11.09.10	0.16	2.30	0.16	1.54	0.49	0.30	0.67	2.12
Summer	18.09.10	0.50	0.45	0.50	0.33	0.43	0.73	1.13	3.92
Summer	25.09.10	0.88	0.37	0.19	0.21	0.19	0.14	0.05	0.12
Summer	04.09.10	1.00	1.21	1.09	1.16	1.18	1.34	1.18	1.25

2.6. VATIATE: Nitrite (mg/L)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	0.06	0.10	0.10	*	0.11	0.09	0.12	0.16
Winter	07.08.10	0.13	0.18	0.38	0.13	0.18	0.39	0.12	0.26
Winter	14.08.10	0.22	0.07	0.23	0.08	0.03	0.14	0.16	0.11
Winter	21.08.10	0.04	0.02	0.02	0.04	0.02	0.04	0.03	0.04
Winter	28.08.10	0.11	0.22	0.09	0.06	0.15	0.11	0.12	0.42
Summer	04.09.10	0.05	0.18	0.01	0.01	0.01	0.01	0.27	0.01
Summer	11.09.10	2.36	0.05	1.23	3.30	0.13	0.18	0.04	0.04
Summer	18.09.10	0.15	0.52	0.21	0.40	0.36	0.11	0.43	1.22

Summer	25.09.10	0.09	0.10	0.08	0.08	0.97	0.04	0.75	0.50
Summer	04.09.10	0.12	0.09	0.07	0.10	0.14	0.10	0.09	0.10

2.7. VATIATE: Nitrate (mg/L)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	0.07	0.01	0.00	*	0.08	0.04	0.03	0.06
Winter	07.08.10	0.32	0.15	0.04	0.12	0.43	0.27	0.31	0.31
Winter	14.08.10	0.07	0.26	0.06	0.29	0.11	0.28	0.18	0.54
Winter	21.08.10	0.02	0.04	0.03	0.05	0.03	0.04	0.08	0.07
Winter	28.08.10	0.03	0.28	0.05	0.03	0.07	0.05	0.06	0.08
Summer	04.09.10	0.02	0.52	0.14	0.61	0.01	0.09	0.41	0.13
Summer	11.09.10	0.66	0.19	0.05	0.08	0.60	0.31	0.22	0.34
Summer	18.09.10	0.11	0.10	0.07	0.17	0.22	0.02	0.07	0.19
Summer	25.09.10	0.10	0.09	0.03	0.25	0.88	0.04	0.34	0.29
Summer	04.09.10	0.03	0.03	0.03	0.04	0.00	0.01	0.03	0.04

2.8. VATIATE: Alkalinity (mgCaCO₃/L)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	130	118	121	*	121	133	118	128
Winter	07.08.10	177	198	155	169	169	155	157	160
Winter	14.08.10	99	66	56	55	76	72	49	46
Winter	21.08.10	30	32	31	21	28	30	30	28
Winter	28.08.10	135	160	155	163	176	186	174	220

Summer	04.09.10	159	136	139	141	152	135	151	145
Summer	11.09.10	135	120	125	124	134	118	114	134
Summer	18.09.10	138	136	133	133	127	128	132	140
Summer	25.09.10	142	143	137	138	149	127	139	143
Summer	04.09.10	153	144	144	158	142	155	148	143

2.9. VATIATE: Total Dissolved Solids (mg/L)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	385	379	373	*	364	359	365	367
Winter	07.08.10	370	352	365	369	372	365	366	364
Winter	14.08.10	437	385	373	374	375	366	367	385
Winter	21.08.10	387	392	405	395	402	404	404	423
Winter	28.08.10	461	411	406	404	412	398	398	396
Summer	04.09.10	392	386	375	383	399	361	381	400
Summer	11.09.10	372	372	357	356	393	366	355	401
Summer	18.09.10	370	372	361	370	369	367	368	371
Summer	25.09.10	383	374	380	382	380	372	376	390
Summer	04.09.10	390	394	387	390	398	386	392	396

2.10. VATIATE: Salinity (ppt.)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	0.40	0.40	0.40	*	0.40	0.40	0.40	0.40
Winter	07.08.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Winter	14.08.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Winter	21.08.10	0.50	0.40	0.40	0.40	0.40	0.40	0.40	0.40

Winter	28.08.10	0.40	0.40	0.50	0.40	0.40	0.40	0.40	0.40
Summer	04.09.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Summer	11.09.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Summer	18.09.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Summer	25.09.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Summer	04.09.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40

2.11. VATIATE: Secchi Disc Visibility (m)

SEASON	DATE	INLET		CENTER			OUTLET		
		SURFACE	BOTTOM	SURFACE	MIDDLE	BOTTOM	SURFACE	MIDDLE	BOTTOM
Winter	31.07.10	0.66	0.66	0.65	*	0.65	0.73	0.73	0.73
Winter	07.08.10	*	*	*	*	*	*	*	*
Winter	14.08.10	*	*	*	0.58	0.60	0.60	0.72	0.67
Winter	21.08.10	0.70	0.66	0.68	0.74	0.68	0.61	0.68	0.73
Winter	28.08.10	0.56	0.66	0.73	0.71	0.62	0.66	0.66	0.74
Summer	04.09.10	0.80	0.94	1.04	1.04	1.10	1.12	1.11	1.00
Summer	11.09.10	0.70	0.72	0.75	0.70	0.74	0.87	0.76	0.85
Summer	18.09.10	0.65	0.58	0.58	0.50	0.62	0.58	0.65	0.62
Summer	25.09.10	0.48	0.45	0.45	0.44	0.40	0.40	0.40	0.40
Summer	04.09.10	0.40	0.55	0.45	0.50	0.50	0.48	0.50	0.52

*Missing values

Appendix 3. Means of Field Data Collection Form from winter to summer months

SAMPLE No	DATE	SEASON	PO ₄ -P (mg/L)	NO ₂ -N (mg/L)	NO ₃ -N (mg/L)	ALKAL- mgCaCO ₃ /L	DO (mg/L)	TEMP (°C)	pH	COND (µS/cm)	TDS (mg/L)	SAL (ppt)	TURBIDITY (m)
1	31.07.10	WINTER	4.18	0.11	0.04	124.14	3.08	16.9	8.31	770	370	0.4	0.69
2	07.07.10	WINTER	2.14	0.22	0.24	167.50	2.86	16.5	8.36	755	365	0.4	0.66
3	14.08.10	WINTER	1.30	0.13	0.22	64.88	5.31	14.7	7.84	796	383	0.4	0.63
4	21.08.10	WINTER	0.75	0.03	0.06	28.75	3.62	15.2	8.26	834	402	0.4	0.69
5	28.08.10	WINTER	1.19	0.14	0.07	171.13	5.54	16.3	6.96	859	411	0.4	0.67
6	04.09.10	SUMMER	5.69	0.10	0.18	144.75	3.05	18.1	6.51	796	385	0.4	1.02
7	11.09.10	SUMMER	0.97	0.01	0.13	125.50	2.33	22.3	6.89	773	372	0.4	0.76
8	18.09.10	SUMMER	1.00	0.49	0.10	133.38	2.78	18.7	6.63	769	369	0.4	0.60
9	25.09.10	SUMMER	0.27	0.58	0.25	139.75	1.89	21.0	8.43	791	380	0.4	0.41
10	04.09.10	SUMMER	1.18	0.127	0.10	148.40	3.49	21.4	8.31	815	392	0.4	0.49

Appendix 4. ANOVA Tables for Physicochemical Parameters

4.1. VARIATE: Dissolved Oxygen

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	38.672	38.672	12.53	<.001
SEASON.DATE_FACTOR	8	62.020	7.752	2.51	0.019
Residual	69	212.917	3.086		
Total	78	313.609			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Dissolved Oxygen	1.000	9.300	3.398	±1.757

4.2. VARIATE: Temperature

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	381.052	381.052	129.06	<.001
SEASON.DATE_FACTOR	8	132.603	16.575	5.61	<.001
Residual	69	203.725	2.953		
Total	78	717.380			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Temperature	13.70	25.3	18.11	±1.757

4.3. VARIATE: Conductivity

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	4304.0	4304.0	4.39	0.040
SEASON.DATE_FACTOR	8	70186.8	8773.3	8.94	<.001
Residual	69	67677.9	980.8		
Total	78	142168.7			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Conductivity	736.0	1013	796.1	±31.32

4.4. VARIATE: pH

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	6.6516	6.6516	15.16	<.001
SEASON.DATE_FACTOR	8	39.2190	4.9024	11.18	<.001
Residual	69	30.2675	0.4387		
Total	78	76.1382			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
pH	4.700	8.810	7.642	±0.6623

4.5. VARIATE: Phosphate

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	29.515	29.515	20.16	<.001
SEASON.DATE_FACTOR	8	369.466	46.183	31.55	<.001
Residual	69	100.997	1.464		
Total	78	499.978			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Phosphorus	0.04600	8.700	2.423	±1.120

4.6. VARIATE: Nitrite

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	1.1114	1.1114	5.72	0.019
SEASON.DATE_FACTOR	8	3.8862	0.4858	2.50	0.019
Residual	69	13.4065	0.1943		
Total	78	18.4041			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Nitrite	0.0100	0.2504	3.3000	±0.4408

4.7. VARIATE: Nitrate

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	0.07054	0.07054	2.92	0.092
SEASON.DATE_FACTOR	8	0.72099	0.09012	3.73	0.001
Residual	69	1.66745	0.02417		
Total	78	2.45898			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Nitrate	0.0000	0.8800	0.1595	±0.1555

4.8. VARIATE: Alkalinity

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	14826.5	14826.5	102.36	<.001
SEASON.DATE_FACTOR	8	129474.1	16184.3	111.73	<.002
Residual	69	9994.9	144.9		
Total	78	154295.5			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Alkalinity	21.00	220.0	124.8	±12.04

4.9. VARIATE: Total Dissolved Solids

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	1070.7	1070.7	6.09	0.016
SEASON.DATE_FACTOR	8	14889.5	1861.2	10.59	<.001
Residual	69	12131.9	175.8		
Total	78	28092.2			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Total Dissolved Solids	352.0	461.0	382.8	±13.26

4.10. VARIATE: Salinity

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	0.0005192	0.0005192	2.05	0.157
SEASON.DATE_FACTOR	8	0.0014744	0.0001843	0.73	0.667
Residual	69	0.0175000	0.0002536		
Total	78	0.0194937			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Salinity	0.4000	0.5000	0.4025	±0.01592

4.11. VARIATE: Secchi Disc Visibility

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
SEASON	1	0.001721	0.001721	0.49	0.488
SEASON.DATE_FACTOR	8	1.827371	0.261053	73.82	<.001
Residual	69	0.208638	0.003536		
Total	78	2.035006			

IDENTIFIER	Min. Value	Max. Value	Mean	s.e
Secchi Disc Visibility	0.4000	1.1200	0.6638	±0.05947

