Original Research Article

Journal of Biological Research & Biotechnology

Bio-Research Vol. 21 No.2; pp. 1953-1960 (2023). ISSN (print):1596-7409; eISSN (online):2705-3822

Macro-vegetation and physicochemical aspects of Tirwum pond in Bauchi Local Government Area of Bauchi State, Nigeria

[§]Akwuma Oyini Daniel and Ezra Abalis Gaya

Department of Biological Sciences, Abubakar Tafawa Balewa University (ATBU) Bauchi, Bauchi State, Nigeria

[§]Corresponding Author: Akwuma Oyini Daniel. Email: edudanak@gmail.com

Abstract

Water is a key player in any biological system and it is vital to quality existence of living things. The abundance, assemblage, density, diversity and kinds of macro-vegetation present in a system are pointers to ecological health and the knowledge of biodiversity upsurge or decline is necessary for management decisions at various levels. In the evaluation of Macro-vegetation and some physicochemical factors of Tirwum pond, samples were collected once a month for six consecutive months. According to the manufacturer's operating procedure as approved by EPA, Colorimeter hach DR 890 was used to determine turbidity, HANNA HI 9813-5 was used to determine total dissolved solids (TDS), (pH) and electrical conductivity (EC), dissolved oxygen (DO) was measured by JPB-70A pen type intelligent dissolved oxygen analyzer, nitrate and phosphate were determined by means of PALINTEST photometer Wagtech 7100. The determination of TSS and TS were by filtration and evaporation methods respectively and temperature was measured in situ using mercury in glass thermometer. 60 quadrats of 1x1m^2 were thrown and a long, double-headed rake dipped down, turned 360degrees within each quadrant and all plants within the quadrant frame were counted and identified. The species richness was six belonging to four families. Diversity and evenness index were 1.69 and 0.94 correspondingly. Most values of pH were within the optimum range. The above 3mg/L of all nitrogen values branded the pond as polluted. The abundance of three macro-vegetation families negatively correlated with dissolved oxygen ($p< 0.01$, $p<0.05$), but positively correlated with Temperature ($p<0.05$). The abundance of macro-vegetation showed negative correlation with EC and TDS ($P < 0.05$). The absence of submerged macrophytes, high concentration of nitrate and low concentration of dissolved oxygen reflected the impaired state of the pond community and the species richness of six is bad for biodiversity at local and global level.

Keywords: Abundance, Diversity index, Macro-vegetation, Physicochemical factors, Pond

Received December 20,2022; **Revised** April 15, 2023; **Accepted** April 26, 2023

https://dx.doi.org/10.4314/br.v21i2.3 Journal Homepage: http://www.bioresearch.com.ng.
Publisher*: Faculty of Biological Sciences, University of Nigeria, Nsukka, Nigeria.*

INTRODUCTION

A move towards biodiversity safety can't ignore ecological carefulness and sustainability. Water is a key player in any biological system and it is very vital to quality existence of living things most especially the aquatic organisms. The water quality effect in any environment goes beyond the plants and animals within the aquatic habitat but reaches human life at the terrestrial habitat. Macro-vegetation is a good reflector of the condition of any environment since they are of low mobility or fixed in water and can't avoid environmental dangers as human do from one place to another (Akwuma *et al.*, 2021). According to EPA (2016), the abundance, assemblage, density, diversity and kinds of macro-vegetation present in a system are pointers to the health of any water body.

Similarly, the knowledge of biodiversity upsurge or decline is necessary for management decisions. According to Diane (2020), diversity index is a numerical measurement that mirrors the quantity or abundance of diverse species and how uniformly the entities are dispersed among those species. Characteristically, the diversity index value upsurges when the number of kinds rises and the evenness rises. Area with pronounced evenness would have great counts of diverse species, however small evenness designates that a small number of species dominate the area. Similarly, according to Nedungadi, *et al.* (2013), the measurement of composition structure over a period of time is useful in the description of trends and tendencies. It permits comparison of dominance of specific plants through the community and mathematically, this is the fraction in percentage of a number of plant species relative to the aggregate in a given space.

As important as the studies between macro-vegetation and environmental influences is, most research in this theme have been in lotic ecosystems (Ferreira and Moreria 1999; Bernez *et al.,* 2004; Hrivnak *et al.,* 2006 and Hrivnak, 2010). However, in the case of lentic ecosystem, these are rare (Mukherjee and Palit, 2012) and the trend still remains. This scarcity is much more in Nigeria and Bauchi State in particular. Chambers *et al.* (2008) pointed out that large gaps still exist in our knowledge of aquatic macrophytes abundance and distribution, and cautioned that numerous threats to fresh water such as eutrophication and alien species introductions will result to the reduction of macro-vegetation diversity. This research is a contribution to subsiding the "large existing gaps in our knowledge of aquatic macrophytes abundance, distribution" and to ascertain ecological condition within the habitat.

MATERIALS AND METHODS

Study area

Bauchi, Nigeria has a tropical grassland average temperature, yearly average rainfall of 1,095mm, and daily mean hotness degree of 25.4^{0c}; average of 8.1 hours of sunshine and it is geographically situated on the North/East hemisphere with GPS coordinates of 10^0 18'50.9724" N and $9^0$50'46.6152" E.

Sampling station

Tirwum pond is the only perennial pond in Tirwum community of Bauchi. This community is a business and agricultural hub. The locals do harvest tuber-producing macrophytes from the pond for consumption. It is located at km 3 Bauchi-Maiduguri express way, Bauchi with a GPS coordinates of $10^0$20'53.9"N $9^0$52'05.1"E. The length is about 95meters, the width is 35meter and it is located 26meters away from the road. Residential houses were on the East and Southern axis of the pond. At the western and Northern axis is tar-road about 26m away and rice farm about 66m away respectively. It was slightly steep in slope and sandy sediment. Land use type is agricultural. Some refuse dumps were noticed directly into it.

Collection of macro-vegetation

A total of 60 quadrats were thrown in the pond; 10 per sampling day. A quadrant of $1x1m^2$ (Goswami *et al.,* 2014) was laid next to each randomly chosen point. A long, double headed rake was dipped down within the quadrant and turned 360 degrees in search of submerged macrophytes. All submerged, emergent and floating plants within the quadrant frame were counted and identified by observing their leaf shape, size and arrangement; checking for the presence of barbs, hair, thorns and noting the flowers and smell then, compare the observation with the images and guidelines for effective identification. Modification of (Annelise *et al*., 2004; Champion and Reeves 2004), observed, and recorded in field sheet following (Nedungadi *et al*., 2013).

Figure1: Map of Bauchi showing the location of Bauchi Local Government where the research took place. (Source nigeriazipcodes.com) accessed on 12/12/2021

Analysis of macro-vegetation

A conventional macro-vegetation metrics such as computation of percentage composition, Shannon-Wiener diversity index were used for the ascertainment of composition, diversity, and evenness of species spread in a community. Diversity indices were ascertained bases on the number of individual species observed in the laid quadrants (Goswami *et al.*, 2014). The Shannon-Wiener diversity and evenness index formula used is H = $-\sum_{i=1}^{S} pi\ In\ pi$

Collection of water samples

Three sets of water samples were taken from three different locations at 2m apart and 1m from the pond margin into the pond water. The samples were collected at the same point each sampling day between 8 – 10 am. A 4-litre sample container was rinsed three times with the sample water. The sample container was grabbed near the bottom and the bottle opening plunged down-ward about 30cm below the water surface with the opening pointed a little upward at a point free of scum and debris until it became filled with water. The container was then properly capped while still under the water and protected from sunlight but preserved in a cooler with ice during transport to the laboratory for analysis. The protection from sunlight was achieved by covering the water sample with black nylon and it was meant to keep the oxygen concentration of the water sample intact by keeping it away from sunlight and the photosynthetic process it may trigger (Delzer, 2003).

Analysis of water samples

According to US EPA (2018), water quality instruments are to be maintained and operated in accordance with the manufacturer's instructions and operating procedure.

Determination of turbidity

Colorimeter Hach DR 890 was used according to the manufacturer's operating manual. This was upheld by EPA (2018). PRGM was pressed and "PRGM?" was displayed. Then, 95 and ENTER were pressed sequentially. The sample cell was filled with 10ml of de-ionized water (blank), and placed into the cell holder and was tightly covered with the instrument cap. Zero was pressed for calibration of the instrument to zero. Another sample cell was filled with 10ml of the sample, placed into the cell holder and tightly covered with the instrument cap. READ was pressed and the result was displayed in Formazin Attenuation units (FAU).

Determination of electrical conductivity (EC)

According to the manufacturer's operating manual as permitted by EPA (2018), the tip of the probe instrument: HANNA HI 9813-5 was removed from its normal position, cleaned with a cotton wool and then immersed into the sample to be tested in a plastic container that minimizes EMC interference. The probe was tapped lightly on the bottom of the beaker to remove any air bubble which may be trapped inside the tip, mS/cm was selected and delayed for a couple of minutes for the temperature sensor to reach thermal equilibrium. It then displayed the measurement automatically compensated for temperature." mS" tag indicated EC mode.

Determination of pH

According to the permission of EPA (2018), the manufacturer's operating manual was followed. The tip of the probe instrument: HANNA HI 9813-5 was removed from its normal position, cleaned with a cotton wool and then submerged into the sample to be tested while pH mode was selected. It was stirred for 10 seconds and allowed for 2 minutes for the reading to adjust and stabilize. The displayed reading was the pH value.

Determination of total dissolved solid

The tip of the probe instrument: HANNA HI 9813-5 was removed from its normal position, cleaned with a cotton wool and then immersed into the sample to be tested in a plastic container that minimizes EMC interference. The probe was tapped lightly on the bottom of the beaker to remove any air bubble which may be trapped inside the tip, ppm was selected and delayed for a couple of minutes for the temperature sensor to reach thermal equilibrium. It then displayed the measurement automatically compensated for temperature." ppm" tag indicates TDS mode. The method was according to the manufacturer's operating manual as permitted by EPA (2018).

Determination of dissolved oxygen

The electrode of an instrument called JPB-70A pen type intelligent dissolved oxygen analyzer was removed from its normal position, cleaned with a cotton wool and immersed in the sample solution, and the electrode was stirred properly and the instrument's screen was keenly observed for a stable value. The stable reading of the instrument was the dissolved oxygen value of the water sample in mg/L. The technique was according to the manufacturer's operating manual as permitted by EPA (2018).

Determination of total solids (TS)

Evaporation method adapted from standard methods for the examination of water and waste water EPA (2018). Evaporating dish was washed and dried in an oven at 104^0C, cooled, weighed and the weight was recorded as W_1. The sample was measured out in 100-200ml after stirring, put in a pre-weighed evaporating dish and allowed until evaporation to dryness in an oven or hot plate occurred. It was thereafter cooled, weighed and the weight was recorded as W_2. TSS (mg/L) = W_2 mg – W_1 mg X1000/sample volume (ml). Where W_2= weight of dish + residue (mg) and W_1= weight of dish (mg).

Determination of total suspended solids (TSS)

According to EPA (2018), filter paper was, weighed and the weight was recorded as W_1. Filtration apparatus were assembled and sample was stirred and 100ml was measured out into a filtration set up. After filtration, the filter paper was washed with few drops of distilled water, carefully removed and transferred to air drying platform for air drying. It was there after weighed and the weight was recorded as W_2.
TSS/L = W_2- W_1 X1000/ sample volume used (ml)
Where: W_2= weight of filter paper + dried residue (mg) and W_1= weight of filter paper (mg).

Determination of nitrate by Palintest photometer Wagtech 7100

A graduated cylinder was rinsed with the sample, filled with 19ml of de-ionized water and 1ml of sample water and was transferred into a test tube that was pre-rinsed. One leveled nitrate test powder was added to the test tube and one nitrate test tablet was added, crushed, mixed and left to settle forming clear separation of the mixture. It was re-shaken and left for 3 minutes, thereafter; 10ml of the supernatant was decanted into nitrate test tube and nitrocol tablet was added and allowed to dissolve. It was allowed to stand for 10minutes for full color development. The instrument was turned on and the appropriate wavelength in "nm" was selected. 10ml of de-ionized water in a suitable test tube was put into the instrument's cell holder, well covered and calibrated

and removed. The 10ml of decanted supernatant in nitrate test tube was placed in the cell holder, well covered and reading pressed, observed and recorded. The determination process was in accordance with the manufacturer's operating manual as suggested by EPA (2018).

Determination of phosphate by Palintest photometer Wagtech 7100

The instrument was turned on and the low range phosphate wavelength 028 (Mg/l PO4) was selected. 10ml of de-ionized water in a suitable test tube was put into the instrument's cell holder, well covered and calibrated by pressing zero, OK in sequential order and removed. Cuvette test tube was filled with water sample to 20ml mark and the first phosphate test tablet was crushed and mixed immediately followed by the crushing and mixing of the second phosphate test tablet. It was allowed to stand for 10minutes for full color development and was placed in the cell holder, well covered and read pressed as the photometer reading was observed and recorded. The determination procedure was in accordance with the manufacturer's operating manual as recommended by EPA (2018).

Determination of temperature

The temperature was measured in situ using mercury in glass thermometer. The probe end of the thermometer was cleansed with de-ionized water, held at the bulb and about three quarter of the instrument was vertically inserted into the water. It was allowed to equilibrate with the sample for at least 60 seconds. This was repeated at the three sampling points each sampling day and the average value was recorded (EPA, 2018).

Statistical analysis

The relationship in-between individual physicochemical parameters and individual species of macro-vegetation were analyzed with a Pearson correlation analysis at 95 and 99% level of confidence. (SPSS 25.0, SPSS Inc. Chicago).

RESULTS AND DISCUSSION

The results of the water parameter test and percentage species composition in Tirwum pond are shown in Tables 1 and 2 respectively. The result of diversity and evenness index of the macrophytes in the study area is 1.6 and 0.94 respectively while the richness of species is only 6 (six). According to an earlier study by Akwuma *et al.*, (2021) Waya Pond in Bauchi had a diversity index of 1.38, evenness of 0.55 and abundance of 12 species. Comparatively, the degree of difference between the diversity indices of Waya and Tirwum pond communities is small to be of any ecological importance.All the pH values were within the range of 6.5 – 9.0 suggested by (EPA, 2017) for fresh water. EPA (2017) reported that the hydrogen/hydroxyl ion concentration (pH), affects most chemical and biological processes in water. It is one of the most important environmental factors limiting species distributions in aquatic habitats. Different species flourish within different range of pH, with the optima for most aquatic organisms falling between pH 6.5 – 8.0 fluctuating or sustained pH outside this range physiologically stresses many species and can result in decreased growth, disease or death. This can ultimately lead to reduced biological diversity.

Electrical conductivity (EC) recorded could be as a result of the conductive state of the surrounding geology. According to EPA (2012), during diurnal variations as a body of water warms up due to sunlight, conductivity increases and as it cools down at night conductivity decreases. Therefore, the low values of EC in this study can be attributed to the effect of early morning sample collection and testing, a period when conductivity was said to be on decline. This result agrees with Akwuma *et al.*, (2021). Similarly, APHA (1999) stated that at most, fresh water can have 2000ppm of TDS and most sources should have much less than that APHA, 1999). Hence, all the TDS and EC values gotten in this study are within the acceptable range. The values of EC and TDS are reflection of the water ionic strength.

Table 1: Percentage species Composition in Tirwum study area

Species	Number of species	Composition (%)
Agrostis stolonifera	18.0	09.8
Ipomea aquatic	30.0	16.3
Lythrum salicaria	25.0	13.6
Nymphaea lotus	26.0	14.1
Nymphaea micrantha	22.0	12.0
Panicum repens	63.0	34.2
Total no. of species	184.0	

Table 2: Water quality Parameters in Tirwum pond

Parameters	**Unit of measurement**	**Mean value**	**Range**
DO	(mg/L)	3.69	0 – 5.73
EC	(mS)	0.41	0 – 0.81
NO_4	(mg/L)	77.83	0 – 129.00
PO_4	(mg/L)	1.23	0 – 3.70
pH		6.00	0 – 7.40
Temp	(^{0}C)	16.60	0 – 26.90
TDS	(ppm)	297.80	0 – 589.00
TS	(mg/L)	0.35	0 – 0.80
TSS	(mg/L)	0.42	0 – 0.90
Turb	(Fau)	106.00	0 – 210.00

[Dissolved oxygen (DO), Temperature (Temp) Electrical conductivity (EC), Total dissolved solids (TDS), Total solids (TS) Total suspended solids (TSS), Turbidity (Turbid), Phosphates ($PO_{4)}$, Nitrate (NO_4)].

Introduction of phosphate rich water into the pond from agricultural runoff, pasture and rangeland runoff can also increase its concentration in October. This was supported by (Tiseer *et al.*, 2008)**.** Similarly, the high concentration of nitrate in October is attributable to massive runoff of organic matter into the pond beyond the ability of the available nitrogen-degrading micro-organisms. This gained the support of **(**Akwuma *et al*. 2021**;** Puckett and Cowdery, 2002). EPA (2017) reported that high rainfall, steep slopes and clay soils promote nitrogen and phosphorus transport via soil erosion and runoff. Values of nitrate were higher in January and February because the lesser the water level, the higher the concentration of the organic matter deposited. Direct atmospheric deposition of nitrogen from combustion sources into the water could be another reason for the values. The minimum nitrate concentration recorded was 46mg/L therefore the pond was in a contaminated condition during the study period. This gained the support of (Mary *et al*. 2018; and Chapman, 1996) who stated that nitrate concentrations in surface water is normally low (< 1 mg/L) but can reach high levels as a result of agricultural runoff, refuse dump runoff or contamination with human or animal wastes. No submerged macrophytes was recorded in this study and according to EPA, (2017) biological parameters indicative of elevated nutrient concentrations includes decreased abundance of submerged rooted macrophytes among others. The low average dissolved oxygen concentration is suggestive of high nutrient concentrations and has therefore labeled the area as polluted. EPA, (2017) stated that nutrient enrichment often leads to decreased DO concentrations. Throughout the study period, the concentration of DO was less than the recommended minimum of 6 mg/L (Akpofure, 2013).

This gained the support of an earlier study by Akwuma *et al*. (2021). Though these nutrients are required by aquatic biota but excessive availability impairs the aquatic community.

The relationship between physicochemical parameters and macrophytes abundance was determined and the following were the significant outcomes: *Panicum repens, Ipomea aquatic* and *Lythrum salicaria* were all positively related with temperature; (r= 0.831, r= 833 and r=843, all at $p<0.05$). Macrophytes abundance was negatively correlated with electrical conductivity and total dissolved solids ($p< 0.05$). Except for the family members of Nympaeaceae, all other macro-vegetation in this study was negatively correlated with dissolved oxygen ($p< 0.05$).
The significant negative correlation with macrophytes as displayed by dissolved oxygen (DO) in this study is attributable to overstimulation of algal growth by high levels of nutrients or organic wastes leading to depletion of DO or creation of anoxic condition, reduced transparency and changes in biotic community composition. This is confirmed by (Chislock *et al.,* 2013).

Positive correlations between macrophytes abundance and temperature correspond with Akwuma *et al.* (2021). Fink (2005) reported that water temperature can affect the metabolic rates and biological activity of aquatic organisms. As such, it influences the chosen habitats of a variety of aquatic life.

CONCLUSION

The species diversity index was 1.69, the evenness of species spread 0.94 while species richness was 6. The absence of submerged macrophytes, high concentration of nitrate and low concentration of dissolved oxygen all reflect the impaired state of the pond community. Absence of an earlier study on this very site is a setback on the needed comparison that will enable the realization of any diversity loss in the area, for how long and at what degree? The revealed species richness of six is bad enough for biodiversity both at the site and global level. Diverse anthropogenic ecologically unfriendly activities triggered it all. Therefore, it is necessary to periodically monitor the water quality in this and other ponds so as to determine whether the identified existing problems are being improved or degrading.

Conflict of interests

Authors have no conflict of interest to declare.

Author contributions

AOD and EAG designed the experiments. AOD carried out the field and laboratory work as well as the analysis of the obtained data under the supervision and guide of EAG. The first draft of the manuscript was put together by AOD and EAG enhanced its value via editing. The manuscript was checked and approved by both authors.

ACKNOWLEDGMENTS

The authors appreciate Yahweh Adonai for His unwavering love and commitment. Akwuma Racheal, an anatomist is well appreciated for her usual support. Thanks to I.S. Bulai & H.I. Yakubu of Civil Eng. Lab. ATBU, for their guidance through the laboratory procedures. Thanks to Shamwilu Saido Balloko Scientific Officer, rural water supply & sanitation agency (RUWASSA) and Elders S. B. Manga and Akwuma Edoba Augustine for their support.

REFERENCES

Akpofure, R. (3013). Physico-chemical and biological characteristics of stagnant surface water bodies (Ponds and Lakes) used for drinking and domestic purposes in Niger Delta, Nigeria. *Journal of Environmental Protection* **4** (9): 920-928

Akwuma, O. D., Ezra, A. G. and Nayaya, A. J. (2021). Assessment of Emergent and Floating Macrophytes in Relation to Some Physicochemical Parameters of Waya Pond, Bauchi, Nigeria. *Open Journal of Bioscience Research* **2** (2): 66 - 73

Annelise G., Carina J.C., Carina V.G., Rene G. (2004). Easy Identification of Aquatic Plants: a guide for the identification of water plants. Department of Water Affairs and Forestry, South-African National Botanical Institute.

APHA, American Public Health Association (1999). Standard Methods for the Examination of Water and Wastewater 20th edition. Baltimore, MD: American Public Health Association

Bernez, I., Daniel, H., Haury, J. and Ferreira, M. T. (2004). Combined effects of environmental factors and regulate of Macrophyte vegetation along three rivers

in Western France. *Applied River Research,* **20**: 43-59

Chambers, P.A., Lacoul, P., Murphy, K. J. and Thomaz, S.M. (2008). Global diversity of aquatic macrophytes in freshwater. *Hydrologia*, **595** (1): 9-26.

Champion, P. and Reeves P. (2004). Macrophyte identification guides. National Institute of Water and Atmospheric Research Ltd. Hamilton 3251

Chapman, D. (1996). Water Quality Assessments A guide to the use of biota, sediments and water in environmental monitoring. 2nd Edition, Chapman and Hall Ltd., London, 651.

Chislock, M. F., Doster, E., Zitomer, R. A. and Wilson, A. E. (2013). Eutrophication: causes, consequences, and controls in aquatic ecosystems. *Nature Education Knowledge*, **4** (4): 10.

Delzer, G.C., & Mckenzie, S. W. (2003). National Field Manual for the Collection of Water-Quality Data. (3rd ed.) U.S. Geological Survey Techniques of Water Resources Investigations book 9.

Diane, K. (2020). Introduction, Simpson index and Shannon-Weiner index. Forest and natural Resources Management, College of Environmental Science and Forestry, State University of New York, Syracuse.

EPA (2012). Total Dissolved Solids in Water: Monitoring and Assessment. The Environmental Protection Agency, https://water.epa.gov/type/rsl/monitoring/vms58.cfm. Accessed on December 12, 2021.

EPA (2017). Sources, Stressors and Responses. Causal Analysis/Diagnosis Decision Information System (CADDIS) **2.** United States Environmental Protection Agency. www.epa.gov/caddis**.** Accessed on December 12, 2021.

EPA (2018). Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Ecosystem Support Division. United States Environmental Protection Agency.

Ferreira, M.T. and Moreira, I.S. (1999). River plants from a Liberian basin and environmental factors influencing their distribution. *Hydrobiologia* **415**: 101-107

Fink, J.C. (2005). Establishing concentrations and turbidity. In Fondriest Environmental, Inc. Water temperature measurement. Retrieved from https://www.fondriest.com. Assessed on 7th February 2021.

Goswami, G., Pal, S., and Palit D. (2014). Studies on the physic-chemical characteristics, macrophyte diversity and economic prospect in Rajmata Dighi: a wetland in Cooch Behar District, West Bengal, India. *NeBio,* **1** (3): 21-27.

Hrivnak, R., Otahelova, H. and Jarolimek, I. (2006). Diversity of aquatic Macrophytes in relation to environmental factors in the Slatina river (Slovakia). *Biologia,* **61**: 417-423

Hrivnak, R., Otahelova, H., Valachovic, M., Balang, P. P. and Kubinska, A. (2010). Effects of environmental variables on the aquatic macrophyte composition pattern in streams; a case study from Slovakia. *Fundamental Applied Limnology* **177** (2): 115-124.

Mary, H. W., Rena, R. J., Jean, D. B., Theo, M., Peter, J. W., Bernard, T. Nolan, Cristina, M. V. and Simeone, G. (2018). Drinking water nitrate and human health: An updated review. *International Journal of Environmental Research and Public Health*. **15** (7):1557.

Nedungadi, P., Raman, R., and McGregor, M. (2013). "Enhanced STEM learning with Online Labs: Empirical study comparing physical labs, tablets and desktops" Frontiers in Education Conference, Oklahoma City, OK, USA. (pp.1585-1590). Doi:101109/FIE2013.

Palit, D. and Mukherjee, A. (2013). Studies on water quality and macrophytes composition in wetlands of Bankura District, West Bengal, India. *Indian Journal of Plant Sciences* **1** (2&3): 221-228.

Puckett, L. J. and Cowdery, T.K. (2002). Transport and fate of nitrate in glacial outwash aquifer in relation to groundwater age, land use practices. *Journal of Environmental Quality* **31** (3): 782-796

Shannon, C.E. (1948). The mathematical Theory of Communication. *The Bell System Technical Journal,* **27**: 379-423 and 623-656

Tiseer, F.A., Tanimu, Y., and Chia, A.M. (2008). Survey of macro vegetation and physicochemical parameters of samaru stream, Zaria Nigeria. *Research Journal of Environmental Sciences,* **2**: 393-400.