Modeling Parameters of Oxygen Demand in the Aquatic Environment of Lake Chad for Depletion Estimation

[1] Peter A. Gwaski, [2] Stephen S. Hati, [3] Naomi P. Ndahi, [4] Victor O. Ogugbuaja
[1, 3, 4] Department of Chemistry, University of Maiduguri, Maiduguri Nigeria
[2] Analytics Division, Stat-DataPro+, Abuja Nigeria

[2] stevehati@yahoo.com

ABSTRACT

Modeling water quality parameter is an important tool for ecosystem sustainability management. This study takes a two-step procedure in developing a simple estimation tool for delineating oxygen demand parameter of concern in the Lake Chad. First, to determine the concentration levels of DO vis-a-viz the level of exertion on the oxygen budget from oxygen demand parameters (BOD, COD and TOC). Secondly to utilize a simple linear regression equation model to estimate the rate of depletion and delineate the parameter of concern. The results of this study generally revealed a healthy state of the aquatic environment of Kwatan Dawashe portion of the Lake Chad at the time of this study. However, it was evident that oxygen demand parameters were season dependent following the intrinsic factors associated with their variations. Thus for a more reliable depletion estimation model this significant seasonal variation was taken into account, thereby delineating COD as the parameter of concern during the dry season. However, this estimation model serves as short term tool for sustainability management process; therefore further studies are required with a larger coverage of the Lake Chad region and model calibration.

Keywords: *Dissolved oxygen, regression model, BOD, COD, TOC*

1. INTRODUCTION

A number of processes have been attributed to exerting oxygen demand in water (reservoir, pond, estuary, lake or river), thereby depleting the sustainable oxygen budget in aquatic environment. These processes consist of the rapid microorganism-mediated oxidation of organic matter, broadly referred to as biological oxygen demand (BOD) and chemical oxygen demand (COD), the presence of chemically oxidized substances in water. Both biotic and abiotic process leads to the occurrence of organic matter in water, such as hydrobiota excretion, atmospheric deposition, surface run-off, industrial, municipal and agricultural inputs [1-2].

The extent of total demand in aquatic environment is usually determined as total organic carbon (TOC) and is related to the sediment oxygen demand (SOD), an important sink variable [3]. TOC covers a very extensive and varied assortment of compounds and materials, gases, dissolved solutes and particles. This parameter serves as a gross measurement of water's cumulative carbon content [4, 2].

The circulation and amount of dissolved oxygen (DO) in water is a quality indicator of water that can be used to estimate the exertion on the oxygen budget. It expresses the volume of oxygen contained in water that is supplied by oxygen transfer across the air–water interface and photosynthesis of aquatic biota [3, 5].
However, other processes involved in depleting DO include atmospheric exchange, physical circulation, turbulence, and water temperature including the effects of climate change [2, 6].

1.1 Lake Chad Resource and Environment

Water surface area exposure of the Lake Chad fluctuates in size between 25, 000 and 15,000 Km^2 and up to 2,000 Km^2 during severe drought, which is equivalent to water volume of 20 – 100 x 10^9 m^3. An average water depth of 2 m, with depth of as much as 7 m in the northern part of the basin and 11 – 12 m in the southern part was recorded [7].

According to Durand [8], the highest water level of Lake Chad lately is attained between November and January yearly (283 m above msl), while during the Sahel drought this level drops to as low as 277 m msl. Subsequently, evaporation exceeds river inflow and the Lake level progressively declines in July. Temperature ranges between 14 and 26 ^{O}C. Apart from rainfall, the Lake water level is fully dependent on the amount of inflow from the Chari and Lagoon Rivers. Also the Delimi River has its main drainage system from Jos and a major stream of the Shari River system which flows North-east (Kumadugu-Yobe River) and drains into Lake Chad, spanning a distance of about 900km [9-10].

In addition to products of intensive agriculture, livestock grazing and fishery, the drainage basin of Lake Chad is known for its production of natural soda, an activity that adds to maintaining freshness to the lake water. Diamonds are also fundamentally the major mineral exploited in the Chad basin, with mining activity on the border and gold mining in the regions of Tandjile and Mayo Kebi [11-12].

1.2 Study Objective

Modeling water quality parameter is a sustainability management tool and has gained significance in tackling aspects and variety of processes that lead to the rapid degradation of the aquatic ecosystems. It is a powerful tool for making projections for lake morphometries and trophic levels, long time behaviour of DO, assessing quantitatively the water

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

quality in lakes, in addition to the study of physical-ecological interactions between the ecological variables [13-16], as well as the effects of climate change [17, 13]. This study takes a two step procedure in developing a simple estimation tool for delineating oxygen demand parameter of concern in the Lake Chad. First, to determine the concentration levels of DO vis-a-viz the exertion level on the oxygen budget from oxygen demand parameters (BOD, COD and TOC). Secondly to utilize a simple linear regression equation model to estimate extent of depletion and delineate the parameter of concern. The result of this model may provide for a short term estimation purposes and planning towards a long term ecosystem pollution management program in portions of the Lake Chad region of Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Kwatan Dawashe portion of the Lake Chad region. Generally, the Lake Chad is positioned at the southern border of the Sahara desert, eastern expanse of the Sahel, 12:20-14:20N, 13:00-15:20E; 280m above sea level [11]. About 100 meters from the shoreline and at equidistance, a composite cluster of four sampling stations were programmed for sampling in this study.

2.2 Samples and Sampling

Surface water and superficial sediments (0-2cm) samples were collected on a monthly basis, for a period of one year (January to December, 2011). Samples were collected in pre-cleaned polythene containers, preserved at about 3^{o}C before analysis. Sampling procedures are guided by details in Radojevic and Bashkin [1].

2.3 Determination of Parameters of Oxygen Demand

Dissolved oxygen (DO) in surface water was determined on site using the calibrated Griffin portable meter (model M-40). The portable meter was calibrated with about 5% HCl solution.

Biological oxygen demand (BOD_5) determination was achieved by collecting portions of each replicating surface water sample in the cluster of each sampling station immediately after each DO measurement, in the amber coloured BOD_5 bottles. These were incubated at 20^{o}C for five days and subsequently measured for DO content. Thus BOD_5 concentration was worked out from the following equation:

$$BOD_5 = \frac{\left(DO_{initial} - DO_{after\ day\ 5}\right) \text{ x Volume of BOD bottle}}{\text{Volume of water sample}}$$

The determination of chemical oxygen demand (COD) was carried out according standard method [19], which consist of refluxing a mixture of 20 ml surface water sample, 0.4 g $HgSO_4$, 2 ml sulphuric acid and 10ml of standard $K_2Cr_2O_7$ solution. Facilitated by few glass beads, the mixture was swirled gently while 30 ml of Ag_2SO_4 solution was slowly added to the reflux system that lasted for about two hours. After cooling, the resulting solution was flushed into Erlenmeyer flask and made up to 150 ml with distilled water. At room temperature, the solution was then titrated with standard ferrous ammonium sulphate (FAS) using ferroin indicator. Blank titration was carried out. COD was then estimated in surface water samples using the following equation:

$$\text{COD (mg/L)} = \frac{(V_b - V_s) \text{ x M x 16000}}{\text{Volume of water sample}}$$

Where V_b = Volume of FAS for blank titration, V_s = Volume of FAS for sample titration and M = Molarity of FAS.

Total organic carbon (TOC) was determined in sediments samples by standard method [19] similar to COD by titrating prepared sample solution against 0.25 M FAS until a wine red end point was attained. Sediments sample preparation entailed air-drying, pulverizing, homogenizing and sieving. Each sample (0.2 g) was placed in a 500ml conical flask and treated with 10 ml of 0.5 M $K_2Cr_2O_7$, while swirling gently, 20ml of 1M H_2SO_4 was added to the mixture. This was thoroughly mixed and allowed to stand for about 40 minutes, after which 200 ml of distilled water was added, followed by cautious adding of 10ml 1M H_3PO_4. Ferroin indicator was added to the mixture and %TOC of the sediments was estimated using the following equation:

$$\%TOC = \frac{(V_b - V_s) \text{ x M x 1.38}}{W}$$

Where V_b = Volume of FAS for blank titration, V_s = Volume of FAS for sample titration and W = Weight of sample in gramme.

2.4 Data Analysis

Data analysis was performed using Analyse-it v2.26 statistical software for Microsoft Excel.

Modeling procedures and statistical techniques were adopted from standardized literatures [20-22]. Product moment correlation coefficients were determined for establishing positive relationships between BOD, COD and TOC preceding the standard regression analysis used to evaluate their relationship with DO.

The model formulated was as follows:

$$A = k - C\ (DO, mg/L)$$

Where A = oxygen demand parameter (BOD, COD; TOC); k = constants determined by regression analysis; C= concentration rate of oxygen demand.

Statistical significance was considered at 95% confidence interval where P<0.05. This decision rule was also implemented at data validation procedure for extraneous outlier that may have resulted from quality control issues, such as reagent blanks, contamination, etc.

3. RESULTS AND DISCUSSION

3.1 Dissolved Oxygen (DO)

The annual DO variation in surface water at the sampling locations of Lake Chad is shown on Figure 1. It revealed that average monthly DO in surface water was highest in August (8.8±0.13 mg/L) and was least in April (6.6±0.43 mg/L) for the year under study. Monthly variation was significant with a variability coefficient of 11.2%.

The average DO in wet season (8.2±0.7 mg/L) was higher than the annual average (7.6±0.8 mg/L) recorded, while average DO in dry season (6.6±0.43 mg/L) was lowest. The average DO difference of about 8% wet season above the dry season was significant.

DO is very crucial to the survival of aquatic life in Lakes [5, 23]. The result of this study reveals that irrespective of seasonal variations, the averages of DO in wet and dry seasons as well as the annual average in the water of Lake Chad for the period under study, meets the universal minimum dissolved oxygen standard of 5 mg/l [24-26]. This generally indicates that the Lake Chad water exhibit the necessary quality to support aquatic lives all year round, thereby supporting high agricultural and commercial activities observed within this region.

Higher DO levels during the wet season than dry season may be attributed to seasonal stratification which occurs as a result of water's temperature-dependent density. Implying that cold water can hold more dissolved oxygen than warm water. For instance, water at 20 OC will be 100% saturated with 8 parts per million dissolved oxygen, while water at 8 OC can hold up to 12 parts per million of oxygen before it is 100% saturated. Other factors for higher DO may be due to large population of plants, algae and cyanobacteria in Lake Water. Also that DO levels can fluctuate significantly from day to night. This is referred to as the diurnal (daily) cycle, resulting from excess oxygen produce by rooted aquatic plants and algae during the daylight hours when they are photosynthesizing, this they must use for life processes during the dark hours [2, 27]. Thus the higher DO levels observed in the wet season of this study also reflected more of the consequent massive aquatic plant growth observed during this period.

An earlier study [28] reported a much higher range (24 -46 mg/L) of DO levels at the Kwatan Turare area of the Lake Chad, than a much earlier studies in the Lake Chad region [29] and in River Yobe [30], which tend to correspond with the findings of this study as well as findings of other Lakes around the world [31, 23].

3.2 Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC)

A comparative illustration of BOD, COD and TOC results is presented in Figure 2. It shows that BOD concentration variation was consistently higher than COD for the period under study. The annual average of BOD and COD vary by about 32% respectively and was statistically significant.

BOD was highest in May (4.4±0.09 mg/L) and lowest in June (3.5±0.4 mg/L), while COD was highest in January (4.1±0.01 mg/L) and lowest in December (1.5±0.3 mg/L). Both BOD and COD showed remarkable sharp transitions between the peak and the bottom values in consecutive months.

The result of TOC presented in percentages (%), on the secondary axis of Figure 2, indicated a multi-months high values as well as low values. TOC maintained high values from January to May, but maintained peak levels (2.3%) in January, April and May. Lowest TOC levels (1.1%) were observed in the months of October and November. Monthly variability was about 27%, and was significant.

Converse to the result of seasonal variations of DO, which presented a lower DO level in the dry season, BOD, COD and TOC were all significantly higher in the dry season than in wet season by about 10%, 30% and 28% respectively.

BOD criteria vary significantly from country to country and from one water guideline program to another. The EU guideline [32] ranges from 3.0 to 6.0 mg/L, while a Class C water criterion for BOD is 10 mg/L [23], although none is below 3.0 mg/L BOD for the safety of aquatic biota and domestic water supply. Thus, the results of BOD for the period under study in this work were within the guidelines. BOD investigation offers the closest measure of oxygen demand processes actually occurring in the natural water system, many uncertain factors such as the pollutants, origin, concentration, the number and viability of active microorganisms present to influence the oxidation of all pollutants have been a challenge to high variability of results [33-34]. However the levels of BOD in this study suggests either low population of microorganism capable of initiating oxidation or low amount of organic matter that can be oxidized by microorganism, by and large, indicating a healthy state of Lake Chad at the time of this study.

The guideline for COD is 200mg/L (WHO) and TOC has been regulated at 2mg/L [4]. The results of this study showed that these parameters were within guidelines.

COD investigation is employed as a measure of both organic and inorganic agents competing for DO in Lake Water. These agents are susceptible to oxidation by a strong chemical oxidant in contrast to biological oxidation in the BOD test [34]. Higher values of COD indicate pollution due to oxidizable organic matter [35], which in previous study [28] around the Lake Chad region may have been due to discharges of domestic wastewater from nearby settlements, surface and ground water carrying chemicals directly from agricultural field into the Lake [28].

TOC levels in this study suggests that the rate at which DO is removed from the water column of Lake Chad may be due to the decomposition of organic matter in the bottom sediments, the respiration rates of benthic communities and the chemical oxidation of reduced substances in the sediment [15, 35-36]. Therefore the moderate level of TOC between BOD and COD expresses a good support for presence of microorganism-mediated oxidation of organic matter.

BOD, COD and TOC results of this study corresponds with the findings of previous studies of Lake Chad [29], river systems around the Lake Chad region [30, 37] and other Lakes around the world [33-34, 38-39].

Higher BOD, COD and TOC, converse to lower DO levels in dry season may be due to the rise in temperature, amplified biological activity, respiration of organisms and the increased rate of decomposition of organic matter [33] as observed in this study.

3.3 Estimation Model for Parameters of Oxygen Demand in the Aquatic Environment

The estimation model for oxygen demand parameters (BOD, COD and TOC) follows ascertaining that there exists a possibly high positive correlation coefficient between these parameters [5, 20].

The association trends of these oxygen demands are presented in the scatter plots of Figure 3a-c indicating their respective level of association in the aquatic system.

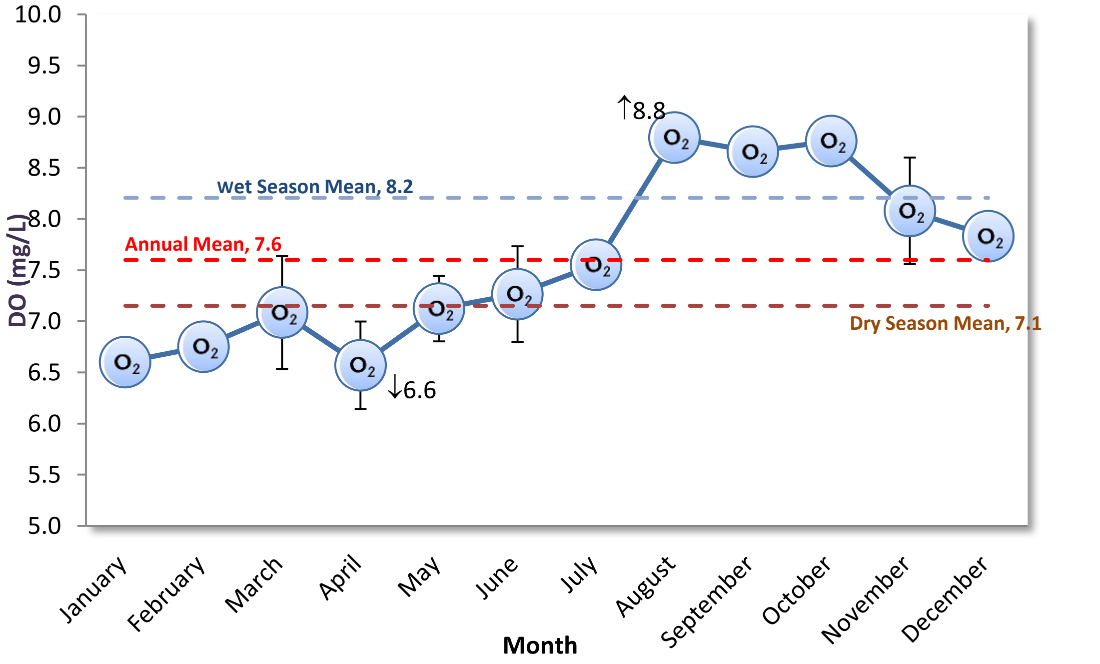

Figure 1: Monthly Dissolve Oxygen at Sampling Points of Lake Chad

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

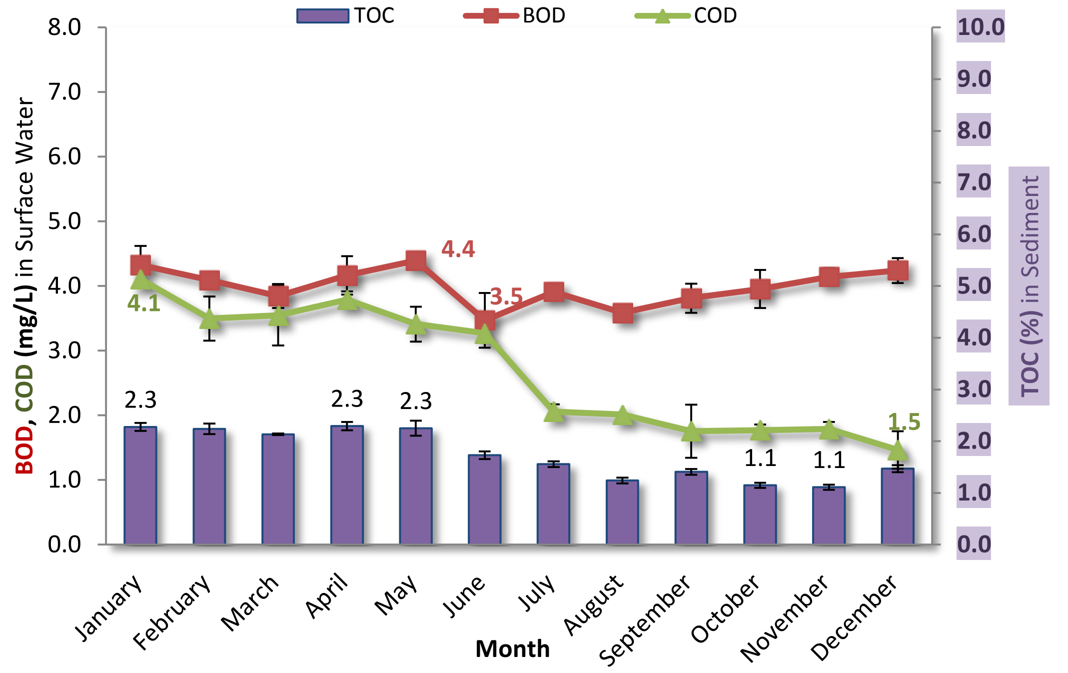

Figure 2: Parameters of Oxygen Demand at Sampling Points of Lake Chad

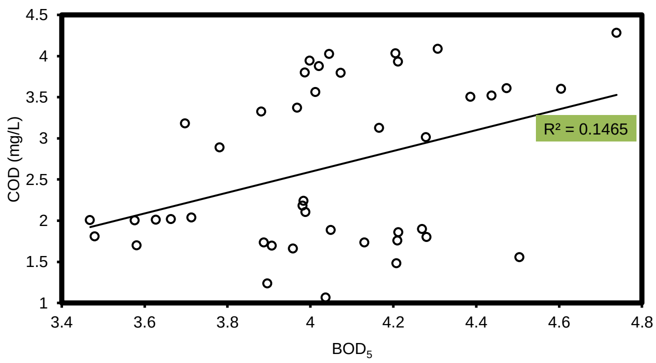

Figure 3a: Scatter plot of BOD_5 against COD

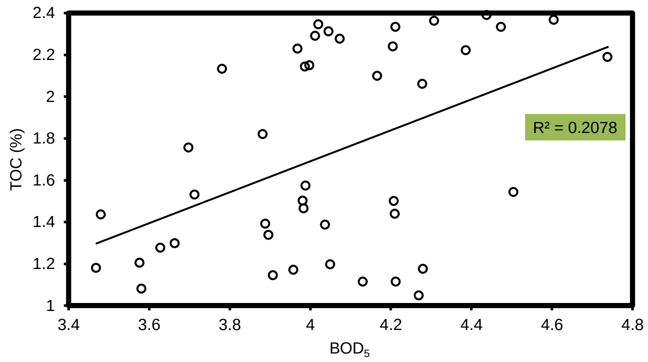

Figure 3b: Scatter plot of BOD_5 against TOC

The plot (Figure 3c) showed that COD and TOC exhibited an almost perfect relationship (r = 0.91). Suggesting that while microorganism-mediated oxidation of organic matter exist in the Lake Chad portion under study, TOC and COD trend tend to show more activity similarity, that posit a high likelihood of COD contributions to the bulk of TOC level of oxygen demand recorded.

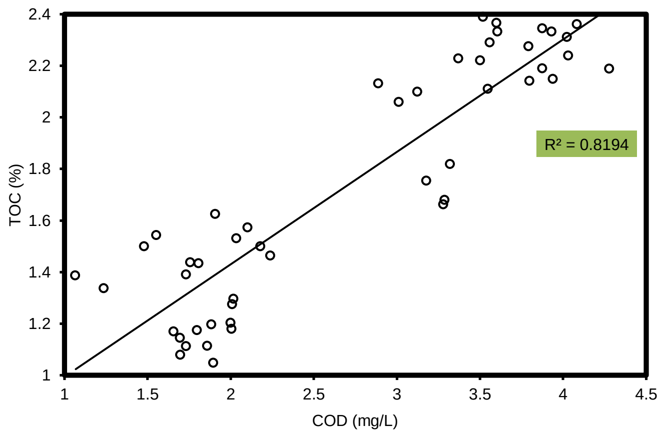

Figure 3c: Scatter plot of COD against TOC

Plots of regression analysis illustrating the relationship between DO and the oxygen demand parameters (BOD_5, COD and TOC) are shown on Figure 4a-c. The plots also show the regression equation with fit expressed for the estimation model. Figure 4a revealed a strong correlation (r = 0.65) between DO and BOD with a regression equation: $BOD_5 = 5.68 - 0.2159DO$ (mg/L), thus indicating that for every unit of DO in surface water, about 0.22 mg/L of BOD was recorded for the period under study.

ARPN Journal of Science and Technology

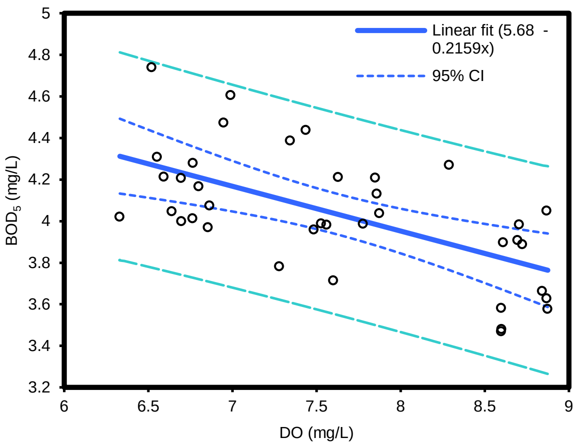

Figure 4a: Regression plot of DO against BOD_5

Figure 4b revealed a strong correlation (r = 0.81) between DO and COD with a regression equation: COD = 9.827 - 0.937DO (mg/L).

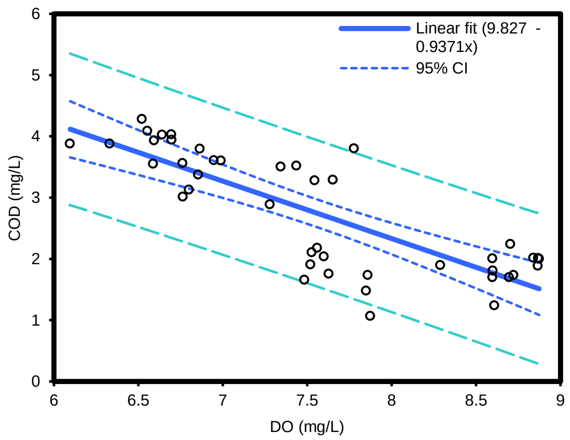

Figure 4b: Regression plot of DO against COD

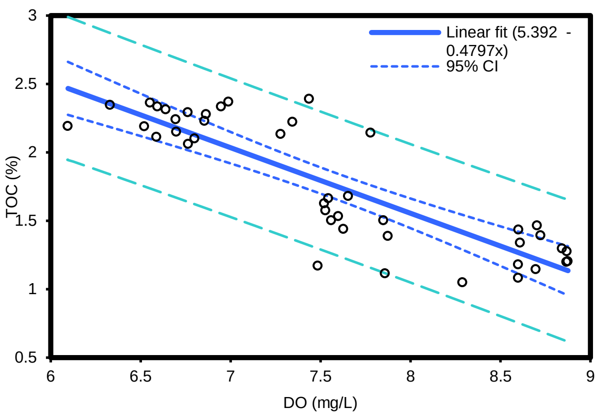

Figure 4c: Regression plot of DO against TOC

Also, Figure 4c revealed a strong correlation (r = 0.86) between DO and TOC with a regression equation: TOC = 5.392 - 0.4797DO (mg/L). These indicated that for every unit of DO in surface water, about 0.9 mg/L of COD and about 0.5 mg/L of TOC was recorded for the period under study.

In aquatic system, TOC is responsible for up to50% of the total oxygen depletion, making it as a critical element in water quality modeling studies [40].

However due to the significant difference in the levels of oxygen demand between seasons, it was also imperative to provide depletion rate estimation values for each of the parameters for the different seasons. Thus, for a more reliable DO depletion estimation that is season dependant the following values from the regression equation model were deduced, as presented on Table 1.

The seasonal depletion estimation values generally correspond to the annual trend between the parameters, but varied significantly between seasons. Thus revealing that the highest rate of depletion being COD (12.63 - 1.34DO (mg/L)) in dry season.

Table 1: Seasonal DO depletion estimate

Oxygen Demand Parameter	Dry Season	Wet Season
BOD_5	4.515 - 0.05DO (mg/L)	4.751 - 0.12DO (mg/L)
COD	12.63 - 1.34DO (mg/L)	6.027 - 0.48DO (mg/L)
TOC	6.095 - 0.61DO (mg/L)	3.645 - 0.27DO (mg/L)

4. CONCLUSION

The results of this study generally revealed a healthy state of the aquatic environment of Kwatan Dawashe portion of the Lake Chad at the time of this study.

However, it was evident that oxygen demand parameters were also season dependent following the intrinsic factors associated with their variations.

Thus for a more reliable depletion estimation model this significant seasonal variation was taken into account, thereby delineating COD as the parameter of concern during the dry season.

However, this estimation model serves as short term tool for sustainability management process; therefore further studies are required with a larger coverage of the Lake Chad region and model calibration.

REFERENCES

[1] Radojevic M. and Bashkin VN (2006) *Practical Environmental Analysis* (2^{nd} Edn), RSC Publishing, UK, pp 248-257

[2] Manahan, S. E. (2005) Environmental Chemistry, 8th Edition CRC Press LLC, Florida USA, Pp. 180, 694.

[3] Chen GH, Leong IM, Liu J, Huang JC, Lo IMC, Yen BC (2000). Oxygen deficit determinations for a major river in eastern Hong Kong, China. Chemosphere 41(1-2):7-13.

[4] O'Connor, J.T. (2004) "Removal of Total Organic Carbon A Technical Review", Part 1 H2O'C Engineering (877) 22-WATER GAC-Capped Filter, Bloomington, Illinois.

[5] Radwan, M., P. Willems, A. El-Sadek and J. Berlamont (2003), Modelling of dissolved oxygen and biochemical oxygen demand in river water using a detailed and a simplified model Intl. J. River Basin Management Vol. 1, No. 2 97–103.

[6] Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P., (2008). Analyzing Regional Aspects of Climate Change And Water Resources. IPCC Secretariat, Geneva.

[7] SATTEC, (1992), Hydrogeological Mapping of Nigeria sheets 4, 5, 14, 15, 16, 26, 27 &28. Final report prepared for Federal Ministry of Agriculture and Rural Development, Nigeria.

[8] Durand, A. (1995) "Quaternary sediments and climates in the central Sahel", African geosciences review, , 2: 323-614.

[9] Anadu, D. I. A. W. Akpan, (19860 "A survey of the functional feeding groups in the Delimi River, Jos, Plateau State Nigeria", Nig. J Applied Fish & Hydrobiol, 1: 25 - 31.

[10] Njoku, D.C. and Keke, I. R. (2003). A Comparative Study on Water Quality Criteria of Delimi River in Jos, Plateau State of Nigeria ASSET Series A 3 (4):143-153.

[11] ILEC: (2012) International Lake Environment Committee, "Promoting Sustainable Management of the World's Lakes and Reservoirs, Lake Chad Database", http://www.ilec.or.jp/database/afr/

[12] Keith, J. O. and Plowes, D. C. H. "Considerations of Wildlife Resources and Land Use in Chad," USAID Technical, Paper 47, 1997.

[13] Stefan, H.G., and Fang, X., (1994). Dissolved Oxygen Model for Regional Lakes Analysis. Ecol. Model. 71, 37–68.

[14] Jassen MA (2001). An Exploratory Integrated Model to Assess Management of Lake Eutrophication. Ecol. Model. 140(1-2):111-124.

[15] Chau KW, Cheng CT, Li CW (2002). Knowledge Management System On Flow And Water Quality Modeling. Expert Syst. Appl. 22(4):321-330.

[16] Arhonditsis GB, Brett MT (2005). Eutrophication model for Lake Washington (USA) Part I: Model description and sensitivity analysis. Ecol. Model. 187(2-3):40-178.

[17] Zhao, M. Y. C. T. Cheng, K. W. Chau, G. Li, (2006) "Multiple Criteria Data Envelopment Analysis For Full Ranking Units Associated To Environmental Impact Assessment", Int. J. Environ. Pollut., 28(3-4): 448-464.

[18] Blumberg, A.F. D.M. Di Toro, (1990), "Effects of climate warming on dissolved oxygen concentrations in Lake Erie". Trans. Am. Fish. Soc. 119, 210–223.

[19] Ademoroti, C. M. A. (1996) "Standard Method for water and Effluents Analysis," Foludex Press Ltd., Ibadan, , pp. 22-23,44-54,111-112.

[20] Barnett V. (2004) Environmental Statistics, Methods and Applications. John Wiley & Sons, Ltd., The Atrium Souther Gate, West Sussex, England

[21] Butts, T. A. Schnepper, D. H. and Evans, R. L. (1970) Dissolved Oxygen Resources and Waste Assimilative Capacity of the La Grange Pool, Illinois River. Illinois State Water Survey, Urbana, Report of Investigation 64,

[22] Dolan, D. M. and Bierman, V. J. (1982) Mass Balance Modeling Of Heavy Metals In Saginaw Bay, Lake Huron J. Great Lakes Res., 8(4): 676-694

[23] Ana, J. G. S. Bileynnie P. Encarnacion, Reheema Myra E. Escultor, Archilles R. de la Cruz, (2012), "Water Quality Report on Calibato Lake 1996-2005", Environmental Quality Management Division (EQMD), Rizal, 15-27.

[24] USEPA, (1999) "Volunteer Lake Monitoring: A Methods Man-ual," EPA 440/4-91-002. Office of Water US Environ-mental Protection Agency, Washington DC,.

[25] WHO, (2002) "World Health Organization Standard for Drink-ing Water," Guidelines for Drinking Water Quality, Vol. 1, Recommendation, France, WHO, 181.

[26] KDHE, (2011) Kansas Department of Health and Environment, Bureau of Water, "Water Quality Standards", White Paper Allowances for Low Dissolved, Oxygen Levels For Aquatic Life Use. Kansas, USA, , 1-6

[27] AWQA: Alberto Water Quality Awareness "Dissolved Oxygen and Alberta Lakes" http://www.awqa.do.al/database/pdf/, 2005

ARPN Journal of Science and Technology

http://www.ejournalofscience.org

[28] Akan, J. C. M. T. Abbagambo, Z. M. Chellube, F. I. Abdulrahman, (2012) “Assessment of Pollutants in Water and Sediment Samples in Lake Chad, Baga, North Eastern Nigeria”, Journal of Environmental Protection, , 3, 1428-1441.

[29] Kolo, B.G. V.O. Ogugbuaja, M. Dauda, (2010) “Seasonal Variation in Dissolved Oxygen and Organic Pollution Indicators of Lake Chad Basin Area of Borno State, Nigeria”, Continental J. Water, Air and Soil Pollution, , 1: 1 – 5.

[30] Waziri, M. V.O. Ogugbuaja, (2010) “Interrelationships between physicochemical water pollution indicators: A case study of River Yobe-Nigeria” American Journal of Scientific and Industrial Research, Am. J. Sci. Ind. Res., 1(1): 76-80

[31] Chandra, S. A. Singh, P. K. Tomar, (2012) “Assessment of Water Quality Values in Porur Lake Chennai, Hussain Sagar Hyderabad and Vihar Lake Mumbai, India”, Chem Sci Trans., 1(3), 508-515

[32] Chapman, D. (1993) “Assessment of Injury to Fish Populations: Clark Fork River NPL Sites, Montana,” In: J. Lipton, Ed., *Aquatic Resources Injury Assessment Report*, Upper Clark Fork River Basin, Montana Natural Resource Damage Assessment Program, Helena, Mont,

[33] Okbah, M. A. S. El. El-Gohary, (2002) “Physical and Chemical Characteristics of Lake Edku Water, Egypt Mediterranean Marine Science”, 3/2, 27-39.

[34] Zhang, C. C., (2007) Fundamentals of Environmental Sampling and Analysis. John Wiley & Sons, Inc., Hoboken, New Jersey Pp. 127-155

[35] Syeda, R. Harakishore K., Msatyakala and Suryanarayanmurty U., (2003) `studies on the physic-chemical parameters of Rankala lake, Kolhapur, Int. J. Env. Protection, 961-963.

[36] Rasheed M, Al-Rousan S, Manasrah R, Al-Horani F (2006). Nutrient fluxes from deep sediment support nutrient budget in the oligotrophic waters of the Gulf of Aqaba. J. Oceanogr. 62(1):83-89.

[37] Maitera, O. N. V. O. Ogugbuaja, J. T. Barminas, (2010) “An assessment of the organic pollution indicator levels of River Benue in Adamawa State, Nigeria”, J. Environ. Chem. Ecotoxicol., 2(7), 110-116.

[38] Shilpa, P. G. Chonde Sonal Goroba, Jadhav Aasawari Suhas, Prakash D. Raut, (2011), “Study of physicochemical and biological characteristics of lakes from Shivaji University Campus, Kolhapur, Maharashtra”, Advances in Applied Science Research, 2 (6):505-519

[39] Marki, M. B. Muller, C. Dinkel, and B. Wehrli (2009), Mineralization pathways in lake sediments with different oyxgen and organic carbon supply. Limnol. Oceanogr., 54: 428–438.

[40] Di Toro, D. M. P. R. Paquin, K. Subburamu, D. A. Gruber, (1990) “Sediment oxygen demand model: Methane and ammonia oxidation”, J. Environ. Eng. ASCE, 116(5):945-986.