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Assessment of Physico-Chemical Characteristics of Water in Agodi Reservoir, Ibadan, Nigeria

Ogungbile, P.*[1], Akande, J. A.[1], Ogunbode, T. O.[1], and Odekunle, O.[1]

[1]Department of Environmental Management and Control, Bowen University, PMB 284,Iwo,Nigeria

E-mail: ogungbilepeter@yahoo.com

*Corresponding Author:
Ogungbile Peter, as above

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Abstract

Physico-chemical analysis of water in Agodi Reservoir in Ibadan, Oyo State was carried out in the rainy and wet seasons using standard methods. The mean values of the parameters measured were compared with the WHO permissible concentrations. One-way ANOVA was used to test for location differences and seasonal variations. The mean values of Total Suspended Solids (TSS) 280.46mg/L, Total Dissolved Solids (TDS) 420.25mg/L, Temperature (T°C) 27.71°C, pH 7.58 Electrical Conductivity (EC) 213.34µs/cm, Sulphate (SO_4^{2-}) 0.03mg/L, Phosphate (PO_4^{3-}) 0.04mg/L, Nitrate (NO_3^-) 0.03mg/L, Chloride (Cl) 0.03mg/l, Total Hardness (TH) 190.07mg/L, Alkalinity (Alk) 183.44mg/L, Dissolved Oxygen (DO) 7.84mg/L, Biochemical Oxygen Demand (BOD) 0.54mg/L and Chemical Oxygen Demand (COD) 86.00mg/L were recorded. Analysis of variance (ANOVA) showed no significant difference in the mean values of all the parameters except for BOD at the test locations. Seasonally, there was no significant difference in the two seasons except in TH. Compared to WHO recommended limits, Temperature TH and COD were above the recommended limits for drinking water. In conclusion, the values obtained for other parameters were within the recommended values of WHO for survival of organisms in an aquatic ecosystem.

Évaluation Des Caractéristiques Physico-chimiques De L'eau Dans Le Réservoir D'agodi, Ibadan, Nigéria

Abstrait

L'analyse physico-chimique de l'eau dans le réservoir Agodi à Ibadan, dans l'État d'Oyo, a été réalisée pendant les saisons des pluies, à l'aide de méthodes standard. Les valeurs moyennes des paramètres mesurés ont été comparées aux concentrations admissibles par l'OMS. Une ANOVA unidirectionnelle a été utilisée pour tester les différences de localisation et les variations saisonnières. Les valeurs moyennes de matières en suspension totales (TSS) 280,46 mg / L, de matières dissoutes totales (TDS) 420,25 mg / L, température (ToC) 27,71 ° C, pH 7,58 Conductivité électrique (CE) 213,34µs / cm, sulfate (SO42-) 0,03 mg / L, phosphate (PO43-) 0,04 mg / L, nitrate (NO3-) 0,03 mg / L, chlorure (Cl) 0,03 mg / l, dureté totale (TH) 190,07 mg / L, alcalinité (Alk) 183,44mg / L, oxygène dissous (DO) 7,84 mg / L, demande biochimique en oxygène (DBO) 0,54 mg / L et demande chimique en oxygène (DCO) 86,00 mg / L ont été enregistrés. L'analyse de variance (ANOVA) n'a révélé aucune différence significative entre les valeurs moyennes de tous les paramètres, à l'exception de la DBO aux emplacements d'essai. En saison, il n'y avait pas de différence significative dans les deux saisons sauf dans TH. Comparativement aux limites recommandées par l'OMS, les températures TH et DCO étaient supérieures aux limites recommandées pour l'eau de boisson. En conclusion, les valeurs obtenues pour d'autres paramètres se situaient dans les valeurs recommandées par l'OMS pour la survie des organismes dans un écosystème aquatique.

Introduction

Water is one of the indispensable components for the continued survival of life on earth. Humans have established communities and flourished around sources of clean, drinkable water. People can survive days without food but not without water. It is a major constituent in all living matters, in the human body comprising up to two-thirds of the biomass. It is essential for all organisms, some of which contain more than 90% of it in their protoplasm. Water is required for translocation of nutrients, transportation of mineral and dissipation of energy (DeBoer and Volkou, 2003). Water is needed for drinking, cooking, and washing and in some workplaces, water is used for agriculture and industry (Chapagain and Hoekstra, 2004). Drinking water, by contrast, requires the highest quality water but in relatively small quantities. Water resources of the world are in oceans, polar ice, icebergs, glacier, groundwater soil moisture, lakes, streams, wetlands, rivers, and atmospheric water. Surface water is replenished by precipitation and naturally lost through evaporation and sub-surface seepage into groundwater.

Water quality describes the condition of water including, physical, chemical and biological parameters. Lawson (2011) analysed water quality with respect to the chemical, physical and biological contents of the water. Water quality of rivers and lakes changes with seasons and geographic areas (UNEP/WHO, 1996). Water quality is determined by many factors such as Total Dissolved Solids, Electrical Conductivity, pH Water Temperature, Total Hardness, Alkalinity Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand. These parameters are often implicated for the survival rate of aquatic organisms.

All water uses have impacts on the quality of the aquatic environment. Human use for almost all purposes results in the determination of water quality and generally limits the further potential use of the water. Anthropogenic activities are the source of particulate dissolved and volatile materials which may eventually reach the water body. Dissolved materials and many particulates are discharged directly to water bodies, while the particulate and volatile materials that pollute the atmosphere are picked up by rain and deposited on land or in water.

The physico-chemical characteristics of a water body can be significantly altered by anthropogenic activities such as various agricultural practices and irrigation. Municipal effluents and industrial discharges into the water bodies have a negative impact on the water qualities by reducing water flow rate (Chitinanat and Triachaiyoporn, 2010). Depending on the quantity and quality of waste input, the physical, chemical and biological balance of receiving waters may be significantly modified resulting in pollution and associated consequences (Akpan *et al*, 2002).

Pollution of water is one of the most serious environmental problems. Water is regarded as polluted when it changes in its quality or composition either naturally or as a result of human activities such that it becomes less suitable for drinking domestic, agricultural industrial, recreational wildlife and other uses for which it would have been suitable in its natural or unmodified state (Goel, 2006). According to (Richman 1997 and GESAMP 1988), water pollution occurs when a body of water is adversely affected due to the addition of large amounts of toxic substances to the water and when it is unfit for the intended use. Cunningham *et al*, 2005 described pollution as any physical or chemical change in water quality that adversely affects living organisms or makes water unsuitable for the desired use.

Water pollution is an environmental hazard. An environmental hazard is any condition, process or state adversely affecting the environment. These hazards can be physical or chemical, and are present in the air, water, and/or soil. Unfortunately, hazardous conditions can cause harm to humans and other organisms within an ecosystem. WHO (1984) estimated that up to 80% of all sickness and diseases in the world are caused by inadequate and/or polluted water.

The World Health Organisation (2013) asserted that dumping of decomposed materials or channeling of debris from domestic and industrial operations into water bodies are also contributors to diminishing the water quality needed for drinking. According to Owa (2013), most of the sewage comes from defecation at river sides, using streams for bathing, dumping of refuse into streams and rivers as well as wash-off of fertilizers from farmlands. A high proportion of life threatening and health-threatening infections are transmitted through polluted water.

Physico-chemical studies are useful to get the exact idea of the quality of water and to make valuable decisions when results are compared with standard values. Considerable advancement has been made analysing the physico-chemical parameters of water, significant among them are Rajesh *et al.,* (2002), Pradhan *et al.,* (2009), Sirvastava *et al.,* (2009), Pretiemo-Clarke *et al.,* 2009; Lawson, (2011) and Edet *et al.,* (2012). The ever-increasing importance and warning to long term sustainability of Agodi Reservoir due to anthropogenic activities makes the present study to be pertinent. The objective of this is to evaluate various physico-chemical parameters of water quality in Agodi Reservoir, in Ibadan with reference to pollution.

Study Area

Agodi Reservoir is situated in Ibadan (Fig. 1), Oyo State, Nigeria and lies between longitude 7° 2' E and 7° 40' E and latitude 3° 35' N and 4° 10' N. The reservoir was human created in 1980 along the path of Ogunpa River following the great

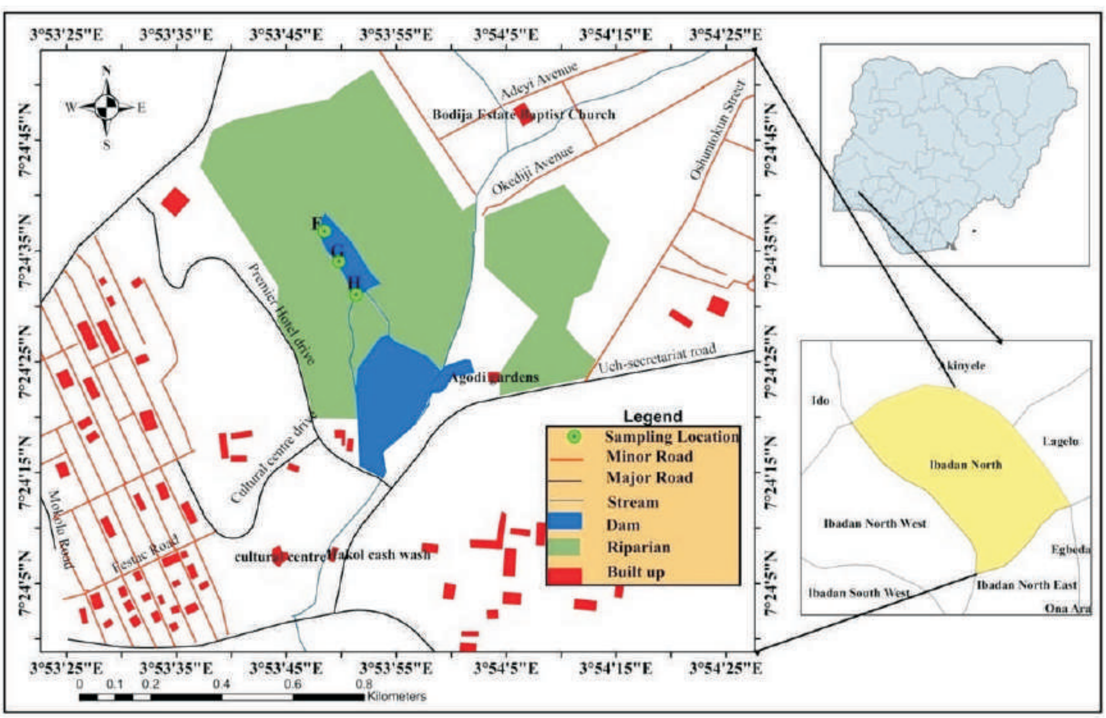

Figure 1: Map of Ibadan showing Sampling locations F, G and H on Agodi Reservoir

flood of that year in the city. The purpose was to serve as a retention basin for excess run-off from the upper section of Ogunpa River and prevent flooding downstream of the river. The reservoir covers an area of 5.2 hectares, stretching about 1km with a maximum depth of about 5m. The advancing Ogunpa River traverses major parts of Ibadan city where it flows across many markets, eateries, schools residential areas, abattoirs, mechanic workshops, parking lots, waste dumps and other areas where wastes are generated before discharging into Agodi Reservoir.

Materials and Methods

Physico-chemical parameters of water samples were done on three selected sites of Ogunpa River. These sites comprise the inlet (F), centre (G) and Outlet (H) parts of Agodi Reservoir. The water samples were collected from the surface area. Physico-chemical analysis from Agodi Reservoir was studied over a twelve (12) month period covering wet and dry seasons. Two (2 litre) plastic bottles meant for collecting the water samples were thoroughly washed with a non-ionic detergent, rinsed with tap water and then soaked in 10% HNO_3 for 48 hours prior to sampling for chemical analyses. Furthermore, the containers were rinsed with distilled water and also rinsed thrice on the site with the water to be sampled. All glassware were washed with a non-ionic detergent, rinsed with tap water soaked in 10% HNO_3 for 48 hours and finally rinsed with distilled water to rule out trace metal contamination. The samples were carefully labelled and taken to the laboratory to assess their physico-chemical quality. Physico-chemical parameters investigated were, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Temperature (T°C), pH, Electrical Conductivity (EC), Sulphate (SO_4^{2-}), Phosphate (PO_4^{3-}), Nitrate (NO_3^-), Chloride (Cl^-), Total Hardness (TH), Alkalinity (Alk), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

The physico-chemical analyses of the water samples were carried out in accordance with Standard Analytical method (APHA, 1995).

Test location differences were examined using one-way Analysis of Variance (ANOVA) at $P<0.05$ to determine if any gradient effect is associated with the pollution dynamics while seasonal variation in the two seasons was examined using T-test statistic at 95% C.I. to show if there was significant difference or not between the dry and wet seasons. Values obtained from the physico-chemical parameters of water were compared with the WHO (World Health Organization) permissible concentrations for those parameters.

Table 1: Mean values of Physico-chemical Parameters in water samples from Agodi Reservoir along with locations (F to H)

Physico-chemical parameters	LOCATIONS			MEAN	WHO STANDARDS
	F	G	H		
TSS (mg/L)	233.60	290.26	266.35	265.40	-
TDS (mg/L)	294.29	310.38	414.29	339.65	500mg/L
Temp (°C)	27.38	27.51	27.38	27.42	25°C
pH	7.27	7.73	7.71	7.57	6.5-8.5
EC (µs/cm)	207.16	200.66	199.22	202.38	1000µs/cm
SO_4^{2-} (mg/L)	0.045	0.045	0.03	0.035	200mg/L
PO_4^{3-} (mg/L)	0.04	0.04	0.04	0.04	250mg/L
NO_3^- (mg/L)	0.03	0.025	0.015	0.025	10mg/L
Cl^- (mg/L)	0.03	0.03	0.03	0.03	250mg/L
TH (mg/L)	175.61	170.65	180.09	175.45	100mg/L
Alk (mg/L)	210.31	184.41	185.66	193.46	400mg/L
DO (mg/L)	8.14	7.83	8.45	8.14	7mg/L
BOD (mg/L)	0.405	0.485	0.610	0.53	6mg/L
COD (mg/L)	81.54	77.66	90.69	83.30	10mg/L

Table 2: Physico-chemical parameters in waters along Agodi Reservoir during the dry season

Physico-chemical parameters	LOCATIONS			MEAN
	F	G	H	
TSS (mg/L)	190.00	383.75	267.63	280.46
TDS (mg/L)	235.13	477.00	548.63	420.25
Temp (^{o}C)	28.20	27.48	27.46	27.71
pH	7.08	7.97	7.70	7.58
EC (µs/cm)	206.38	223.00	210.63	213.34
SO_4^{2-} (mg/L)	0.03	0.03	0.03	0.03
PO_4^{3-} (mg/L)	0.04	0.04	0.04	0.04
NO_3^- (mg/L)	0.04	0.03	0.01	0.03
Cl^- (mg/L)	0.03	0.03	0.03	0.03
TH (mg/L)	193.38	187.94	188.89	190.07
Alk (mg/L)	219.06	158.76	172.50	183.44
DO (mg/L)	8.25	7.22	8.05	7.84
BOD (mg/L)	0.51	0.50	0.62	0.54
COD (mg/L)	81.13	75.38	100.5	86.00

Table 3: Physico-chemical Parameters in water along Agodi Reservoir during the wet Season

Physico-chemical parameters	LOCATIONS			MEAN
	F	G	H	
TSS (mg/L)	277.19	208.75	265.06	250.33
TDS (mg/L)	353.44	143.75	279.94	259.04
Temp (^{o}C)	26.56	27.54	27.30	27.13
pH	7.46	7.49	7.72	7.56
EC (µs/cm)	208.13	178.31	187.81	191.42
SO_4^{2-} (mg/L)	0.04	0.06	0.03	0.04
PO_4^{3-} (mg/L)	0.04	0.04	0.03	0.04
NO_3^- (mg/L)	0.02	0.02	0.02	0.02
Cl^- (mg/L)	0.03	0.03	0.03	0.03
TH (mg/L)	157.84	153.41	171.25	160.83
Alk (mg/L)	201.56	210.06	198.81	203.48
DO (mg/L)	8.03	8.43	8.85	8.44
BOD (mg/L)	0.48	0.47	0.60	0.52
COD (mg/L)	80.94	79.94	80.88	80.59

Table 4:Physico-chemical analyses, Gradient effect and Seasonal variation

	Gradient along with last locations on Agodi Reservoir (F-H)			Seasonal variation Agodi Reservoir
Physical	*Slope	r^2	Gradient effect (dy/dx), ANOVA at R<0.05	(F & H) T-Statistics at P<0.05
TSS	+ve	0.70	0	0
TDS	+ve	0.23	0	0
Temp	+ve	0.35	0	0
pH	+ve	0.86	0	0
EC	-ve	0.62	0	0
Chemical				
SO_4^{2-}	+ve	0.003	0	0
PO_4^{3-}	-ve	0.71	0	0
NO_3^-	-ve	0.99	0	0
Cl^-	+ve	0.80	0	0
TH	+ve	0.37	0	1
Alk	-ve	0.87	0	0
DO	+ve	0.63	0	0
BOD	+ve	0.89	1	0
COD	+ve	0.46	0	0

Note: For gradient (dy/dx) and seasonal variation (1) = significant established (0)Not significant established

•Slope a slanting course from horizontal

Results and Discussion

Physical Parameters of Water

Table 1 gave the mean values of TSS, TDS, Temperature, pH, and EC in Agodi Reservoir. Tables 2 and 3 showed the mean values of TSS, TDS, Temp, pH, and EC in dry and wet seasons, while Table 4 showed their gradient effect and seasonal variation.

Total Soluble Solids (TSS) (Tables 1-4)

The mean value of TSS in the water samples was 265.40mg/L (Table 1). At P<0.05, one-way analysis of variance (F-statistic) showed no significant differences in TSS at the various locations on Agodi Reservoir, which imply no gradient effect (Table 4). The mean value of TSS in the dry season was 280.46mg/L (Table 2) and the mean value during the wet season was 250.33mg/L (Table 3). Linear regression of TSS in the water is positive with strong correlation as shown in equation (1) T-test statistics at 95% C.I. showed no significant difference which implies no seasonal variation (Table 4).

$$\text{TSS: } Y = 8.896X + 242.58 \quad (r^2 = 70\%) \qquad (1)$$

Note: that in all equations 1 to 5 to be represented

Y = specific physical parameter (dependent variable)

X = distance from source in meters (independent variable)

Total Dissolved Solid (TDS)

At P<0.05, one-way analysis of variance (F-statistic) showed no significant differences in TDS at the various locations which imply no gradient effect (Table 4). A linear regression of TDS along the sample locations in Agodi Reservoir showed a weak positive correlation (Eqn. 2). The dry season was 420.25mg/L (Table 2) while the wet season TDS was 259.04mg/L (Table 3). T-test statistic at 95% C.I. showed no significant difference between the two seasons (Table 4). The mean concentration of TDS in the water body was 339.65mg/L (Table 1).

$$\text{TDS: } Y = 27.75X + 257.26 \quad (r^2 = 23\%) \qquad (2)$$

Temperature (T°C)

The mean annual temperature of the water was 27.42°C (Table 1). In the dry season, the average temperature was 27.71°C (Table 2) and in the wet season, it was 27.13°C (Table 3). One-way analysis of variance (F-statistic) showed no significant difference in temperature in all the sampling locations (Table 4). Linear regression of T°C along sample locations showed a weak positive correlation (Eqn. 3). T-test statistics at 95% C.I. showed no significant difference in temperature for the two seasons.

T°CY = 0.1229X+27.079 (r^2=35%)............ (3)

pH

The pH of Agodi Reservoir was generally alkaline with a mean value of 7.57 (Table 1). The mean value in the dry season was 7.58 (Table 2) while in the wet season was 7.56 (Table 3). One-way analysis of variance (F-statistic) showed no significant difference in pH for the two seasons.

pH Y = 0.188X+7.1884 (r^2=86%)............. (4)

Electrical Conductivity (EC)

Mean EC in the water body was 202.38µs/cm (Table 1). The mean values of EC in dry and wet seasons were 213.34µs/cm and 191.42µs/cm respectively (Tables 2 and 3). T-test statistics at 95% C.I. showed no significant difference in two seasons (Table 4). One-way analysis of variance (F-statistics) showed no significant difference in EC at the three various locations which implies no gradient effect (Table 4). A linear regression of EC along the sample locations showed a weak negative correlation (Eqn. 5).

EC Y =6.06X+210.84 (r^2=62%)......... (5)

Chemical Characteristics of Water Body

Mean values of So_4^{2-}, PO_4^{3-}, NO_3^-, Cl^-, TH, Alk, DO, BOD and COD in Agodi Reservoir are presented in Table 1. Tables 2 and 3 presented the mean values for the dry and wet seasons while Table 4 showed the gradient effect and seasonal variations sulphate (So_4^{2-}).

The mean value of sulphate in the water body of Agodi Reservoir was 0.035mg/L (Table 1).

The mean values of sulphate in the dry season and wet season were 0.03mg/L and 0.04mg/L respectively (Tables 2 and 3). One-way analysis of variance (F-statistic) showed no significant difference in sulphate at all the sampling locations which imply no gradient effect (Table 4).

T-test statistic at 95% C.I. showed no significant difference between the two seasons (Table 4). A linear regression of SO_4^{2-} along sample locations showed weak negative regression (Eqn. 6).

SO_4^{2-}: Y = -0.0005X+0.0379 (r^2=03%)..... (6)

Note: that in all equations 6 to 14

Y = chemical parameter measured in mg/L (dependent variable)

X = distance from source in metres (independent variable)

Phosphate (PO_4^{3-})

The mean values for phosphate were 0.04mg/L (Table 1). The mean value of PO_4^{3-} both in the dry and wet seasons were 0.04mg/L (Tables 2 and 3). One-way analysis of variance (F-statistics) showed that phosphate was not significantly different between locations at P<0.05 which implies no gradient effect (Table 4). T-test statistics at 95% C.I. showed no significant difference between the two seasons. A linear regression of PO_4^{3-} along sample locations showed a strong negative correlation (Eqn. 7).

PO_4^{3-}: Y =-0.001X+0.0387 (r^2=71%)..... (7)

Nitrate (NO_3^-)

The mean value of Nitrate was 0.025mg/L (Table 1). The mean value of NO_3^- in the dry season was 0.03mg/L (Table 2) while the mean value of NO_3^- in the wet season was 0.02mg/L (Table 3). T-test statistics at 95% C.I. showed no significant difference which implies no seasonal variation in the two seasons (Table 4). One-way analysis of variance (F-statistic) results showed no significant difference (P<0.05) in Nitrate at the various locations which implies no gradient effect. A linear regression of NO_3^- along with locations sample showed a strong negative correlation (Eqn. 8).

$NO_3^-: Y = 0.0021X + 0.0265 \quad (r^2 = 100\%)$........ (8)

Chloride (Cl^-)

The mean concentration of chloride in the water samples was 0.03mg/L (Table 1). The mean values of Cl^- in the dry and wet seasons were the same value of 0.03mg/L (Tables 2 and 3). T-test statistics at 95% C.I. showed no significant difference which implies there was no seasonal variation in the two seasons (Table 4). One-way analysis of variance (F-statistics) at P<0.05 showed no significant differences in Cl^- at the various locations which imply no gradient effect (Table 4). A linear regression of Cl^- along sample locations showed a resultant strong positive correlation (Eqn. 9).

$Cl^-: Y = 0.0024X + 0.0258 \quad (r^2 = 80\%)$.......... (9)

Total Hardness (TH)

Mean TH value in the water for the test period was 175.45mg/L (Table 1). TH during the dry season was 190.07mg/L, while the wet season was 160.33mg/L (Table 2 and 3). One-way analysis of variance (F-statistic) at P<0.05 showed that there was no significant difference in TH in all the locations, which implies no gradient effect (Table 4). T-test statistics at 95% C.I. showed significant seasonal variation which could be as a result of higher carbonate and bicarbonate in the dry season. A linear regression of TH along the sample locations showed a weak positive correlation (Eqn. 10).

$TH: Y = 3.7205X + 163.14 \quad (r^2 = 37\%)$........ (10)

Alkalinity (Alk)

Mean alkalinity value averaged 193.46mg/L (Table 1). At P<0.05, one-way analysis of variance (F-statistic) showed no significant differences in Alk at the various location which implies no gradient effect (Table 4). Mean value of Alkalinity in the dry season was 183.44mg/L (Table 2) while the mean value during the wet season was 203.48mg/L (Table 3). A linear regression of Alk along sample locations showed a strong negative correlation (Eqn. 11). T-test statistics at 95% C.I. showed no significant seasonal variation.

$Alk: Y = -8.677X + 214.15 \quad (r^2 = 87\%)$......... (11)

Dissolved Oxygen (DO)

The mean value of DO was 8.14mg/L (Table 1). The mean values of DO in the dry and wet seasons were 7.84mg/L respectively (Tables 2 & 3). T-test statistics at 95% C.I. showed no significant difference in DO between the two seasons. One-way analysis of variance (F-statistic) results at P<0,05 showed no significant difference between the locations implying no gradient effect (Table 4). A linear regression of DO along the sample locations showed a positive correlation (Eqn. 12).

$DO: Y = 0.2389X + 7.7596 \quad (r^2 = 63\%)$.......... (12)

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand of the water body averaged 0.53mg/L (Table 1). Mean values of BOD in the dry and wet seasons were 0.54mg/L and 0.52mg/L respectively (Tables 2 % 3). One-way analysis of variance (F-statistics) at P<0.05 showed a significant difference in BOD (Table 4). T-test statistics at 95% C.I, showed no significant difference between the two seasons. A linear regression of BOD along sample locations showed a strong positive correlation (Eqn. 12).

$BOD: Y = 0.06X + 0.467 \quad (r^2 = 84\%)$............ (12)

Chemical Oxygen Demand (COD)

The chemical oxygen demand of water samples from Agodi Reservoir was 83.30mg/L (Table 1). At P<0.05, one-way analysis of variance (F-statistics) showed no significant difference in the values obtained from all the locations which imply no gradient effect. The mean value of SOD during the dry season was 86.00mg/L (Table 2) and the value for wet season 80.88mg/L (Table 3). A linear regression of COD along the sample locations showed a positive correlation (Eqn. 13).

$COD: Y = \quad 045X + 76.30 \quad (r^2 = 45\%)$.... (13)

Discussion

There is no legal standard for Total Suspended Solids in water. The sources of TSS in the water may arise from erosion from urban runoff, agricultural land, and wastewater discharges. The mean value of TSS in the wet season was higher than the dry season due to rainfall effect which transports wastes which include organic and inorganic wastes that are suspended in water. The high concentration of TSS has the capacity to alter the water's visual, lower the physical characteristic of the water by absorbing light. The effect can make the waters warmer and reduce the ability of the water to hold oxygen that is required for aquatic life. Rate of photosynthesis in the aquatic plants will decrease as a result of reduced light penetration caused by the high TSS of water. Suspended solids can clog fish gills, reduce growth rate reduce resistance to disease and stop egg and larval development (Lawson, 2011).

Total dissolved solids (TDS) in drinking water by WHO is 500mg/L WHO (2013). This limit had been below by the waters of Agodi Reservoir. Drinking water becomes significantly and increasingly unpalatable at the TDS levels greater than about 1000mg/L. Water with high TDS tastes salty. High salt level expressed by TDS concentrations can also decrease the aesthetic values of water. According to (Holms*et. al.*, 2002) indicated that drinking water with high TDS value may not produce adverse health effects in the short term but there is the possibility of salt overload in sensitive individuals in the long term.

The temperature of water is one of the most important factors in an aquatic environment. The mean Temperature of Agodi Reservoir was above 25°C standard limit for temperature in drinking water by WHO (2011). The high temperature in the water body of Agodi Reservoir could be as a result of the effect of municipal waste discharged in the water. The result was in consonance with the report of Chindah *et al.*, (1998). Also, the recorded temperature in this study was in agreement with the observations of Alabaster and Lloyd (1980) who indicated that the temperature of natural inland waters in the tropics generally ranged between 20°C and 35°C. Furthermore, the results compare favourably with Lagos Lagoon waters observed by Emmanuel and Onyema (2007).

pH regulates most of the biological processes and biochemical reactions. The pH of Agodi Reservoir is alkaline and is within the standard limit for pH in drinking water by WHO which is 6.5 – 8.5 (WHO, 2011). The pH of water greater than 7 and lower than 8.5 is adequate for biological productivity, while pH lower than 4 to aquatic organisms (Abowei, 2010). The pH of natural waters is highly affected by the concentrations of carbon (IV) oxide which is acidic (Boyd, 1979). Phytoplankton and aquatic plants make use of carbon (IV) oxide during the day for the process of photosynthesis which causes the pH of water bodies to increase during the day and reduces at night (Boyd and Lichtkoppler, 1979). It was reported that the pH values between 6.5 and 9 are considered adequate for fish production, while the acid and alkaline values of 4.0 and 11.0 can cause the death of organisms in aquatic ecosystems.

Electrical conductivity largely depends on ionic concentration or dissolved inorganic substances. The values of EC obtained were below the WHO standard, 1,000µs/cm.

According to Boyd (1979) the Electrical Conductivity of freshwater fluctuates between 50 to 1,500hrs/cm and 10,000hrs/cm in some polluted waters. The result, therefore shows that the study area is freshwater. The low EC in the study area could be that mainly organic matters were introduced by anthropogenic activities and inorganic substances. Evaporation and misplacement of freshwater can increase the EC of the water body.

The mean concentration of sulphate was below 200mg/L recommended for drinking water and aquatic life by WHO (2011). This result is similar to that reported for Epie Creek by Uzonfuo and Bariweni (2001). The sulphate in Agodi Reservoir can be attributed to biological removal by phytoplankton especially by diatoms and silicoflagellates (Dulta, 2008).

Basic nutrients like phosphate and nitrate determine the productivity of lake water. The value of PO_4^{3-} was below 250mg/L of PO_4^{3-} recommended for drinking water by WHO (2011). Saxena (1998) reported that lakes with phosphate concentration

>10.0, 10.0-20.0 and >20mg/L are categorized to be oligotrophic, mesotrophic and eutrophic respectively. Hence, Agodi Reservoir may be classified under oligotrophic.

Surface water can be polluted by sewage and other wastes rich in nitrates discharge into the water body. Nitrate concentration in the water samples was below 10mg/L of WHO maximum concentration recommended for drinking water by WHO (2011). The low concentration of NO_3^- recorded in this study could be due to losses of nitrogen by denitrification. This is the process whereby bacteria convert nitrate to nitrogen gas, N_2 or N_2O. This occurs when poor aeration limits free oxygen forcing the bacteria to use the oxygen in the nitrate for their respiratory process instead of oxygen chloride which occuring naturally in the form of salts of sodium, potassium, and calcium. The mean concentration of chloride was below 250mg/L recommended for drinking water by WHO (2011). Lewis and Morris (1986) they reported that levels of chloride higher than 20mg/L are advantageous in intensive freshwater fish culture.

The mean total hardness of the water in Agodi Reservoir was above 100mg/L standard limit for total hardness in drinking water by WHO (2011). Kannan (1991) reported arbitrary classification of water hardness as follows: 0-60mg/L; soft, 61-120mg/L; moderately hard, 121-160mg/L, hard and >160mg/L very hard. On the basis of Kannan's classification, Agodi Reservoir may be classified very hard. Piper *et al.*, (1982) reported that requisite hardness is advantageous because environmental calcium inadequacy in water may cause poor survival reduced growth or poor resistance in fry. Mathur *et al.,* (2008) opined that the sources of hardness in water bodies in done to the addition of calcium and magnesium through surface run-off from agricultural land and other catchment areas. The alkalinity of water is a measure of levels of bicarbonates, carbonates, and hydroxides. The concentration of alkalinity in the water sampled from Agodi Reservoir was below 400mg/L recommended by WHO for drinking water (2011). Weathering of rocks is typically the dominant source of alkalinity for inland waters. Boyd (1978), water with high alkalinity tends to be more buffered than that of low alkalinity.

Dissolved oxygen is the amount of gaseous oxygen dissolved in water. Oxygen is absorbed directly from the atmosphere, by rapid water movement or as a waste product of plant photosynthesis. Dissolved oxygen is important for the survival of fish and other aquatic organisms.

Dissolved Oxygen of 5.0mg/L and above is reported desirable for fish survival Boyd and Lichtkoppler (1979). Nwadiaro and Oranusi (1982) reported the dissolved oxygen value of 7.29mg/L in their analyses of drinking water quality of some rivers in the Niger Delta. Moses (1979) reported dissolved oxygen values ranging from 2.8 to 4.5 with the lowest values at Eban Station. Low DO have been reported of polluted water with untreated sewage, sawdust, petrochemicals, detergent, and industrial effluents. According to Ali *et al.*, (2000) dissolved oxygen level of about 9.0mg/L is considered good for fishing, while high DO (>20mg/L) is harmful to fish and can cause physiological dysfunctions and developmental abnormalities in fertilized eggs and larvae. Therefore, the dissolved oxygen level 8.14mg/L is considered to be adequate to sustain aquatic organisms.

The Biochemical Oxygen demand of Agodi Reservoir was below the standard limit of 6mg/L by WHO (2011). When BOD concentrations are high, dissolved oxygen levels decreases due to the oxygen that is available in the water being used by bacteria. Low concentration of DO in water will make fish and other aquatic organisms not to survive. This, in essence, means that the low BOD recorded in this study supports the survival of fish and other aquatic organisms. The low concentrations of NO_3^- and PO_4^{3-} in the body of water might have contributed to the low BOD. At high BOD levels, organisms such as macro-invertebrates that are more tolerant of low DO may appear and become increased. Ogidiaka *et al.,* (2012) in their study of Physico-chemical Parameters and Benthic Macro-invertebrates of Ogunpa River and COD values and abundance of pollution tolerant macro-invertebrate.

The COD concentration in Agodi Reservoir was above the standard limit of 0mg/L by the WHO (2011). The high COD of the water indicates the pollution status of the water body. The sources of COD may be as a result of domestic drains and the use of soap and detergents used in laundry and car wash, discharged into the reservoir.

Conclusion

The study showed that Agodi Reservoir's water exhibited high Temperature, TH, DO and COD when compared with their WHO permissible concentrations. Higher pH value indicates a slightly alkaline nature of the water body. It was observed that TDS, EC, SO_4^{2-}, PO_4^{3-}, NO_3^-, Cl^-, Alk and BOD were below the WHO recommended allowable limit for drinking water. There was no gradient effect established for all the physico-chemical parameters studied except for the BOD. Seasonal variations showed no significant difference in all the physico-chemical parameters except for TH which showed a significant difference for the wet and dry seasons.

On the whole, the study revealed that water body can be classified as good for survival, metabolism, and physiology of aquatic organisms. Based on the aforesaid, regular monitoring of the physico-chemical parameters of the water body should be put in place. It is further recommended that in-lets of water discharged be suitably treated before being discharged into Agodi Reservoir.

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