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Studies of Water and Sediment Quality of Owalla Dam, Osun State, Nigeria

[1*]Abdus-Salam, N., [2]Bale, R.B., [1]Taorid, R. and [2]Adeniyi, O.O.

[1]Department of Chemistry, University of Ilorin, Nigeria
[2]Department of Geology and Mineral Sciences, University of Ilorin, Nigeria

Abstract
Dam water and sediment were collected from ten different locations on Owalla dam to evaluate the quality of the water. The average values of most physical-chemical parameters, the pH, temperature, total dissolved solid (TDS), NO_3^-, total hardness (TH) were within World Health Organization (WHO) and United State Environmental Protection Agency (USEPA) guidelines for drinking water. There was correlation between the results of Biochemical Oxygen Demand (BOD), sulphate and phosphate which were higher than the USEPA, Standard Organization of Nigeria (SON) or Canadian standard for drinking water. This is an indication of high load of organic pollutants. The dam sediments are texturally immatured coarse sands dominantly comprised of sub-angular to sub-rounded quartz, alkali feldspars with clay and iron-oxide coatings. The sediments geochemical composition is essentially silica, alumina and iron oxide. Toxic trace elements including Cd and Pb occur in very minor to insignificant concentrations with Igeo (index of geo-accumulation) values classifying the sediments as unpolluted. The sediments are also characterised by variably-high CIA (chemical index of alteration) values (av. 60) which is an indication that their derivation was from moderate to high tropical weathered source areas.

Keywords: *Owalla dam, physicochemical parameters, geo-accumulation index, chemical index of alteration, biochemical oxygen demand*

Introduction

The proportion of water in all living beings and the relevance of water to physiological processes of life affirm that water is life. Water is an indispensable natural resource, a basic need of living beings and a precious national asset to human development. Although, over 70 percent of the planet is water and people have long acted as if these very bodies of water could serve as a limitless dumping ground for domestic and industrial wastes (Adekola and Eletta, 2007, Kalwale and Savale, 2012). This attitude has made majority of fresh water bodies undesirable for man's needs. Water is vital to our existence in life and its importance in our daily life makes it imperative that thorough microbiological and physico-chemical examinations be conducted on

*Corresponding author:
E-mail address nasalami2002@yahoo.co.uk

water (Lamikaran, 1999). The interactions of pollutants, particularly the chemicals, with the natural properties of water is a major concern and has influenced its uses (Mustapha and Omotosho, 2005, Unanam and Apkan, 2006), hence, there is the need for appropriate planning, development and management of water resource. The water need of man for basic physiological purposes had been estimated at about 2 litres per person per day. However, a daily supply of 140 – 160 litres per capita per day (Lpcpd) is considered adequate to meet the needs for all domestic purposes (Gleick, 1996) but WHO recommended value is 120 Lpcpd. In absolute terms, by 1986 each rural dweller in Nigeria had access to 25 Lpcpd while the urban counterpart had access to 60 Lpcpd. Bottom sediments are known to act as sinks for pollutants such as petroleum hydrocarbons, heavy metals, pesticides, allied agro-chemicals (Forstner et al., 1998, Fleeger et al., 2003, Adekola and Eletta, 2007). Furthermore, adsorption of organic and inorganic contaminants from diverse sources onto sediments (Adekola et al, 2011) and remobilization of contaminants in aquatic system make the study of sediment an important water quality parameter. These pollutants are released under favourable conditions into bodies of water, thereby rendering it undesirable for its legitimate uses. Hence, analysis of sediment becomes valuable tool to assess and monitor water quality and track contaminants transport in water regime. Heavy metal load in water environment is best understood through the analysis of water, sediment and suspended particulate matter (Hejabi and Basavarajappa, 2013). Evaluation of heavy metals and some ionic radicals in water body may reveal the extent of anthropogenic input and serve as a guide to the uses of the water in its present condition. There are numbers of such evaluations on lakes and dams in Nigeria. Some of the water and sediments evaluations include that of Zaria dam (Oniye et al, 2002), Awba lake, Ibadan (Ugwumba and Ugwumba, 1993), Moro lake, Kwara State (Mustapha and Omotosho, 2005), Shiroro lake, Niger State (Koloanda and Oladimeji (2004), Kainji lake, Niger State (Adekola et al, 2010), Egbe Reservoir, Ekiti State (Edward and Ugwumba, 2010), Oyun Reservoir, Kwara State (Mustapha, 2008). Bioavailability of heavy metal depends on the sediment characteristics, nature of the metal species, and duration of contact between the metal and the adsorbing surface, the physico- chemical properties of the water matrix (Adekola et al, 2010, Iwegbue et al, 2007). A good knowledge of the chemical qualities of raw water is necessary so as to guide its suitability for use (Okonkwo et al., 2008). This research was undertaken to evaluate heavy metals and some anions in Owalla dam water body in order to determine the extent of anthropogenic inputs which gave the understanding to the present quality.

Description of Study Site

The Erinle river dam renamed as Owala dam is located on the Erinle-River approximately 12km upstream of the Okinni town and forms part of the Osogbo-Ede water supply extension scheme. The study area lies between Lat 7°44′30.44″ and 7°57′00.79″ N, Long 4°26′21.71″

Figure 1: Area view of the sampling points

and 4°41′23.48″ East of the Greenwich Meridian with elevations ranging from 250m to over 400 m above sea level (Fig. 1). The region is classified as tropical with mean annual rainfall of about 1400 mm and the raining season covers eight months (April to November). The Owala dam is also a northern extension of the old Ede dam on the Erinle-River and, Eko-Onde dam on Otin River to the north. The expanded reservoir was designed to improve on the existing water supply system of cities such as Osogbo, Ede, Ife, Gbongan, Erin-Osun, Ilobu and Ifon as well as other towns and rural communities in Osun central, Osun West and Ife area in Osun state. The reservoirs created behind the dam extend some 12 km northward along the Erinle river and its Otin river tributary with maximum width of 3.5 km. The reservoir covers about 14 km^2 at the normal water level, and about 15 km^2 at maximum water level.

Water and sediment sampling

Water samples were collected both from the surface and underlying at a depth of about 5m with the aid of a Van Dorn water sampler from ten sampling locations (Fig.1). The two were mixed together in order to produce a representative sample and stored in a 2-liter size plastic bottles which had been previously washed with hot water and detergent, and rinsed with 1 M HNO_3. The collected water samples were then acidified with the 1 ml of 1M HNO_3. The dam sediment was collected from ten different locations (Table 1) with the aid of a stainless bottom grab. The content of the grab was emptied into a black polythene bag at each location (Adekola et al., 2010). Samples were immediately transported to the laboratory where loose particles and plants debris were removed manually from the sediment prior to chemical treatment. The sediment samples were air-dried in the laboratory before crushing with agate mortar to small particle sizes.

Analysis

The pH, TDS and conductivity of the water sample were taken at the sampling points with the aid of Hana portable pH/EC/TDS/temperature proof tester model HI 98129. The temperature was measured with the aid of mercury bulb field thermometer. The DO, BOD and COD were determined by standard methods (Ademoroti, 1996, APHA, 1992). Nitrate determination was based on the reaction of nitrate ion and brucine sulphate in a 13 N H_2SO_4 solution at 100 ^OC (Annual Book of ASTM Standards, 1976). A number of reactor test tubes were set up for nitrate standard solutions, the water samples and the blank containing 10 ml of each solution. A 10 ml of 13N H_2SO_4 solution.

Table 1: GPS coordinates reading of the sampling points.

Sites	Coordinates (Lat, Long.)	Elevation above sea level (m)
1	N 7°53′47.34″, E 4°32′15.32″	342
2	N 7°53′53.20″, E 4°31′53.69″	338
3	N 7°54′01.46″, E 4°32′02.43″	341
4	N 7°54′01.91″, E 4°32′42.36″	339
5	N 7°54′11.80″, E 4°32′20.55″	344
6	N 7°54′15.89″, E 4°33′02.29″	341
7	N 7°54′47.13″, E 4°32′40.40″	342
8	N 7°54′36.46″, E 4°33′12.06″	340
9	N 7°55′25.93″, E 4°32′52.95″	337
10	N7°54′56.58″, E 4°33′34.74″	340

Table 2: Summary of the Particle Size Distribution of Owalla Dam Sediments

Sample	Mean	Sorting	Skewness	Kurtosis
Owalla 1S	1.13 (Me. sand)	1.18 (P. sorted)	0.12 (F. skewed)	0.65 (Platykurtic)
Owalla 2S	-0.6 (V. C. sand)	1.32 (P. sorted)	0.36 (F. skewed)	1.62 (V. platykurtic)
Owalla 3S	-1.7 (V. C. sand)	1.11 (P. sorted)	0.25 (F. skewed)	0.56 (Platykurtic)
Owalla 4S	-1.8 (V. C. sand)	0.08 (Mo. sorted)	-4.03(S. C. skewed)	-0.14 (V. platykurtic)
Owalla 5S	-0.47 (V. C. sand)	1.00 (P. sorted)	-0.64 (S C. skewed)	0.84 (V. platykurtic)
Owalla 6S	0.5 (C. sand)	0.9 (P. sorted)	0.89(N. symmetrical)	0.65 (Platykurtic)
Owalla 7S	-1.4 (V. C. sand)	0.94 (P. sorted)	-0.08(C. skewed)	0.49 (V. platykurtic)
Owalla 8S	-1.06 (V. C. sand)	1.05 (P. sorted)	0.85 (S. F. skewed)	0.87 (Platykurtic)
Owalla 9S	-1.01 (V. C. sand)	0.77(Mo. sorted)	1.56(S. F. skewed)	1.89 (V leptokurtic)
Owalla 10S	0.88 (C. sand)	0.73(Mo. sorted)	0.3 (F. skewed)	1.04 (Mesokurtic)

Me – Medium, V – Very, C – Coarse, P – Poorly, Mo – Moderately, F – Fined, S – Strongly, N - Near

0.5 ml of brucine-sulphonilic acid reagent was added while, with gentle swirling, the pH was adjusted to 7 using acetic acid or sodium hydroxide. The reactor tubes were immersed in a thermostated water bath maintained at 100 ^{O}C for 25 min. The reactors were removed and immersed in cold water until it attained thermal equilibrium (~25 ^{O}C). The absorbance of the nitrate standard solutions and the samples were spectrometrically determined against the blank at 410 nm. The amount of nitrate was obtained from equation 1:

$$Nitrate - N\ (mg/l) = \frac{\mu g NO_3 - N}{ml\ of\ sample} \qquad (1)$$

Nitrate (NO_3^-) in mg/l = mg/l nitrate - N × 4.43

Sediment Analysis

The dam sediments were petrologically characterised by wet sieving and use of binocular petrological microscope. Sieving provided information on the sediments particle size distribution which were statistically analysed and interpreted (Table 2) according to Friedman (1961) and Pettijohn (2004).The sieved dam sediments clay fractions were analysed for geochemical composition of major and trace elements by inductively coupled plasma mass spectrometer (ICP-MS) (Tables 3,and 4). The compositions have been used to deduce the Index of Geoaccumulation for measuring the pollution status (Table 7) of Owalla Dam (Mueller, 1969).

Results and Discussion

The petrographic studies (Table 3) revealed that the sediments have greater percentages of quartz and minute clasts of feldspar, muscovite and rock fragments. The quartz are heavily fractured due to erosion but with little or no clay or iron oxide coatings. The quartz grains morphology ranges from angular to round with the angular particles predominating and a pointer to closeness of sources of derivation. The ICP-MS obtained provided information on the geochemical composition of the sediments (Tables 3 and 4) and showed that the CIA (ChemicalIndex of Alteration) varies from

Table 3: Major Elements Composition of Owalla Dam Sediments

Trace and Rare Elements	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI
Owalla 1Cl	64.37	12.38	5.47	0.25	0.27	0.14	4.89	1.1	0.15	11.7
Owalla 2Cl	66.52	13.27	2.75	0.18	0.54	0.79	6.03	1.03	0.1	9.9
*Average Crustal Abundance	66.8	5.05	4.09	2.30	4.24	3.56	3.19	0.54	0.15	

*Wedepohl, 1995

62.32 to 90.49 (Table 5). The high variations in CIA values may, however, be due to the low concentrations (sometimes below or near detection limits) of the alkalis and alkaline earth elements rather than variable degrees of source area of weathering. Nevertheless, the high CIA values greater than 60 is an indication of moderate to high weathering conditions in the source area (Nesbitt and Young, 1982). The major element oxide compositions of the Owalla Dam sediments are 65% silica, 13% Al_2O_3 and 4% Fe_2O_3 which reflect constituents' domination by quartz, feldspars and iron oxide phases (Table 3). The silica, SiO_2 increases with alumina (Al_2O_3), titania (TiO_2) and potash (K_2O) but inversely varies with magnesia (MgO), lime (CaO) and soda (Na_2O). The absolute amount of quartz and the chemically unstable grains such as the feldspars determine the extent and range of chemical variations. The higher concentration of K_2O and Na_2O compared to CaO contents reflect derivation from source rocks rich in alkali feldspars and muscovite. High Al_2O_3 could be attributed to the presence of clays and subordinate micas.

The geochemical result based on ICP-MS analysis showed that the CIA (Chemical Index of Alteration) for Owalla 1 is 90.49 and 62.32 for Owalla 7 (Tables 3 and 4). The high variations in CIA values may, however, be due to the low concentrations (sometimes below or near detection limits) of the alkalis and alkaline earth elements rather than variation in the degree of weathering of the study areas. Nevertheless, the high CIA values greater than 60 indicates moderate to high weathering conditions in the source area (Nesbitt and Young, 1982).

Table 4: Trace Elements Composition of Owalla Dam Sediments

Trace and Rare Elements	Cu	Pb	Zn	Ag	Ni	Co	Mn	As	U	Th	Cd	V	La	Cr	Ba
Owalla 1Cl	40.9	34.8	82	<0.1	23	14	147	<1	6.5	14	0.2	63	42	53	305
Owalla 2Cl	40.7	78.2	128	<0.1	8	7	731	<1	5.5	36	0.1	32	47	29	518
Average crustal abundance	17	75	52	55	19	12		1.4	2.5	10	0.1	53	32		668

Table 5: Geo-accumulation Index for the Owalla Dam Sediments

METALS	Pb	Se	Ar	Cr	Cd	Ba
I-geo	0.135-0.45	0.64	- 0.49 - 0.59	0.5 - -0.89	-0.051- (-0.352)	-0.523 -(-0.292)
Class	Unpolluted	Unpolluted	Practically unpolluted	Practically Unpolluted	Practically Unpolluted	Practically Unpolluted

Geo-accumulation index (*Igeo*) was used to assess heavy metal accumulation in sediments as introduced by Muller (1979) to measure the degree of metal pollution in aquatic sediments studies (Praveena *et al.,* 2008).

$$Igeo = Log2\left(\frac{Cn}{1.5Bn}\right) \qquad 2$$

Where, Cn is the measured concentration of a heavy metal in stream sediments, Bn is the geochemical background value in average shale of element n and 1.5 is the background matrix correction due to terrigenous effects.

The geo-accumulation index classification consists of seven classes (0-6), ranging from background concentration to very heavily polluted: < 0 (class 0) background concentration, 0-1 (class 1) unpolluted, 1-2 (class 2) moderately polluted, 2-3 (class 3) moderate to high pollution, 3-4 (Class 4) heavily polluted, 4-5 (Class 5) highly to very highly polluted, 5-6 (Class 6) very heavily polluted (Kumar and Edward, 2009). The geo-accumulation index (Table 5) of the Owalla Dam sediments varies between unpolluted (<0) for Ar, Cr, Cd and Ba; and unpolluted to moderately polluted (0-1) for Pb and Se.

The pH of the water samples ranges from 6.7 to 7.35 with 7.05 as the average value (Table 6) which is within the WHO permissible range for portable water (WHO, 2006). This value is also healthy for aquatic organisms and productivity of fish (Ehiagbonare and Ogunride, 2010). The temperature of the water samples has values between 29-30.5°C and has average value of 29.5°C. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems (WHO, 2006). Although, no guideline is provided for temperature by USEPA and WHO, the SON drinking water standards proposed ambient temperature. The value of total dissolved solids of the water sample is between 27-56 mg/l with an average value of 46.2 mg/l. This is within the permissible limits of drinking water standards (500 mg/l) of WHO and SON. The presence of dissolved solids in drinking water may affect its taste but does not pose any significant health risk (WHO, 1996).

The Nitrate concentration varies between 0.27 and 0.63 mg/l with an average value of 0.46 mg/l (Table 6). This is within the permissible limits of drinking water standards of WHO (50 mg/l), USEPA (10 mg/l) and SON (50 mg/l).

Table 6: Results of Some Physicochemical Parameters of Owalla Water Samples

Sites	pH	Temp. (°C)	TH (mg/l $CaCO_3$)	TDS (mg/l)	EC (µS/cm)	DO	BOD	COD
1	7.05±0.25	30.5±2.5	30±0.0	29±4.0	0.07±0.00	100±20	14±6	10±4
2	7.1±0.2	30±2.0	32±0.0	27±6.0	0.11±0.02	96±2	18±10	7±1
3	7.2±0.0	29±1.0	26±0.0	55±13	0.10±0.02	74±14	24±12	7±5
4	6.7±0.5	29±1.0	22±0.0	48±5.0	0.09±0.01	104±0.0	20±2	7±3
5	7.0±0.2	29±1.0	30±0.0	47±13	0.09±0.01	104±34	22±2	12±4
6	6.85±0.55	29.5±1.5	29±0.0	50±13	0.11±0.02	68±2	28±12	5±1
7	7.2±0.2	29.5±1.5	29±0.0	50±14	0.09±0.02	90±30	15±7	7±1
8	7.3±0.2	29.5±1.5	25±0.0	55.5±9.5	0.13±0.00	70±20	21±9	9±5
9	6.75±0.65	29.5±1.5	33±0.0	44.5±12.5	0.12±0.01	56±14	17±9	11±1
10	7.35±0.15	29.5±1.5	30±0.0	56±13	0.11±0.01	73±9	18±8	8±4
WHO	6.5-8.5	-	500	-	250	-	-	-
USEPA	6.5-8.5	-	-	500	-	-	-	-
SON	6.5-8.5	Ambient	-	500	100	-	-	-

Sulphate concentration is between 90.6 and 334 mg/l with average value of 182.8 mg/l. This falls within the permissible limit of WHO and USEPA. The average sulphate concentration was, however higher than the limit of 100 mg/l by (SON, 2007). USEPA (2002) reported that the presence of high levels sulphate (above 250 mg/l) in drinking water may lead to diarrheal and, as well, cause detectable taste and odour.

Phosphate concentration ranges from 0.05 to 0.10 mg/l and has average value of 0.08 mg/l. According to USEPA (2002), phosphate concentration in reservoirs must not exceed 0.025 mg/l in order to control algae growth. The high level of phosphate in the sampled water may be due to effect of agricultural runoff (Nagendrappa et al., 2007). Chloride concentration ranges from 40-120 mg/l with average value of 74 mg/l. This is within the guideline values of the various standards. According to WHO (2006), chloride concentration in excess of 250 mg/l may give rise to detectable taste in water. The hardness of the water sample ranges from 22-33 mg$CaCO_3$/l and has average value of 25.9 mg $CaCO_3$/l (Table 6). The dam water is soft on the basis of WHO classification (WHO, 2008).

The dissolved oxygen content ranges from 56-104 mgO_2/l and has average value of 83.5 mg O_2/l. There is no health-based guideline proposed for dissolved oxygen content but extremely high concentration may cause increase in concentration of ferrous ion in solution, with subsequent decolouration at the tap when it is aerated (WHO, 2006). A healthy body of water should have DO value that is not less than 5.2 mg O_2/L while high values may pose challenge and stress to fish in the environment (Ehiagbonare and Ogunride, 2010, Asia and Akpornor, 2007). BOD value ranges from 14 to 28 mg O_2/l with an average value of 18.5 mg O_2/l (Table 2). The relatively high value of BOD is an indication of high load of organic pollution possibly from agricultural run-off (Asia and Akporhonor, 2007) or animal manure (APHA, 1992) from poorly managed livestock operations, especially cattle grazing, and decomposition of the wastes by microorganisms (Phiri et al., 2005). The high BOD value is in agreement with the

Table 7: Concentrations of some heavy metals and anions in Owalla Dam water samples

Sites	Chloride (mg/l)	Iron (mg/l)	Zinc (mg/l)	Mn (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)
1	60±0.0	1.25	0.112	0.050	0.49±0.33	214.3±49.7	0.09±0.02
2	40±0.0	1.25	0.120	0.060	0.49±0.29	209±37	0.09±0.01
3	50±0.0	0.97	0.076	0.081	0.52±0.24	127.6±37	0.10±0.01
4	40±0.0	0.88	0.091	0.010	0.40±0.17	334±4	0.10±0.01
5	120±0.0	1.02	0.113	0.030	0.34±0.22	90.6±8.2	0.09±0.0
6	90±0.0	1.31	0.092	0.081	0.49±0.30	177.2±94.8	0.10±0.04
7	100±0.0	0.84	0.102	0.060	0.42±0.26	172.8±8.2	0.06±0.01
8	50±0.0	1.09	0.070	0.050	0.27±0.11	123.5±41.1	0.08±0.02
9	120±0.0	1.26	0.144	0.060	0.57±0.38	168.3±77.7	0.05±0.0
10	70±0.0	0.79	0.006	0.060	0.63±0.53	210.3±19.7	0.06±0.02
WHO	250	3	5	0.4	50	500	-
USEPA	250	0.3	5	0.2	10 as N	250	0.025
SON	250	0.3	3	0.05	50	100	-

results of sulphate and nitrate determinations. The COD varies from 5 to 12 mg O_2/l and has average value of 9.0 mg/l According to Indian Standard Specification ISI, (1983) the permissible limit of COD for drinking water is 255 mg/l.

Iron concentration ranges from 0.79 to 1.31 mg/l with average value of 1.066 mg/l for the dam water samples (Table 7). These values are within the permissible limit of drinking water standards. The WHO (1996) declared that iron in water above 3 mg/l may pose aesthetic problem and also promote undesirable bacterial growth (iron bacteria) within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping. Zinc concentration varies between 0.006 and 0.144mg/l and has average value of 0.093mg/l which is below the threshold limit. Zinc imparts an undesirable taste to water at a threshold concentration of about 4 mg/l (WHO, 2006). Manganese is usually present in water alongside iron and is used principally as an oxidant in the manufacture of iron and steel alloys (WHO, 2006). The manganese level in the analyzed water samples ranges from 0.010 to 0.081 mg/l with an average value of 0.054 mg/l (Table 7). This is the threshold limits for drinking water standards of WHO (0.4 mg/l) and SON (0.2 mg/l). Concentration of manganese was slightly above the limit of proposed USEPA, (2002). According to WHO (2006), the presence of manganese in drinking water may be objectionable to consumers if it is deposited in water mains and causes water discolouration. Cadmium and lead were below detection limit of the instrument used.

Conclusion

It is evident from the results of the water and Igeo-index of sediment analyses that the dam is not adversely impacted upon by human activities. Although many of the parameters analyzed fall within permissible limits of drinking water standards, the pollution potential of the dam was high evidenced from the high value of BOD which showed correlation with sulphate and Phosphate levels which exceed maximum permissible limits. The reported level of phosphates may not be toxic to people drinking the water but there is the need for phosphate removal in order to prevent algae growth and choking of the waterway. The predominant activity of the people in this area is farming and application of nitrogenous fertilizers may not be ruled out as a contributing factor to the slight elevation of nitrate. The major element oxide compositions of the Owalla Dam sediments are 65% silica, 13% Al_2O_3 and 4% Fe_2O_3 which reflect constituents' domination by quartz, feldspars and iron oxide phases. The Owalla dam is practically unpolluted based on the geochemical index analysis

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