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Hydrological characterization of twelve water catchments in Nigeria

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Abstract: - Twelve water catchments (WCs) in Ogbomosho, south west of Nigeria were evaluated for their hydrological characterization with respect to domestic and irrigation activities. Both physiochemical and biological parameters (limnological properties) were determined which include pH, total alkalinity (TA), CO_3^{2-}, HCO_3^-, NO_3^-N, SO_4^{2-}, N, P, K, Na, Ca, Mg, dissolved oxygen (DO), electrical conductivity (ECw), biochemical oxygen demand (BOD), total solids (TS), total dissolved solids (TDS), chlorophyll a,b,c and phaeophytin. Temperature fluctuation of the water catchments was measured in-situ to avoid samples coming into contact with the surrounding air using mercury in glass thermometer. Soil samples collected from the bottom of the water catchments were determined for chemical properties such as N, P, K, Na, Ca, Mg, and SO_4^{-2} following recommended procedures. These parameters were investigated based on the perceived research consent of their efficacy in characterizing water catchments hydrologically along safety and pollution divides. The limnological properties were configured into ranking compared with standards to evaluate the degree of contamination or suitability of the WCs for domestic and irrigation purposes. Results obtained indicated pH values of the catchments ranging from 5.8 to 7.4 with corresponding TA between 0 and 296 mgL^{-1} suggesting high level of dissolved carbon dioxide (DCO_2) and traces of untreated wastewater in most of the catchments. Based on ranking of the limnological properties of the WCs, WC4, WC5, WC6 recorded indices between 65 and 95 signifying that cumulatively these three WCs were more prone to pollution and could affect human health at consumption while WC2, WC3, WC 7 and , WC 10, aligned between 95 and 120 indicating mild to medium pollution and WC1, WC 11, and WC 12 oscillated between 120 to 145 picturing WCs approaching standards (132) while WC8 ranged between 145 and 170 revealing WC 8 as catchment with little or no tendency for hazards at drinking. Similarly, WC2, WC8, recorded soil reference (SR) between 50 and 60 suggesting possible interference of organic decomposition between the soil stratum and water in the catchment, however, WC1, WC4, WC5, WC6, WC7 and WC 12 recorded SR between 40 and 50 showing possible adjustment of the soils in the WCs of various salinity levels and WC 3, WC9, WC 11 revolving between 30 and 40 projecting the WCs with minimal pollution. Moreover, WC 10 only recorded value between 20 and 30, an inference of the soil stratum void of absolute contamination. Generally, WC2, WC8, appeared polluted both in limnological properties and basic soil conditions while WC9, WC10, WC11, and WC3 reflected high scale of ranking on limnological properties with low scale of SR possibly indicating little or no interaction between the soil base and the water in the catchments. Contrary wise, WC6 was high in SR but low in limnological properties. This trend suggests the presence of oxygen saturation in some of the WCs. Overall results indicated that WC4, WC5, WC6 require major water treatment prior to its usage for irrigation to avoid salt deposition at the crop root base, while WC2, WC3, WC7, WC9 and WC10 were considered relatively safe for drinking. WC1, WC11, WC2 requires some measure of precaution before drinking, however, WC12, and WC 8 could be consumed with little or no fear of infection.

Keywords: *- Hydrology, limnology, water quality, Nigeria, domestic, irrigation*

I. INTRODUCTION

Nigeria exhibits such demographic features that call for a holistic approach to forestall future crises while catering for the basic water needs of the populace. The agricultural labour force of the country stands at 70

% with population growth of 3.5 %, death rate of 105/1000 births, net migration of 27/1000, HIV/Aids infection at 5.4 % coupled with inflation monster of 12.5%. In addition to the features evident in Nigeria, the country is also susceptible to high risk of mortality arising from poor resource management viz-a-viz air, surface and water pollution. Consequently, extensive research studies are therefore indispensable to ensure that various water catchments especially shallow wells used for domestic and agricultural purposes are less vulnerable to environmental hazards. This will prevent large scale loss of human life, economic crisis, social and ecosystem collapse.

Water is one of the most indispensable resources given to humanity as a gift. Humanity either survives or collapses by the quality of water available, assessable and consumable. Water quality therefore becomes an important focal point that requires holistic evaluation in view of its importance to human existence. Howard et al., (1985) reported that generally water in nature is pure especially in its evaporation state. However, during condensation and the liquid water flowing through the hydrologic circle contacts are made made with materials beneath the surface of the earth thereby accumulating impurities and contaminants. These contaminants are aggravated by human activities due to the use of agricultural chemicals, pesticides and burning of fuels. Usually, drinking water is expected to be free of suspended solids, turbidity with moderate quantity of dissolved inorganic solids, but completely free of organics, toxic substances and pathogens (Howard et al., 1985), while water for irrigation is much below that of drinking water.

Qualitatively therefore, information on water quality, pollution or contamination can only be validated through physiochemical and biological properties (limnological). Contaminants involving turbidity and hydrogen sulfide easily detect by smell (Self, 2010) while limnological tests are conducted to determine bacteriological concentration as it affects human nutrition and physiochemical properties that identify impurities and other dissolved substances affecting water for domestic purposes. As a rule of the thumb, water with pH values lower than 5 results in pipe corrosion because most metals become more soluble in low pH, while pH greater than 8.5 suggests a significant amount of bicarbonates of Na, CA or Mg has thereby caused hardness (Romano, 2007). Edhira and Vasil (2008) further expatiated that high $C0_3^{2-}$ cause Ca and Mg ions to form insoluble minerals, leaving sodium as the dominant ion in solution thus raising the pH level to about 8.5. This scenario results in soil particle dispersion, crusting with attendant water infiltration and permeability problems and eventual crop failure. Moreover, the most damaging effects of poor quality irrigation water as reported by Edhira and Vasil (2008) are an excessive accumulation of soluble salt, thereby leading to the flotation of clay and humus particles and eventual plugging up of large silos. Invariably, plugging action reduces water movement into and through the soil, thus crop roots cannot assess water from the soil even though pool of water may be observed on the soil surface. Although, salts may harm plant growth physically (Wilcox, 1955), however, specific limits of permissible salt concentrations for irrigation water may be difficult to be stated because of the wide variation in salinity tolerance among different plants, therefore field-plots studies of crops on soils prone to salinity levels would provide valuable information relating to specific crop dynamics to salt tolerance (Todd, 1980; Richard, 1954).

Water quality for domestic and human consumption goes side by side with irrigation water standards. For example, environmental hypoxia (insufficient oxygen) occurring in water catchments such as ponds, wells and rivers suppress the presence of aerobic organisms and by extension, such water when applied to crops could end up contaminating the soil from which nutrients are transported through the roots of the plants. In addition, nitrates in drinking water are capable of infecting young children with "blue baby syndrome" although can be an N - source for soil fertility (Bander, et al., 2007). Moreover, poor quality water either for domestic or irrigation has an effect on human and crop health, while environmental sustainability is in jeopardy. Therefore the knowledge of water quality for domestic and agricultural activities is indispensable and critical to water management issues. In view of the uniqueness of quality water to human health, issues relating to water management are indispensable. For example, water containing impurities such as CH_4 to just between 1 to 2 mgL^{-1} could result in an explosion in wells and storage tanks (Heath, 1964). Likewise, temperature fluctuations need to be stabilized to avoid exposure of soluble materials arising from organic decomposition (Black and Handshaw, 1966) thereby rendering the water catchments unsafe for consumption. Moreover, increasing demand in the existing water supply necessitates sustainable studies on alternative water sources like wells. This study aims at hydrological characterization of twelve water catchments along domestic and irrigation water divides.

II. MATERIALS AND METHODS

Twelve water catchments (WCs) (wells) distributed uniformly across Ogbomosho metropolis of the south west, Nigeria was investigated and characterized based on their suitability for domestic and irrigation activities in 2009/2010 rainfall season. Six of the WCs were located at the town centre, prone to effluents as stadium east (WC1), General East (WC2), High Court (WC3), Stadium West (WC4), Kuye (WC5), General West (WC6), while six others were positioned within Ladoke Akintola University of Technology, (LAUTECH) at Chemical Engineering Departmental Laboratory (WC7), Faculty of Agricultural Engineering Research Field (WC10), Nursery/Primary of LAUTECH (WC1), and Department of Pure and Applied Mathematics (WC12).

Twenty physiochemical and limnological properties which include acidity/alkalinity (pH), total (TA), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) nitrates (NO_3-N), sulphates (SO_4^{2-}), phosphorus (P), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), dissolved oxygen (DO), electrical conductivity (ECw), biochemical oxygen demand (BOD), total solid (TS), total dissolved solids (TDS), chlorophyll (a,b,c), and pheophytin were determined according to standard laboratory procedures. Conductivity was measured within the period recommended by WHO (1996) to prevent chemical adulteration of samples with storage time, while DO, BOD and other sensitive properties were measured within 24hrs of sampling (Miroclav, 1999). The temperature of the WCs was measured in situ at 10:00am and 2:00pm respectively to avoid the water samples coming into equilibrium with the surrounding air using a glass thermometer mercury-filled with 0.1^0C graduations (WHO, 1996).Soil samples obtained from the bottom of the WCs were analyzed for chemical properties. These include nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg) and sulphates (SO_4^{2-}) following standard methods. Three types of chlorophyll (a, b, c) found in phytoplankton were measured using spectrophotometer methods (WHO, 1996) to assess the ecological status of the water catchments.

In view of the difficulties encountered in interpreting analysis of the chemical quality of groundwater and soil conditions due to numerous elements involved, the result of the analysis of the twelve WCs and the corresponding soil environments was subjected to ranking (Tables 3&4). The lowest number was assigned to the results of the analysis with the highest tendency for contamination while the highest number of results with the lowest possibility of contamination to ensure uniform comparability and resolve the complexities involved in the response of individual elements in the laboratory work in conformity with WHO standards.

III. RESULTS

The average temperature of WCs ranged from 26.2^0C (10:00am) to 27^0C (2:00pm), 26.3^0C (10:00am) to 27.1 ^{0}C (2:00pm), 26.5^0C (10:00am) to 26.9^0C (2:00pm), 25.3^0C (10:00am) to 26.5^0C (2:00pm), 25.5^0C (10:00am) to 26.7^0C (2:00pm), 25.6^0C (10:00am) to 26.8^0C (2:00pm), 26.4^0C (10:00am) to 26.5^0C (2:00pm), 26.5^0C (10:00am) to 27.7^0C (2:00pm), 26.5^0C (10:00am) to 29.5^0C (2:00pm), 26.4^0C (10:00am) to 27.2^0C (2:00pm), 26.5^0C (10:00am) to 26.8^0C (2:00pm), 26.6^0C (10:00am) to 27.8^0C (2:00pm), for WC1 to W12 respectively. Physiochemical and limnological properties of the twelve WCs are presented in Table I. Average pH values ranged from 5.8 (WC2) to 7.4 (WC7). Three WCs (WC2, WC8 and WC1) recorded pH values below the normal range for irrigation and domestic activities estimated at between 6.5 to 8.5 (Edlira and Vasil, 2008). Total alkalinity, primarily considered as a function of hydroxide, carbonate and bicarbonate concentrations was highest for WC4. Seven of the WCs showed concentrations of alkalinity above 150 MgL^{-1}. However, six were within the recommended limit for drinking water of 400mgL^{-1} (Gordon and Hamlin, 2009) (Table 3). The most influential water quality guideline on crop productivity was attributed to salinity hazard as measured by electrical conductivity (Bandar et al., 2007), WC2 and WC4 recorded values above 500mgL^{-1} compared to others. The results of DO and BOD of the WCs are presented in Table 1. Besides, WC4, WC5, WC7, recording DO above the threshold limit, WC1, WC6, WC8, WC9, WC10, WC11, WC12 fall within the recommended value for drinking water at 5mgL^{-1}, while WC2, WC3 slightly exceeded the standard limit. Chlorophyll a, b, c of the WCs followed a similar trend with DO and BOD. The highest values of chlorophyll a, b, c were obtained from WC11 (12, 23, 24.5) and the least from WC4 (4, 9, 10).

IV. DISCUSSIONS

The trend observed in the temperature dynamics reveals the extent to which temperature characterizes the biological species present and their corresponding rates of activity (Howard, 1985). WC4 exhibits the average lowest temperature at 10:00am followed by WC5, and WC12, the highest. This scenario suggests possible aggravated growth of algae in WC12 thereby generating tasting, odor problems, and decreasing viscosity, (Howard et al., 1985) undesirable in drinking water. Similarly, at 2:00pm. WC9 recorded the highest temperature at 29.5^0C closely followed by WC8 and WC3, WC4, the least showing preference of WC3 and WC4 to others as evident in accelerated dissolution of solids typical of increased temperature beyond the normal (Howard et al., 1985) inimical to human health. Physiochemical and limnological properties obtained suggested WC2, WC8 and WC1 unsuitable for domestic activities, although, in the light of shortage of irrigation water, WC2, WC8 and WC1 could be mildly treated with gypsum for re-use of agricultural purposes. However, for drinking water, pH values above 8.3 are not desirable because of the presence of carbonates and hydroxide concentration in addition to bicarbonates (WHO, 1996). The phenomenon observed in total alkalinity possibly indicated that the application of water from these water catchments for crop production may cripple the plant ability to compete with ions in the soil solution for water with possibility of physiological drought (Bandar, et al., 2007). In a similar trend, WC1, WC2, WC3, WC4 and WC6, recorded sodium concentration above 30mgL^{-1} while others ranged from 10.53 mgL^{-1} to 29.2 mgL^{-1}. This observation is possibly due to the greater proportion of sodium ion (Na^{+}) compared to Ca^{2+} and Mg^{2+} in water, thereby causing low permeability within the soil stratum, limited aeration with corresponding reduction in crop growth (www.derm.qld.gov.au, 2009). .Nitrates concentration of the WCs were within the threshold values, although WC1, WC3, WC5, WC6 and WC7 exhibited values suggestive of possible metabolism to ammonia with evolution of nitrite capable of oxidizing iron atoms in haemoglobin to ferric ion Fe^{3+} and resulting into methemoglobinomia in infants other wise known as blue baby syndrome (Kim-Shapiro et al., 2005; Romano and Zheng, 2007). Likewise nitrates in drinking water at levels above the standard poses an immediate threat to young children, but can be significant N sources credited towards soil fertility and crop production (Edhira et al., 2008; Addiscott and Benjamin, 2004; Kim-Shapiro et al.,2005). The marginal increase shown in DO and BOD should not however be dismissed with a wave of the hand in view of the fact that an insignificant amount of poison in solution is dangerous as the concentrated one with a similar solution, both are deadly. Moreover, the average BOD values ranged from 5.8 (WC12) to 12 (WC2) with 10 out of the WCs described as being very polluted respect to domestic activities according to Miroslav (1999).

The results recorded for chlorophyll a, b, c appeared divergent from the conventional trend, however WC4 was above the limit in most of the parameters measured. An overall result obtained indicated that WC2, WC8, WC1, and WC5 exhibited parameters that rendered them safe for drinking while WC3, 4, 7, 8, 9, 10, 11 and 12 could be considered for irrigation.

V. CONCLUSION

In marked contrast to the large seasonal variation of surface water temperature typical of temperate climates as opposed to tropical regions, ground water temperature tends to remain relatively constant, an important advantage for drinking water and industrial uses (Todd, 1980). Although saline groundwater has traditionally been regarded as an undesirable resource, modern technological advances had reversed this role. Advances in desalination techniques suggest that saline groundwater is a potentially important water supply source where shortages are imminent. (Todd, 1980). Consequent on the above information and the available modern technology, the twelve water catchments could be treated for both domestic and irrigation activities.

VI. REFERENCES

[1] Addiscott, T.M. and Benjamin, N. 2004. Nitrate and Human Health. Wikipedia, the Free Encyclopedia.
[2] Bander, T.A, Waskom, R.M. and Davis, J.G.2007. Irrigation Water Quality Criteria. Colorado State University Extension No. 506.
[3] Black, W. and Hanshaw, B.B. 1996. Chemical geohydrology, in Advances in Hydro science (V.T. Chow, Ed), V.2. Academic press, New York, pp 49-109.
[4] Blosch, J., CUtknecht, D. and Lordache, V. (Ed). 2004.Report on the International Workshop "Hydrology and Limnology-Another Bounding in the Dambe River Basin" A contribution to the UNESCO IHP-VI Ecohydrology project. International Association for Dambe Research (LAD) Environmental Science and Technology (EAWAG), Switzerland.
[5] Edhira, S. and Vasil, K.2008. Irrigation Water Quality and its effect upon soil. Tirana Agricultural University, Tirana Albania.
[6] Edhira, S. and Vasil, K.2008. Irrigation Water Quality and its effect upon soil. Tirana Agricultural University. Tirana Albania BALWOIS-Ohrid Republic of Macedonia.
[7] Follet, R.H. and Soltapour, P.N. 2010. Irrigation water Quality Criteria. Colorado State University, Fact Sheet 0.506.
[8] Gordon, Johnson and Hamlin Zhang, 2009. Classification of Irrigation Water Quality. Oklahoma Cooperative Extension Fact Sheets. http://www/osuextra.com
[9] Health, R.C. 1964. Seasonal temperature fluctuations in surficial grand water Albanu, New York, U.S. Geological Survey Prot. Paper 475-D, pp 204-205.
[10] Howard, S.P. Donald, R.R. and George, T. 1985. Environmental Engineering. McGraw-Hill Book Company, New York.
[11] Jamie, B. and Richard, B. 1996. Water Quality Monitoring. A practical guide to the design and implementations of freshwater quality studies and monitoring programme.
[12] Kim Shapiro, D.B., Gladwin, M.T, Patel, R.P and Hogg, N. 2005 between nitrate and haemoglobin: the role of nitrite in haemoglobin-mediated hypoxic vasolidatio Journal of Inorganic Biochemistry 99 (I): 237-246.
[13] Miroslav, R. and Vladimir, N.B. 1999.practical environmental analysis. The royal society of chemistry, Thomas Graham House. Science Park, Milton Road Cambridge CB4 OWF, UK MPG Books Ltd. Bodmin, Cornwall,U.
[14] Richard, L.A. (ed). 1954 Dignosis and improvement of saline and alkali soils. Agric Handbook 60, U.S. Dept. Agric. Washington D.C. 160pp.

[15] Romano, N and Zeng C.2007. “Acute toxicity of sodium nitrate, potassium nitrate and potassium chloride and their effects on hemolymph composition and gill structure of early juvenile blue swimmers crabs (portunus Pelagius, Linnaeus 1958) (Ecapots, Brachura, Portunidae).

[16] Seft, J.R. 2010. Domestic Water Quality Criteria. Colorado State University, Extension, no. 0.513.

[17] Todd, D.K 1980. Groundwater Hydrology. Second Edition Berkeley, California.

[18] USEPA, 2010. National Primary Drinking Water Standards and National Secondary Drinking Water. Washington, DC, 20450 Environmental Toxicology and Chemistry, 26:1955-1962.

Table 1: Physiochemical and Limnological Properties of Twelve Water Bodies in Ogbomosho, South West, Nigeria

S/N	Properties	Symbols	Units	WB1	WB2	WB3	WB4	WB5	WB6	WB7	WB8	WB9	WB10	WB11	WB12
1	Acidity/Alkalinity	pH		6.3	5.8	6.8	7.2	6.9	7.4	6.5	6.2	6.6	6.9	7.3	6.7
2	Total alkalinity	TA	mg L^{-1}	64	0	104	552	72	296	168	16	256	160	208	216
3	Carbonate	$CO3^{2-}$	mg L^{-1}	0	0	0	552	0	296	0	0	0	0	0	0
4	Bicarbonate	HCO_3^{2-}	mg L^{-1}	64	0	104	0	72	0	168	16	256	160	208	216
5	Nitrates	NO_3^{-N}	mg L^{-1}	0.81	0.07	0.42	0.1	0.47	0.47	0.37	0.11	0.17	0.07	0.11	0.03
6	Sulphate	SO_4^{2-}	mg L^{-1}	10.3	2.53	8.81	18	10.2	10.7	3.09	2.63	10.5	7.11	7.73	2.24
7	Phosphorus	p	mg L^{-1}	0.28	0.19	0.1	0.1	0.02	0.28	0.35	0.19	2.15	0.5	1.66	0.17
8	Sodium	Na	mg L^{-1}	35.6	33.21	38.1	39	29.2	39.7	17	12.2	9.72	10.53	16.2	19.44
9	Potassium	K	mg L^{-1}	9.72	11.34	7.02	12	4.68	14.8	3.9	4.68	3.12	10.53	4.68	4.68
10	Calcium	Ca	mg L^{-1}	28.5	27.5	19.3	66	32.3	48.8	1.75	14.3	2.75		17.75	12
11	Magnesium	Mg	mg L^{-1}	11	10.5	8.25	13	10.1	11.8	6.93	6.73	4.15	3.9	5.5	5.73
12	Dis.Oxy.	DO	mg L^{-1}	4.5	6	5.8	9.5	8	5	8	4	5	14	4.5	5
13	Conductivity	ECw	µScm $^{-1}$	385	510	420	505	420	370	420	380	440	4.5	380	405
14	Bio Ch Ox De.	BOD	mg L^{-1}	8.5	12	10.5	13	10	7	8	10	6	400	6	5.8
15	Total Solid	TS	mg L^{-1}	220	420	320	440	370	250	350	240	350	9	210	420
16	Tot.Dis. Sol.	TDS	mg L^{-1}	140	220	230	340	280	180	250	190	280	305	110	150
17	Chlorophyll	a	µg L^{-1}	5	5	7	4	8	9	7	10	6	200	12	8
18	Chlorophyll	b	µg L^{-1}	9	14	11.5	9	16.5	16.5	16.5	16	12.5	10	23	16.5
19	Chlorophyll	c	µg L^{-1}	10	16	12	10	17	17.5	17	16.5	13	21	24.5	17.5
20	Pheophytin		µg L^{-1}	11.6	17.2	14.4	12.4	17.8	18.4	18.8	17.8	14.2	24	25	18

Table 2: Basic Soil Information of Twelve Water Catchments in Ogbomosho, Nigeria

Properties	Symbols	Units	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10	WC11	WC12
Nitrogen	N	mg L^{-1}	175	319	661	593	236	866	441	258	988	752	988	494
Phosphorus	P	mgkg-1	102.5	122.5	133.58	102.5	102.5	112.5	92.5	92.5	112.5	830	103	123
Potassium	K	mgkg-1	19.50	19.5	253.5	58.5	19.5	19.5	19.5	58.5	58.5	546	58.5	19.5
Sodium	Na	mgkg-1	20.25	20.25	202.5	162	40.5	20.25	20.25	20.25	40.25	384.75	40.5	20.25
Calcium	Ca	mgkg-1	219.75	31.75	nd	12	129	16.25	5.75	25.50	25.50	198.75	nd	3.25
Magnesium	Mg	mgkg-1	457.2	133.75	394.38	360.63	333.13	70.63	685.62	66.25	202.5	369.38	737.50	146.88
Sulphates	SO42-	mgkg-1	140	131.88	191.87	83.75	56.25	156.25	143.75	231.87	231.87	236.25	171.87	296.25