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Full Length Research Paper

Physico-chemical properties and heavy metal content of water sources in Ife North Local Government Area of Osun State, Nigeria

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The water quality examination in Ife–North Local Government of Osun State Nigeria was conducted by determining the physico–chemical parameters of 40 samples. Surface water, bore holes, wells and pipe borne water samples were collected from major towns in the Local Government Area and analyzed. Results showed temperature range of 26.5 to 33.0°C, pH (6.53 to 8.90), conductivity (63.0 to 1039.0 µS/cm), resistivity (0.00 to 0.02mΩ.cm), salinity (300.00 to 700.00 mg/L), total solids (90.00 to 1175.00 mg/L), total dissolved solids (37.80–622.50mg/l), suspended solids (34.50 to 794.00 mg/L),dissolved oxygen (4.48 to 9.48 mg/L), Biological Oxygen Demand (BOD_5) (0.69 to 6.74 mg/L), chloride (3.64 to 184.04mg/L), Nitrate (1.08 to 53.03 mg/L), phosphate (4.99 to 23.07 mg/L) and sulphate (6.02 to 28.95 mg/L). Results of Atomic Absorption spectrophotometric analysis (AAS) of samples for dissolved trace metals; (Cd, Pb, Mn, Zn, Cu, Cr and Fe), showed mean metal concentration to vary widely depending on the source of the water sample as follows: Pb (0.29 ± 0.05 to 6.69 ± 0.53 mg/L), Cd (0.77 ± 0.06 to 2.24 ± 0.08 mg/L), Zn (0.03 ± 2.15 to 0.22 ± 4.64 mg/L), Cu (0.18 ± 16.34 to 0.41 ± 5.00 mg/L), Fe (6.00 ± 0.21 to 31.75 ± 0.80mg/L) and Mn (0.14 ± 6.12 to 0.23 ± 99.11 mg/L). The results obtained for the physical parameters agreed with the limits set by both national and international bodies for drinking and domestic water with few exceptions.

Key words: Quality, physico-chemical, atomic-absorption-spectrophotometer, domestic, recreational, Ife-North-Local-Government.

INTRODUCTION

Water is a universal solvent essential to man for various activities such as drinking, cooking, industrial and agricultural processes, waste disposal and human recreation. The two main problems man contends with are the quantity (source and amount) and quality of water in Nigeria (Adeniyi, 2004). In view of its occurrence and distribution pattern, water is not easily available to man in the desirable amount and quality. This is a problem experienced in most cities and towns in the developing nations not to mention their rural settings. These factors have lead to the growing rate of water borne diseases like Typhoid fever and Cholera experienced in this part of the world (Edwards, 1993). Even in the developed nations like the United States of America, cases of outbreaks of diseases associated with contaminated portable water was reported (Moore et al., 1993).

Water quality is a term that is most frequently used, but rarely defined, probably because it has no fixed definition, but apparently fairly well understood by users. Thus, the quality of water is a reflection of the source environment and the activities of man, including the use and management measures. However, the desirable properties of water quality should include: Adequate amount of dissolved oxygen at all time, a relatively low organic content, pH value near neutrality, moderate temperature, and freedom from excessive amount of infectious agents, toxic substances and mineral matter (Adeniyi, 2004).

Various factors are responsible for water pollution, which makes it quite undesirable for portability. Such factors include: Sewage discharge, which contributes to oxygen demand and nutrient loading to a destabilized

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Table 1. Physico-Chemical Properties of Water Sources from Edunabon Town. CV: coefficient of variation, SON: Standard Organization of Nigeria, SD: standard deviation, * WHO Maximum Permissible limit.

Parameter	Minimum	Maximum	Mean ± SD	CV	Pipe-bornewater	SON limit
pH	7.670	8.713	8.01±0.32	3.94	7.666	6.5-8.5
Temp (℃)	26.250	30.500	28.95±1.25	0.04	29.000	-
DO (mg/l)	5.517	8.10	7.26±0.78	0.11	9.483	-
BOD (mg/l)	1.035	6.55	3.16 ±1.69	0.52	4.311	-
TS (mg/l)	90.000	860.000	404.00 ± 247.62	0.61	140.000	1500*
TDS (mg/l)	42.300	622.500	307.96 ± 202.82	0.00	80.950	500*
SS (mg/l)	34.500	237.500	96.05 ± 63.59	0.66	59.050	-
Conductivity (µS/cm)	70.650	1039.000	498.39 ± 350.10	0.70	133.500	1000
Resistivity (mΩ)	0.000	0.010	0.003 ±0.005	1.61	0.010	-
Salinity (mg/l)	300.000	700.000	490.00 ± 119.72	0.24	400.000	-
Chloride (mg/l)	12.760	184.040	76.17 ± 66.39	0.87	16.400	200-600
Nitrate (mg/l)	1.900	52.150	32.35 ± 22.26	0.69	1.080	50-100
Sulphate (mg/l)	6.020	27.940	15.66 ± 8.41	0.54	21.020	150
Phosphate (mg/l)	5.370	10.510	7.50 ± 1.65	0.22	6.630	-

aquatic ecosystem (DWAF and WRC, 1995; WRC, 2000), agricultural practices and industrialization. Pollution easily arises when population growth outmatches availability of potable water due to inadequate urban planning process coupled.

Ife-North Local Government area is one of the Local Government areas in Osun state, Nigeria, established two decades ago. It is in the rain forest region of south-western Nigeria with the towns: Edunabon, Moro, Yakoyo and Ipetumodu located within latitude 7°31'-7°33'N and longitude 4°E. The location of the Pre–Degree Study Center run by the authority of Obafemi Awolowo University (O.A.U), Ile–Ife, plus the already existing Federal Government College and the State School of Science has led to rapid population growth of the area. An investigation through major towns in the local government revealed that the major water sources for most activities is groundwater (well and boreholes), and sometimes streams and rivers during the dry season. These water sources are the alternatives to the inconsistent flow of pipe borne water supply, which would have been more reliable source of safe water for the growing population. Therefore, constant monitoring of river water and groundwater quality in the area is needed so as to record any alteration in the quality, which may lead to outbreak of health disorder or serious health effect.

MATERIALS AND METHODS

A total of forty (40) sampling sites were selected that comprises 33 hand-dug wells, 4 bore holes, 1 stream, 1 river and 1 pipe borne water source representing the various sources of drinking water in the area. The samples were collected within a period of nine months from March to November, 2007. The period span through the two seasons of the year, that is, the rain and dry seasons. Ten water samples (including surface water, well water, bore holes and pipe borne) were collected from each town using the pre-washed polythene containers.

The pH, temperature and Dissolved Oxygen (DO) were determined and recorded immediately at the site. The Dissolved Oxygen (DO) was determined by using the Winkler's Method (Ademoroti, 1996). The conductivity, Total Dissolved Solid (TDS), salinity and resistivities were determined in the laboratory using the Jenway conductimeter model MC METTLER TOLEDO. The chloride was determined by argentiometric method, phosphate by Vanadate-molybdate method, sulphate by turbidimetry method and nitrate (NO_3^-) by UV spectrophotometeric method (APHA, 1992). The Total Solids (TS), Dissolved Solids (DS) and Suspended Solids (SS) were determined gravimetrically (Ademoroti, 1996).

Samples were digested and analysed with Alpha 4, Atomic Absorption Spectrophotometric (Chem. Tech Analytical) using standard methods established by APHA (1992) for metals determination. Exactly 2.5 ml of concentrated HNO_3 (Analar grade) was added to 25 ml of water sample in a clean Teflon beaker. The mixture was heated on a hot plate to concentrate the sample to about 10 ml. Heating of the sample continued with periodical addition of 1 ml portion of concentrated HNO_3 until a clear solution was obtained. The clear solution was then allowed to cool after which it was transferred into 25 ml standard flask and made up to the mark with distilled water. Blank samples were prepared for background correction using the method as described.

The analytical procedure described was quality controlled. Quality assurance study was carried out in terms of recoveries of metals from a spiked sample in order to ascertain the efficiency of the analytical procedures. This was done by spiking water with known amount of standard of the metals and recovered as described by AOAC (1990).

RESULTS AND DISCUSSION

Tables 1 to 4 show the physico–chemical parameters of the water samples from each of the four towns investigated. The pH values of the water ranged from about neutral to slightly alkaline (6.526 to 8.905) and the mean pH values of the water from each town is presented in Figure 1. pH values of all the water sources

Table 2. Physico-chemical properties of water sources from Moro town. CV: coefficient of variation, SON: Standard Organization of Nigeria, SD: standard deviation, *: WHO maximum permissible limit.

Parameter	Minimum	Maximum	Mean ± SD	CV	Pipe-borne water	SON limit
pH	7.10	8.03	7.69 ± 0.33	0.04	7.66	6.5-9.2*
Temp (℃)	27.50	32.00	29.95 ± 1.40	0.05	29.00	-
DO (mg/l)	5.86	9.48	7.20 ± 1.02	0.14	9.48	-
BOD (mg/l)	1.035	4.31	2.346 ± 1.06	0.45	4.311	-
TS (mg/l)	140.00	525.00	317.50 ± 156.23	0.49	140.00	1500*
TDS (mg/l)	37.80	327.00	169.06± 109 .90	0.65	80.95	500*
SS (mg/l)	55.05	351.70	157.45 ± 87.37	0.56	59.05	-
Conductivity (µS/cm)	63.00	728.00	346.68 ± 213.68	0.62	133.50	1000
Resistivity (mΩ)	0.00	0.020	0.01 ± 0.01	1.42	0.010	-
Salinity (mg/l)	300.00	500.00	410.00 ± 73.79	0.18	400.00	-
Chloride (mg/l)	3.64	58.310	33.62 ± 17.97	0.54	16.40	200-600
Nitrate (mg/l)	1.08	52.16	27.36 ± 21.33	0.78	1.08	50-100
Sulphate (mg/l)	6.21	28.95	15.55 ± 8.73	0.56	21.02	150
Phosphate (mg/l)	4.99	10.89	7.09 ± 1.62	0.23	6.63	-

Table 3. Physico-chemical properties of water Sources from Yakoyo town. CV: coefficient of variation, SON: Standard Organization of Nigeria, SD: standard deviation, *: WHO maximum permissible limit.

Parameter	Range	Mean ± SD	CV	Pipe-borne water	SON limit
pH	6.526 - 8.267	7.57 ± 0.68	0.09	7.670	6.5-8.5*
Temp (℃)	29.500 - 33.00	30.80 ± 0.98	0.03	29.000	-
DO (mg/l)	5.690 - 7.41	6.81 ± 0.64	0.09	9.483	-
BOD (mg/l)	1.035 - 7.24	2.30 ± 1.84	0.08	4.311	-
TS (mg/l)	250.000 - 890.00	517.00 ± 216.95	0.42	140.00	1500*
TDS (mg/l)	83.40 - 773.00	288.90 ±255.25	0.88	80.950	500*
SS (mg/l)	77.20 - 607.00	339.66 ±155.29	0.46	59.050	-
Conductivity (µS/cm)	136.90 - 474.50	307.79 ±120.51	0.39	133.500	1000
Resistivity (mΩ)	0.00 - 0.01	0.002 ±0.004	2.10	0.010	-
Salinity (mg/l)	400.00 - 500.00	435.00 ±47.43	0.11	400.00	-
Chloride (mg/l)	18.230 - 69.75	47.42 ± 22.91	0.48	16.40	200-600
Nitrate (mg/l)	4.070 - 75.23	36.32 ± 21.03	0.58	1.08	50-100
Sulphate (mg/l)	6.160 - 23.61	14.55 ± 5.83	0.40	21.02	150
Phosphate (mg/l)	5.620 - 13.40	8.09 ± 2.10	0.26	6.63	-

fall within the range of 6 to 9, set by World Health Organization (WHO, 1971) and Standard Organisation of Nigeria (SON, 2007). The pH values, which give the indication of acidity and alkalinity of the waters show that the surface and ground waters in the area are safe for agricultural, recreational and domestic uses.

The electrical conductivity (EC) of the water samples ranged between 63 and 1039 µS/cm. The salinity values of all the water sources ranged between 300 and 700 mg/L. The EC of water is a useful and easy indicator of its salinity or total salt content. In this study, it was discovered that the EC of some borehole waters from Edunabon and Ipetumodu (Tables 1 and 4) were quite high (907.5 yo 1039 µS/cm), which is likely due to some soluble minerals from the bedrocks. The salinity values are less than 1000 mg/L set by the World Health Organization (WHO, 1979) and Standard Organisation of Nigeria (SON). This implies that the waters are not saline.

The total solids (TS) and the total dissolved solids (TDS) of the water samples in the area are below 1500 and 500 mg/L limits, respectively for drinking water by WHO. Few exceptions were found in boreholes at Edunabon and Ipetumodu where the total dissolve solids were 622.50 and 545 mg/l, respectively. Two well waters near the borehole at Edunabon have dissolve solids of 501 and 565.50 mg/L close to the set standard values. Some treatments such as addition of coagulants may be

Table 4. Physico-chemical properties of water sources from Ipetumodu town.

Parameter	Range	Mean ± SD	CV	Pipe-borne water	SON limit
pH	7.55 - 8.90	8.16 ± 0.38	0.05	7.67	6.5-9.2*
Temp (℃)	30.00 - 32.50	31.15 ± 0.85	0.03	29.00	-
DO (mg/l)	4.483 - 7.41	6.12 ± 0.98	0.16	9.48	-
BOD (mg/l)	3.10 - 6.74	5.59 ± 1.13	0.20	4.31	-
TS (mg/l)	212.50 - 1175.00	525.70 ± 358.71	0.68	140.00	1500*
TDS (mg/l)	83.90 - 545.00	258.62 ± 147.98	0.57	80.95	500*
SS (mg/l)	84.00 - 794.00	267.18 ± 271.63	1.02	59.05	-
Conductivity (µS/cm)	143.00 - 907.50	430.96 ± 245.90	0.57	133.50	1000
Resistivity (mΩ)	0.00 - 0.01	0.002 ±0.004	2.10	0.010	-
Salinity (mg/l)	400.00 - 600.00	470.00 ± 82.33	0.18	400.00	-
Chloride (mg/l)	7.29 - 171.09	77.24 ± 50.98	0.66	16.40	200-600
Nitrate (mg/l)	5.11 - 53.03	38.10 ± 18.57	0.49	1.08	50-100
Sulphate (mg/l)	7.44 - 25.33	14.02 ± 5.76	0.41	21.02	150
Phosphate (mg/l)	5.99 - 23.07	10.45 ± 5.43	0.52	6.63	-

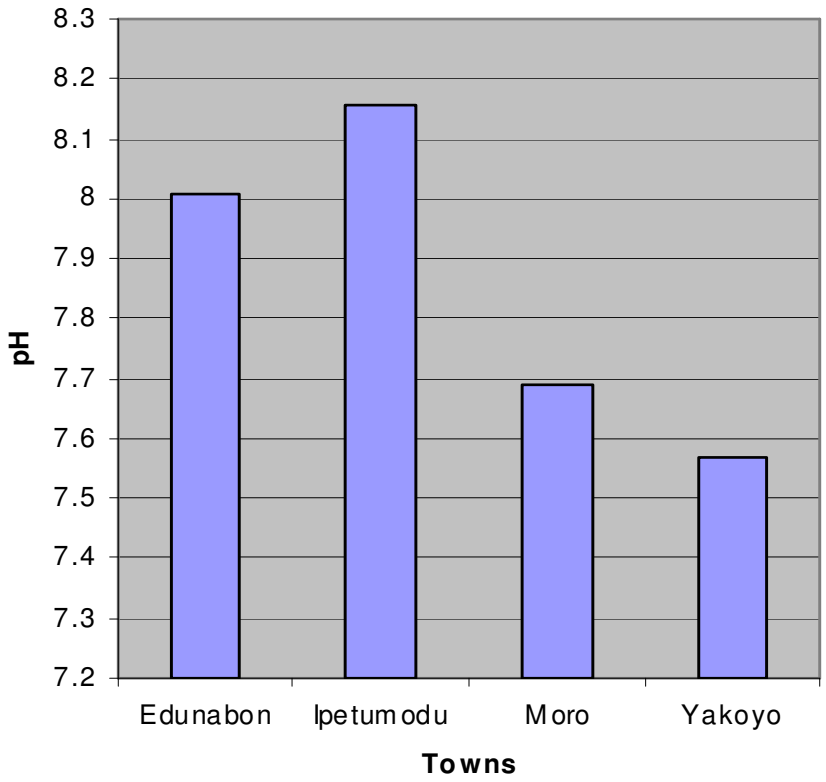

Figure 1. Mean pH values of waters from the four towns.

required to make these waters suitable for domestic purposes

The concentrations for Chloride ranged between 3.64 and 184.04 mg/L and for nitrate, it ranged between 1.08 and 53.03 mg/L. The highest phosphate value of 23.07 mg/L was obtained for water at Ipetumodu, while for sulphate 28.95 mg/L, was obtained at Moro water samples. In this study, the lowest value, 3.64 mg/L of chloride obtained was for the surface water at Moro Town. This parameter is an indication that the stream will conveniently support aquatic life without ecological effect (Fried, 1991). Our results showed nitrate content to be high (above 45 mg/L) in most of the ground water samples, but low in the surface waters and pipe-borne

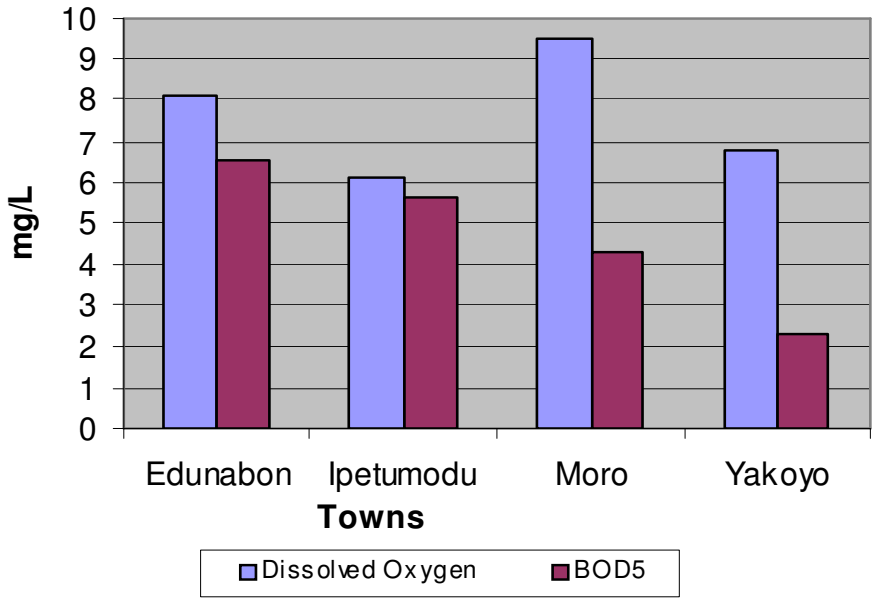

Figure 2. Mean values of dissolved Oxygen and BOD5 for the four towns.

Table 5. Metals wavelength (nm) and percentage (%) Recovery from spiked water samples.

Recovery (%)	Wavelength (nm)	Element
68.10	214	Zn
63.60	228	Cd
79.00	284	Pb
72.93	324	Cu
106.00	403	Mn
81.33	248	Fe
74.41	357	Cr

water. The surface water is free of Algae cover as a result of eutrophication and consequently suffers no depletion in the dissolved oxygen, unlike the ground waters as evident from our results. The use of ground water as potable water in this local government could pose serious health problems associated with high nitrate concentration if not controlled. The phosphate levels are generally high, which could explain the observed blue-green algae growth on the walls of most of the sampled wells. While all the values obtained for the concentrations of sulphate in water samples fall below the recommended values for drinking water, most of the concentrations of phosphate exceed the 5 mg/L set as standard in South Africa and Nigeria (Morrison et al., 2001; SON, 2007). Persistence of high concentration of phosphate at this level in the surface water for a long time may lead to eutrophication of the water body, which can reduce their recreational use and also endanger aquatic life.

The DO and Biochemical Oxygen Demand after five days (BOD_5) were found within the range of 4.483 to 9.483 mg/L and 0.690 to 6.745 mg/L, respectively. The mean values of the DO and BOD_5 for the four towns are plotted in Figure 2. Also only 15% of the water samples have BOD values above the 6 mg/L, the recommended limit for BOD in drinking water (WHO, 1971). BOD values of water from Ipetumodu town ranged between 3.104 and 6.745 mg/L, but the mean value is still less than the limit value. This suggests that the water from the whole area is less polluted by organic matter and they could support aquatic life. The DO is an important water quality parameter and has special significance for aquatic organisms in natural waters (Willock et al., 1981). The highest DO value (9.485 mg/l) obtained for the tap water may be due to aeration process during water treatment.

The quality control study for the elemental characterisation of water samples were obtained as percentage recoveries of the metals from spiked water samples (Table 5). It shows that the percentage recovery of Cd is low relative to others. This is unexpected and is difficult to explain, however, it is not unlikely that the low value

Table 6. Mean ± SD concentration (mg/L) of metals in the various water sources in the area.

Water source element	Pipe borne	Borehole	Stream	River	Hand-dug well	SON limit
Pb	2.79 ± 1.16	4.55 ± 2.76	0.29 ± 0.05	6.69 ± 0.53	4.01 ± 3.82	0.01
Cd	1.43 ± 0.14	1.39 ± 1.02	2.24 ± 0.08	0.77 ± 0.06	0.98 ± 0.67	0.003
Zn	12.00 ± 0.27	14.77 ± 0.38	6.19 ± 0.24	4.64 ± 0.22	147.3 ± 30.4	3.0
Cu	3.02 ± 0.06	1.16 ± 0.05	3.51 ± 0.05	2.15 ± 0.03	46.35 ± 0.07	1.0
Cr	5.00 ± 0.41	16.34 ± 0.18	20.11 ± 0.30	5.06 ± 0.19	113.78 ± 0.27	0.05
Fe	13.63 ±2.15	23.25 ±10.61	6.00 ± 0.21	31.75 ± 0.80	14.12 ± 9.95	0.3
Mn	17.50 ± 0.16	99.14 ± 0.23	11.32 ± 0.20	6.12 ± 0.14	93.65 ± 0.16	0.2

obtained may be due to matrix effects. Other percentage recoveries are adjudged acceptable and confirmed the efficiency of the analytical procedure described in this study.

Table 6 represents the mean of the concentrations of metals in the different water samples. The concentration of Pb ranges from 0.29 to 6.69 mg/L. The concentration of Mn and Zn in the water sources are 0.14 to 0.23 mg/L and 0.22 to 0.41mg/L, respectively, while that of Cu range from 0.03 to 0.07 mg/L. Cadmium concentration is in the range of 0.18 to 0.41 mg/L. Concentration of Pb is generally high in all the waters from the four towns. The lowest value recorded (0.29 mg/L) for stream Olubo (Moro Town) may be as a result of the fact that the stream was located in a serene environment in the outskirt of the town where no industrial or domestic activities are taking place. In fact, very little agricultural activities were noticed around the stream. On the contrary, the high concentration of the elements in river Sasa, (6.69 mg/L) may be as a result of the direct release of domestic waste containing Pb from human activities at the riverbank and vehicular exhausts. The highest value of Pb (6.98 mg/L) recorded for the pipe borne water is the same in all the towns in the Local Government since the pipe borne water is from the same source. The value obtained could be associated with the wearing of lead from metal pipes into the water during water distribution. However, it appears that the possible source of this element is the geology of the area since its value is generally high, even in ground-water (boreholes and hand-dug wells). The concentration of Pb obtained for the stream is higher than the WHO limit of 0.01 mg/L and maximum contaminant level (MCL) of 0.015 mg/L for drinking water (Nkono and Asubiojo, 1997). Therefore, the stream needs to be treated so that the lead level meets these standards before it could be safe for drinking and use for domestic activities. The surface water may not also support recreational purposes until the Pb level is reduced since lead level above 0.1 mg/L may result in neurological damage in young children (Fatoki et al., 2002).

The concentrations of Mn and Zn in all the samples fall below the WHO limits of 0.1 and 5.0 mg/L highest desirable level for Mn and Zn in drinking water. They also meet the 0.18 and 0.002 mg/L levels for Mn and Zn, respectively in water meant for aquatic ecosystem use (Fatoki et al., 2002). On this basis, the surface waters (stream Olubo and River Sasa) can support aquatic life if other conditions are favourable. The concentration of Cu is also below 1.0 mg/L set as the maximum that is allowable for drinking water, hence may not pose any danger to the community.

Cadmium concentration was generally high in all the water sources with mean concentration range of 0.77 to 2.24 mg/L. Factors such as the dumping of agricultural wastes, addition of impure chemicals during water purification (in the case of pipe borne water), leaching of metals from wastes site to the ground water plus rural and urban water run-off could be responsible for the observed high concentrations of Cd. WHO level of Cd in drinking water is 0.01 mg/L (Nkono et al., 1997). The level in water for aquatic system is 0.15 to 0.25 mg/L (Fatoki et al., 2002). This suggests that the water sources from the studied area may pose threat to man and aquatic organism.

Iron has the highest concentration of all the elements studied with mean concentration range of 6 to 31.75 mg/L. The values obtained may not be unconnected with the geology or the mineral nature of the soil in the studied area. The lowest value (6 mg/L) obtained exceed the 1.0 mg/L permissible level recommended by WHO for Fe in drinking water (Fatoki et al., 2002). Hence, the waters may have taste and aesthetic problem.

Except for the ground waters (hand-dug wells) at Ipetumodu town with chromium concentration of 0.05 mg/L, all the waters analyzed have chromium concentration above the limit of 0.05 mg/L set by WHO (Nkono and Asubiojo, 1997). Only 5% of the water samples are within the set standard for Cr in drinking water, while others are above it. This could be due to wide range use of Cr in metal plating, pipes or from the wastes that get to the surface and ground water through run-offs.

Conclusion

The quality evaluation of water sources in Ife North Local Government Area of Osun State, Nigeria revealed that

the pH, conductivity, salinity, total solids, total dissolve solids, suspended solids and the chloride contents were found mostly within the limits set by both National and International standard regulatory bodies for drinking and domestic waters (SON, 2007; WHO, 1970, 1971, 1979). Few exceptions were observed in the phosphate concentration, BOD_5 and the total dissolved solids, which were found to be a little above the set standards in few samples. There is a direct relationship between the conductivity, salinity and the total dissolved solids in most of the samples. This phenomenon is expected, as it is an appraisal to the accuracy and reliability of our findings. Similarly, apart from Pb, Cd and Fe, all the other elements were found within the limits recommended by Standard Organisation of Nigeria for drinking water quality and WHO. It is therefore, observed that the water sources from the studied area have a lot of potentials for wide applications to the people if only they can be subjected to further treatments that will reduce drastically, the concentration of the few identified elements that may pose some danger to health and the society

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