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ASSESSMENT OF UNDERGROUND WATER QUALITY AND POLLUTION SOURCES APPORTIONMENT IN A GROWING URBAN CENTRE IN OSUN STATE SOUTH WESTERN NIGERIA.

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Abstract

Cases of water-associated diseases and deaths have been reported globally especially in developing countries. Thus, a research was conducted to assess the quality of underground sources in a growing urban centre, in Osun State, Nigeria. A sample of well water, that each one was collected from each of the 15 political wards across the five quarters in the town. Physico-chemical parameters were determined and analyzed using standard laboratory techniques. Factor analysis was used to determine the dominant water quality parameters. The results revealed that Nitrate, Phosphate, Sodium, potassium, Calcium, Sulphate, pH, Total Alkalinity, Total Suspended Solids, Total Hardness and Total Dissolved Solids are generally within the maximum permissible limits. Temperature, Electrical Conductivity, and coliform counts were generally above the acceptable limits. The results showed that underground water sources are susceptible to contaminations. It is recommended that proper treatment of the water should be carried out before consumption to safeguard human health.

Keywords: *Water quality, Pollution sources, urban centre, Human health, Osun State.*

1. INTRODUCTION

Periodic assessment of water quality is highly imperative and also recommended to ensure that man consumes safe water that will guarantee his health. It is a fact that both surface and subsurface sources are available for man’s varied uses. The fact that these sources are open to pollutants which often distort the integrity of such water has made it important that their qualities are assessed over time and space. For instance, Olimax and Sikorska (1975) and Piecznska et al. (1975) among other publications noted that the addition of various kinds of pollutants and nutrients through industrial sewage, agricultural run-off etc. into the water bodies brings about a series of changes in the physicochemical and characteristics of water. Apart from this, fresh water resource, according to Mahananda et al. (2005), is becoming day-by-day at the faster rate of deterioration especially its quality, the issue which is now a global problem. Mahananda et al. (2010) in buttressing this observation stated that the discharge of toxic chemicals, over-pumping of aquifers and contamination of water bodies with a substance that promote algae growth are some of the today's major causes of water quality deterioration.

According to Vollenwider (1998), the consequences of these contaminations in water, especially surface sources include: bad taste, bad odour, unattractive colour, water hardness, staining or frothing and corrosiveness. The man has thus, as an alternative, resorted to the exploitation of underground sources. This source has become increasingly important especially in developing nations because of its fair quality. It is less open to pollutants and when even contaminated water is introduced to the surface of the earth, it undergoes natural treatment in the course of infiltration before it replenishes or added to the antecedent groundwater. However, the indiscriminate location of well/boreholes and anthropogenic activities could lead to its pollution especially from domestic effluents (Meena and Bhargava (2012).

It has been discovered that there is a relationship between quality of underground water and the geology of an area (Johnson (1975), Adediji (2005), and Abdulahi et al. (2011). In addition, Abdulahi et al. (2011) stated that pollutants may be introduced into underground water through anthropogenic discharges which include home effluents, airborne particles, especially in unprotected hand-dug wells. The consequences of consuming such contaminated water are evident in various water-associated diseases such as typhoid, dysentery, schistosomiasis among others and even deaths. World Health Organization (WHO) (1997) reported that 40% of deaths in developing nations are water-related. Similarly, WHO (2004) noted that 5 million children died annually for consuming water of poor quality while an estimated 500 million cases of diarrhoea, according to WHO (2011) occur every year in children below 5 years in parts of Asia, Africa, and Latin America.

In Nigeria, cases of deaths and diseases associated with consumption of water of poor quality have been reported. For instance, National Bureau of Statistics (2009) reported that 444, 484 and 10432 cases of typhoid fever among other cases were respectively reported in 2003, 2004 and 2005 in Oyo State. Similarly, Ezenwaji and Otti (2013) reported that the poor quantity and quality of water supply to various communities in Anambra State are responsible to some level of mortality of pregnant women as noted from the contribution of water-related diseases of 32.4% to the problem. Other cases of water-associated diseases were equally reported by various researchers in Osun State (Fadare and Olawuni, 2008), Ogun State (Anake et al. 2013), and Niger Delta (Nwidu et al. 2008).

It has therefore become imperative that the quality of water is closely monitored so that human health can be safeguarded. This research examines the quality of underground water in Iwo.

2. STUDY AREA

This study was carried out in Iwo, the headquarters of Iwo Local Government Area (LGA) in Osun State, Nigeria (Figure 1). Iwo has an area of 245km^2 with a population of 191,348 according to 2006 population census (National Population Commission (NPC), 2006). It is located between on the coordinates of 7^{o}38'N and 4^{0}11'E.

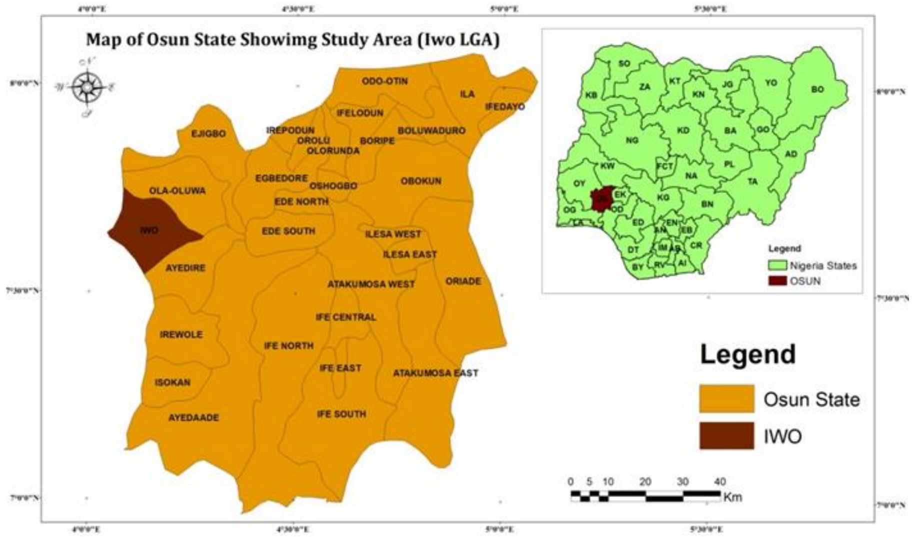

Figure 1. Map of Nigeria showing the location of Osun State.

Iwo is divided into 4 quarters namely Gidigbo, Isale-Oba, Molete, Oke-Adan and Oke-Oba out of which 15 political wards were carved out. While Gidigbo, Molete, and Oke-Adan has 3 wards each, Isale-Oba and Oke-Oba has 4 and 2 wards respectively. Its agriculturally rich advantage makes it a major trading centre for cocoa, kola nuts, foodstuffs, meat and timber. The popular Odo-Ori market attracts traders from within and outside the State. Iwo is also strategic because the railway tracks from Ibadan passes through the town which helps the commercial and economic development of Iwo and its suburbs. The major source of potable water in Iwo is from Aiba Water Reservoir located within Government Forest Reservation Area in the town. This Water Works has not been able to discharge its responsibilities as expected, the problem linked to poor management, poor maintenance culture, corruption and also increase in the population of the area. The town has witnessed a tremendous increase in the population especially since the inception of such institutions as Bowen University, Reality Radio-Vision station, Sharia College of Nigeria and the Oloba Cattle Hub. The persistent erratic supply of water from the Water Works and the quest for another alternative have led to the exploitation of underground and surface sources.

3. METHODS OF STUDY

3.1 Data Collection and Analysis

A sample each was collected from each of the 15 wards in Iwo LGA for water quality and bacteriological studies. Samples were collected in 2L plastic bottles that have been previously soaked in 10% nitric acid for 48 hours and rinsed with distilled water. The containers were rinsed three times on the site with well water before collecting the water samples. All samples were filtered with cellulose acetate filters before transporting to the laboratory. The samples were stored in the refrigerator prior to analysis in order to ensure the physical properties were maintained. The results of laboratory analysis were assessed and compared with the internationally acceptable standard. Also, a multivariate statistical method was used to determine the parameters of water quality that dominate the explanation of the underground water in the study area.

3.2 Determination of Physico-chemical parameters

All the reagents used were of analytical grade and the instruments were pre-calibrated appropriately prior to measurement. PH, Water temperature, and electrical conductivity were determined in-situ using Tester II dual range meter (Eutech instruments, Malaysia) after calibrating with a standard buffer solution of 4 and 10. Sulphate, Phosphate and Nitrate, Total Alkalinity (TA), Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and Total Hardness (TH) were determined by the procedure described by Ademoroti (1996). Sodium, Calcium and Potassium were determined using a flame photometric technique (APHA, 1998). The coliform count was carried out using three tube array of the Most Probable Number (MPN) technique using MacConkey broth.

4. RESULTS AND DISCUSSION

The results of the analysis are presented in Table 1a, 1b.

Table 1a. Physico-chemical contents of underground water in Iwo.

S/No	Name of Quarters	WARD NO	pH	Temp (oC)	EC (uScm^{-1})	PO_4^{3-} mg/L	SO_4^{2-} mg/L	Na mg/L	K mg/L
1	Gidigbo	WARD1	6.52	26.90	230	0.007	0.014	0.053	0.048
2		WARD2	6.92	26.10	270	0.010	0.051	0.042	0.028
3		WARD3	7.10	28.50	260	0.025	0.026	0.047	0.082
4	Isale-Oba	WARD4	7.02	28.40	160	0.016	0.012	0.008	0.040
5		WARD5	7.17	28.00	90	0.021	0.030	0.061	0.081
6		WARD6	6.99	26.10	270	0.028	0.111	0.062	0.077
7		WARD7	7.09	26.40	230	0.013	0.041	0.039	0.048
8	Molete	WARD8	6.50	27.90	280	0.020	0.021	0.038	0.020
9		WARD9	6.80	26.50	160	0.029	0.059	0.053	0.042
10		WARD10	7.12	28.40	270	0.017	0.020	0.083	0.047
11	Oke-Adan	WARD11	8.17	26.90	190	0.011	0.036	0.023	0.019
12		WARD12	7.13	27.90	50	0.015	0.048	0.033	0.065
13		WARD13	6.43	28.00	190	0.028	0.060	0.043	9.046
14	Oke-Oba	WARD14	6.90	28.40	100	0.019	0.033	0.011	0.030
15		WARD15	6.99	28.10	150	0.20	0.040	0.028	0.033

Source: Authors' fieldwork (2014)

Table 1b. Physico-chemical contents of underground water in Iwo.

S/No	Name of Quarters	WARD NO	Ca mg/L	NO_3^- mg/L	TH mg/L	TDS mg/L	TSS mg/L	Alkalinity mg/L	Coliform count (MPN/100ml)
1	Gidigbo	WARD1	0.073	0.033	420.0	81.0	200	240.0	93
2		WARD2	0.062	0.021	248.0	184.0	200	437.50	9
3		WARD3	0.033	0.020	315.0	122.0	400	160.00	3
4	Isale-Oba	WARD4	0.031	0.017	406.0	44.0	200	225.00	4
5		WARD5	0.028	0.018	268.0	40.0	200	160.00	93
6		WARD6	0.081	0.016	385.0	120.0	200	240.00	9
7		WARD7	0.058	0.018	450.0	100.0	0.00	160.00	0
8	Molete	WARD8	0.043	0.012	315.0	90.0	200	125.50	9
9		WARD9	0.055	0.012	450.0	124.0	200	160.00	0
10		WARD10	0.043	0.021	406.0	120.0	400	240.00	15
11	Oke-Adan	WARD11	0.017	0.009	375.0	40.0	600	240.00	0
12		WARD12	0.082	0.009	408.0	120.0	200	225.00	9
13		WARD13	0.058	0.013	248.0	120.0	0.00	160.00	7
14	Oke-Oba	WARD14	0.023	0.011	248.0	100.0	400	281.0	23
15		WARD15	0.011	0.014	420.0	90.0	200	200.0	0

Source: Authors' fieldwork (2014)

(1) pH: This is a measure of the intensity of acidity or alkalinity, and the concentration of hydrogen ion in water. The pH values of the underground water as presented in Figure 2 range between 6.43 in Ward13 and 8.17 in Ward11. This implies that the water is alkaline and fall within the limit recommended by the World Health Organization (2005). Mahananda et al. (2001) had attributed the alkaline nature of water to a high temperature which reduces the solubility of CO_2.

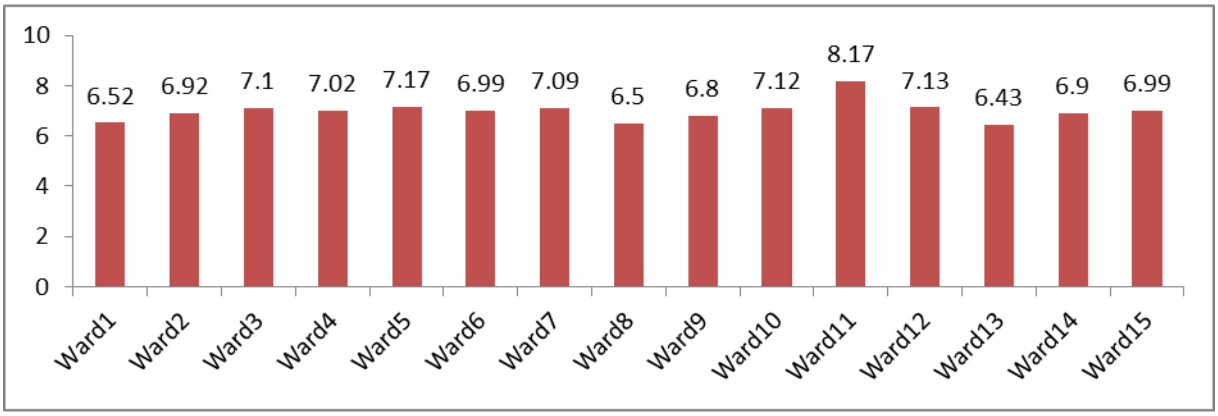

Figure 2. pH status of the borehole water sample

(2) Electrical Conductivity (EC): This is a measure of the capacity of water to conduct electric current. Prakash and Somashekar (2006) had observed that ground water tends to have high EC when compared to the surface water because of the presence of high amount of dissolved salts. According to the results as shown in Figure 3, the EC range between 150µ∫cm^{-1} in Ward12 and 280µ∫cm^{-1} in Ward8.

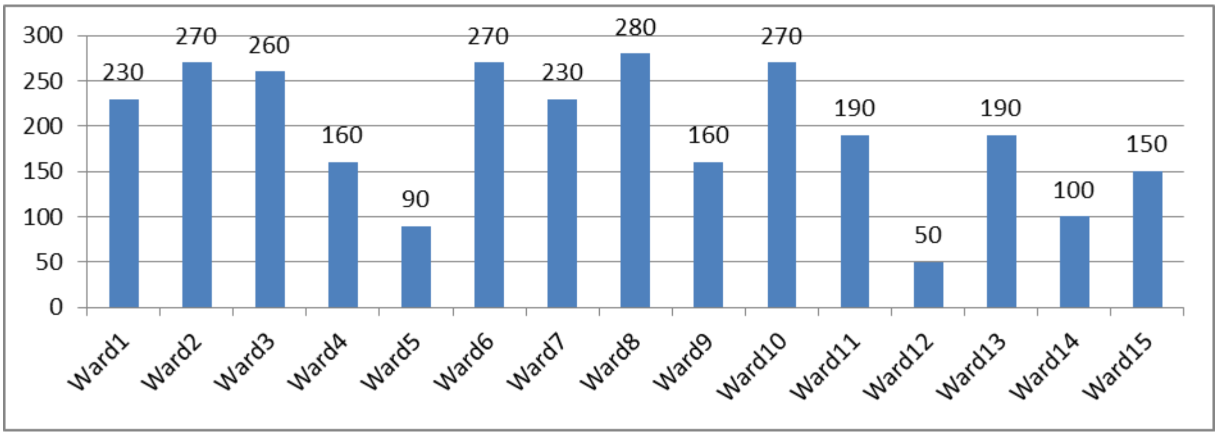

Figure 3. Electrical Conductivity of the Underground Water (uScm-1)

This is generally high when compared with the maximum Permissible of 250µ∫cm^{-1} by WHO recommendation. The generally high values may be attributed to the running and domestic effluents which contain dissolved solids.

(3) Temperature: The temperature of the underground water ranges from 26.1°C in Ward6 to 28.5°C in Ward3. This is shown in Figure 4.

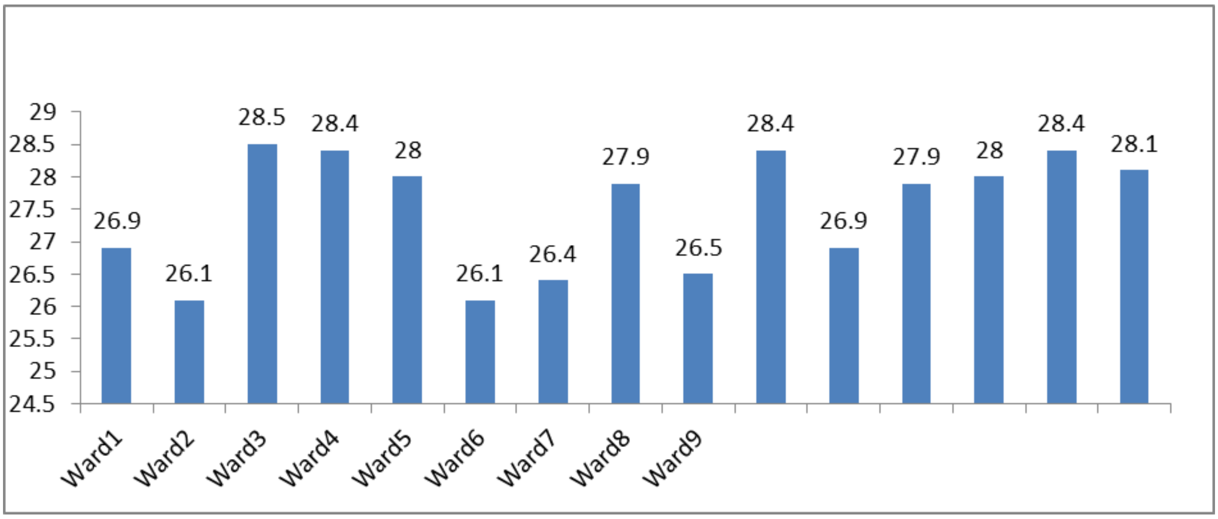

Figure 4. Temperature of the underground water (oC)

This is quite high exceeding the maximum standard of 25ºC recommended by WHO (2005). The Implication of this result is that there is room for the growth of algae and other microorganisms in water. The high temperature in the borehole is similar to Chukwu (2008). The high temperature could be attributed to the depth of the water as also observed by Mahananda et al. (2010).

(4) Total Dissolved Solids (TDS): This reveals the general nature of water quality or salinity. TDS concentrations values as shown in Figure 5 range from 40 in Ward11 to 800 mg/L in Ward3 and Ward14. This parameter is generally low except in lieu of 500mg/L standard. However, Ward2, Ward5, Ward7, Ward9 and Ward15 were exceptionally high with 800mg/L, 1400mg/L, 1600mg/L, 1200mg/L and 800mg/L respectively.

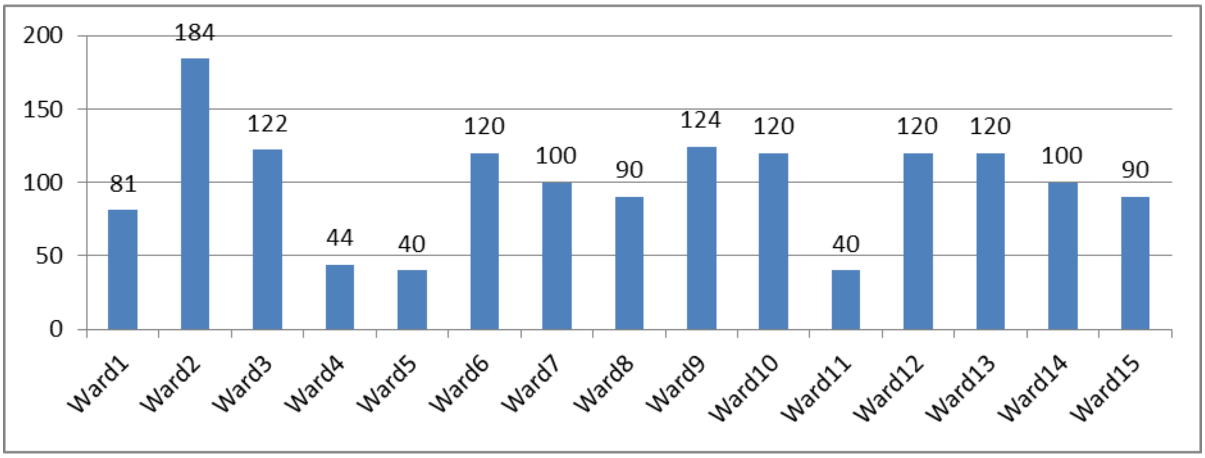

Figure 5. Total Dissolved Solids in the underground water (mg/L)

The high contents of TDS has been found to reduce the palatability and may cause gastro-intestinal irritation in man (see Rabinove et al., 1958 and Mor et al., 2006). High TDS contents could be attributed to the release of contaminants into the underground water which is mainly of carbonates, bicarbonates, chlorides, Phosphates, and nitrates of Calcium, Magnesium, Sodium, Potassium and manganese, organic matter, salt and other particles Mahananda et al. (2010).

(5) Total Hardness (TH): Hardness in water, according to Jafar and Loganathan (2012) is caused by carbonates, fluorides and Sulphate of Calcium and magnesium. The dominant cations include calcium, magnesium, strontium, ferrous and manganese ions. The TH in the study area ranges from 248mg/L in Ward2 and Ward14 to 450mg/L in Ward7 and Ward9. This is presented in Figure 6.

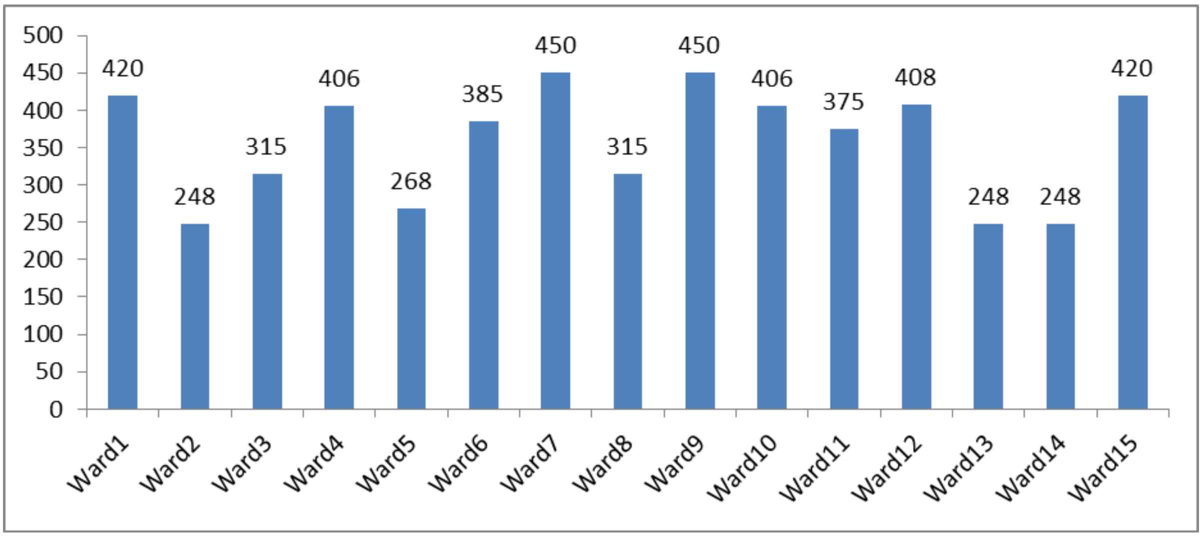

Figure 6. Total Hardness of the underground water (mg/L)

The TH is generally within 500mg/L limit recommended. Jafar and Logonathan (2012) observed that the hardness may be advantageous in certain conditions if the corrosion in the pipes by forming a thin layer of scale and reduces the entry of heavy metals from the pipe to the water (Shrivasatva and Patil, 2002).

(6) Total Alkalinity (TA): The results as presented in Figure 7 show that TA of the underground ranges from 125mg/L in Ward8 to 437mg/L in Ward2.

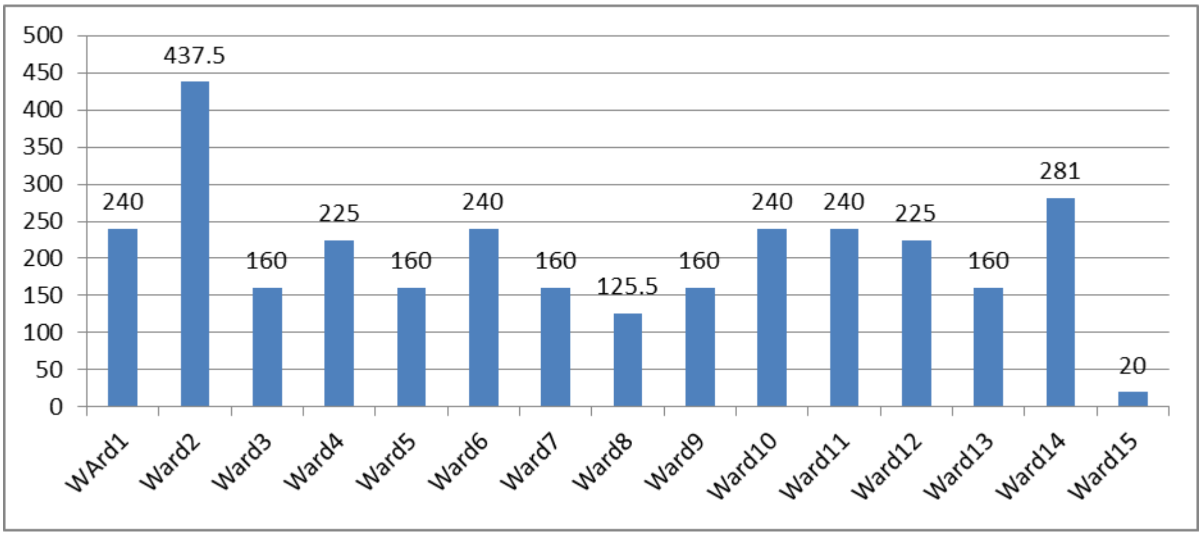

Figure 7. Total Alkalinity of the underground water (mg/L)

The high alkalinity impacts water with unpleasant taste and may be deleterious to human health with high pH, TDS, and TH (Jafar et al. 2012). According to Mahananda et al. (2010), the alkalinity of water is caused mainly due to OH, CO3, HCO3, ions. It is an estimate of the acidity of water to resist change in pH upon addition of acid.

(7) Nitrate: The results shown in Figure 8 show that the nitrate contents range from 0.009mg/L in both Ward11 and Ward12 to 0.033mg/L in Ward1 indicating the borehole water have been affected by nitrate.

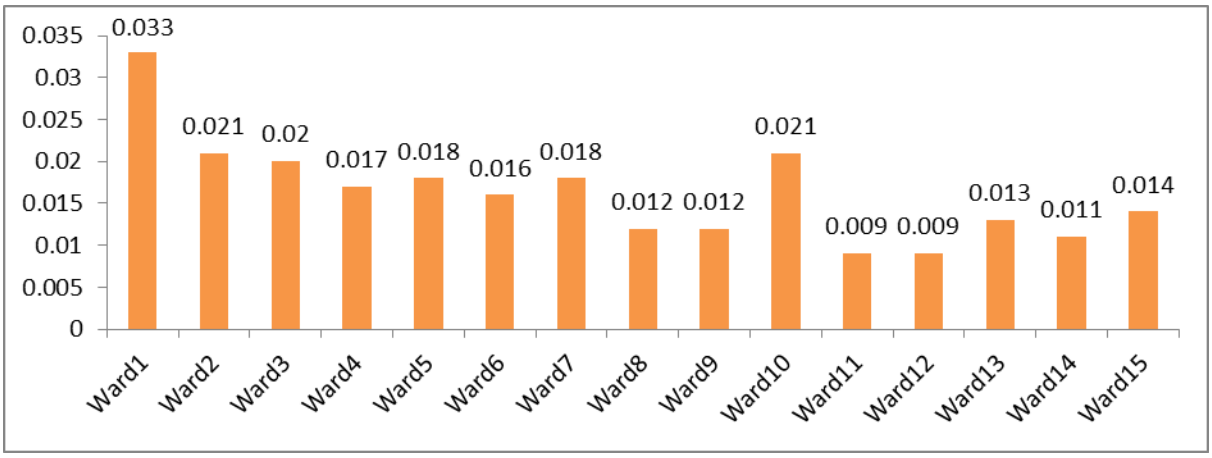

Figure 8. Nitrate concentration of the borehole water

The main sources of nitrates is groundwater according to Agrawal et al. (1999) include human and animal wastes, application of fertilizers and chemicals, seepage and silage through the drainage system. The nitrates values in the boreholes studied fall below the 10mg/L maximum permissible by WHO, thus making water safe consumption from nitrate point of view. Nitrate content above the maximum permissible is dangerous to pregnant women and poses a serious health threat to infants between 0 and 6 months according to Mahananda et al. (2010) and WHO (2011).

(8) Sulphate: According to Figure 9, sulphate concentration in the well water range between 0.012mg/L in Ward4 and 0.111mg/L in Ward6, which extremely below the 200mg/L acceptable standard (WHO 2005).

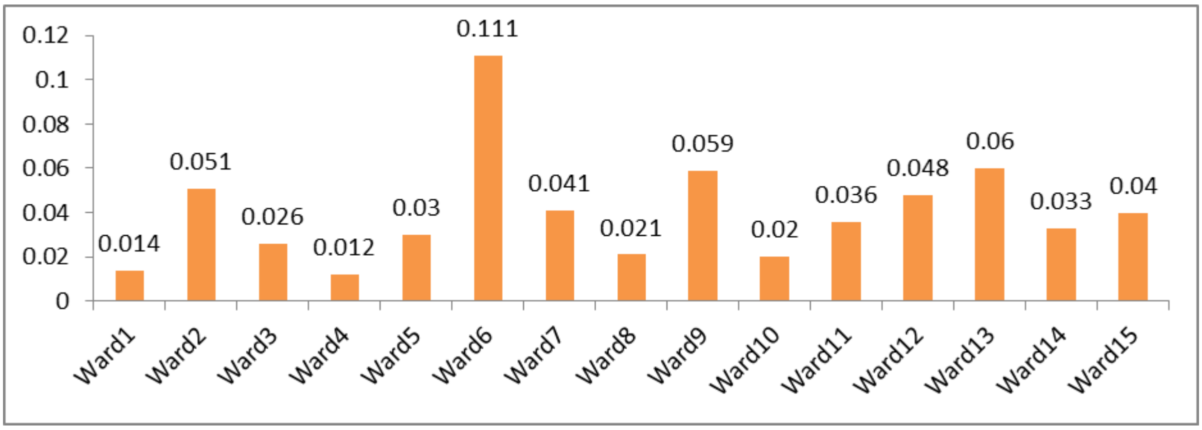

Figure 9. Sulphate concentration of the borehole water (mg/L)

A sulphate ion is one of the major anions occurring in natural waters many of which are readily soluble in water. (Jafar et al. 2012). It was further stated that most of the sulphate components originate from the oxidation of sulphite ores, the presence of shales and the solution of gypsum and anhydrite. It was also observed that sulphate ion is reduced to sulphate ion under anaerobic conditions which establishes equilibrium with hydrogen ion to form hydrogen sulphide.

(9) Phosphate: The results as shown in Figure 10 show that PO4 values range between 0,.007mg/L in Ward1 and 0.029mg/L in Ward9 which were well below the permissible limit.

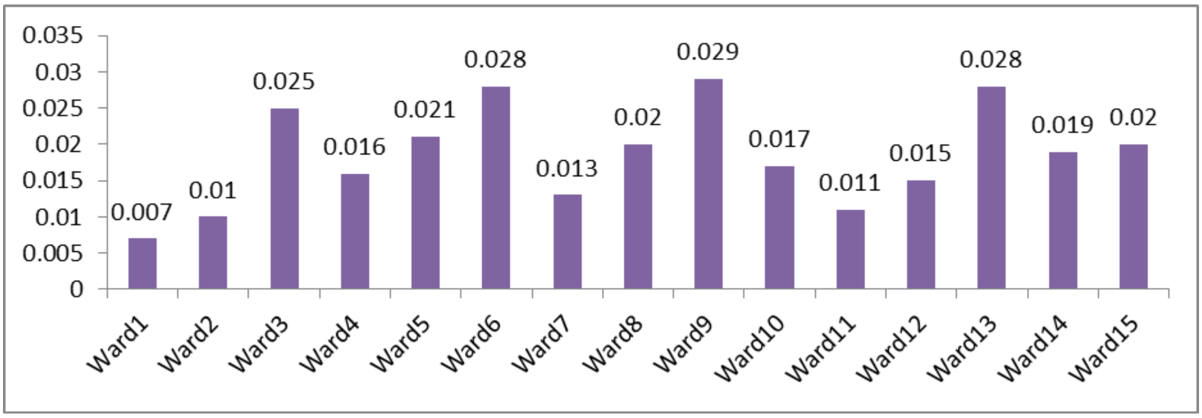

Figure 10. Phosphate concentration of the borehole water (mg/L)

Phosphate according to Jafar et al. (2012) enter the groundwater from phosphate-containing rock fertilizers and percolation of sewage and industrial wastes. According to Jafar et al. (2012), phosphate rock which is primarily tricalcium phosphate (Ca3(PO4)2 and apatite, (CaF2.3Ca3(PO4)2) is sparingly soluble in water.

(10) Sodium: The result as presented in Figure 11 show that sodium contents range from 0.008mg/L in Ward4 to 0.083mg/L in Ward10 , the values which were well below 200mg/L upper limit permissible by WHO (2005).

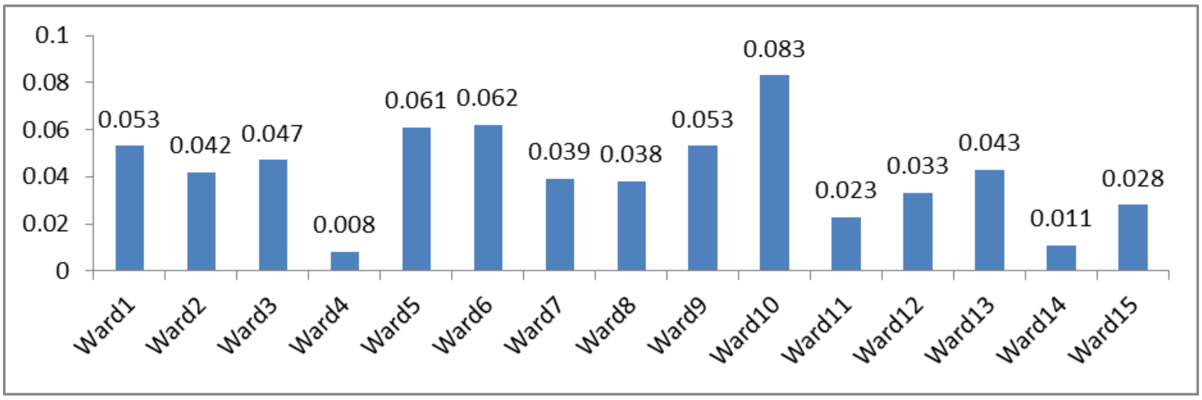

Figure 11. Sodium concentration of the underground water (mg/L)

Sodium plays an important role in the human body according to Jafar et al. (2012). It was further stressed that the flux of these ions through cell membrane and other boundary layers send signals that turn metabolic reactions on and off.

(11) Potassium: The results of potassium concentration as presented in Figure 12 ranges from 0.019mg/L in Ward11 to 0.082mg/L in Ward3.

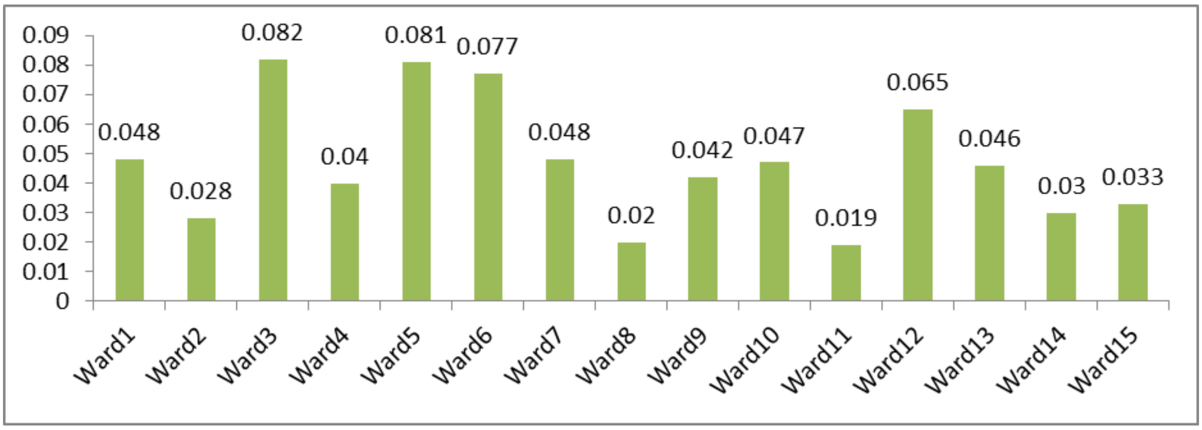

Figure 12. Potassium concentration of the underground water (mg/L)

These equally fall below the maximum limit permissible of 12mg/L by WHO standard. According to Jafar et al. (2012), sodium and potassium concentrations are influenced by the cation exchange mechanism. The results imply that the water is safe for human drinking from the viewpoint of potassium contents. Where the potassium content in water is in excess, the consumption of such water poses a health threat as it may lead to nervous and digestive disorder (Raja and Venketesan, 2010).

(12) Calcium: Jafar et al. (2012) observed that calcium is essential for nervous system and for the formation of bones and teeth. The results showed that the calcium ranges from 0.011mg/L in Ward15 to 0.082mg/L in Ward12. This is presented in Figure 13. These imply that the calcium content in the well water is within the limit recommended by WHO of 75mg/L.

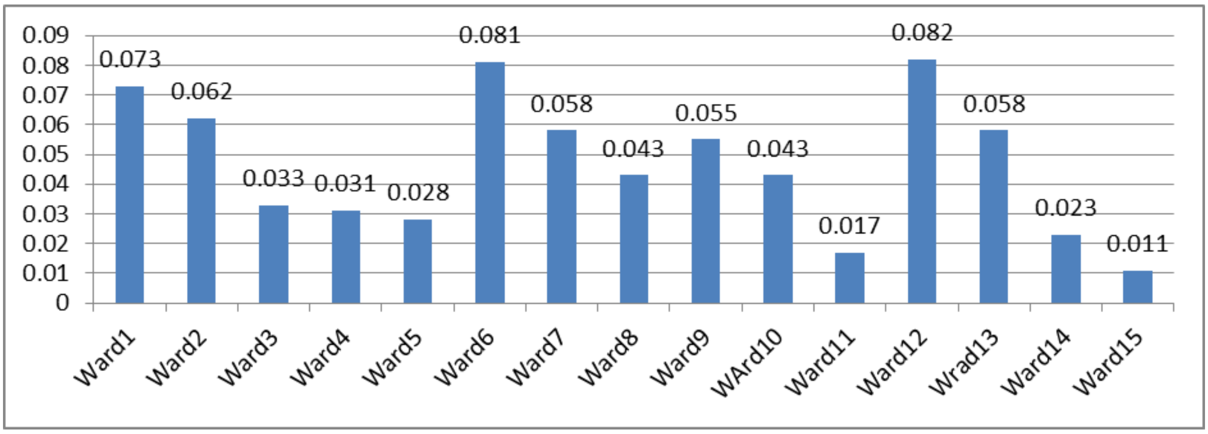

Figure 13. Calcium concentration of the underground water (mg/L)

Calcium ions presence in groundwater is particularly derived from leading of limestones, dolomites, gypsum, and anhydrite. However, calcium ion is also derived from cation exchange process according to Krihnakumar et al. (2009). It is noted that the excess of calcium ion causes kidney or bladder stone and irritation in urinary passages.

(13) Total Coliform: The result presented in Figure 14 show that the coliform count ranges from 0ml/100ml in Ward7, Ward11, and Ward15 to 93ml/100ml in Ward1 and Ward5. The generally high values of the coliform count in the study area are the indication of increasing pollution of the underground sources by organic means especially through the discharge of sewage and domestic effluents into the underground water.

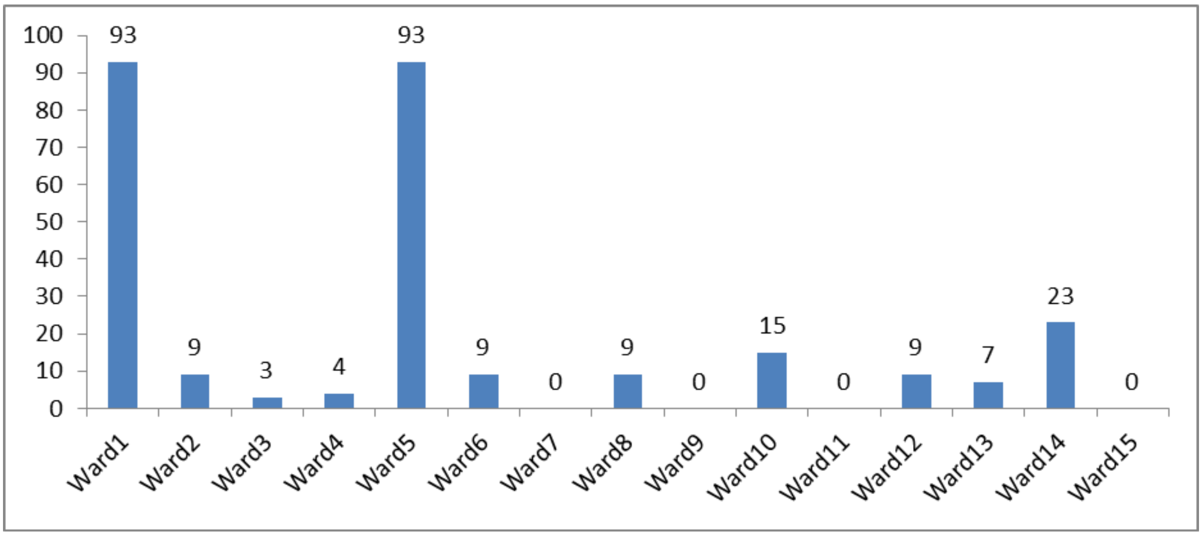

Figure 14. Coliform count of the underground water (100/ml)

This value generally exceeds the limit permissible by WHO (1984), the findings, which suggests that the well water samples examined here are not safe for human consumption (see also Adejuwon et al. (2011) and to Odeyemi et al. (2011).

(14) Total Suspended Solids (TSS): The results shown in Figure 15 show that TSS values range from 0mg/L in Ward7 and Ward13 to 600mg/L in Ward11 well below 500mg/L maximum permissible by Nigerian Industrial Standard (NIS) (2008).

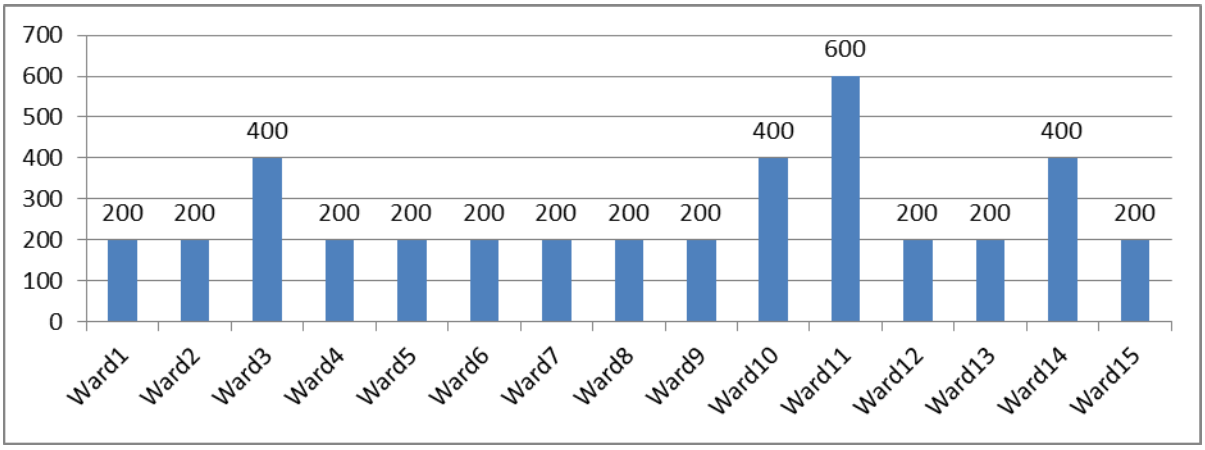

Figure 15. Total Suspended Solids concentration of the underground water (mg/L)

Apart from the value in Ward 11, the TSS is generally low, the result in agreement with Wahab et al. (2012). American Public Health Association (APHA) (1989) had stated that water high in suspended solid may be aesthetically unsatisfactory for bathing. The effect of the presence of total suspended solids in the turbidity due to silt and organic matter. Low TSS concentration in the borehole studied indicates that the water is averagely free of pollutants.

4.1 Sources of pollution to the underground water

The results of factor analysis as presented in Table 2 revealed that the dominant parameters of the underground water in Iwo town are temperature, coliform count, pH, potassium, electrical conductivity and total hardness with their respective factor loadings of 85.6, 80.7, 92.5, 89.7, 92.6, 92.0.

Table 2. Water Quality Factor Loadings and % Variance as generated from Factor analysis

S/No	Water Quality parameter	Loading	% Variance	% Cumulative Variance
1	Temperature	85.6	18.10	18.10
2.	Coliform Count	80.7	16.73	34.85
3.	pH	92.5	15.00	49.83
4.	Potassium	89.7	14.63	64.46
5.	Electrical Conductivity	92.6	12.40	76.86
6.	Total Hardness	92.0	10.50	87.36

Source: SPSS-generated

The 6 physicochemical parameters which were extracted from the 14 parameters analysed dominates the explanation of the quality of the underground water in the study area up to 87.36%. Table 2 shows that temperature contributed 18.10%, coliform (16.73%), pH (15.0%), potassium (14.63%), electrical conductivity (12.40%) and total harness (10.50%). The general implication of this result is that there are contaminations and also leakage of faecal remnants which possibly indicates that the underground sources are close to dumping sites, septic tanks and possibly through erosion. This is also in agreement with the findings of Donga M et al. (2007) and Basamba et al. (2013). Thus, effort should be geared towards minimizing the concentration of these dominant parameters for the safety of man.

5. CONCLUSION

An assessment of the quality of the underground water sources was conducted in Iwo town. The result showed that most quality parameters are within the permissible standard recommended by WHO and NIS. However, there is slight exception especially the temperature and the coliform counts of the water which are generally above the acceptable maximum. Likewise, 6 parameters were extracted by factor analysis namely temperature, coliform count, pH, potassium, electrical conductivity and total hardness. It is suggested that constant monitoring of the water quality is required to checkmate increase in the concentration especially the coliform count. Treatment of the water in the study area is required before consumption in order to safeguard human health.

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