International Journal of Basics and Applied Sciences
Insan Akademika Publications
P-ISSN: 2301-4458; E-ISSN: 2301-8038

Quality Assessment of Shallow Groundwater in Some Selected Agrarian Communities in Patigi Local Government Area, Nigeria

J. J. Musa[1*], and J. J. Ahanonu[2]

[1] Department of Agricultural and Bioresources Engineering,
Federal University of Technology, P M B 65, Minna, Nigeria
jogric2000@yahoo.com,

[2] Research Assistant, Department of Agricultural and Bioresources Engineering,
Federal University of Technology, P M B 65, Minna, Nigeria
josephjohnahanonu@yahoo.com

* Corresponding Author

Abstract *– A study was conducted to determine the biological, chemical and physical drinking water quality from shallow wells in agrarian communities. An in-situ membrane filtration test kit was used to determine the microbiological quality of water and a photometer was used for the chemical analyses. Water samples were collected from protected shallow wells during wet and dry seasons of the year 2012 to determine the change in quality with different seasons. The results of the analysis show that Gapkan had the least value of pH of 6.7 while Lade had the highest value of 8.4. ANOVA (P<0.05) showed pH to be statistically higher during the wet season than in the dry season. The conductivity during the wet season was observed to range between 1210 µS/cm and 1678 µS/cm for Kpada and Gakpan communities respectively. Turbidity values during the wet season ranged between 4 and 7 NTU while dry season analysis ranged between 2 and 3 NTU. Sulphate concentration was the lowest at 431 mg/L in Fey and highest of 532 mg/L at Duro and Rifun Woro during the wet season. Chloride content within the wet season varied between 260 and 269 mg/L while that of the dry season varied between 124 and 130 mg/L. Highest and lowest concentrations of nitrate recorded during wet season was 0.42 and 0.23 mg/L for Kusogi and Fey respectively. The colour observed during the wet season ranged between 17 TCU and 19TCU while that of the dry season ranged between 10 and 13 TCU. Current status of the water in the study areas are fit as source of drinking water for the community, though plans should be put in place for mini treatment plants that can serve these communities to enhance good drinking water delivery..*

Key Words – *Agrochemicals, agriculture, groundwater, potable, wastewater, water, shallow well*

1 Introduction

Water is the essence of life and safe drinking water is a basic human right essential to all (Versari, et. al., 2002). It is essential for the wellbeing of mankind and for sustainable development. Though, necessary for human survival, many are denied access to sufficient potable drinking water supply and sufficient water to maintain basic hygiene. The effects of drinking contaminated water results in thousands of deaths every day, mostly in children under five years in developing countries (WHO, 2004a). Thus, access to safe clean water and adequate sanitation is a fundamental right and a condition for basic health (Palamuleni, 2002). The use of shallow ground water sources for drinking and other domestic purposes is a common feature for many low income communities in developing countries.

Ground water which occurs beneath the earth surface is considered free from contamination, hence usable but anthropogenic as well as natural factors are affecting the quality as well as quantity of this valuable resource. It has been estimated that once pollution enters the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other uses. Therefore, understanding the potential influences of human activity on ground water quality is important for protection and sustainable use of ground water resources (Jehangir, et. al., 2011). Shallow wells are normally located in the valleys where the groundwater table is relatively high (1-4m below ground level) and infiltration of rain and river water plays a main part in groundwater recharge (Pritchard et al., 2008).

Ground water contamination is the result of polluted water infiltrating through the soil and rock and eventually reaching the ground water. This process might take many years and might take place at varying distances from various wells where such contaminations are found. Once the ground water is contaminated, it is very difficult to remediate. No doubt that the new technologies will always reduce the pollution level (Geetha, et al., 2008). Human health, agricultural development and the ecosystems are all at risk unless water and land systems are effectively managed (Kehinde et. al., 2009).

Pollution of ground water refers to any deterioration in the quality of the water resulting from the activities of man. This definition also includes apparently natural processes like saltwater encroachment into freshwater- bearing aquifers in coastal areas resulting from the artificial lowering of ground-water heads. Most pollution of ground water results from the disposal of domestic, municipal and industrial wastes on the land surface, in shallow excavations including septic tanks, or through deep wells and mines; the use of fertilizers and other agricultural chemicals; leaks in sewers, storage tanks, and pipelines; and animal feedlots. The magnitude of a pollution problem depends on the size of the affected area, the amount of the pollutant involved, the solubility, toxicity, and density of the pollutant, the mineral composition and hydraulic characteristics of the soils and rocks through which the pollutant moves, and the effect or potential effect on ground-water use.

Due to the increase in population growth and elevated living standards and coupled with the ever increasing demands for clean water around the world, more water is required for growing environmental concerns such as aquatic life, wildlife refuges, scenic values, and riparian habitats (Li, et al., 2007). The upsurge in population and the establishment of industries involved in the manufacture of various agrochemicals, petrochemical and house-hold products have resulted to the increase in the production of hazardous substances including heavy metals in developing countries (Oguzie and Okhagbuzo, 2010). Application of various agrochemicals and fertilizers for improved and increased agricultural produce can release contaminants of various categories such as nitrate, bacteria, viruses, and hazardous household chemicals to the subsurface, posing potential threats to nearby wells and surface water. The impact of human activities in and around agricultural farmlands is felt on the physical and chemical properties of water on which the sustenance of the various forms of life is dependent upon.

Past and present pollution of land with heavy metals as a result of atmospheric deposition and the application of fertilizer have led to an increase in the levels of heavy metals in the soil of farmland and uncultivated land. These heavy metals of human origin, together with amounts that are naturally occurring in the soil, cause emissions into groundwater and surface water (Bonten and Groenenberg, 2008). Depending on the area under study, underground water quality in basins are based on various factors such as, influx of industrial effluent, influx of water through rainfall, soil, agriculture pattern etc., so we can say that by these factors, the underground water quality can be varied qualitatively and quantitatively.

For most communities, the most secure source of safe drinking water is pipe-borne water from municipal water treatment plants. Often, most of water treatment facilities do not deliver or fail to meet the water requirements of the served community; due to corruption, lack of maintenance or increased population. The scarcity of piped water has made communities to find alternative sources of water: ground water sources being a ready source. Wells are a common ground water source readily explored to meet community water requirement or make up the short fall (Adekunle, 2009).

The lack of safe drinking water and adequate sanitation measures lead to a number of diseases such as cholera, dysentery, salmonellosis and typhoid, and every year millions of lives are claimed in developing countries. Diarrhea is the major cause for death of more than 2 million people per year world-wide, mostly children under the age of five. It is a symptom of infection or the result of a combination of a variety of enteric pathogens (Zamxaka et. al., 2004).

The use of physic-chemical properties of water to assess water quality gives a good impression of the status, productivity and sustainability of such water body (Mustapha, 2008). The evaluation of potable water supplies for coliform bacteria is important in determining the sanitary quality of drinking water (Zamxaka et. al., 2004).

The aim of this study is to evaluate the sources of potable water from the different locations in Patigi Local government area of Kwara State and to clarify the concerns about the quality and safety of water used as drinking water within the locality.

2 Methodology and Materials

2.1 Study site

Patigi is one of the sixteen local government areas of Kwara State, north central area of Nigeria. The surface mean annual temperature ranges from 24 to 41^{0}C and the mean annual precipitation of 86 – 1100 mm (IMS, 2011). The vast area has a population of 600,000 (NPC, 2009). The area is one of the largest fadama lowland areas of the State with river Niger as a major water source for irrigation and other farming activities. The most common sources of drinking water are mainly open wells, water vendors and boreholes which are mostly not functional. Due to the rural nature of the study area, pipe-borne water is not provided for in most of the communities except in Patigi Township which is not supplied for domestic use on regular bases. The quality of water supplied by water vendors cannot be guaranteed.

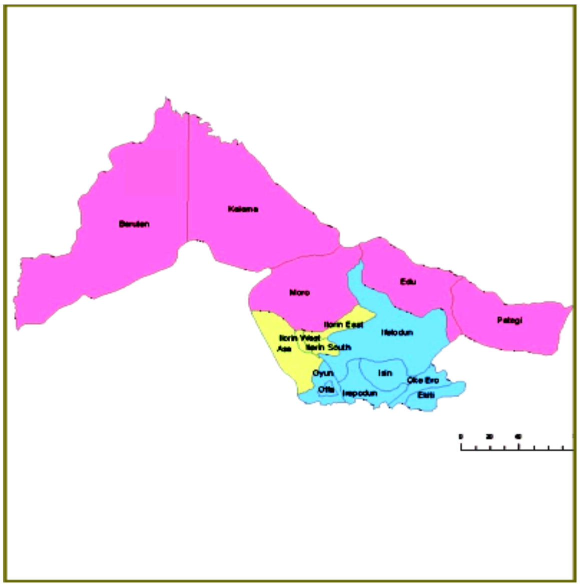

Figure 1: Map of Kwara State

Existing wells within some selected communities were high rates of agricultural activities are known to take place and farm locations were not far from the residential areas of the farmers were considered. The areas covered during the study period are presented in Table 1 below.

Table 1: Areas covered during the study period in Patigi Local Government Area of Kwara State.

S/no	Location	Sample Label	No of samples collected
1	Gakpan	G	4
2	Duro	D	4
3	Kapda	K	4
4	Kusogi	K_u	4
5	Sokingi	S	4
6	Patigi	P	4
7	Lade	L	4
8	Rifun Woro	R_w	4
9	Tankpafu	T	4
10	Fey	F	4

This area is characterized by extensive agricultural operations located in low-relief basins underlain by shallow, alluvial aquifers of River Niger. The most widespread and common type of crops grown in these areas are cereal crops. Farm operations in this region are family owned arable farms with an average land size of nearly 10 acres some of which are irrigated during the dry season.

2.2 Sample Collection and Analysis

Samples were collected in clean 1.5 liter plastic jars with screw caps and labeled with appropriate codes of the first letter of the name of the community and then a number ranging between 1and 4 depending on the total number of samples collected from the location. Some parameters such as pH, electrical conductivity and Total dissolved solids, total hardness, calcium, magnesium, chloride, nitrate and sulfate were determined using standard methods for examination of water samples quality.

The in situ parameters, pH, electrical conductivity and total dissolved solids were measured using potable digital meter, EXTECH pH-100 and HM digital EC/TDS/Temperature COM-100. Total hardness, calcium and chloride were determined using titrimetric method. Nitrate and sulfate was determined using HACH DR/2000 direct reading spectrophotometer. Total solids and magnesium were determined by gravimetric and Atomic absorption spectrophotometer (AAS), respectively (Balogun et al., 2012). Water samples intended for chemical analyses were vacuum filtered through 0.45-lm nylon membranes. Samples intended for dissolved metal analyses were preserved with concentrated nitric acid, and all samples were kept on ice until they could be refrigerated. Field duplicates were collected on three occasions. Samples collected for isotopic analyses were filtered, frozen, and shipped overnight to the lab. Isotope analyses have been used in a number of previous studies as a tool for identifying nitrate sources (Wilcox et. al., 2005).

The samples were chemically analysed at the Water Laboratory of the Federal Ministry of Water Resources in Minna, Nigeria. The instrument performance check solutions and calibration blanks were analyzed for every 10 samples. Alkalinity was measured by titration with hydrochloric acid according to Standard Method 2560 (American Public Health Association, American Water Works Association, and Water Environment Federation 1995a).

3 Results and Discussion

Surveillance of water quality to ensure microbiological and chemical safety is a vital public health function most especially in our local and small communities as most of the agricultural products and local labour are from there. Four sets of results were collected each for the two identified season (wet and dry) in the year 2012. Almost all the water samples collected from shallow wells showed evidence of previous human impact on the basis of these constituents. Although most of the parameters tested had higher concentrations than average values of WHO (2004b) and NSDWQ (2007). The physco-chemical properties of water from the various wells used for domestic purposes in the various agrarian communities were analyzed during the dry and wet seasons of the year 2012. The results obtained are presented in Tables 2 and 3.

Table 2: Average Physico-chemical parameters determined during wet season for the year 2012

Parameters and units	Samples and location										Water Quality Standard	
	Gakpan	Duro	Kpada	Kusogi	Sokingi	Patigi	Lade	Rifun Woro	Tankpafu	Fey	WHO	NSWDQ
Temperature (^{0}C)	32	33	35	33	32	33	35	34	34	36	Ambient	Ambient
pH	6.7	7.3	7.4	7.8	7.9	8.1	8.4	8.3	8	7.6	8.5	6.5-8.5
Conductivity (µS/cm)	1678	1450	1230	1210	1658	1230	1562	1653	1548	1340	1000	1000
Turbidity (NTU)	4	6	6	7	5	6	5	6	5	6	5	5
Sulphate (mg/L)	550	532	561	556	531	532	533	532	527	531	500	400
Suspended solid (mg/L)	460	428	380	425	478	385	437	461	462	434	400	500
Chloride (mg/L)	260	269	263	267	269	269	260	264	267	268	250	NS
Ca^{2+} (mg/L)	268	297	247	268	284	258	259	258	258	258	250	NS
Chromium (mg/L)	0.057	0.065	0.06	0.055	0.054	0.051	0.054	0.053	0.045	0.055	NS	0.05
Magnesium (Mg^{2+}) (mg/L)	0.03	0.04	0.02	0.03	0.03	0.03	0.04	0.03	0.05	0.045	0.05	0.02
Sodium (mg/L)	230	240	198	256	275	301	300	253	213	238	NS	200
Potassium (mg/L)	312	301	298	320	301	256	300	306	375	406	200	NS
Zinc (mg/L)	2	2.4	2.6	2	1.5	2.9	3	2.7	3.6	3.5	5	3
Nitrate (mg/L)	0.3	0.35	0.38	0.42	0.29	0.27	0.24	0.26	0.28	0.23	0.2	0.2
Copper (ppm)	0.88	0.86	0.87	0.97	0.59	0.68	0.98	1	1.1	0.75	1.3	1
Iron (mg/L)	0.35	0.28	0.41	0.32	0.31	0.33	0.32	0.35	0.31	0.32	0.3	0.3
Cadmium(ppm)	0.0045	0.041	0.043	0.042	0.039	0.035	0.014	0.014	0.012	0.014	0.005	0.003
Lead (ppm)	0.019	0.019	0.018	0.012	0.018	0.01	0.014	0.015	0.014	0.012	NS	0.01
Colour (TCU)	19	18	19	19	17	18	18	19	19	17	15	
Odor	O	O	O	O	O	O	O	O	O	O	UO	UO
Hardness (as $CaCO_3$) (mg/L)	250	230	245	250	254	276	180	198	200	202	NS	150
E. Coli count (cfu/mL)	2	1.7	1.8	2	2	2.3	2.3	1.7	2	1.6	NO	10

Table 3: Average Physico-chemical parameters determined during dry season for the year 2012

Parameters and units	Samples and location										Water Quality Standard	
	Gakpan	Duro	Kpada	Kusogi	Sokingi	Patigi	Lade	Rifun Woro	Tankpafu	Fey	WHO	NSWDQ
Temperature (^{0}C)	47	47	46	46	47	47	46	47	46	46	Ambient	Ambient
pH	6.9	7.3	7.1	7.2	7.2	7.4	7.8	7.6	7.4	7.6	8.5	6.5-8.5
Conductivity (µS/cm)	1176	1098	1056	1210	1256	1076	1232	1256	1324	1231	1000	1000
Turbidity (NTU)	3	3	2	2	3	3	2	3	3	3	5	5
Sulphate (mg/L)	289	350	231	249	321	362	363	352	287	311	500	400
Suspended solid (mg/L)	248	312	256	312	267	298	372	312	321	344	400	500
Chloride (mg/L)	130	129	129	127	129	129	130	124	127	128	250	NS
Ca^{2+} (mg/L)	241	253	212	246	234	216	218	128	197	258	250	NS
Chromium (mg/L)	0.035	0.032	0.041	0.04	0.047	0.039	0.039	0.041	0.031	0.027	NS	0.05
Magnesium (Mg^{2+}) (mg/L)	0.021	0.032	0.017	0.024	0.024	0.021	0.032	0.021	0.041	0.037	0.05	0.02
Sodium (mg/L)	176	185	169	181	183	187	198	179	185	197	NS	200
Potassium (mg/L)	187	157	182	162	171	140	182	198	198	194	200	NS
Zinc (mg/L)	0.79	1.5	1.2	1.6	1.4	1.2	1.9	1.7	1.8	2.1	5	3
Nitrate (mg/L)	0.17	0.11	0.13	0.11	0.15	0.11	0.12	0.11	0.11	0.18	0.2	0.2
Copper (ppm)	0.82	0.81	0.75	0.87	0.61	0.61	0.97	0.77	0.95	0.68	1.3	1
Iron (mg/L)	0.25	0.18	0.21	0.32	0.21	0.33	0.3	0.25	0.28	0.27	0.3	0.3
Cadmium(ppm)	0.0025	0.0041	0.0043	0.0042	0.0039	0.0035	0.0032	0.0035	0.0024	0.0012	0.005	0.003
Lead (ppm)	0.009	0.009	0.008	0.012	0.008	0.01	0.014	0.015	0.014	0.012	NS	0.01
Colour (TCU)	12	12	10	13	12	13	13	12	12	10	15	
Odor	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO
Hardness (as $CaCO_3$) (mg/L)	142	143	143	146	147	143	149	146	148	143	NS	150
E. Coli count (cfu/mL)	0	0	0	0	0	1.7	1.8	0	0	0	NS	NS

Where UO means unobjectionable, O means objectionable and NS means Not Specified

3.1 Temperature

The temperature wet season ranged between the lowest value of 32 °C which were obtained from Gakpan and Sokingi respectively while maximum temperature during the wet season was observed in Fey which could be attributed the nature of the soil within the area as the most common type of soil here is the red clay type. The highest of 46 and 47 ^{0}C of temperature was observed during the dry season for almost areas under consideration. Dry season temperature was significantly higher ($P<0.05$) than the wet season. It was observed that all the temperatures were within the ambient temperature range that which is recommended by both WHO (2004b) and NSDWQ (2007).

3.2 pH and Alkalinity

The acidity or basicity of domestic water is expressed as pH (< 7.0 acidic; > 7.0 basic). The normal pH range for domestic or drinking water is from 6.5 to 8.5 according to WHO (2004b) and NSDWQ (2007). The pH ranged between 6.7 and 8.4 during the wet season of the year 2012. Gapkan had the least value of pH of 6.7 while Lade had the highest value of 8.4. During the dry season, the pH values in Gakpan increased from 6.3 to 6.9 which also was the lowest pH value while others were observed to reduce in the pH values. The highest value of pH recorded during the dry season was 7.8 for Lade community. ANOVA ($P<0.05$) showed pH to be statistically higher during the wet season than in the dry season. The values generally were found to be within the recommended range for WHO and NSWDQ respectively for both seasons. Abnormally low pH's are not common in Nigeria, but where observed to occur it may cause accelerated corrosion of the various metal mediums which the water may be stored for future use. High pH's above 8.5 are often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution.

3.3 Conductivity

The variations in conductivity during the wet season was observed to range between 1210 µS/cm and 1678 µS/cm while during the dry season the average values of electrical conductivity ranged between 1056 and 1324 µS/cm for Kpada and Tankpafu agrarian community respectively. When the results were compared with the recommended values of WHO (2004b) and that of NSWDQ (2007), it was observed that all the values for both the wet and dry seasons were found to be higher than the recommended values of WHO and NSWDQ. This shows that most of the water considered for domestic purpose was discovered to have high salt content which supports the conduction of electricity in the various water samples tested. This may also be attributed to the high rate of chemical and fertilizer application to the various agricultural lands. Some of which are retained in the soil while others are dissolved into the various water bodies in the area and they in turn find there ways into the various wells. Thus, the high rate of electric conductivity.

3.4 Turbidity

Turbidity values during the wet season ranged between 4 and 7 NTU while that of the dry season ranged between 2 and 3 NTU. It was observed that wet season for the 2012 had a high rate of impurities flowing into the various open wells which were observed to be poorly lined with Kusogi having the highest value of 7 NTU and Gakpan having the lowest of 4 NTU. Clarity of water is said to be a major factor in consumer satisfaction. Thus, turbidity has been used over many years as an indicator of drinking water quality and as an indicator of the efficiency of drinking water coagulation and filtration processes. Thus the results obtained from the ten study wells during the wet season for the year 2012 were found to be higher than the recommended values of WHO (2004b) and NSWDQ (2007) while the results obtained for the dry season were below the recommended values of the two regulatory bodies. In general this result corresponds with the works of Zamxaka et al., (2004). Turbidity has been described as a relatively crude method of detecting a wide variety of particles from a wide assortment of sources as it provides no information about the nature of the particles. Turbidity in water is caused by the presence of colloidal and suspended matter (such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms). The added presence of turbidity increases the apparent, but not the true colour of water.

3.5 Sulphate

The fluctuations in the average sulphate concentration in wells of selected agrarian community in Patigi Local Government area of Kwara State can be observed in the Tables 2 and 4. Sulphate concentration was the lowest at 431 mg/L in Fey and highest of 532 mg/L at Duro and Rifun Woro respectively during the wet season. It was further observed that the sulphate content of most of the wells studied were relatively lower values compared with the recommended standard of WHO (2004b) and NSWDQ (2007). The values observed during the dry season were observed o be below the recommended values of both WHO and NSWDQ. Kpada had the lowest sulphate value of 231 mg/L which goes to confirm that the community is not close to any water body which could transfer this chemical into the various wells within the community. The average highest value of 363 mg/L was obtained from the Lade community. Sulphate was significantly higher in the wet season, while the order of averagely higher concentration among the agrarian communities are Duro, Rifun Woro, Sokingi, Tankpafu, Kpada, Kusogi, Gapkan, Lade, Patigi and Fey.

Sulfate is a naturally occurring anion. High concentrations of sulfate in drinking water may cause transitory diarrhea (U.S. Environmental Protection Agency, 1990b). However, toxicity is rarely a problem, except at very high concentrations where high sulfate may interfere with uptake of other nutrients. Sulphate in irrigation water has fertility benefits, and irrigation water in Colorado often has enough sulphate for maximum production for most crops.

3.6 Suspended Solids

Sediment is usually measured as a concentration of Total Suspended Solid (TSS).The TSS concentration was found to be remarkably high in all the wells within the agrarian communities considered for this study. During the wet season, TSS ranged between 527 and 550 mg/L which can be attributed to the nature of soil within the areas. During the dry season, it was observed that TSS was generally low. The highest value of TSS during the dry season was 372 mg/L in Gapkan community while the lowest value was 248 mg/L in Gapkan. All the samples for the wet season were found to be off the range of the recommended values for WHO (2004b) and NSWDQ (2007) while those of the dry season were within. This finding followed a similar trend with the works of Adejuwon and Adeniyi (2011).

3.7 Chloride

In this study, chemical analysis revealed presence of high concentrations of chloride in water from the shallow wells during the wet season which is manifested through the saltiness of water from wells. Chlorides are present in all waters with sources ranging from sedimentary rocks (particularly the evaporates), Salt 'seeps', oil field drainage, domestic and industrial contaminants (Adejuwon and Adeniyi, 2011). According to Bello and Makinde (2009), the chosen locations are located within the

Nupe basin area which may likely account for the chloride content within the various wells under consideration. The chloride content within the wet season varied between 260 and 269 mg/L while that of the dry season varied between 124 and 130 mg/L. When these values were compared with those of the recommended values of WHO (2004b) though that of NSWDQ was not available, it was observed that the values obtained during the wet season were higher than that of WHO while during the dry season the values were relatively low. Chloride is one of the constituents found in human excreta. Like nitrate, the chloride in the samples could be possibly traced to fecal contamination of shallow wells. Chloride increases with fecal coliform which is significant to coliform count.

3.8 Nitrate

The highest mean concentration of nitrate recorded during the wet season was 0.42 mg/L which was obtained from Kusogi while the lowest average recorded value of 0.23 mg/L was obtained for Fey. Though, the amount of nitrates determined during wet season was relatively higher when compared with the recommended values of WHO (2004b) and NSWDQ (2007). This can be attributed to high rate of inorganic fertilizer and chemical application on the surrounding farmlands. On the overall, the nitrate content during the wet season was found to be higher when compared with the recommended values of WHO and NSWDQ.

A decrease as observed generally in the dry season with the lowest concentration of 0.17 mg/L recorded from Lade, where high rate cereal crop plantation is practiced. ANOVA at $P<0.05$ shows significant difference in the nitrate concentration during the seasons and within the various communities. Nitrate was higher in the rainy season and the order of magnitude in the concentration among the communities was Fey, Lade, Rifun Woro, Patigi, Tankpafu, Sokingi, Gakpan, Duro, Kpada and Kusogi.

Nitrate is one of the major anions in natural waters, but concentrations can be greatly elevated due to leaching of nitrogen from farm fertilizers. The mean concentration of nitrate nitrogen (NO -N, nitrate measured as nitrogen in testing) in a typical surface water supply would be around 0.2 to 2 mg/L; however, the individual wells considered in this study showed a significantly higher concentrations during the wet season with a slight reduction during the dry season.

3.9 Colour

The appearance of water can be a significant factor in consumer satisfaction. Low levels of colour and turbidity are also important for drinking water. The colour observed during the wet season ranged between 17 TCU and 19TCU while that of the dry season ranged between 10 and 13 TCU. The colour for wet season was observed to be higher than the recommended value of WHO (2004b) while NSWDQ regulatory body in Nigeria did not have a recommended value. Fey and Sokingi had the least colour value during the wet season while communities such as Gapkan, Kpada, Kusogi and Rifun Woro had 19 TCU colour rating all as against the recommended value of 15 TCU by WHO (2004). The sources of colour in water can include natural metallic ions (iron and manganese), humic and fulvic acids from humus and peat materials, plankton, dissolved plant components, iron and sulfur bacteria, and industrial wastes or the dissolved soil particles within the area as most of the soil in this area are either clay or loam soils. This is in conformity with the works of Adejuwon and Adeniyi (2011).

Pure drinking and domestic water is a colourless liquid. Therefore, colour in water is suggestive of the presence of foreign, water-soluble substances (organic and inorganic). Thus the coloured appearance of water obtained from the shallow wells during the wet season from the ten study areas suggest contamination, which may have its origins in dissolved products of the decay of dead natural vegetation as rainwater infiltrates to the groundwater table or it may be due to surface runoffs making input into poorly covered or lined wells.

3.10 Hardness

Hardness is generally defined as the sum of the polyvalent cations present in water and expressed as an equivalent quantity of calcium carbonate ($CaCO_3$). The most common such cations are calcium and magnesium. This can also be defined to be a measure of the capacity of the water for precipitating soap. It is this aspect of hard water that is the most perceptible to consumers. From the various samples collected during the wet season, it was observed that it ranged between 180 and 276 mg/L for $CaCO_3$. These values were found to be higher than the recommended value of NSWDQ (2007) which is stated to be 150 mg/L $CaCO_3$ while the WHO (2004b) did not have any specified value. Wells in Patigi township recorded the highest value of water hardness value of 276 mg/L $CaCO_3$ while Lade had the least value of 180 mg/L $CaCO_3$. The other agrarian had varying values, though areas with such high value of hardness were observed to be highly involved in agricultural activities which imply that more chemical application in the area. Those having between 75 and 150 mg/L CaCO3 are said to be moderately hard. Those having from 150 to 300 mg/L $CaCO_3$ are hard, and waters having more than 300 mg/L $CaCO_3$ are classified as very hard. Calcium is of importance as a component of scale.

3.11 Cadmium

The various communities considered for this study are areas which are mostly without electricity power supply, thus much batteries are used to power most of their electrical appliances. At the expiration of these sources of power supply, they are discarded anywhere within their vicinity. Cadmium occurs as an impurity in zinc which is mostly used as roofing materials in all the communities. Due to reactions of rain water with these roof materials (iron zinc), some of the dissolved materials find their way into the surrounding open shallow wells thus increasing the presences of cadmium.

During the wet season, cadmium values ranged between 0.0045 and 0.043 ppm. The values in communities like Kpada, Kusogi, Sokingi and Patigi were found to be high; this can be linked to their proximity to a mining location in the area. When the values obtained were compared with the recommended values of WHO (2004b) and NSWDQ (2007), the obtained values were observed to be higher than the recommended ones. The dry season values ranged between 0.0012 and 0.0043 ppm. The observed values were found to be below the recommended values of WHO and NSWDQ. This reduction in values of the dry season shows that the high rate of runoff and infiltration activities occurring within the communities during the wet season the higher values of cadmium.

3.12 Chromium

Primary sources of chromium in water is usually from mining areas, wastes from electroplating operations which is not a practice in the all the communities considered for this study, and garbage or refuse dump sites which is very much common in all the study areas. The chromium values during the wet season ranges between 0.045 and 0.065 mg/L while that of the dry season ranged between 0.032 and 0.047 mg/L. It was observed that the values obtained during the wet season were slightly higher than the recommended value of NSWDQ (2007) though no recommended value for WHO (2004b) was observed. The obtained values during the dry season were observed to lower compared to the value of NSWDQ (2007). This could be linked also to the rate of runoff and infiltration activities within the various communities.

Chromium in excess is toxic thus leading to liver and kidney damage, internal hemorrhage, and respiratory disorders, as well as causing cancer in humans and animals through inhalation exposure, but it has not been shown to be carcinogenic through ingestion exposure (U.S. Environmental Protection Agency, 1985a; U.S. Environmental Protection Agency, 1991e).

3.13 Copper

Copper is commonly found in drinking water (U.S. Environmental Protection Agency, 1985a) though it is a nutritional requirement. Lack of sufficient copper leads to anemia, skeletal defects, nervous system degeneration, and reproductive abnormalities. During the wet season the obtained values from the study areas ranges between 0.59 and 1.10 ppm while during the dry season it ranges between 0.61 and 0.97 ppm. These values were observed not to be higher than recommended values of 1.3 ppm for WHO (2004b) and 1.0 ppm for NSWDQ (2007). When the values were further compared against the seasons, it was observed that the values obtained during the wet season were higher than that of the dry season. Thus the values were not statistically significant.

3.14 Lead

Lead occurs in drinking water primarily from corrosion of lead pipe and solders and faucets constructed with leaded brass, especially in areas of soft or acidic water. The values obtained during the wet season ranged between 0.01 and 0.019 ppm while that of the dry season ranges between 0.008 and 0.015 ppm. When the values obtained for both seasons were compared with the standards of WHO (2004b) and NSWDQ (2007), it was observed that the values obtained during the wet season were higher while that of dry season was found to be below the recommended values which again could be linked to the effect of runoff and infiltration activities.

Health effects of lead are generally correlated with blood test levels. Infants and young children absorb ingested lead more readily than do older children and young adults. Lead exposure across a broad range of blood lead levels is associated with a continuum of pathophysiological effects, including interference with heme synthesis necessary for formation of red blood cells, anemia, kidney damage, impaired reproductive function, interference with vitamin D metabolism, impaired cognitive performance, delayed neurological and physical development, and elevations in blood pressure (U.S. Environmental Protection Agency, 1988b).

3.15 Iron

The values of iron concentration in all the shallow groundwater bodies considered for this study during the wet season ranged between 0.28 and 0.41 mg/L. Only the Duro community wells had low iron content which fell within the WHO and NSWDQ recommended values of 0.3 mg/L. During the dry season, the values of iron from the study area ranged between 0.18 and 0.33 mg/L. Patigi community was observed to have the highest value of 0.33 mg/L which could be attributed to the washing of some iron materials around the edges of the well which will find their ways into the same. All fell within the WHO and NAFADC permissible limit for samples analyzed during the dry season. The samples analyzed during the wet season was significantly higher ($p<0.05$) than that of the dry season but still within the permissible limit of 0.3 mg/L that is based on taste and appearance rather than detrimental health effect with an exception to that of Patigi. Iron is not considered hazardous to health. In fact, instead it is an essential element for good health because it transports oxygen in the blood. Iron is considered a secondary or aesthetic contaminant (WHO, 2004b).

3.16 Zinc

Zinc commonly occurs in source waters and may leach into finished waters through corrosion of galvanized metal roofing sheets which mostly used in these communities. The zinc content during the wet season ranged between 3.5 and 5.4 mg/L while during the dry season it ranges between 0.79and 2.1 mg/L. Some of the obtained values for the wet season were found to be within the recommended values of WHO but above that of NSWDQ. The average value of the wells in Duro community had a high zinc content of 5.4 mg/L. The values obtained during the dry season were within the recommended ranged of value of both WHO and NSWDQ. Drinking water containing zinc typically contributes the basic requirement of 15 mg/L for male and 12 mg/L for female as recommended by WHO.

3.17 Sodium

The result shows that concentration of sodium (Na^+) was in the range of 198 mg/L at Kpada to 301 mg/L at Patigi during the wet season while during the dry season the concentration ranged between 169 mg/L at Kpada to 198 mg/L at Tankpafu. There is a significant relationship between the values of wet season and that of the dry season. Water containing sodium (Na^+) is in some cases absorbed by the soil. Such soils containing large proportion of sodium (Na^+) with carbonate and chloride or sulphate are termed as alkali or saline water, respectively. Sodium is a naturally occurring constituent of drinking water. Food is the major source of sodium. Of a suggested maximum daily intake of 2400 mg, drinking water, at a typical concentration of 20 mg/L, contributes less than 2 percent, assuming consumption of 2 L/day. Average adult intake is 10,000 mg/day.

3.18 Microbiological Water Quality

Microbiological water quality results show that the water is polluted with traces of E. coli during the wet season with the values ranging between 1.6 and 2.3 cfu/mL. Patigi and Lade had the highest value of 2.3 cfu/mL which may be because of the population in the two communities as it is the commercial nerve centers for the local government area. During the dry season, E. coli count in the communities considered were observed to be zero except for Patigi and Lade which had values of 1.7 and 1.8 cfu/mL respectively. This is in conformity with the works of Fasunwon et al., (2008); Oludare and Sikiru (2012); and Faparusi et al., (2011).

In terms of total coliform, the results show that approximately 100% of the shallow wells tested in the dry and wet season did meet the drinking water guidelines set by WHO and NSWDQ with maximum of 50 TC/100ml for untreated water. All the wells studied met the standard in at least three of the four samples. There was a noticeable increase in the number of coliform counts in the wet season compared to the dry season. This increase could be attributed to the fact that pollutants are easily transported to water points by rain water.

4 Conclusion

Underground water is believed to be the purest form of water because of the purification properties of the soil, however, source of contamination could be due to improper design and construction of wells, shallowness, and proximity to toilet, refuse dump sites, and agricultural farm sites which serve as source of contamination. Thus, proper well location is essential, good sanitation of environment and control of human and agricultural activities that affect quality of drinking water. Water quality should be controlled in order to minimize acute problem of water related diseases. Domestic treatment of borehole water is also an essential means of improving water quality and regular cleaning of water reservoirs with appropriate cleaning reagents. Constant monitoring of water quality stands as a good mean of detecting earlier the deviation of drinking water from the standard.

It was observed that the wells were all located within the residential area of the various communities; traces of agricultural chemical contaminants were seen during the wet season which most were still within the WHO and NSWDQ limits while during the dry season the amount of these parameters reduced.

Thus, it is concluded that with the current status of the water in the various communities considered for this study is fit as a source of drinking water for the community, though plans should be put in place for mini treatment plants that can serve these communities to enhance good drinking water delivery.

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