LAUTECH Journal of Civil and Environmental Studies
Volume 6, Issue 1; March 2021
DOI: 10.36108/laujoces/1202.60.0121

Hydrochemistry and Quality assessment of Groundwater from Constituency Water Projects, Pategi Local Government Area

[1]Gana, A. J., [1]Ibitogbe, E. M, [1]Ejigboye O. P, [1]Osagie-Asabor, E. J and [2]Amodu, M. F.

[1] Department of Civil Engineering, Landmark University, Omu-Aran, Kwara State, Nigeria.
[2] Department of Agric and Bio Systems Engineering. Landmark University, Omu-Aran, Kwara State Nigeria.

Corresponding E-mail: gana.abu@lmu.edu.ng

Submitted on: 18/12/2020; *Accepted on: 01/03/2021*

Abstract
Water is vital for life sustenance hence adequate, safe and *accessible supply must be made available to all. The remote village of Tankpaful located in the town of Pategi has recently witnessed the installation of new boreholes to harness groundwater as an improved source of drinking water. However, there is no known information about the quality of these sources. Hence, this paper aims to investigate the quality of groundwater samples from these boreholes in terms of their physico-chemical, heavy metals* and *biological parameters* and *also provide baseline information about the nature of the underground aquifer in this community. Groundwater samples (n=20) were obtained from* r*andomly selected boreholes in the study area* and *examined for their physicochemical, heavy metal* and *biological parameters following standard procedures recommended by the American Public Health Association* and *compared to guideline values. Pearson's correlation test was done to examine the relationship between measured parameters. With the exception of pH (5.58)* and *total hardness (296.99mg/L), all physico-chemical parameters were within guideline values specified by the WHO* and *SON. For heavy metals, mean values for Iron (0.32mg/L), Chromium (0.22mg/L)* and *Nickel (0.4mg/L) were found to exceed the given standard limits as well. The findings revealed that boreholes were mainly acidic which could be of natural origin such as mineral dissolution. Based on correlation analysis, the major mineral groups contributing to total hardness is the K-Cl group (1.00). We recommend that regular monitoring should be done to ensure guideline values are not breached while residents should be educated on the need to maintain these water sources to prevent deterioration.*

Keywords: Groundwater, Water quality, Health implications, Hydrochemistry, Tankpaful, Pategi.

Introduction
Access to potable and safe water in addition to adequate sanitation and hygiene is necessary for sound health, environmental sustainability and economic prosperity (United Nations, 2017). Groundwater serves as a major global source for drinking, irrigation and industry (Brindha and Elango, 2012). It is an important natural source that serves many people, especially in developing countries, as a reliable source of drinking water. Groundwater is generally considered to be much cleaner than surface water. However, several factors such as discharge of industrial, agricultural and domestic wastes, land use practices, geological formation, rainfall patterns and infiltration rate affects the groundwater quality and once contamination of groundwater in aquifers occurs, it persists for hundreds of years because of very slow movement in them (Patil and Patil, 2011). Groundwater is often consumed without treatment which poses threat to the health of its users (Abatneh *et al*., 2014). Poor water quality can cause disease outbreak, which contributes to the rates of ill health conditions of any community (Hunter *et al.*, 2010). Providing safe drinking water is a very crucial task that communities in the African continent are faced with (Salami *et al.*, 2014). It has the highest

number of persons with no access to potable water (Armah *et al.*, 2018). The World health organization has reported an annual mortality rate for an estimated 3.4 million persons who die from water sanitation and hygiene related causes, the majority of them being from Africa (World Bank, 2010). Thus, assessment of groundwater quality based on health and safety regulations specification before domestic use is highly imperative. Many laboratory procedures and tools involving parameter evaluation of groundwater resources such as pH, acidity, temperature, salinity, turbidity, alkalinity, electrical conductivity, total soluble solids (TSS), total dissolved solids (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO) and heavy metal concentration have been previously applied (Edwin *et al.*, 2015; Rahmanian *et al.* 2015; Dissmeyer 2000). It is believed that estimated parameters with concentrations higher than those specify by the World Health Organization (WHO) and other health regulatory bodies suggest poor drinking water quality (WHO 2011). This great challenge has motivated researchers and governmental agencies around the globe to engage in series of investigations (Tuzen and Soylak 2006; Heydari and Bidgoli 2012).

Tankpaful is a remote village located in the town of Pategi *"small hill"* which is one of the largest fadama lowlands in Kwara state with River Niger as the primary source of water. Abstraction of water from hand-dug wells has been their major source of drinking water until very recently when boreholes were installed to provide improved source of water. Hence, this paper investigates the quality of groundwater from these boreholes in terms of their physico-chemical, heavy metals and biological parameters and also provide baseline information about the nature of their underground aquifer.

Materials and Methods

Tankpaful is small village located in Pategi Local Government Area of Kwara state and about 3 km away from the local government headquarters. It is centred at geographical coordinates of Latitude 8°43′59"N and Longitude 5°45′00"E. It is home to the Nupe tribe who exhibit a linguistic repertoire of the Yoruba dialect. Their economic activities include farming and fishing due to proximity to the River Niger. However, there are also a sizable number of civil servants in the community. The dominant topography is marked by the peneplain of the Niger River Trough producing a level land surface across the study area.

Geology and Hydrogeology of the study area

The geology of the entire region is such that it entails exposures of alternating sandstones, shales, siltstones, claystones and directly overlays the basement formation (Obaje, 2009). The basement formation is the Pre–Cambrian to lower Paleozoic basement gneisses and schist.The sandstone (Nupe) consists of fine and coarse grained sandstones and siltstones interlaced with thin beds of carbonaceous shales and clays (Megwara and Udensi, 2014). According to Bello and Makinde, (2007), the study area is characterized by secondary permeable formations with the following lithology; laterite, sandy clay/clayey sand, fractured basement and fresh basement rocks as shown in figure 1. Borehole log reports (carried out in 1998 by UNICEF-RUWATSAN project) also confirm the northern and central parts of Pategi Local Government Area to be predominated by porous and permeable formations due to Sandstone deposits (Bello and Makinde, 2007).

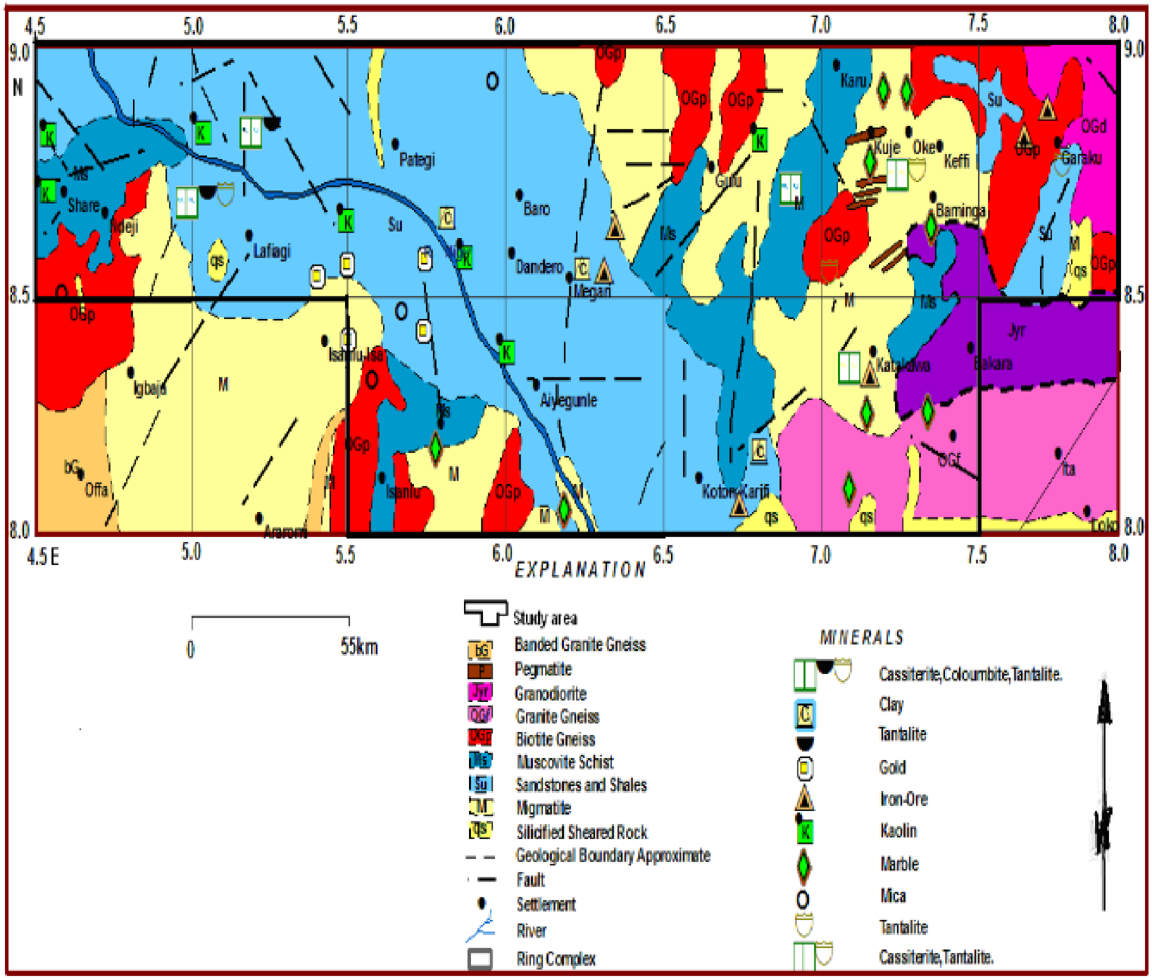

Figure 1: Geological and mineral map of the study area (Adapted from Megwara and Udensi, 2014).

Sample collection

The sampling exercise was done during the beginning of rainy season (May, 2020). Water samples were collected from randomly selected boreholes (n=20) which were allowed to run for 5 to 10 minutes before filling the prewashed with dilute HNO_3 and distilled water bottles. and subsequently analyzed for different water quality parameters. The standard method recommended by the American Public Health Association (APHA 2005), to ensure quality and consistency of data, was followed during the sample collection, handling, preservation and analysis. The analytical tests were carried out at the Environmental Laboratory of Landmark University, Omu-Aran, Kwara State.

Physico-chemical and Heavy metal determination

All chemical reagents used in these analyses were of analytical grade and careful calibration of instruments was done prior to the analyses. A total of 28 water quality parameters was analyzed. The Temperature, Electrical conductivity (EC), Total dissolved solids (TDS) and pH were measured on site using a HI-2550 pH/ORP/ISE, EC/TDS/NaCl Benchtop Meter (HANNA instruments). Dissolved oxygen (DO) was tested by electrometric method using a sensitive membrane covered electrode. Color was determined spectrophotometrically at a wave length of 450 and 465 nm as described by (APHA, 2017). Total hardness (TH), Total Alkalinity (TA), Magnesium $(Mg)^{2+}$, Potassium $(K)^{+}$, Calcium $(Ca)^{2+}$, Chloride $(Cl)^{-}$, Sulphate $(SO_4)^{2-}$, Nitrate $(NO_3)^{-}$, Nitrite $(NO_2)^{-}$, Phosphate $(PO_4)^{3-}$, Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Chromium (Cr), Nickel (Ni) and Aluminium (Al) were analyzed in the laboratory using the standard methods suggested by the American Public Health Association (APHA, 2017). All parameters were reported in mg/L, with exception of EC (µS/cm) and pH (unitless).

Data Analysis
Descriptive statistical analysis was carried out using SPSS statistical software (version 22.0). The results were presented as minimum, maximum, mean and standard deviation (SD). The mean values were then compared to the set standards given by WHO and SON as either acceptable or unacceptable.

Results and Discussion
The results of the analyses for each water sample (mean values) was compared to respective standard/guideline values given by the World health organization (WHO) (Ref) and Standard Organization of Nigeria (SON) (Ref). Each of the physico-chemical (Temperature, Turbidity, Colour, Odour, EC, TDS, TH, TA, DO, BOD, COD pH, Cl^-, Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-}, NO^{3-}, NO^{2-}, PO_4^{3-}) and heavy metals (Cr, Ni, Al, Fe, Cu and Zn). The parameters as compared with WHO and SON guideline values are displayed in Table 1.

pH
The pH values obtained for boreholes investigated were as follows; mean (5.58±0.53) and ranged from 4.94 to 6.22 as shown in Table 1. The borehole water samples were acidic with values below guideline values given by (6.5-8.0), as stated by the Nigerian Standard for Drinking Water Quality (SON) and the world health organization. Low levels of pH in most wells and springs could be connected with carbon dioxide (CO_2) saturation in the aquifer (Byamukama, 2000, Yasin *et al.*, 2015). It is also worthy of note that acidic water can lead to corrosive action on metal pipes and plumbing network (McFarland *et al.*, 2008).

Electrical Conductivity
The recorded EC for groundwater samples have a recorded mean value of 44.4±4.93 µs/cm, with a range between 39.17µs/cm and 51.92 µs/cm (Table 1). The value obtained for EC of water samples are within the maximum permissible limit (1000 µs/cm) as specified by both SON and WHO. Salinity is a factor that determines EC levels. This parameter is usually of organoleptic concern (Ahmed, 2000).

TDS
TDS has also been categorized (Sojobi, 2016) into four different types namely freshwater (TDS < 1,000 mg/L) as type 1; brackish water (1000 < TDS < 10,000 mg/L) as type 2; saline water (10,000 < TDS < 100,000 mg/L) as type 3; and type 4 as brine water with TDS > 100,000 mg/L. The mean TDS value for water samples within the study area was found to be 22±2.75 mg/l, with maximum value and minimum value of 25.96 and 18.59 mg/l, respectively. The TDS values are below permissible value (500 mg/l) of the SON and WHO. TDS shows the degree of salinity of any water sample. High level of TDS in water, make water unfit for consumption and cause corrosion in containers used for water storage (Elemile, 2019).

Turbidity
According to the EPA (Environmental protection agency) (Acrylamide, 2009), turbidity is the level of cloudiness in water. Usually, a correlation exists between total amount of suspended solid and turbidity (Osarenmwinda and Idaehor, 2019). The turbidity of borehole samples obtained ranges

from 0 to 0.2 with a mean value of 0.06±0.09 NTU. The guideline value by WHO is 1 NTU while the SON suggests 5 NTU as the permissible value. The turbidity values for water samples are within the limit for both standards.

Total Hardness

From the examined borehole samples, mean value for total hardness is 296.99±27.45 mg/l and measured concentration value ranges from 263.2 mg/l to 331.92 mg/l as shown in Table 1. The total hardness values for the samples exceed the permissible limit (150 mg/l) stated by SON and WHO. Water with high level of hardness is not desirable for domestic use as it forms scales on containers and utensils used for cooking, moreover it requires more soap for washing (Padmapriya, 2015).

Total Alkalinity

The mean total alkalinity concentration value obtained for borehole sample is 61.69±5.81 mg/l. The highest total alkalinity value recorded is 71.12 mg/l and Lowest value of 56.4 mg/l. These values are within allowable range (20 - 200mg/l) specified by WHO. Alkalinity indicates the level of bicarbonates, hydroxides and sometimes presence of silicates and phosphates (Heydari *et al.*, 2013). The constituent of rocks in aquifer influence alkalinity value in water (Ref).. The Nigerian standard for drinking water does not specify guideline value for total alkalinity.

Potassium (K^+)

The potassium values of all water samples varied from 3.76 to 4.74 mg/l, with mean value of 4.24±0.39 mg/l. The values for the examined water samples are within potassium permissible value (250mg/l) specified by WHO. Potassium is a vital and essential element for living organisms hence found in all human and animal tissues Meride and Ayenew (2016).

Calcium (Ca^{2+})

The calcium level in borehole samples ranged from 82.91 to 116.17 mg/l and a mean value of 99.95±13.52 mg/l. Study carried out by Sojobi *et al.* (2015), Irepodun Local Government showed a relatively lower value as compared to this study. Nwankwoaala *et al.*, (2014) suggested that the presence of calcium ions could be attributed to feldspar and mica dissolution. Conversely, Kim *et al.* (2014) ascribed it to the precipitation of carbonate minerals. The Nigerian standard for drinking water does not specify guideline value for Ca. The calcium value obtained for samples is below the permissible limit (150mg/l) by WHO.

Chloride

Chloride concentration of the water samples has a maximum value of 2.84 mg/l and minimum of 2.26 mg/l, with mean value of 2.55±0.24 mg/l. The SON and WHO allowable limit of chloride in water is 250 mg/l, therefore the level of chloride concentration is within permissible value of SON and WHO.

Sulphate

The level of sulphate in the water samples ranged between 7.4 and 11.85 mg/l, with mean value of 9.99±1.75 mg/l. The maximum permissible limit by Nigerian standard for drinking water and WHO is 250 mg/l, therefore the sulphate level in the water samples is within allowable limit by SON and WHO.

Nitrate

The mean nitrate concentration in the groundwater samples is 0.36±0.03 mg/l. The measured values range from 0.32 mg/l to 0.4 mg/l (Table 1). The nitrate level in the samples is below the permissible limit (50mg/l) stated by WHO. Relatively higher values of nitrate (95.80 ± 8.45 mg/l) were reported by Yasin *et al*., (2015). According to Reimann *et al*., (2003), lifetime exposure to elevated nitrate and nitrite concentrations will lead to health issues such as diuresis and increased starch deposits.

Phosphate

From the examined water samples, mean value for phosphate is 12.79±1.65 mg/l. Maximum phosphate value recorded is 10.3 mg/l and minimum value of 14.58 mg/l. The Nigerian standard for drinking water does not specify guideline value for phosphate. The phosphate level found in samples exceed allowable limit (0.5 mg/l) specified by WHO.

Iron

The iron concentration in the water samples obtained ranges from 0.28 to 0.36 mg/l with a mean value of 0.32±0.03mg/l. The iron value exceed the permissible limit 0.3 mg/l established by both SON and WHO. Iron is natural occurring metal in water, it can be found as minerals in rocks across the soil profile. Exposure to excess iron can lead to serious health challenge such as alzheimer disease, kidney, liver, and respiratory disorder (Farina *et al.,* 2013).

Magnesium

Magnesium level found in this study ranged from 4.23 to 5.93 mg/l with mean value of 5.1±0.69 mg/l. The magnesium value of sample does not exceed the allowable limit (20mg/l) for SON and WHO. Magnesium is attributed to magnesium rich carbonate bearing rocks situated in aquifers such as basalts, hematite and kaolinite Trostle *et al*. (2014).

Manganese

The value of manganese ranged between 0 and 0.03 mg/l for borehole water samples, with mean value of 0.02±0.01 mg/l. The guideline value by WHO and SON is 0.2 mg/l, the manganese value for borehole samples is within limit for both standard.

Copper

The copper level in the groundwater samples ranged from 0.38 to 0.47 mg/l with a mean value of 0.42±0.02 mg/l. The guideline value by WHO is 2 mg/l and SON specify 1 mg/l, the copper value for borehole samples is within limit for both standard. Previous study shows high values of copper may lead to chronic anaemia (Hegazy *et al.,* 2010).

Zinc

Zinc concentration of water samples has a maximum value of 2.37 mg/l and minimum of 1.88 mg/l, with mean value of 2.12±0.2mg/l. The Zinc value obtained for water samples is below the permissible limit (3mg/l) by WHO and SON.

Chromium

The chromium level in borehole samples ranged from 0.2 to 0.25 mg/l and a mean value of 0.22±0.02mg/l. The SON and WHO allowable limit of chromium in water is 0.05 mg/l, therefore the level of chromium concentration exceed permissible value of SON and WHO.

Nickel

The nickel values of all water samples varied from 0.36 to 0.45 mg/l, with mean value of 0.4±0.04 mg/l. The nickel level in the samples exceed the permissible limit (0.02 mg/l) stated by SON and WHO. Nickel is an essential trace metal but harmful in large quantity to human health (Genchi *et al.*, 2020).

Aluminium

From the examined water samples, mean value for aluminium is 0.02±0 mg/l (Table 2). The values for aluminium (0.2mg/l) are within permissible value specified by WHO. These values are lower than those reported by Siti Farizwana (2010) at Johor, Malaysia. This difference is a result of the excessive amount of (aluminium sulphate) alum added during the water treatment process. Since the groundwater (boreholes) as perceived by the consumers are pristine, they would hardly require the use of alum.

Dissolved Oxygen

The mean value of DO is 0.02±0 mg/l and ranged between 0.36 to 0.45 mg/l for borehole water samples. The guideline value by WHO is 6.5 - 8 mg/l and SON specify 7.5 mg/l. The value of DO obtained is not within acceptable range as stated by W.H.O. Dissolved oxygen shows water quality and health status of water bodies (Sarda and Sadgir, 2015).

Biological Oxygen Demand

BOD determines oxygen required by carbon materials in water samples. The value of BOD of the analysed water samples ranged from 2.82 to 3.56 mg/l, with mean value of 3.18±0.29 mg/l. The guideline value by WHO is 6 mg/l and SON specify 0 mg/l, the BOD value for the groundwater samples is within permissible limit for WHO but above SON limit. Further treatment is needed to protect public health (Chukwu, 2008).

Health related influence from drinking water

Water is vital for life sustenance hence adequate, safe and accessible supply must be made available to all (Ayenew, 2004). Previously, several research studies have shown that many factors alter drinking water quality leading to health problems (Mora *et al.*, 2009; Tamasi and Cini, 2004). From the earlier results discussed, all the water samples fall within the stated guideline values with the exception of pH, TH, Ca^{2+}, Fe, Zn, Cr and Ni. The pH of drinking water has an indirect health effect by causing changes in other water quality parameters which includes solubility of metals and survival of pathogens (Ho *et al*., 2003). High levels of Iron, Zinc and Chromium could present carcinogenic health risk to adults and children while exposure to Ni results in allergies. This is illustrated in Table 2.

Pearson's correlation

Pearson's correlation, (r) was the statistical tool adopted to show how the observed groundwater parameters correlate with each other. It shows the association between two or more continuous variables. A positive correlation is denoted by positive value ($r = +1$) while a negative correlation is denoted by a negative value ($r = -1$) and all values fall within this domain. A non-existing relationship is denoted by ($r = 0$). This study has adopted the classification model by Sojobi (2016); Perfectly correlated ($r = 1$), very strongly correlated ($\pm0.9 \leq r < 1$), strongly correlated ($\pm0.7 \leq r < 0.9$), moderately correlated ($\pm0.5 \leq r < 0.7$) and poorly correlated ($r < \pm0.5$). The Pearson's correlation values for the assessed water quality parameters are shown in Table 2.

Table 1: Physico-chemical, heavy metals and biological parameters of sampled boreholes.

Parameters	Units	Mean	Min	Max	SD	WHO	SON	Remark	Value	Previous studies
EC	uS/cm	44.40	39.17	51.92	4.93	1000	1000	Within limit	42.7 - 320	Okoro *et. al* (2012)
TDS	mg/L	22.00	18.59	25.96	2.75	500	500	Within limit	166 -184	Ezeribe *et al*. (2012)
Turb.	NTU	0.06	0.00	0.20	0.09	1	5	Within limit	0.01 - 0.01	Sojobi *et al.*, (2016)
pH		5.58	4.94	6.22	0.53	6.5 - 8.0	6.5-8.5	Exceed limit	6.5 - 8.9	Ezeribe *et al*. (2012)
TH	mg/L	296.99	263.2	331.92	27.45	150	150	Exceed limit	12.70 – 13.50	Elemile *et al.*, (2019)
TA	mg/L	61.69	56.40	71.12	5.81	20 – 200		Within limit	3.0 - 19.0	Okoro et. al (2012)
K^+	mg/L	4.24	3.76	4.74	0.39	250		Within limit	20.83 – 27.51	Meride and Ayenew (2016)
Ca^{2+}	mg/L	99.95	82.91	116.17	13.52	150		Within limit	18.33 - 21.00	Elemile *et al.*, (2019)
Cl^-	mg/L	2.55	2.26	2.84	0.24	250	250	Within limit	26.67 - 37.6	Elemile *et al.*, (2019)
SO_4^{2-}	mg/L	9.99	7.40	11.85	1.75	100	100	Within limit	4.2 - 101	Aladejana and Talabi *et al.*, (2012)
NO_3^-	mg/L	0.36	0.32	0.40	0.03	50	50	Within limit	3.2 - 6.4	Moshin et. al (2013)
PO_4^-	mg/L	12.79	10.3	14.58	1.65	0.1		Within limit	0.5 – 1.45	Okoro *et al.*, (2017)
Fe	mg/L	0.32	0.28	0.36	0.03	0.3	0.3	Exceed limit	ND	Sojobi *et al.*, (2016)
Mg^{2+}	mg/L	5.10	4.23	5.93	0.69	20	20	Within limit	0.75 – 0.94	Sojobi *et al.*, (2016)
Mn	mg/L	0.02	0.00	0.03	0.01	0.2	0.2	Within limit	0.00-0.36	Zhang *et al.*, (2020)
Cu	mg/L	0.42	0.38	0.47	0.04	2	1	Within limit	0.002 – 1.0	Ibe et. al (2020)
Zn	mg/L	2.12	1.88	2.37	0.20	3	3	Exceed limit	0.02 – 0.29	Sojobi *et al.*, (2016)
Cr	mg/L	0.22	0.20	0.25	0.02	0.05	0.05	Exceed limit	ND	Sojobi *et al.*, (2016)
Ni	mg/L	0.40	0.36	0.45	0.04	0.02	0.02	Exceed limit	0.19 – 0.29	Elemile *et al.*, (2019)
Al	mg/L	0.02	0.02	0.02	0.00	0.2	0.2	Within limit	0.02 – 1.59	
DO	mg/L	5.30	4.70	5.93	0.49	4*	7.5*		5.78 – 7.78	Elemile *et al.*, (2019)
BOD	mg/L	3.18	2.82	3.56	0.29	0	6	Within limit	9.8 – 62.8	Yasmin *et al.*, (2012)

Table 2: Parameters which may be of health concern in the village of Tankpaful

Parameters	Units	Health risk	References
pH	-	No direct effect however may cause gastrointestinal problems in sensitive individuals	*Khan et al., (2013)*
Total Hardness	mg/l		
Iron	mg/l	Toxic in high levels	*Shan et al., (2011)*
Chromium	mg/l	Contact dermatitis	*Shan et al., (2011)*
Nickel	mg/l	Hand eczema and allergies	*Filon ei al., (2009)*

The parameters exhibiting very strong correlation with EC are TDS (0.991) and TA (0.983), PO_4 (0.723) and NO3 (0.709) are strongly correlated while DO (-0.857) and BOD (-0.857) are negatively correlated. For TDS, cations such as Fe (0.303), Mg (0.459) and Cu (0.469) contribute positively although they are poorly correlated while anions such as NO3 (0.746) and PO4 (0.785) are strongly correlated. K and Cl was perfectly correlated with TH and pH with values of 1.000 and 0.998 respectively. Ca was strongly correlated with values of 0.751 for Total hardness and 0.762 for pH. Of all the cations, K is strongly correlated with a correlation value of 0.726 and is the major contributing parameter to Total alkalinity alongside Cu, Ca, Fe, Mg, and Mg with correlation values of 0.560, 0.437, 0.358, and 0.224 respectively. Cl was Strongly correlated with a value of 0.726 while moderately correlated with values of 0.594, 0.557 and 0.239 were observed for NO_3, PO_4 and SO_4 respectively. Based on correlation analysis, the major mineral groups contributing to total hardness is the K-Cl group (1.00). The result revealed 11% of parameters were perfectly correlated ($r = 1$), 5.9% very strongly correlated ($\pm 0.9 \leq r < 1$), 7.1% strongly correlated ($\pm 0.7 \leq r < 0.9$), 16.9%.
moderately correlated ($\pm 0.5 \leq r < 0.7$) and 58.9% poorly correlated ($r < \pm 0.5$) as shown in Figure 3. The majority of the samples were poorly correlated with each other indicating that the availability of a certain parameter might not lead to the detection of another.

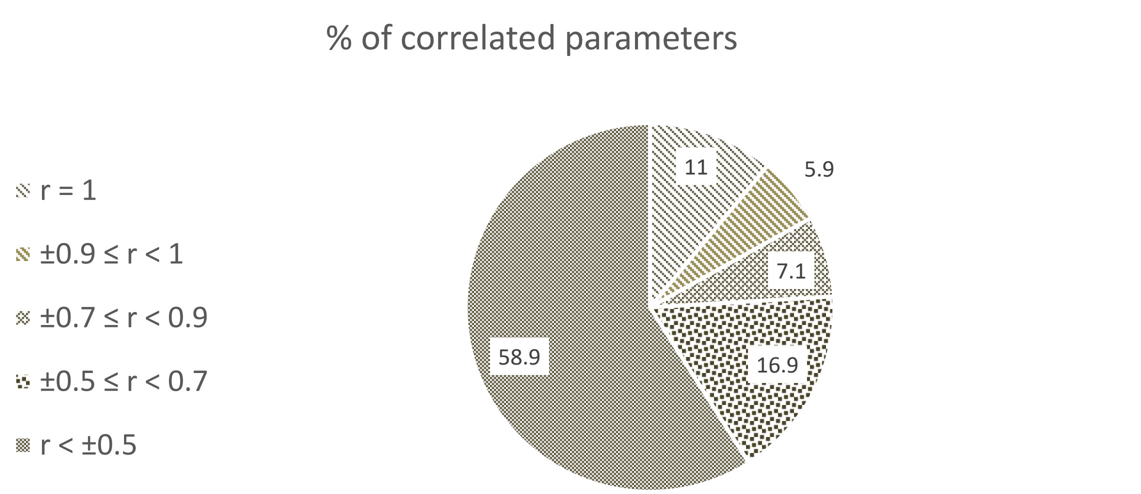

Figure 3: Percentage of parameters correlated based on classification model.

Table 3: Correlation between Water quality parameters of the collected samples.

	EC	TDS	Turb.	pH	TH	TA	K^+	Ca^{2+}	Cl^-	SO_4^{2-}	NO_3^-	PO_4^-	Fe	Mg^{2+}	Mn	Cu	Zn	Cr	Ni	Al	DO	BOD
EC	1.000																					
TDS	**0.991**	1.000																				
Turb.	-0.794	-0.854	1.000																			
pH	0.461	0.341	0.082	1.000																		
TH	0.515	0.399	0.023	**0.998**	1.000																	
TA	**0.963**	0.920	-0.629	0.683	0.727	1.000																
K^+	0.514	0.398	0.025	**0.998**	**1.000**	0.726	1.000															
Ca^{2+}	0.250	0.153	0.277	0.762	0.751	0.437	0.754	1.000														
Cl^-	0.514	0.398	0.025	**0.998**	**1.000**	0.726	**1.000**	0.754	1.000													
SO_4^{2-}	0.259	0.263	0.020	0.082	0.094	0.239	0.097	0.614	0.097	1.000												
NO_3^-	0.709	0.746	-0.521	0.034	0.081	0.594	0.081	0.101	0.081	0.613	1.000											
PO_4^-	0.723	0.785	-0.683	-0.126	-0.072	0.557	-0.072	-0.076	-0.072	0.514	**0.968**	1.000										
Fe	0.327	0.303	0.112	0.292	0.302	0.358	0.305	0.669	0.305	**0.932**	0.691	0.529	1.000									
Mg^{2+}	0.396	0.469	-0.380	-0.335	-0.298	0.224	-0.297	0.002	-0.297	0.752	0.882	0.888	0.693	1.000								
Mn	0.327	0.303	0.112	0.292	0.302	0.358	0.305	0.669	0.305	**0.932**	0.691	0.529	**0.920**	0.693	1.000							
Cu	0.501	0.459	-0.222	0.487	0.502	0.560	0.505	0.811	0.505	0.693	0.265	0.217	0.574	0.254	0.574	1.000						
Zn	0.327	0.303	0.112	0.292	0.302	0.358	0.305	0.669	0.305	**0.932**	0.691	0.529	**1.000**	0.693	**1.000**	0.574	1.000					
Cr	0.327	0.303	0.112	0.292	0.302	0.358	0.305	0.669	0.305	**0.932**	0.691	0.529	**0.890**	0.693	**0.930**	0.574	**1.000**	1.000				
Ni	-0.108	-0.213	0.358	0.664	0.636	0.112	0.634	0.198	0.634	-0.622	-0.565	-0.658	-0.402	-0.870	-0.402	-0.202	-0.402	-0.402	1.000			
Al	-0.108	-0.213	0.358	0.664	0.636	0.112	0.634	0.198	0.634	-0.622	-0.565	-0.658	-0.402	-0.870	-0.402	-0.202	-0.402	-0.402	**1.000**	1.000		
DO	-0.857	**-0.883**	0.711	-0.171	-0.226	-0.758	-0.224	0.067	-0.224	-0.227	**-0.891**	**-0.897**	-0.365	-0.613	-0.365	-0.103	-0.365	-0.365	0.265	0.265	1.000	
BOD	-0.857	**-0.883**	0.711	-0.171	-0.226	-0.758	-0.224	0.067	-0.224	-0.227	**-0.891**	**-0.897**	-0.365	-0.613	-0.365	-0.103	-0.365	-0.365	0.265	0.265	**1.000**	1.000

Conclusion

Drinking water-related diseases are a major burden on human health. It is usually due to the excessive amount of physical, chemical and biological parameters accumulated in drinking water sources. According to Meride and Ayenew (2016), improving access to safe drinking-water can result in tangible benefits to health. The samples were analyzed for intended water quality parameters following internationally recognized and well established analytical techniques. On the basis of findings, it was concluded from the study that the physico-chemical, heavy metal and biological parameters of the drinking water collected from the newly installed boreholes, are consistent with World Health Organization standard (WHO) for drinking water except for pH, TH, Fe, Cr and Ni which exceed the desirable limit in some samples and require treatment before its utilization. Treatment methods such as electrochemical coagulation, active carbon adsorption, and filtration should be adopted prior to use. There is a need for consistent observation of these water sources since they are the major drinking water source for the community.

References

Abatneh, Y., Sahu, O., and Yimer, S. (2014). Purification of drinking water by low cost method in Ethiopia. *Applied Water Science*, *4*(4), 357-362.

Abatneh,Y., Sahu, O.,andYimer, S. (2014). Purification of drinking water by low cost method in Ethiopia. Applied Water Science, 4, 357–362.

Aladejana, J. A., and Talabi, A. O. (2013). Assessment of groundwater quality in Abeokuta Southwestern, Nigeria. *Int. J. Eng. Sci*, *2*, 21-31.

APHA (*2005*) Standard methods for the examination of water and waste water, 21st edn. American Public Health Association, Washington, DC

Armah, F. A., Ekumah, B., Yawson, D. O., Odoi, J. O., Afitiri, A. R., and Nyieku, F. E. (2018). Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon*, *4*(11), e00931.

Ayenew, T. (2004). Environmental implications of changes in the levels of lakes in the Ethiopian Rift since 1970. *Regional environmental change*, *4*(4), 192-204.

Bello, A. A., and Makinde, V. (2007). Delineation of the aquifer in the South-Western part of the Nupe Basin, Kwara State, Nigeria. *J. Am. Sci*, *3*(2), 36-44.

Brindha, K., and Elango, L. (2012). Impact of tanning industries on groundwater quality near a metropolitan city in India. *Water Resources Management*, *26*(6), 1747-1761.

Brindha, K., and Elango, L. (2012). Impact of tanning industries on groundwater quality near a metropolitan city in India. *Water Resources Management*, *26*(6), 1747-1761.

Byamukama, D., Kansiime, F., Mach, R. L., and Farnleitner, A. H. (2000). Determination of Escherichia coli contamination with chromocult coliform agar showed a high level of discrimination efficiency for differing fecal pollution levels in tropical waters of Kampala, Uganda. *Applied* and *Environmental Microbiology*, *66*(2), 864-868.

Chukwu, O. (2008). Analysis of groundwater pollution from abattoir waste in Minna, Nigeria. *Research Journal of Diary Science*, *2*(4), 74-77.

Dissmeyer, G. E. (2000). *Drinking water from forests* and *grass*lands*: a synthesis of the scientific literature* (Vol. 39). US Department of Agriculture, Forest Service, Southern Research Station.

Dissmeyer, G. E. (2000). *Drinking water from forests* and *grass*lands*: a synthesis of the scientific literature* (Vol. 39). US Department of Agriculture, Forest Service, Southern Research Station.

Economic, U. N., and Council, S. (2017). Progress towards the Sustainable Development Goals: report of the Secretary-General (E/2017/66). *Retrieved online from: https://undocs. org/E/2017/66 [Accessed: Wed. 15 February 2019]*.

Edwin, N., Ibiam, U. A., okorie Igwenyi, I., Ude, V. C., and Eko, S. N. (2015). Evaluation of physicochemical properties, mineral and heavy metal content of drinking water samples in two communities in South-East, Nigeria: a puplic health implication. *Evaluation*, *5*(9).

Elemile, O. O., Raphael, D. O., Omole, D. O., Oloruntoba, E. O., Ajayi, E. O., and Ohwavborua, N. A. (2019). Assessment of the impact of abattoir effluent on the quality of groundwater in a residential area of Omu-Aran, Nigeria. *Environmental Sciences Europe*, *31*(1), 1-10.

Ezeribe, A. I., Oshieke, K. C., and Jauro, A. (2012). Physico-chemical properties of well water samples from some villages in Nigeria with cases of stained and mottle teeth. *Science World Journal*, *7*(1), 1-3.

Farina, M., Avila, D. S., Da Rocha, J. B. T., and Aschner, M. (2013). Metals, oxidative stress and neurodegeneration: a focus on iron, manganese and mercury. *Neurochemistry international*, *62*(5), 575-594.

Filon, F. L., D'Agostin, F., Crosera, M., Adami, G., Bovenzi, M., and Maina, G. (2009). In vitro absorption of metal powders through intact and damaged human skin. Toxicology in vitro, 23(4), 574-579.

Genchi, G., Carocci, A., Lauria, G., Sinicropi, M. S., and Catalano, A. (2020). Nickel: Human health and environmental toxicology. *International journal of environmental research* and *public health*, *17*(3), 679.

Guppy, L., and Anderson, K. (2017). *GLOBAL WATER CRISIS : THE FACTS United Nations University Institute for Water*,*Environment* and *Health*. Hamilton, Canada.

Harlin, J., and Kjellén, M. (2015). Water and development: from MDGs towards SDGs. *Water for development—charting a water wise path, SIWI report*, *35*, 8-14.

Heydari, M. M., and Bidgoli, H. N. (2012). Chemical analysis of drinking water of Kashan District, Central Iran. *World Applied Sciences Journal*, *16*(6), 799-805.Acrylamide, O. C. (2009). National Primary Drinking Water Regulations. *Kidney*, *2*(4-D), 0-07.

Heydari, M. M., Abbasi, A., Rohani, S. M., and Hosseini, S. M. A. (2013). Correlation study and regression analysis of drinking water quality in Kashan City, Iran. *Walailak Journal of Science* and *Technology (WJST)*, *10*(3), 315-324.

Ho, K. C., Chow, Y. L., and Yau, J. T. S. (2003). Chemical and microbiological qualities of The East River (Dongjiang) water, with particular reference to drinking water supply in Hong Kong. *Chemosphere*, *52*(9), 1441-1450.

Hunter, P. R., MacDonald, A. M., and Carter, R. C. (2010). Water supply and health. *PLoS medicine*, *7*(11), e1000361.

Hegazy, A. A., Zaher, M. M., Abd El-Hafez, M. A., Morsy, A. A., and Saleh, R. A. (2010). Relation between anemia and blood levels of lead, copper, zinc and iron among children. *BMC research notes*, *3*(1), 1-9.

Isah, M. A., Chiroma, M. A., and Ishiyaku, A. I. H. B. (2015). Water Pollution Sources for Hand-Dug Wells (HDW) in the Ancient City of Bauchi Metropolis, Nigeria. *International Journal of Scientific* and *Research Publications*, *5*(6), 2250-3153.

Kim, K. H., Yun, S. T., Park, S. S., Joo, Y., and Kim, T. S. (2014). Model-based clustering of hydrochemical data to demarcate natural versus human impacts on bedrock groundwater quality in rural areas, South Korea. *Journal of Hydrology*, *519*, 626-636.

McFarland, M. L., Provin, T. L., and Boellstorff, D. E. (2008). Drinking water problems: corrosion. *Texas A*and*M Agrilife Extension*, 51130-19537.

Megwara, J. U., and Udensi, E. E. (2014). Structural analysis using aeromagnetic data: case study of parts of Southern Bida Basin, Nigeria and the surrounding basement rocks. *Earth science research*, *3*(2), 27.

Meride, Y., and Ayenew, B. (2016). Drinking water quality assessment and its effects on resident's health in Wondo genet campus, Ethiopia. *Environmental Systems Research*, *5*(1), 1.

Mora, A., Mac-Quhae, C., Calzadilla, M., and Sánchez, L. (2009). Survey of trace metals in drinking water supplied to rural populations in the eastern Llanos of Venezuela. Journal of environmental management, 90(2), 752-759.

Nwankwoala, H. O., Amadi, A. N., Oborie, E., and Ushie, F. A. (2014). Hydrochemical factors and correlation analysis in groundwater quality in Yenagoa, Bayelsa State, Nigeria. *Applied Ecology* and *Environmental Sciences*, *2*(4), 100-105.

Obaje, N. G. (2009). *Geology* and *mineral resources of Nigeria* (Vol. 120). Springer.

Okoro, H. K., Adeyinka, A., Jondiko, O. E., and Ximba, B. J. (2012). Physico-chemical analysis of selected groundwater samples of Ilorin town in Kwara State, Nigeria. *Scientific Research* and *Essays*, *7*(23), 2063-2069.

Okoro, N., Omeje, E. O., and Osadebe, P. O. (2017). Comparative analysis of three borehole water sources in Nsukka Urban Area, Enugu State, Nigeria.

Osarenmwinda O, and Idaehor AG. (2019). Bacteriological and physicochemical analyses of well water used for drinking in Ekpoma-Edo State, Nigeria. Journal of Microbiology and Experimentation, 7(6):280–284. DOI: 10.15406/jmen.2019.07.00271

Oyem, H. H., Oyem, I. M., and Ezeweali, D. (2014). Temperature, pH, electrical conductivity, total dissolved solids and chemical oxygen demand of groundwater in Boji-BojiAgbor/Owa area and immediate suburbs. *Research Journal of Environmental Sciences*, *8*(8), 444.

Padmapriya, R., Saranya, T., and Thirunalasundari, T. (2015). Phyllanthus emblica-A biopotential for hard water treatment. *Int. J. Pure App. Biosci*, *3*(3), 291-295.

Patil, V. T., and Patil, P. R. (2011). Groundwater quality of open wells and tube wells around Amalner town of Jalgaon district, Maharashtra, India. *E-Journal of Chemistry*, *8*(1), 53-58.

Rahmanian, N., Ali, S. H. B., Homayoonfard, M., Ali, N. J., Rehan, M., Sadef, Y., and Nizami, A. S. (2015). Analysis of physiochemical parameters to evaluate the drinking water quality in the state of Perak, Malaysia. *Journal of Chemistry*, *2015*.

Reimann, C., Bjorvatn, K., Frengstad, B., Melaku, Z., Tekle-Haimanot, R., and Siewers, U. (2003). Drinking water quality in the Ethiopian section of the East African Rift Valley I—data and health aspects. *Science of the Total Environment*, *311*(1-3), 65-80.

Salami, A. O., Stampini, M., Kamara, A. B., Sullivan, C. A., and Namara, R. (2014). Development aid and access to water and sanitation in Sub-Saharan Africa. *Water International*, *39*(3), 294-314.

Sarda, P., and Sadgir, P. (2015). Assessment of Multi Parameters of Water Quality in Surface Water Bodies-A Review. *International Journal for Research in Applied Science* and *Engineering Technology*, *3*(8), 331-336.

Shan, W., Yue-heng, H. U., and Dan, Z. U. O. (2011). Discussion on parameter choice for managing water quality of the drinking water source. *Procedia Environmental Sciences*, *11*, 1465-1468.

Siti Farizwana, M. R., Mazrura, S., Zurahanim Fasha, A., and Ahmad Rohi, G. (2010). Determination of aluminium and physicochemical parameters in the palm oil estates water supply at Johor, Malaysia. Journal of Environmental and Public Health, 2010.

Sojobi, A. O. (2016). Evaluation of groundwater quality in a rural community in North Central of Nigeria. *Environmental monitoring* and *assessment*, *188*(3), 192.

Tamasi, G., and Cini, R. (2004). Heavy metals in drinking waters from Mount Amiata (Tuscany, Italy). Possible risks from arsenic for public health in the Province of Siena. Science of the Total Environment, 327(1-3), 41-51.

Trostle, K., Derry, L., Vigier, N., and Chadwick, O. (2014). Magnesium isotope fractionation during arid pedogenesis on the Island of Hawaii (USA). *Procedia Earth* and *Planetary Science*, *10*, 243-248.

Tuzen, M., and Soylak, M. (2006). Evaluation of Metal Levels of Drinking Waters from the Tokat-Black Sea Region of Turkey. *Polish Journal of Environmental Studies*, *15*(6).

World Bank. (2010). *World development indicators 2010*. The World Bank.

Yasin, M., Ketema, T., and Bacha, K. (2015). Physico-chemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia. *BMC research notes*, *8*(1), 541.

Zhang, Q., Xu, P., and Qian, H. (2020). Groundwater Quality Assessment Using Improved Water Quality Index (WQI) and Human Health Risk (HHR) Evaluation in a Semi-arid Region of Northwest China. *Exposure* and *Health*, 1-14.