Environmental Technology & Science Journal
Vol. 11 No. 1 June 2020

Physico-Chemical Analysis of Ground Water for Domestic Use in Some Selected Communities in Minna

Saidu M[1*], Agbese E[1], Asogwa E[1] & Gbongbo J[2]
[1]Department of Civil Engineering, Federal University of Technology, Minna
[2] Department of Civil Engineering, Niger State Polytechnic, Zungeru
mohammed_saidu@futminna.edu.ng

Received: 15/4/2020 **Reviewed: 2/5/2020** **Accepted: 14/6/2020**

Water is one of the main important abiotic components of the environment which plays a vital role of maintaining human health. The study was carried out to assess the quality of ground water in terms of physico-chemical parameters of the selected Boreholes in some communities in Minna and its environs. The water samples were collected from the selected communities and analysed for both wet and dry seasons using standard method of water examination and compared the results with various standards. The physico-chemical parameters like; pH, EC, temperature, TDS, TSS, Turbidity, Alkalinity, Ca, Mg, CO_2, F-, Cl-, NO_2-, NO_3-, and $PO_4^{2.-}$ were analysed. pH turbidity, TDS, TSS and Electrical conductivity values observed during the analysis were all within the WHO and NSDWQ permissible limit. The results also showed Cu, Mn and Pb were below the WHO and NSDWQ permissible limit while Manganese was above the permissible standards in some communities like Jatai, Rafiyashi and LapaI gwari which recorded concentrations of 0.27, 0.18 and 0.23mg/l respectively against WHO standard of 0.1mg/l, hence the need for proper treatment of the water samples before consumption was recommended.

Keywords: Groundwater, Borehole, physicochemical, water, WHO, NSDWQ

Introduction

Water is most vital liquid for maintaining human life on the earth. Next to oxygen, water is highly essential constituent of ecosystem (Kolekar, 2017) and vital to human life (Behailu *et al.,* 2017). About 71% of the Earth's surface is covered with water, 97% of this water exists in oceans that are not suitable for drinking and only 3% is fresh water. 2.97% of this fresh water can be found as glaciers and ice caps and remaining little portion of 0.3% is available as a surface and ground water for human use, which are found in different locations (Behailu *et al.,* 2017; Kolekar, 2017).

Groundwater refers to the water located in the pore space of soil and rocks. In most cases it is useful to distinguish between sub-surface water, that is, closely associated with surface water and deep sub-surface water in aquifer (Mohsin *et al.,* 2013). Availability of fresh water in the world continues to decrease due to high demand on ground water as a source of drinking water, agricultural, industrial and recreational activities (Adeleye *et al.,* 2014). Ground water constitutes nearly half of the world drinking water and for irrigation purpose in the world (Popoola *et al.,* 2019). The quality and quantity of ground water is currently threatened by a combination of over-abstraction, microbiological and chemical contamination which results from human activities such as domestic waste, mineral exploration, salinization and agricultural activities in the form of husbandry, irrigation and forestry (Reda, 2015; Mohsin *et al.,* 2013). The degree of severity of groundwater pollution depends also on the types and amount of waste, disposal methods, climate, and hydrologic properties of the aquifer, recharge capacity of the area and rate of pumping out of water (Kumari & Rani 2014). Groundwater is prevalently used to serve the domestic demands hence it should be matched with domestic water quality standards. Thus, it is pertinent that its quality must be checked from time to time so as to ensure the supply of safe drinking water (Kody *et al.,* 2016).

It has been observed that majority of the population in developing countries are not adequately supplied with potable water, however the use of water from sources like shallow wells, boreholes, springs and streams that render the water unsafe for domestic and drinking purposes due to high possibilities of contamination (Reda, 2015; Onyango *et al.,* 2018). In order to ensure a safe public health, water supply for human consumption must be free from pathogens, chemical toxic and physically clean and appealing to taste (Sharma & Bhattacharya, 2017). In Niger State, majority of the population depends on groundwater as the main source of portable water supply both for drinking, domestic, industrial and agricultural uses (Adegbehin *et al.*, 2016; Adeleye *et al.*, 2014). The increase in this proportion was as a result of unreliable public water and unstable power supply. Groundwater exploitation in the state is mainly through hand-dug wells and boreholes, despite a seemingly successful geophysical survey. As a result, groundwater has increased success rate, particular reference to borehole use and some are limited yield but depends on locations (Idris-Nda *et al.,* 2015).

The use of groundwater as the major source of potable water in both urban and rural areas in Niger State has assumed such a high proportion that attention has turned fully to it. Against the backdrop of poor, erratic and unreliable public water by the state government (Idris-Nda *et al.,* 2015). Therefore, people resolved to use of borehole as a reliable source of water supply to their communities. The study is aim at determining the physico-chemical parameters for both wet and dry season of the water sample quality and comparing the results obtained to Nigeria Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO). The study was able to show the level of physico-chemical qualities of the selected boreholes which gave details of permissible limit compared to standards.

Literature Review

Extensive literature and theoretical works have been conducted on assessment of ground water supply in both the rural areas and urban areas and the quality and quantity were determined.

Kody *et al.* (2016) carried out research on determination of some physicochemical properties of ground Water from Dalanj area. In this study, analysis was carried for fifty ground water samples collected from different sources in Dallang town and surrounding area. The aim was to evaluate the different parameters that determine drinking water quality in the area compared with WHO guidelines. The parameters determined include pH values, electrical conductivity (EC), Turbidity and TDS. Spectrophotometric analysis was carried for determination of nitrate and fluoride. Chloride (Cl^-), total alkalinity and total hardness were determined titrimetrically. Atomic Absorption spectroscopy was used for determination of copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb) concentrations. They reported that the results obtained when compared to WHO standards which indicated high concentrations of total dissolved solids content, carbonate, calcium, and magnesium ions, thereby inferring that the ground water sources studied were suitable for drinking. Also, Fluoride concentrations in some sources exceeded the permissible limit.

In a similar study, Moshin *et al.* (2013) assessed and compared the ground water quality with WHO standards and its related diseases in Bahawalpur City, Pakistan. Three sample areas of Satellite town, Shahdrah and Islamic Colony were chosen and two water samples were taken from each area. Data collection was based on questionnaire and laboratory analysis of water samples. The researchers studied certain physical and chemical parameters like total dissolved solids (TDS), electrical conductivity (EC), pH, hardness and alkalinity to find out quality of the ground water. From their findings it was ascertained that groundwater quality in Bahawalpur was deteriorating. The situation was much worse in Islamic colony where 48%, 55% and 41% residents have diluted, brackish and water with slight smell respectively. The study also reveals that laboratory analysis of water parameters indicates significant contamination in ground water. EC, TDS, hardness, pH etc. were considerably high from WHO permissible limits. Such poor quality of water may lead to severe waterborne diseases like diarrhea, cholera etc. In Islamic colony, about 36% residents have been facing serious diseases. To save local residents study suggests; regular monitoring of water quality should be practiced; more water filtration plants should be installed by local govt. to provide safe drinking water etc.

Kumari and Rani (2014) also reported on the assessment of water quality index of ground Water in Smalkhan, Haryana studied water quality index and correlation analysis of ground water in Smalkhan tehsil, Panipat district, Haryana, so as to ascertain the quality of water for public consumption, recreation and other purposes. The water samples collected were analysed for Physico-chemical parameters and the concentration obtained from the parameters was used to calculate Water Quality Index (WQI) and correlation metrics. The values of WQI of samples were found in the range of 89.09 - 146.67, the analysis of results reveals that most water samples analyzed were unfit for drinking and other domestic purposes, thus the reason was attributed to highly Industrialized and anthropogenic activities in the area.

Physical aspects of drinking water quality are mainly classified as; temperature, colour, odour, taste, turbidity, pH, electrical conductivity, and total dissolved solids and regards to examination of quality test categorized in to physico-chemical and aesthetical parameters (De Zuane, 1996). The physico-chemical examinations are as follows: Water pH, Total dissolved solid, Turbidity and Electrical conductivity.

The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. It has no direct adverse effect on health; however, a sample is considered to be acidic if the pH is below 7.0 and alkaline if the pH is above 7.0 (Rahmanian *et al.,* 2015). According to the WHO standards, pH of water should be 6.5 to 8.5 It is significant to measure pH at the similar time as chlorine residual since the effectiveness of disinfection with chlorine is extremely pH dependent: where the pH exceeds 8.0, disinfection is less effective. To check that the pH is in the optimal range for disinfection with chlorine (less than 8.0), simple tests may be conducted in the field using comparators that are used for chlorine residual. (Muhammad & Nur, 2013).

Number of chemical contaminants have been identified to cause adverse health effects in humans because of prolonged exposure through drinking water. These include both organic and inorganic chemicals including some pesticides. Some of them are toxic to humans or affect the aesthetic quality of water. In this regard, the WHO has put forward guideline values that set limits for many of the contaminants in drinking water. Nigeria has its own drinking water quality specification in line with the international norms and values. The NSDWQ quality and Standards of water are based on what WHO have stipulated legally binding drinking water quality specifications set limits for not only the physico-chemical parameters but also for Microbiological and radiological parameters (WHO 2011).

Study Area

Minna is located on latitude 9.5836^0 N and longitude 6.5463^{0}E. It is located at the north-eastern part of the land that makes up Niger State along the Lagos-Kano railway track as shown in Figure 1. It enjoys a strategic location and relatively easy accessibility from all parts of the country.

Minna and environs have a combination of dry and wet season, a hybrid of northern and southern Nigeria climate. Progressively it has a decreased in length and amount of rainfall from south to north with a mean annual rainfall between 110mm in the north to 1600mm in the south. The wet season has duration, which changes from 150 days in the north to 210 days in the south. Air temperature in the area is fairly constant during seasonal variables and the mean temperature does not exceed 23°c which is between March and June with the lowest minimum temperature usually in December and January. In October it experiences dry season with northeast trade winds from Sahara which brings about Harmattan that last between December and February which the relative humidity as low as 14°c (Olayemi *et al.,* 2014).

Materials and Methods

Materials

Materials used for the preparation and analysis of the water from various source of the water samples are distilled water, reagents, burettes, Pipettes, Conical flask, 250ml beaker, Funnel and 2ml syringe. These chemicals and Reagents were obtained from Department of Water Resources Aquaculture and Fisheries Technology (WAFT), Civil Engineering and Centre for Genetically laboratories Research Federal University of Technology, Minna as shown in Table 1.

Methods

Experimental method

Water samples were collected using 750ml plastic bottles. The containers were cleaned with warm water and soap and rinsed with double distilled water. The glass containers were washed by soaking in aqua regia (3 parts con. HCL and 1 part (HNO3) and rinsed with tap water and finally distilled water. Table 3 shows details summary of the method used.

Sample Collection

Nine (9) different sample collection points were identified as shown in Figure 2. The main reason of sampling is to collect representative samples. This representative sample means a sample in which relative proportions or concentrations of all pertinent components would be the same as in the material being sampled. The nine (9) collection points were selected as shown in Table 2, because they were well built, have been used for a long period of time. Samples were collected during dry and wet seasons. Ground water samples from the boreholes were collected in polyethylene sample bottles. The sample bottles were washed with deionized water and dried at room temperature. The sample bottles were rinsed several times with the water source at the point of collection to ensure sufficient flushing before sampling. These water samples are collected and were taken to the Department of Water Resources Aquaculture and Fisheries Technology (WAFT), Civil Engineering and Centre for Genetically laboratories Research Federal University of Technology, Minna, laboratory in an icebox jar to avoid unusual change in water quality and stored in a refrigerator (4°C) before analysis and standard methods were followed as listed by American Public Health Association (APHA) (APHA, 2012). pH and temperature were determined at the collection points using HI 8424 Hanna instruments electrode/ probe meter.

The following parameters were analyzed, pH, Turbidity, Temperature(^{0}C), Colour, Electrical Conductivity (EC), Total Dissolved solids (TDS), total hardness (TH), Ca^{2+}, Mg^{2+}, alkalinity, Cu, Fe, Mn, K, Ca (hardness), Mg (hardness), nitrate (No_3-), ($NH_4^{++}NH_3$), Phosphate, sulphate chloride and fluoride were determined using the WHO guideline for physical and chemical analysis of water quality parameters in the laboratory (WHO, 2011).

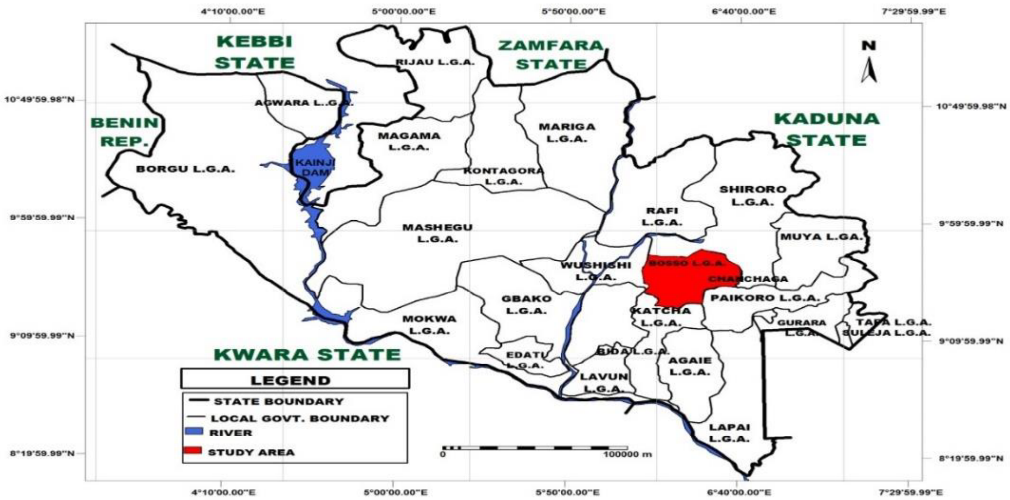

Figure 1: Niger State showing the Study location

Table 1: List of equipment/Apparatus used during the experiment

SN	Equipment/Apparatus	Manufacturer	Specification
1	Electric oven	Genlab Windies	Model N50SF
2	Rex pH 125		Not applicable
3	Weighing balance		
4	Beaker	Pyrex England	250-500ml
5	Measuring cylinder	Pyrex England	10-100ml
6	UV Spectrophometer		YM1208
7	Conductivity meter	Jenway	Model 4010
8	Crucible	Not applicable	500ml
9	AAS		
10	Conical flask	Pyrex England	250-1000ml
11	Spatula	Not applicable	Not applicable
12	TDS meter		
13	Thermometer		
14	Auto- clave	Gulex medical, England	LS - B75L-III
15	Incubator	Gulex medical, England	SHP – 250
16	Hot air oven	Gulex medical, England	SHP – 500
17	Distiller	Corning New York 14830	MP - 3A
18	Fridge	Thermacool	HRF - 250N
19	Microscope	Olympus	
20	Petridish	Silver Health	

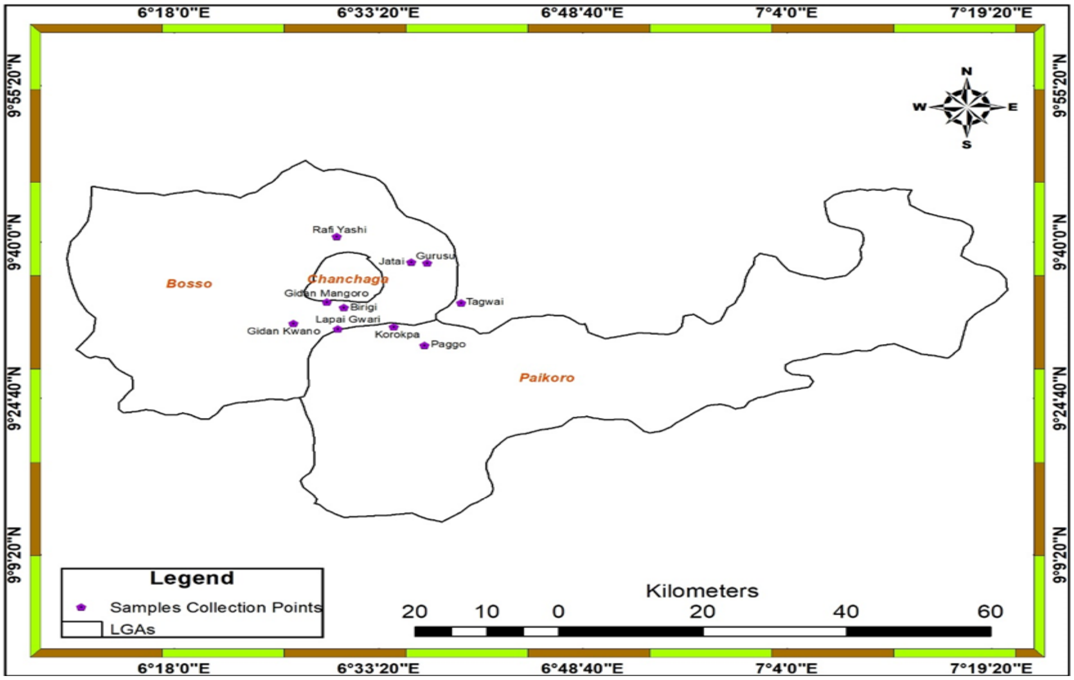

Figure 2: Minna showing Sampling Locations

Table 2: Samples Collection Locations Names

S/N	Location Names	Source	Longitude	Latitude
1	Tagwai	Borehole	6.6590	9.5670
2	Jatai	Borehole	6.5967	9.6338
3	Lapai Gwari	Borehole	6.5052	9.5246
4	Birigi	Borehole	6.5126	9.5594
5	Paggo	Borehole	6.6132	9.4980
6	Gurusu	Borehole	6.6170	9.6322
7	Gidan Mangoro	Borehole	6.4912	9.5683
8	Rafin Yashi	Borehole	6.5035	9.6751
9	Korokpa	Borehole	6.5749	9.5278

Results and Discussion

The physico-chemical parameters examined for both dry and wet seasons were presented in Table 4. Plate 1 showed a typical rural borehole. This research was conducted in the Minna North, West, East and South which comprises of three (3) Local Government Areas within the state capital. The research was conducted in nine (9) of the communities. Samples were taken in November for dry season and in July for wet season. Samples were collected in the early hours of the morning. This was to ensure that the water had not been disturbed much through human activities which can affect the temperature and total dissolved solids (TDS) content. A total of twenty (20) boreholes were sampled. Thorough physico-chemical analyses were carried out on all the samples for the entire duration. The parameters analyzed from the samples were the temperature, TDS, TSS, pH, conductivity, alkalinity, fluoride, carbon dioxide, and hardness.

The presence of trace metals such as lead, manganese and copper were also analyzed. The nutrient levels were also analyzed to determine the presence and levels of phosphate, nitrates and chloride in the samples. The topographic conditions as well as kind and type of human activities in the immediate environs (100 meters) of the sample sites were taken into consideration at the time of sampling since they have a high tendency of contributing to the level and nature of contaminants.

In the present study, the fluctuation of pH in the samples is from 5.93 to 7.71 in dry season and 5.30 to 6.90 in raining season (wet) in different communities. Although, the results show slightly higher in Gurusu, Tagwai and Paggo during wet season. And also shows little above the minimum limit in Jatai, Rafi Yashi, Korokpa, Birgi and Lapai Gwari, this may be due to run off during the raining season as shown in Table 3. The results are similar to that of Oyem *et al* (2014) and Edwin *et al*. (2015). The concentration is still within the safe limit of 6.5 to 8.5 standards set by WHO and NSDWQ. Therefore, it has no health implication with respect to pH.

Plate 1: Typical rural borehole located at Birgi village

Table 3: Borehole Water Quality Results for Dry and Wet Seasons

	DRY SEASON									WET SEASON										
Sample locations	Jatai	Gurusu	Rafi Yashi	Tagwai	Korokpa	Pago	Birgi	Gidan Magoro	Lapai Gwari	Jatai	Gurusu	Rafi Yashi	Tagwai	Korokpa	Pago	Birgi	Gidan Magoro	Lapai Gwari	NSDWQ PL	WHO PL
Temp	29.1	29.6	29.5	29.3	28.9	29.2	29.3	29.3	29.0	28.9	29.0	29.10	28.9	29.0	28.8	29.1	29.1	29.1		
pH	7.72	6.65	7.06	5.93	7.22	6.53	6.73	6.57	6.94	6.20	6.90	6.20		6.70	6.80	6.50	6.60	5.80	6.5-8.5	
Cond	489.00	288.00	492.00	492.00	394.00	690.00	207.00	169.00	452.00	350.00	251.00	557.00	59.00	404.00	415.00	277.00	163.00	434.00	1000.0	1000.0
TDS	220.00	179.00	299.00	82.00	300.00	232.00	198.00	88.00	321.00	235.001	168.00	373.00	39.00	271.00	278.00	186.00	109.00	291.00	500.0	500
TSS	0.00	10.00	7.00	11.00	4.00	5.00	0.00	5.00	7.00	0.00	14.00	7.00	13.00	6.00	4.00	0.00	3.00	5.00	500.0	500
Fluoride	0.55	0.66	0.95	0.10	0.10	0.70	0.37	0.20	0.98	0.65	0.71	1.10	0.00	0.97	0.80	0.48	0.22	0.95	1.5	1.5
Chloride	31.36	24.12	33.77	19.20	19.20	91.66	19.30	24.12	34.73	20.50	23.80	46.40	14.00	25.20	40.80	17.30	17.30	43.20	250.0	250
Magnesium	3.36	2.40	6.83	9.73	9.73	4.14	23.86	3.87	4.92	13.9	8.78	39.50	2.17	49.80	52.00	11.00	8.05	22.00	0.20	50.0
Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05
Manganese	0.27	0.25	0.18	0.05	0.00	0.08	0.09	0.08	0.23	0.27	0.18	0.06	0.05	0.00	0.08	0.09	0.08	0.23	0.20	0.10
Phosphate	0.158	0.128	0.128	0.050	0.311	0.187	0.244	0.173	0.308	0.27	0.25	0.18	0.05	0.00	0.08	0.09	0.08	0.23	-	0.04
Nitrate	0.04	0.03	0.03	0.05	0.10	0.11	0.04	0.05	0.04	0.07	0.06	0.19	0.01	0.10	0.13	0.02	0.02	0.15	0.20	3.00
Calcium	35.32	26.07	33.64	15.98	37.85	32.80	18.50	17.66	48.78	70.80	39.60	56.40	9.60	25.20	40.80	36.00	32.40	17.60	75.00	75.00
Copper	0.28	0.14	0.07	0.34	0.43	0.96	0.16	0.23	0.91	0.28	0.14	0.07	0.34	0.43	0.96	0.16	0.23	0.16	1.00	1.00

It can be deduced that the temperatures of the water supplied to the communities through different sources are within the permissible threshold of ambient temperature for both NSDWQ and WHO. The temperature of the selected communities is far low than 320c, since it was reported by Mohammed and Nur, (2013) that any water that is above 32 ^{0}C is considered unfit for public use. The seasonal variation makes no significant difference. The result of the electrical conductivity depicts that the EC values in dry and wet season for various communities are 83 to 690 µS/cm and 81 to 557 µS/cm respectively as shown in Table 3, which is below the NSDWQ and WHO maximum permissible limits of 1000 µS/cm, the relatively high value in dry season may be due to human activities. Conductivity is an indicator of hardness and alkalinity value and also that of dissolved solids. Chindo *et al.* (2013), reported that conductivity is proportional to the dissolve solids. The Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) values found in the bore hole water supply systems within the two seasons in the study ranges from 41.0 to 373 mg/l and 0 to 293mg/l respectively. The health risks are not significant as the values of TDS are much less than 500mg/l and 1000 mg/l, which is the NSDQW and WHO standard maximum permissible limits respectively, the low values of TDS and TSS is attributed to lack of industrial discharge within the study area. In the study area, the fluoride concentration was ranging between 0.00 – 1.10 mg/l for both wet and dry which is below the allowable limit of 1.5 mg/l for both NSDQW and WHO. This resulted is related to that of Chindo *et al. (*2013) who work on similar research. The chloride (cl^-) concentrations of the laboratory result were ranging from 12.06 – 91.66 mg/l for dry season and 14.0 to 47.5 mg/l for wet season. From the result of the analysis carried out on total hardness, it can be deduced that there is increase in concentration of hardness during wet season in different communities beyond the permissible NSDWQ standard of 150mg/l but within WHO limit of 300 mg/l. Even though, magnesium (mg^{2+}) concentration was expected in raw and finished water supply system between range 1.8-62mg/l, and 0.8-49mg/l respectively (Sengupta, 2013).

The laboratory result of the study areas show the range 0.53 to 52 mg/l for both wet and dry seasons, the permissible NSDWQ standard of 0.2mg/l was exceeded but within that of WHO of 50mg/l, except for Paggo community borehole. There is no trace of lead (Pb^{2+}) concentration in all the samples analyzed, at the various communities for both dry and wet seasons. The maximum permissible limit guidance level for Cupper(cu^{2+}) which is 1.00mg/l for both WHO and NSDWQ was not violated at all points of sample locations in the study area. Manganese (Mn^{2+}) recorded concentrations within the permissible limit of WHO (0.1mg/l), in all the town except in Jatai, Rafiyashi and Lapaigwari which recorded concentrations of 0.27, 0.18 and 0.23mg/l respectively. In the same vein, the Mn^{2+} concentration in all the towns are within the required limit as stipulated by NSDWQ (0.2mg/l) except in Jatai and Lapaigwari which recorded 0.27mg/l and 0.23mg/l respectively. The maximum concentration of phosphate (PO_3^{4-}) 3.48mg/l as recorded in Rafiyashi during the rainy season falls within the WHO criteria of 5.0mg/l. Nitrate and Nitrite recorded their maximum concentrations during rainy season as 23.80mg/l and 0.19mg/l respectively both at Rafiyashi also 0.536mg/l and 0.15 during dry season at the same Rafiyashi which are all within the standard as stipulated by the two regulatory bodies. The optimum concentration of both fluoride and chloride are 1.0mg/l and 91.66mg/l at Rafiyashi during rainy season and Pago during dry season respectively, which are all within the stipulated limits. Calcium (ca^{2+}) witnessed the maximum concentration of 48.78mg/l and 63.6mg/l both at Lapaigwari during dry and rainy season respectively but within the limits given by the regulatory bodies.

Conclusion

The study examined the groundwater samples for some selected physic-chemical parameters. The values of pH turbidity, TDS, TSS and Electrical conductivity values observed during the analysis were all within the WHO permissible limit. The concentration of total coliform in both dry and rainy season in the study area ranges from 1.0mg/l to 20mg/l which are above the permissible limit as stipulated by WHO and NSDWQ, hence the need for proper treatment of the water samples before consumption. The levels of trace metals investigated like Cu, Mn and Pb were all below the WHO guideline levels. Hence the trace metal concentration does not pose any health hazard to consumers, except for Manganese that was above the permissible standards in some communities like Jatai, Rafiyashi and Lapaigwari which recorded concentrations of 0.27, 0.18 and 0.23mg/l respectively against WHO standard of 0.1mg/l which need to be treated before consumption.

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