Quality Assessment of Groundwater Using Geochemical Parameters in Sabon-Gida Village and Its Environs, Zamfara State

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Abstract-* Geochemical parameter studies on the groundwater quality of Sabo Gida Village and its environs were undertaken. The objectives of the study were to determine the concentration of the anion and cation in the water samples, to determine the effect of interactions between the groundwater and the aquifer or surface contamination, and to compare the concentration level with the WHO standard. The geochemical study was carried out on 5 water samples, 1 from each of the 5 locations was for water geochemical analyses. The geochemical analyses involved the application of an Atomic Absorption Spectrometer (AAS), a Flame spectrophotometer, and titration in chemical units. The magnesium (Mg) concentrations show a minimum value of 0.25mg/l, highest value of 2.1mg/l and an average value of 0.91 mg/l, the concentration values for Fe from 0.00-0.52 mg/l with average value of 0.16 mg/l, The Nitrate (NO_3) ions concentration varies between 0.00-7.3 mg/l with an average value of 3.91 mg/l, Sulphate (SO_4^{2-}) ion concentration varies between 0-59 mg/l with an average value of 63 mg/l, Chloride (Cl^-) ion concentration varies between 0.02-18.7 mg/l with the average value of 10.67 mg/l, Fluoride (F^+) ion concentration varies between 0-0.95 mg/l with an average value of 0.45 mg/l are all within the safety limits of WHO standard. Escherichia coli concentration ranges from 0-18, which is above the acceptable limits as per the WHO NSDWQ standards. It is suggested that the water should be treated to reduce the anomalous concentration levels of Escherichia coli to a tolerable level in order to avoid health hazards in the community.

***Index Terms-* Groundwater Quality, Geochemical Parameters, Zamfara State, Hydro Geochemistry, Escherichia Coli (E. Coli), Nitrate (NO_3), Sulphate (SO_4^{2-}).**

I. INTRODUCTION

The availability of clean and safe water supply has direct influence on economic well-being, health, and quality of life of any society [13]. Understanding the quality of groundwater with its temporal and seasonal variation is important because it is the factor that determines the suitability for drinking, domestic, agricultural and industrial purposes [1].

Hydro geochemistry of groundwater is determined by its chemical and biogeochemical constituents. The exploration and exploitation of groundwater as a major resource to meet the growing population in some urban cities located in the basement complex rocks of Nigeria have been a subject of discussion [14].

The suitability of a particular groundwater for certain utilities such as public water supply, irrigation, industrial application, cooling, heating, and power generation largely depends on sediments, lithologic content, temperature, possible temporal variations caused by climatic conditions, as well as water quality [11]. The chemistry of groundwater is due to several processes like soil/rock–water interaction during recharge and groundwater flow, prolonged storage in the aquifer, dissolution of mineral species [15]. These processes are related to weathering of minerals which generally exerts an important control on groundwater chemistry. This process generally dominates the concentration of the major cations [2].

Water for human consumption and agriculture is stored as groundwater, which is the world's largest liquid freshwater supply [3].

Despite the fact that climate change has caused significant spatial-temporal precipitation variability and has affected reservoir storage volume, groundwater remains an important and reliable source of water; however, pollutants do occasionally reach the aquifer as a result of natural or human factors. Inadequate waste disposal sites, which have an impact on all natural resources, are one of the major threats to the quality of groundwater designated for human use. [4].

This has a big influence on the environment and on people's health, when maintained incorrectly, landfills represent a serious threat to groundwater quality [5].

Groundwater is the water present beneath Earth's surface in rock and soil pore spaces and in the fractures of rock formations [18]. About 30 percent of all readily available freshwater in the world is groundwater. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water [21]. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table [19]. Groundwater is recharged from the surface; it may discharge from the surface naturally at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called ground water.

Typically, groundwater is thought of as water flowing through shallow aquifers, but, in the technical sense, it can also contain soil moisture, permafrost (frozen soil), immobile water in very low-permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults. It is likely that much of Earth's subsurface contains some water, which may be mixed with other fluids in some instances [19].

Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water [19]. Therefore, it is commonly used for public water supplies. For example, groundwater provides the largest source of usable water storage in the United States, and California annually withdraws the largest amount of groundwater of all the states. Underground reservoirs contain far more water than the capacity of all surface reservoirs and lakes in the US, including the Great Lakes. Many municipal water supplies are derived solely from groundwater [11]. Over 2 billion people rely on it as their primary water source worldwide.

Use of groundwater has related environmental issues. For example, polluted groundwater is less visible and more difficult to clean up than pollution in rivers and lakes. Groundwater pollution most often results from improper disposal of wastes on land. Major sources include industrial and household chemicals and garbage landfills, excessive fertilizers and pesticides used in agriculture, industrial waste lagoons, tailings and process wastewater from mines, industrial fracking, oil field brine pits, leaking underground oil storage tanks and pipelines, sewage sludge and septic systems. Additionally, groundwater is susceptible to saltwater intrusion in coastal areas and can cause land subsidence when extracted unsustainably, leading to sinking cities (like Bangkok)) and loss in elevation (such as the multiple meters lost in the Central Valley of California). These issues are made more complicated by sea level rise and other changes caused by climate changes which will affect the water cycle [9]. Groundwater can be thought of in the same terms as surface water: inputs, outputs and storage. The natural input to groundwater is seepage from surface water. The natural outputs from groundwater are springs and seepage to the oceans. Due to its slow rate of turnover, groundwater storage is generally much larger (in volume) compared to inputs than it is for surface water. This difference makes it easy for humans to use groundwater unsustainable for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a groundwater source is the upper bound for average consumption of water from that source. Groundwater is naturally replenished by surface water from precipitation, streams, and rivers when this recharge reaches the water table. Groundwater can be a long-term 'reservoir' of the natural water cycle (with residence times from days to millennia), as opposed to short-term water reservoirs like the atmosphere and fresh surface water (which have residence times from minutes to years). Deep groundwater (which is quite distant from the surface recharge) can take a very long time to complete its natural cycle.

II. METHODOLOGY

2.1 Material and methodology

During the course of the field work different equipment and materials were used to achieve the exercise which includes; topographic map of the study area, a GPS for locating positions in the map, sterilized water bottles, and a sample bag to store the water samples. Geochemical analysis was carried out by using Atomic Absorption Spectrophotometer (ASS), and a Buck PFP-7 Flame Photometer.

2.2 Sampling

Three (3) water samples, one each from the locations were collected into 75cl sterile plastic bottles from borehole tap, well and reservoir for geochemical analysis. The collected water samples were acidified with drops of concentrated hydrochloric acid (HCl) for preservation in the field. The collected samples were later preserved in refrigerator for about a week before taken for analysis. The procedures followed were as described in the work of [6]

2.3. Location of sampling point.

Table 1: The Location of sampling point.

S/N	Coordinate		Name of location
1	12° 8’ 20" N	6° 46' 34" E	SAKALAWA
2	12° 7' 46"N	6° 46’ 48" E	FUG
3	12° 13' 51"N	6° 47’ 14"E	SABO GIDA
4	12° 9’ 58" N	6° 46' 35" E	RUKA
5			

2.4 Laboratory descriptions for geochemical analysis

2.4.1 Flame emission for Na and K

Flame photometry is an atomic emission method for the routine detection of metal salts, principally Na and K. Quantitative analysis of these species is performed by measuring the flame emission of solutions containing the metal salts. Solutions are *aspirated* into the flame. The hot flame *evaporates* the solvent, *atomizes* the metal, and excites a *valence electron* to an upper state. Light is emitted at characteristic wavelengths for each metal as the electron returns to the ground state. Optical filters are used to select the emission wavelength monitored for the analyte species. Comparison of emission intensities of unknowns to either that of standard solutions, or to those of an internal standard allows quantitative analysis of the analyte metal in the sample solution.

Flame photometry is a simple, relatively inexpensive, high sample throughput method used for clinical, biological, and environmental analysis. The low temperature of the natural gas and air flame, compared to other excitation methods such as arcs, sparks, and rare gas plasmas, limit the method to easily ionized metals. Since the temperature isn't high enough to excite transition metals, the method is selective toward detection of alkali and alkali earth metals. On the other hand, the low temperatures render this method susceptible to certain disadvantages, most of them related to interference and the stability (or lack thereof) of the flame and aspiration conditions. Fuel and oxidant flow rates and purity, aspiration rates, solution viscosity, concomitants in the samples and others affect these. It is therefore very important to measure the emission of the standard and unknown solutions under conditions that are as nearly identical as possible.

This experiment will serve as an introduction to sodium analysis by flame emission photometry and will demonstrate the effects of cleanliness and solution viscosity on the observed emission intensity readings. The instrument is calibrated with a series of standard solutions that cover the range of concentrations expected of the samples. Standard calibrations are commonly used in instrumental analysis. They are useful when sample concentrations may vary by several orders of magnitude and when the value of the analyte must be known with a high degree of accuracy. This experiment does not produce hazardous waste.

2.4.2 Procedure for operating the Buck PFP-7 Flame Photometer

Consult your Teaching Assistant for operating instructions for the Buck PFP-7 Flame Photometer. Allow a sufficient warm-up period. Be sure to aspirate deionized-distilled water between samples to clean out the sample tube and aspirator. Sodium is ubiquitous. It is imperative that you use scrupulously cleaned glassware to obtain good results.

2.4.3 Standard Preparations

Prepare sodium chloride standard solutions by volumetric dilution of the stock solution. The following approximate concentrations should be made: 5, 10, 25, 50, 75, and 100 □g/mLas Na. Be sure to use clean methods. Use ultra-pure deionized-distilled water to clean your glassware and for dilution of the 1000 □g/mLstandard. Prepare these standards in scrupulously clean volumetric glassware and transfer the solutions to plastic bottles. Glass often is made from high sodium glass. Allowing extremely high or low pH solutions to stand in glass could alter the sodium concentrations in solution. Prepare 25 □g/mLNa solutions in other solvents, 10% Ethanol, 50% Ethanol, 50% Glycerin. Standard solutions may be pre-prepared by the laboratory instructor or may be made up as a class or group project.

III. RESULT AND DISCUSSIONS

Five (5) water samples were collected from Sabo Gida and its environs for geochemical study in order to determine the concentrations of cation and anion elements. The summary of the concentrations of dissolved elements in the groundwater collected was presented in Table 2. The cation and anion results were compared with World Health Organization Standards [7]. The initial standards considered include, maximum contaminant levels (MCLS) of World Health Organization [7]. The implications of the MCLS are the enforceable standards which specify allowable level of a contaminant in public water.

3.1.1 Physical parameters

The pH value of the five samples ranged between7.48-8.26 with an average value of which correspond to the weakly acidic medium. Acidity in water may cause gastrointestinal problems to human health. The Total Dissolve Solid (TDS**)** measured for the samples ranges between 296- 381 with an average of 154.5, which is within the 500 mg/l set limit of NSDWQ, which means it is consumable for drinking. The Electrical Conductivity (EC) measured for the five samples ranges between 527-771 µs/cm with an average value of µs/cm, which is within the set limit (1000 µs/cm). EC designate the enrichment of salt in groundwater, and this varies with changing weather in the semi-arid climate, nutrient constituent and evaporation [8].

Table 2: The results for physical parameters

Locations	PH	Color	EC	TDS	Turbidity	Salinity	Temperature
LOC.1	7.48	10	771	381	0.39	1.4	28.2
LOC.2	7.74	6	539/751	296/374	0.78/1.13	4.2	28.2
LOC.3	8.13	10	668	334	1.2	30.8	28.1
LOC.4	8.26	8	527	363	1.15	22	28.3
LOC.5	8.14	10	729	364	1.41	1.8	28.4
Highest value	8.26	10	771	381	1.41	30.8	28.4
Lowest value	7.48	6	527	296	0.39	1.4	28.1
WHO mg/l	6.5-8.5	15	1000	500	5	200	Ambient
NSDWQ	6.5-8.5		1000	500	5	200	Ambient

3.1.2 Physiochemical Parameters

The summary of the concentrations of dissolved elements and compounds in the groundwater collected from Sabo Gida and its environs, Zamfara State, Nigeria was presented in Tables 3. Analytical results of the investigated cations and anions were compared with World Health Organization (WHO) and Nigeria Drinking Water Quality Standards (NDWQS). The initial standards considered include maximum contaminant levels (MCLs), secondary maximum contaminant levels (SMCLs) erected by USEPA (2012) and [6].

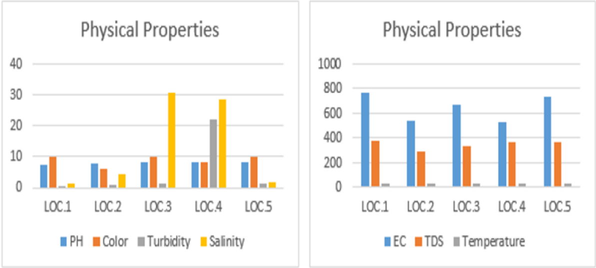

Figure 1: Bar chart of physical parameters concentration

The implications of the MCLs are the enforceable standards that specify the allowable level of a contaminant in public water [9].

The geochemical analysis results of water samples obtained show that all the measured parameters, which are Mg, Fe, Cl, SO4, NO3, F, and EC concentration values, are within the standard limits of WHO and NSDWQ. The magnesium (Mg) concentrations show a minimum value of 0.25mg/l, a highest value of 2.1mg/l and an average value of 0.91 mg/l (Table 3). These values are far less than the maximum concentration limit specified by the WHO put at 30 mg/l. The Iron (Fe) concentration varies from 0.00-0.52 mg/l with an average value of 0.16 mg/l compared with 0.3 mg/l standard limit recommended by the WHO (2012).

The Nitrate (NO_3) ion concentration varies between 0.00-7.3 mg/l with an average value of 3.91 mg/l, compared to the WHO standard limit of 50 mg/l. Sulphate (SO_4^{2-}) ion concentration varies between 0-59 mg/l with an average value of 63 mg/l compared to the WHO standard limit of 250 mg/l. Chloride (Cl^-) ion concentration varies between 0.02-18.7 mg/l, with the average value of 10.67 mg/l. The Cl^- ion concentration value is within the WHO standard limit of 200 mg/l.

Fluoride (F^+) ion concentration varies between 0-0.95 mg/l with an average value of 0.45 mg/l compared to the WHO standard limit of 1.4 mg/l. The F ion concentration value is within the WHO value. Escherichia coli concentration ranges from 0 – 18, which is above the acceptable limits as per the WHO NSDWQ standards.

Table 3: The results for physicochemical parameters

Locations	Mg	Fe	NO3	S04	F	Cl	E-coli
LOC.1	2.1	0.52	1.5	58	0.95	0.02	18
LOC.2	0.76	0.21	4.40	10	0.01	11	0
LOC.3	0.25	0.06	2.30	14	0.53	18.7	TNTC
LOC.4	0.76	0.00	7.30	46	0.02	16.2	3
LOC.5	0.31	0.01	4.03	59	0.76	3.4	TNTC
Highest value	2.1	0.52	7.3	59	0.95	18.7	18
Lowest value	0.25	0.00	1.5	10	0.01	0.02	0
Average value	0.91	0.16	3.91	63	0.45	10.67	
WHO mg/l	30	0.3	50	250	1.5	200	0
NSDWQ		0.3	50	100	1.5	200	0

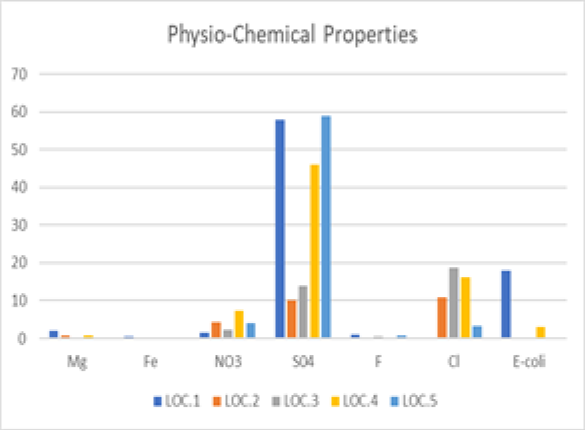

Figure 2: Summary of the bar chart of physicochemical concentration

3.1.2.1 Magnesium ion (Mg^{2+})

The magnesium (Mg) concentrations show a minimum value of 0.25mg/l, a highest value of 2.1mg/l and an average value of 0.91 mg/l (Table 2). These values are far less than the maximum concentration limit specified by the WHO put at 30 mg/l. The distribution of Mg^{2+}concentration in the locations investigated shows that location one (1) is relatively high compared to other locations, while other locations maintain a fairly equal concentration values.

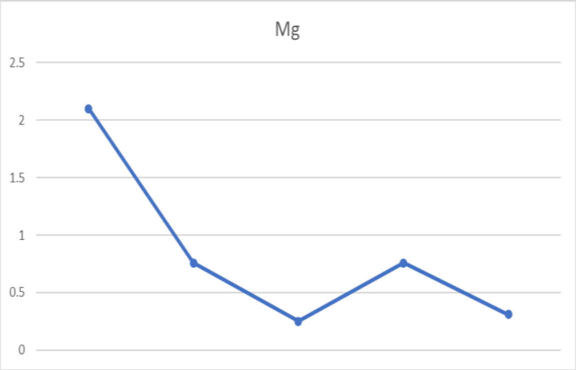

Figure 3. Variation plot Mg concentrations

Iron (Fe^{2+})

The Iron (Fe) concentration varies from 0.00-0.52 mg/l with average value of 0.16 mg/l compared with 0.3 mg/l standard limit recommended by WHO (2912). The distribution of Fe^{2+} concentration in the locations investigated shows that location 1 is the highest while the other locations are relatively moderate to low in concentration.

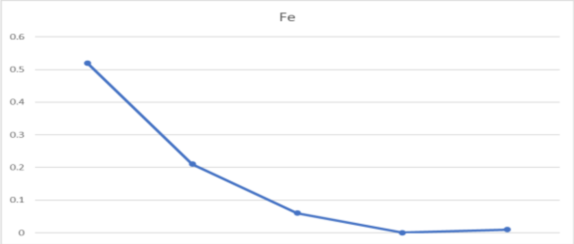

Figure 4. Variation plot of Fe concentrations

Nitrate (NO_3)

The Nitrate (NO_3) ion concentration varies between 1-5-7.30 mg/l with an average value of 3.91mg/l, compared to the WHO standard limit of 45 mg/l. The NO_3 ion concentration value is within the WHO value.

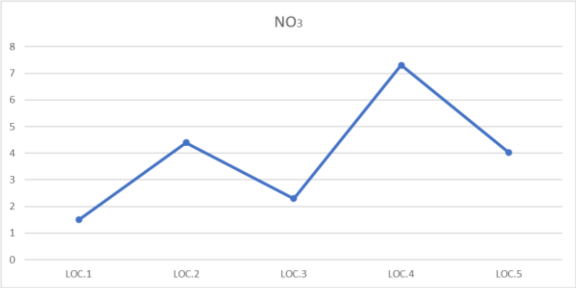

Figure 5. Variation plot NO3 concentrations

Sulphate (SO_2^{-4})

Sulphate (SO_4^{2-}) ion concentration varies between 0-59 mg/l with an average value of 63mg/l compared to the WHO standard limit of 250 mg/l. TheSO_2^{-4}ion concentration value is within the WHO value. Locations 1, 4, and 5 have the highest values, while locations 2 and 3 have the lowest values.

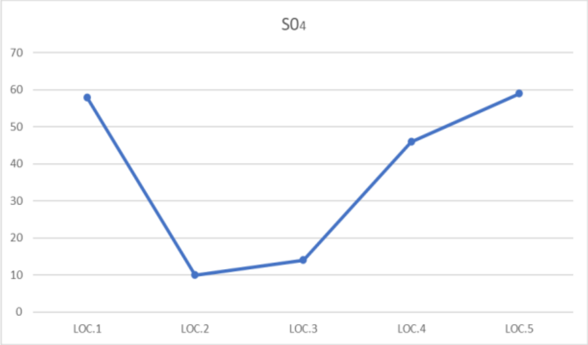

Figure 6. Variation plot of SO4 concentrations

Fluoride ion (F^-)

Fluoride (F^+) ion concentration varies between 0.01-0.95 mg/l with an average value of 0.45mg/l compared to WHO standard limit of 1.4 mg/l. The F ion concentration value is within the WHO value. The F ion concentration value is within the WHO value. Location 1 has the highest value, while location 2 has the lowest.

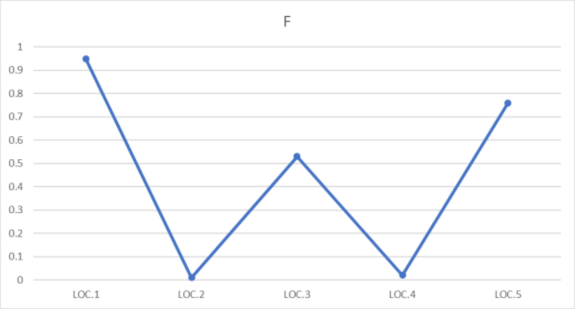

Figure 7. Variation plot F concentrations

Chloride ion (Cl^-)

Chloride (Cl^-) ion concentration varies between 0.02-18.7 mg/l with the average value of 10.67mg/l. The Cl^- ion concentration value is within the WHO standard limit of 200 mg/l. Locations 3 and 4 have the highest value.

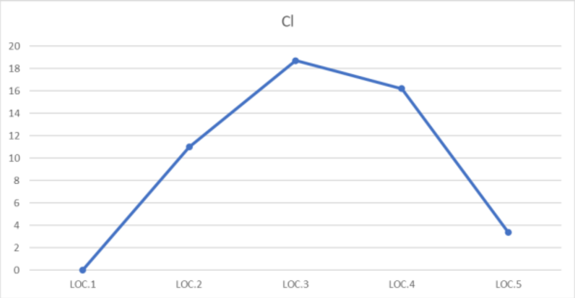

Figure 8. Variation plot Cl concentrations

Escherichia coli

Escherichia coli concentration ranges from 0-18, which is above the acceptable limits as per WHO NSDWQ standards.

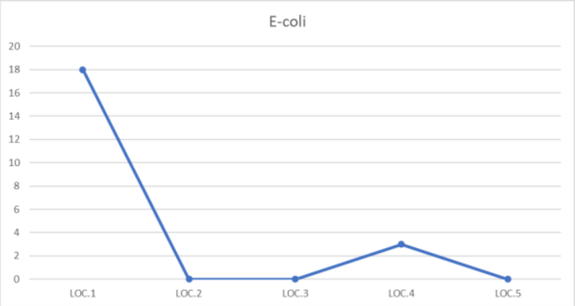

Figure 9. Variation plot E. coli concentrations

IV. CONCLUSION

The geochemical and physicochemical assessment of groundwater from five locations in Sabon-Gida village and its environs, Zamfara State, revealed that most parameters are within acceptable limits for drinking water as prescribed by the World Health Organization (WHO, 2012) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2015). The pH values (7.48–8.26), electrical conductivity (527–771 µS/cm), total dissolved solids (296–381 mg/L), magnesium (0.25–2.1 mg/L, avg. 0.91 mg/L), iron (0.00–0.52 mg/L, avg. 0.16 mg/L), nitrate (0.00–7.3 mg/L, avg. 3.91 mg/L), sulphate (0–59 mg/L, avg. 63 mg/L), chloride (0.02–18.7 mg/L, avg. 10.67 mg/L), and fluoride (0–0.95 mg/L, avg. 0.45 mg/L) concentrations were all below the respective maximum permissible limits.

However, the most critical finding is the presence of Escherichia coli (E. coli) in concentrations ranging from 0 to 18 CFU/100 mL (with TNTC in some samples), which significantly exceeds the WHO and NSDWQ guideline of zero coliforms per 100 mL for potable water. This indicates microbial contamination likely originating from surface sources, poor sanitation, inadequate well protection, or fecal pollution in the vicinity.

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