The Water Chemistry and Geotourism Potentials of Gwash and Environs, Central Nigeria

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Abstract:
The work is centered on the water chemistry and geotourism potentials of the Gwash area of North-central Nigeria. The area is situated in the North-Eastern part of the Jarawa Complex in Nigeria and covers an area that is approximately 22.5 square kilometers. Most of the water samples showed genetic relationship as reflected from the study and analyses of Piper plots and polygons on Stiff plots with only a few samples from unrelated tributaries of the waterfall displaying different shapes. The quantitative analysis of chemical constituents and physical parameter of the water samples illustrate a predominantly Mg-HCO3 water type. The waterfall has a fluctuating velocity of water flow due to seasonal rainfall as is typical with tropical regions of the world. Although a little to no research have been documented as far as the Gwash waterfall is concerned, the waterfall presents vast potentials for geotourism and the authors are positive that adopting some of the suggestions and recommendation included in this work can provide an alternative means of revenue generation in the central part of Nigeria and the whole country at large.

Keywords: Hydrochemistry, geotourism, piper, stiff, gwash waterfall

1. Introduction
The groundwater flows slowly through the rocks and it dissolves many minerals from the bedrock. The slow percolation of water results in a prolonged contact through the minerals. Many minerals are dissolved by the groundwater as it passes over them and in time quasi-chemical equilibrium can be reached between the groundwater and the minerals. By this process the groundwater gets saturated by certain dissolved solids. The ability to dissolve the mineral constituents determines the chemical nature of groundwater. The geochemistry of groundwater is an important topic after the publication of the work done by Back and Hanshaw (1965). It usually contains some amount of dissolved mineral ions. The amount of ions, concentration and the type of ion will determine the usage of the water for various purposes. The Geomorphology of an area also has a great influence on its touristic attributes, especially when it exhibits control over the nature and type of physical features emanating from it. Hence, the objective of this work is to classify the water samples analyzed into classes based on the cations and anions present in the water, to determine the interaction of the waters with their environment and to carry out preliminary geotourism potentials study of the area.

1.1. The Study Area
The Study area is located in the North eastern part of the Jarawa Complex of Jos east local government area in Nigeria. It is bordered by longitudes 8°58’32” E and 9°00’E and latitude 10°00’N and 9°56’11”N and flows in a SW-NE direction (fig 1). The area lies between the Naraguta hills and Shere hills whose potentials for geotourism has long been utilized from decades ago up to this present day(Goki et al., 2018). It covers an area of about 22.5 Square kilometres and is poorly accessible (fig.1)
The drainage pattern characterized by the branching of tributary streams in a model resembling tree branches, with some network of fractures and joints meeting at varying angles hence exhibits a dendritic pattern of drainage (Fig.2a). The area is subject to heavy seasonal fluctuations in flow as a result of seasonal rains of the north central, Nigeria. Between the month of June and October, flow increases dramatically and the water looks muddy as a result of some dissolved chemical elements in water. However, during the dry season, the velocity of water flow reduces and appears settled and clean. The source of the drainage can be traced to Shere hills, where it gushes down from the top and extends to neighbouring villages (Gwashi and Durbi) passing through Mazah down towards the neighbouring Toro local government in Bauchi state. The topography of the study area is generally moderate to high and the fall flows over a steep region that is about 1380m above sea level reflected in the DEM (Fig.2b).

3. Methodology

The sample bottles were washed with the water samples, filled and closed air-tight. Proper labelling including the sample numbers and locations were done. A total of ten surface water samples were taken along the waterfall area and its tributaries at intervals from downstream to upstream. The samples were acidified with two drops of tetraoxosulphate (VI) acid (H₂SO₄) in order to preserve the samples and also to prevent unwanted reactions. The samples were stored at normal room temperature before it was transported to the laboratory for analysis. The analysis carried out on the samples was to detect the major and minor constituents of the samples collected.

The methods used for the analysis were titrimetry using Digital HachTitrator Model 1690 only for HCO₃ and Spectrometry using Hach Digital Spectrometer Model 2400 for the analysis of the Cations and Anions. Piper, Stiff and Ion balance diagrams were plotted using the analytical data obtained from the water chemistry analysis to determine water type and water quality. The diagrams were created using rock wares aq/QA software.
The geotourism aspect of the study area was unraveled as a result of field work by traversing through valleys and climbing of hills while the utilization of the fall was discovered through interaction with the locals.

4. Result and Discussion

Results are presented in Tables 1 and 2 below. Piper and Stiff diagrams were plotted and analysed in order to characterize the water samples.

| S/N | Sample Point | HCO$_3^-$ | SO$_4^{2-}$ | SiO$_2$ | NO$_3^-$ | Mn$^{2+}$ | K$^+$ | Mg$^{2+}$ | Ca$^{2+}$ | Na$^+$ | Cu$^{2+}$ | F |
|-----|--------------|-----------|-------------|--------|--------|----------|------|----------|--------|------|--------|---|
| 1   | K001         | 76.00     | 28.43       | 28.00  | 22.50  | 0.012    | 2.20 | 8.14     | 12.05  | 0.25 | 0.463  | 0.087 |
| 2   | K002         | 62.5      | 26.50       | 33.00  | 31.50  | 0.105    | 3.27 | 13.09    | 13.09  | 0.45 | 0.215  | 0.305 |
| 3   | K003         | 82.00     | 29.35       | 34.00  | 34.50  | 0.257    | 5.30 | 12.00    | 17.50  | 2.03 | 0.257  | 0.350 |
| 4   | K004         | 179       | 19.21       | 0.19   | 15.32  | 0.017    | 2.76 | 1.009    | 6.93   | 0.99 | 0.030  | 0.097 |
| 5   | K005         | 223       | 9.97        | 19.50  | 5.032  | 0.031    | 9.90 | 15.30    | 11.90  | 0.01 | 0.03   | 0.011 |
| 6   | K006         | 200       | 6.98        | 40.53  | 11.96  | 0.001    | 6.00 | 16.90    | 21.97  | 0.002| 0.16   | 0.017 |
| 7   | K007         | 164       | 5.97        | 19.98  | 7.99   | 0.03     | 7.89 | 15.98    | 13.8   | 0.007| 0.038  | 0.015 |
| 8   | K008         | 250       | 5.73        | 51.00  | 10.73  | 0.002    | 7.50 | 7.62     | 8.63   | 1.03 | 0.71   | 0.00  |
| 9   | K009         | 230       | 9.87        | 35.00  | 9.99   | 0.005    | 8.53 | 14.50    | 13.63  | 1.56 | 0.055  | 1.110 |
| 10  | K010         | 300       | 5.62        | 4.00   | 5.00   | 0.006    | 7.50 | 18.00    | 21.17  | 0.051| 0.006  | 0.00  |

**Table 2: Water Analysis for Anions**

![Stiff Diagram](image-url)

**Figure 3: Stiff Diagram**
4.1. Water Chemistry

4.1.1. Physical Parameters

4.1.1.1. Total Dissolved Solid (TDS)

Is the residue left when a certain amount of water is vaporized. Concentrations expressed in mg/l are essentially equivalent to ppm except in saline water where the total dissolved solids (TDS) is equivalent to 7000mg/l. The chemical composition of water is bound to be affected by the environment from which it originated as well as human and natural processes such as evaporation, precipitation, weathering, erosion and runoff leaching are major factors. The aim of carrying out this research is to determine the level of interaction the water in the study area has with the environment. The TDS in water sample can be represented by the sum of the ionic concentration of the major constituents which are
usually Ca\(^{2+}\), Mg\(^{2+}\), K\(^{+}\), Cl\(^{-}\), HCO\(_{3}\) and SO. Samples K010, K008 have highest dissolved solids 358.320 mg/L and 290.048 mg/L respectively while K001 has the lowest TDS value 150.562 mg/L (Table 2).

4.2. Conductivity

Varied between 182 µmho/cm – 334 µmho/cm, the lowest value 182.84 µmho/cm was at K001 and highest 333.73 µmho/cm at K010 with an average value of 244.983 µmho/cm. The conductivities compared with total dissolved solid of water samples are slightly higher with average values 241.0352 mg/L and 244.983 µmho/cm for TDS and conductivity respectively. This may be as a result of increase in concentration due to ion exchange between the rocks and water.

| Samples | Dissolved Solids (Mg/L) Measured | Density (G/cm3) Calculated | Conductivity (µmho/cm) Calculated | Hardness (CaCO\(_{3}\) Mg/L Calculated | Water Type |
|---------|---------------------------------|-----------------------------|-------------------------------|---------------------------------|------------|
| K001    | 150.562                         | 0.99714                     | 182.84                        | 63.609                          | Mg-HCO\(_{3}\) |
| K002    | 151.457                         | 0.99714                     | 203.68                        | 86.59                           | Mg-HCO\(_{3}\) |
| K003    | 184.064                         | 0.99714                     | 235.62                        | 93.114                          | Mg-HCO\(_{3}\) |
| K004    | 226.148                         | 0.9972                      | 190.72                        | 21.459                          | Ca-HCO\(_{3}\) |
| K005    | 275.946                         | 0.99724                     | 266.57                        | 92.72                           | Mg-HCO\(_{3}\) |
| K006    | 264.723                         | 0.99723                     | 278.65                        | 124.45                          | Mg-HCO\(_{3}\) |
| K007    | 216.327                         | 0.99719                     | 232.01                        | 100.26                          | Mg-HCO\(_{3}\) |
| K008    | 292.757                         | 0.99725                     | 245.99                        | 53.074                          | Mg-HCO\(_{3}\) |
| K009    | 290.048                         | 0.99725                     | 280.02                        | 93.745                          | Mg-HCO\(_{3}\) |
| K010    | 358.320                         | 0.9973                      | 333.73                        | 126.99                          | Mg-HCO\(_{3}\) |

Table 2: Physical Parameters and Generated Water Types For The Samples

4.3. Source of Major Ion

The dissolved ions in groundwater samples are generally governed by the lithology, velocity and quantity of groundwater flow, nature of geochemical reactions, solubility of salts and human activities (Karnath, 1991, 1999; Bhatt & Saklani, 1996). The concentration of carbonate is caused by the CO\(_{2}\) present in the soil zone formed from the weathering of parent materials. The weathering is caused by the alternate wet and dry conditions characteristic of the tropical climate of the area. The generally high concentration of HCO\(_{3}\) in most of the samples can be attributed to the dissolution of the silicate minerals orthoclase, plagioclase, hornblende, olivine and biotite of country rocks by carbonic acid. The hydrogeochemical reactions dictate that the groundwater in the area will acquire cations besides SiO\(_{2}\).

Sample K0010 and K006 contain the highest Mg\(^{2+}\) (18.00 mg/l and 16.90 mg/l) and Ca\(^{2+}\) (21.17 mg/l and 121.97 mg/l) concentration respectively. The dominance of Mg\(^{+}\) suggests that the ions result from silicate weathering and/or dissolution of soil salts (Table 1).

Samples K001, K002, K003 have the highest SO\(_{4}\)\(^{2-}\) concentration (28.00, 26.5, 29.35 mg/l) and NO\(_{3}\) concentration (22.50, 31.50 34.5 mg/l) respectively (Table 1). The SO\(_{4}\)\(^{2-}\) could be a by-product of the oxidation of sulphides from the granitic rocks. Although, igneous rocks contain small amount of soluble nitrate, its presence in water either emanates from organic sources or from industrial and agricultural chemicals.

Anthropogenic activities also increase the ion concentration (TDS, Na\(^{+}\), SO\(_{4}\)\(^{2-}\) and NO\(_{3}\)\(^{-}\)), especially after the rainy season when the water table is nearer to the surface. Changes in the ionic concentration between the pre-and post-rainy seasons signify active infiltration which can affect the salt content of wells within a short period. As entry of dissolved ions into the aquifer system is caused by percolation, they mix with groundwater and flow laterally (Chourasia 2007). Mixing of high TDS with low TDS water along the flow path also promotes leaching of salts present in the soil zone during vertical recharge from rainfall and return seepage from irrigation, and results in poor groundwater quality. This, in turn, reduces agricultural productivity and affects health.

4.4. Water Type

The water type – e.g., Ca-HCO\(_{3}\), Mg-HCO\(_{3}\) or Na-SO\(_{4}\) – is determined by finding the predominant inorganic cation and anion, figured on the basis of electrical equivalents. In determining water type, Aq•QA software accounts whenever possible for the carbonate speciation in solution, using the sum in electrical equivalents of the CO\(_{3}\)and HCO\(_{3}\) concentrations to represent carbonate. If carbonate is the dominant anion by this criterion, Aq•QA states the water type in terms of whichever of the species is present in larger equivalent concentration (e.g., Ca-HCO\(_{3}\), Mg-HCO\(_{3}\) or Na-CO\(_{3}\)) as reflected in (Table 2).

4.5. Genetic Relationship

From the piper diagram plotted above (fig.4), the water samples are composed mainly of Mg-HCO\(_{3}\) type water. All water samples as shown on the stiff plots tend to display similar shapes implying genetic relationship between all samples with the exception of samples K002 and K008 (fig.3) with shapes that do not correspond in any way, implying a different source.
4.6. Geotourism Potentials

Geotourism promotes tourism to geosites and the conservation of geo-diversity and an understanding of Earth Sciences through appreciation and learning. This is achieved through independent visits to geological features, use of geo-trails and viewpoints, guided tours, geo-activities and patronage of geosite visitor centers (Ruchkys, 2007). In other words, Geo-tourism is best practice tourism that sustains or even enhances the geographical character of a place, such as its environment, heritage, and well-being of its residents. It also enhances geographical character by developing and improving it in ways distinctive to the locals, reflective of differentiation and cultural pride. Hence, this paper intends to fully bring out the potentials of the Gwash waterfall and other attributes related to the area as it is of relevant tourist interest with streams and an abundance of flora and fauna deposits.

![Figure 6: Gwash Waterfall](image)

The topography of the study area which is the key factor controlling the formation of the waterfall; it is generally moderate to high and the fall flows over a steep region that is about 1100m above sea level (Fig. 5). The waterfall serves as a recreation centre for swimming as well as a source of water, well consumed by the inhabitants of this locality. Hence, a need to check for its suitability for consumption as mineral enrichment from underlying rocks can change the chemistry of water, making it unsuitable for consumption (Ako et al. 1990). The potential of the waterfall fall cannot be over emphasized as among other uses, it could be utilized for the following:

- A stop for picnicking and enjoying the scenery.
- It can be used for movie production, shooting local soap operas and commercials.
- The tapestry of the hills, trees, streams and village may provide inspiration for artist, Craft people, writers, musicians, couples etc.
- It can also be a potential source of income both for the locals who may serve as tour guides or provide feeding and accommodation to the tourist as well as economic regeneration for the government.
- It can be an everlasting product that serves as alternative source of revenue when properly accessed.

However, certain factors contribute to inhibit the maximum utility of the above-mentioned potentials and these include:

- Lack of income.
- Lack of investment from both government and private organizations
- Cost of development very is high
- Poor access to the fall
- It does not have a plunge
- The rate of flow is seasonal (the volume of flow increases during the rainy season and decreases during the dry season) hence, it cannot be used to generate hydroelectricity.

Notwithstanding, the geo-tourism potential of the Gwash waterfall is underutilized. The tourism organization in Nigeria is still a developing organization hence it has not done much in fully bringing the waterfall to the spotlight. This has resulted in low tourism activities in the area and has hindered public and individual inventors committed to bringing out a good tourist stop out of this very attractive waterfall. This paper is an appeal to the government and private investors to develop the place and to bring it to international standard as it will not only be of great benefit to local residents alone but also to the government. Although efforts are being made to construct a major road that will aid accessibility into the area. Various minor roads and footpaths are also available.

5. Conclusion

The water chemistry of Gwash waterfall showed predominantly Mg-HCO3 type water controlled by the environment in which the water passed and mostly affected by weathering and dissolution of the rocks on which the water flowed. Although no research has been documented as far as the gwash waterfall is concerned, the waterfall presents vast potentials for geotourism and the authors are positive that adopting some of the suggestions and recommendation
included in this paper can provide an alternative revenue generation in the central part of Nigeria and the whole country at large.

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