Preliminary assessment of groundwater Hydrogeochemistry in Kanye Area, SE Botswana

Nata T. Tafesse[1]*, R.B.M. Mapeo[1] , K. Laletsang[1] and Tshenolo K. Segobaetso[1]

[1:] University of Botswana, Geology Department, Private Bag UB 00704, Gaborone, Botswana

***: Corresponding author:** Tafessen@ub.ac.bw; ORICD ID: 0000-0002-4687-7540

Abstract. A hydrogeochemistry study was conducted in Kanye region, located in south east of Botswana, to determine the main composition controlling mechanisms in the groundwater chemistry of the area. Groundwater samples were collected and analyzed. The samples were analyzed for major cations, anions and some trace elements such as As, Ba, Br, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn. To determine the mechanism of salinization and water–rock interaction bivariate graph of the parameters Ca^{2+} + Mg^{2+} versus HCO_3^- + SO_4^{2-} was used. The groundwater is neutral to alkaline and fresh. The dominant cations in the groundwater are magnesium and calcium, and the dominant anions are bicarbonate and chloride. The prevailing hydrochemical facies is Mg-Ca-HCO3. The major composition controlling mechanisms in the groundwater chemistry of the area was identified as silicate weathering.

Keywords: Botswana, Groundwater, Hydrogeochemistry, Hydrochemical facies, Kanye.

1. Introduction

The study area is located in the Southern District of Botswana and is bound by latitude 25.545376° S and 24.254817°S and longitudes 25.070533° E and 25.503821°E covering an area of approximately 2500 km^2 (Figure 1).

Groundwater is the main source of water supply for the Kanye area and the surrounding settlements. There are seven developed wellfields in the area for this purpose and supply water for the communities, which have a population of about 45,000, and the surrounding settlements. These wellfields are named after the villages and localities that surround the main settlement of Kanye (Kgwakgwe, Ramonnedi, Selokolela, Ranaka, Lotlhakane West, Lotlhakane East and Segwagwa) - thus called the Kanye wellfields.

The Kanye region is underlain by Neoarchean to Paleoproterozoic that include the Neoarchean Gaborone Granite Complex, rhyolites and volcano-sedimentary rocks of the Lobatse Group. The chemical, volcanic and siliciclastic sedimentary rocks of the Transvaal Supergroup and the continental redbeds of the Waterberg Group cover the basement rocks (Carney et al., 1994; Moore et al., 1993; Mapeo et al., 2006; Franchi and Mapeo, 2019).

A hard rock terrain underlies much of the Kanye area, with aquifer formations being of a fractured nature; hence groundwater potential and occurrence are related to the presence of fractures and fissures such as joints, faults and bedding planes that developed due to tectonic deformation. The three major potential aquifers are the Chert Breccia Aquifer in areas underlain by the Kgwakgwe Chert Breccia Formation; the Dolomite Aquifer in the Ramonnedi area underlain by extensive dolomite formations that extend to Lotlhakane West; and the Waterberg Sandstone Aquifer in the Moshaneng-Selokolela areas. The groundwater in the Waterberg Sandstone Aquifer is mainly within fractured zones, because of minor to negligible primary porosity in these metamorphosed siliciclastic sedimentary rocks.

2. Methods

Thirteen groundwater samples were collected across different wellfields and from boreholes drilled in different rock types during the rainy and dry seasons between the years 2018 and 2019. The samples were analyzed using Inductively Coupled Plasma Mass Spectrometers (ICP/MS) for cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) at the Department of Geology

hydrogeochemistry and geochemistry laboratory in the University of Botswana and for the anions (F^-, HCO_3^-, Cl^-, SO_4^{2-}, and NO_3^-) the samples were analyzed using ion chromatography at the Department of Water Affairs in Gaborone, Botswana, which is accredited with the Botswana Bureau of Standards (BOBS). The samples were also analyzed for the trace elements such as As, Ba, Br, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn using Inductively Coupled Plasma Mass Spectrometers (ICP/MS) at the Department of Geology hydrogeochemistry and geochemistry laboratory in the University of Botswana.

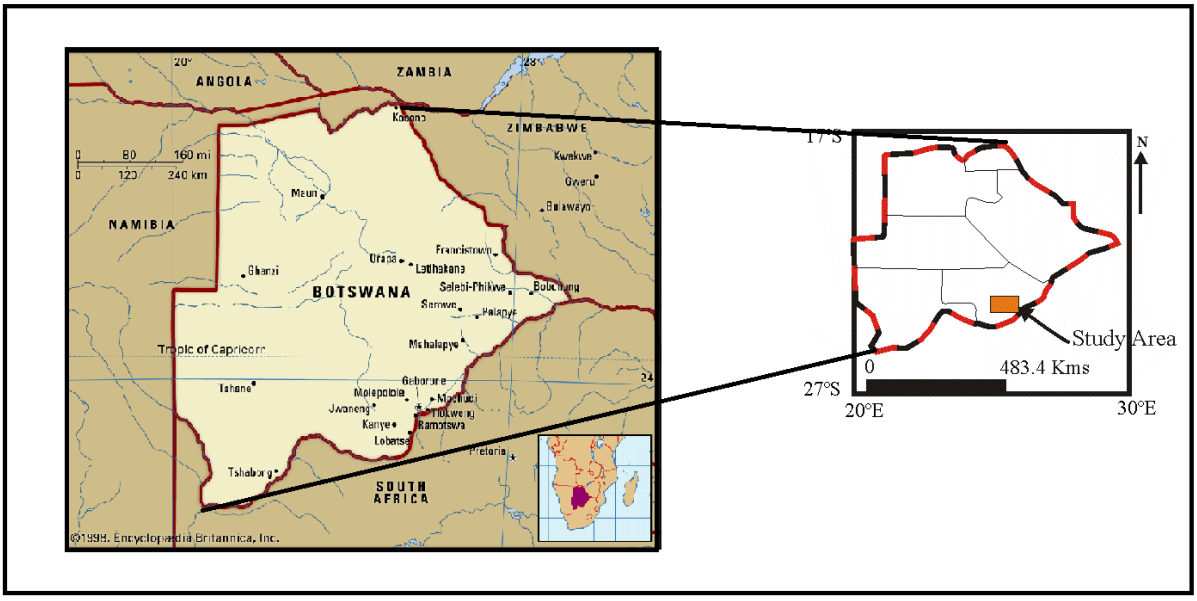

Figure 1. Location of the study area,

For the analyzed samples, physicochemical parameters such as electrical conductivity (EC), pH, the temperature of the groundwater and surface water, and total dissolved solids (TDS) were measured in-situ using the Hach Portable multi-parameter meter in the field.

To determine the mechanism of salinization and water–rock interaction bivariate graph of the parameter $Ca^{2+} + Mg^{2+}$ versus $HCO_3^- + SO_4^{2-}$ (Gebrehiwet et al., 2021) was used.

3. Results and Discussions

The groundwater is neutral to alkaline and fresh. The pH ranges from 7.08 to 7.89, with an average of 7.54. EC and TDS range from 212.7 to 898 µS/cm and 67 to 630 mg/l, with a mean value of 543 µS/cm and 263 mg/l, respectively. The recorded temperature of the groundwater samples ranged between 22.50 and 26.95°C, with an average of 24.88°C.

The chemical analyses of the water samples revealed that the following groundwater facies are recognized in Kanye area: Mg-Ca-HCO3, Ca-Mg-HCO3, Mg-HCO3 and K-Cl-HCO3 constituting 61.5%, 15.4%, 15.4%, and 7.7% of the total water samples, respectively.

The dominant cations in the water samples are magnesium and calcium. Cations content indicates that 61.5% of the water samples follows the following trend; $Mg^{2+} > Ca^{2+} > Na^+ > K^+$. The remaining samples follow different trends: 15.4% shows $Ca^{2+} > Mg^{2+} > Na^+ > K^+$, and the last three samples, which each of them take up 7.7% of the total number of samples, are each unique and follow the following trends $Mg^{2+} > Na^+ > K^+ > Ca^{2+}$, $Mg^{2+} > K^+ > Ca^{2+} = Na^+$ and $K^+ > Na^+ > Ca^{2+} = Mg^{2+}$.

The dominant anions are bicarbonate and chloride. Anion content indicates that 46.1% of the total water samples show $HCO_3^- > Cl^- > NO_3^- > SO4^{2-} > F^-$, 38.5% $HCO_3^- > Cl^- > SO4^{2-} > NO_3^- > F^-$ and the remaining two samples each of them equally 7.7% show $Cl^- > HCO_3^- > NO_3^- > SO4^{2-} > F^-$ and $HCO_3^- > Cl^- = SO4^{2-} > NO_3^- > F^-$.

In all the analyzed groundwater samples, generally based on the mean values of the analyzed parameters, the trace elements are in the order of abundance as Ni > Fe > As > F > Pb > Br > Ba > Cd and Mn > Zn > Cu > Cr.

A plot of $Ca^{2+} + Mg^{2+}$ versus $SO4^{2-} + HCO3^-$ (Figure 2) was used to determine the role of dissolution of carbonate minerals (calcite, dolomite, and gypsum) and weathering of silicate minerals as a mechanism of salinization in the studied area. According to Datta and Tyagi (1996), a scatter diagram of $(Ca^{2+} + Mg^{2+})$ versus $(HCO_3^- + SO_4^{2-})$ can be used for this purpose.

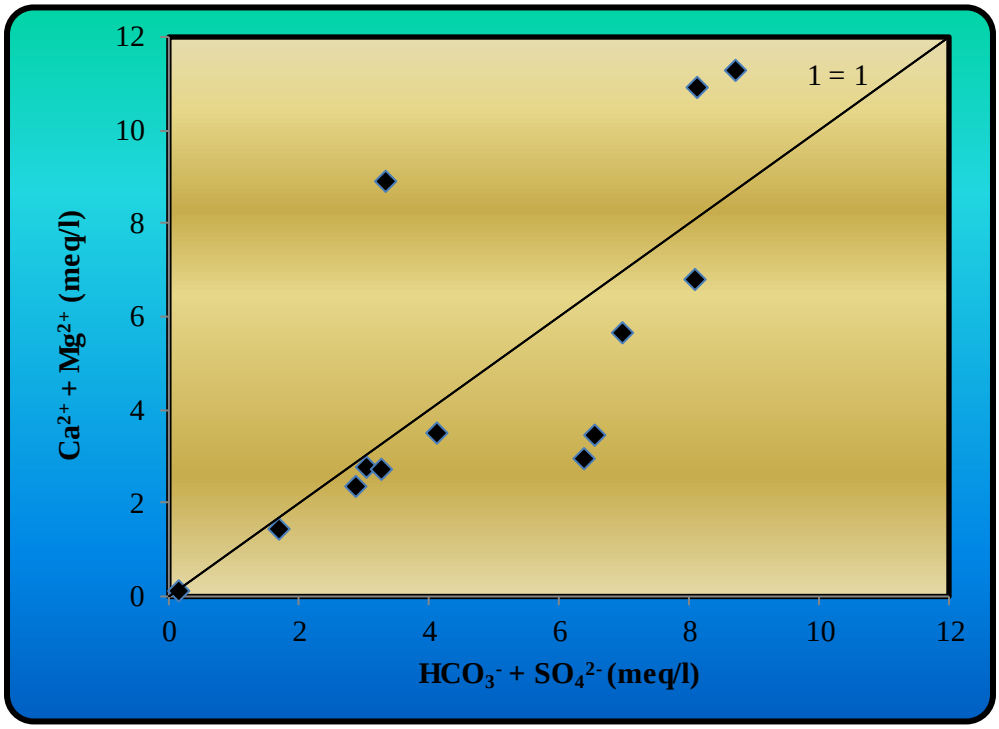

Figure 2. $Ca^{2+} + Mg^{2+}$ versus $HCO_3^- + SO_4^{2-}$ in the groundwater of the Kanye area.

As shown in Figure 2, 69.2% of the total samples were laying below the equiline, revealing that weathering of silicate minerals was the dominant composition-controlling process, whereas, in those samples above the equiline, which constituted 23.1% of the total samples, congruent dissolution of carbonate minerals and gypsum were the prevailing process. The sample fell along the equiline (7.7% of the total sample) was due to both silicate weathering and dissolution of carbonate minerals (including gypsum). This indicates that silicate weathering was the main source for Ca^{2+}, Na^+, HCO_3^- ions in the groundwater of the Kanye area (Mayback, 1987; Elango and Kannan, 2007; Elango et al., 2003).

$$2NaAlSi_3O_8 + 9H_2O + 2H_2CO_3 \rightarrow Al_2Si_2O_5(OH)_4 + 2Na^+ + 2HCO_3^- + 4H_4SiO_4 \quad (1)$$

$$CaAl_2Si_2O_8 + 2CO_2 + 3H_2O \rightarrow Al_2Si_2O_5(OH)_4 + Ca^{2+} + 2HCO_3^- \quad (2)$$

4. Conclusion

The groundwater is neutral to alkaline and fresh. The dominant cations in the groundwater are magnesium and calcium and based on the mean values of the analyzed parameters, the trend of the cations dominantly is $Mg^{2+} > Ca^{2+} > Na^+ > K^+$. The dominant anions are bicarbonate and chloride and based on the mean values of the analyzed parameters, the trend of

the anions dominantly is HCO_3^- > Cl^- > NO_3^- > $SO4^{2-}$ > F^-. In all the analyzed water samples, generally based on the mean values of the analyzed parameters, the trace elements are in the order of abundance as Ni > Fe > As > F > Pb > Br > Ba > Cd and Mn > Zn > Cu > Cr.

The major groundwater facies in the study area is Mg-Ca-HCO3. Silicate weathering is the major process that controls the chemical composition of the groundwater.

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