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Research Article

Hydrochemical characterization of Katana thermals waters, Lake Kivu watershed

Bagalwa M. L.[1], Bagalwa M. J. J.*[2], Karume K.[3]
[1]Département de Géophysique, Centre de Recherche en Sciences Naturelles/Lwiro, République Démocratique du Congo
[2]Département de Biologie, Centre de Recherche en Sciences Naturelles/Lwiro, République Démocratique du Congo
[3]Observatoire volcanique de Goma, Département de Géochimie et Environnement, Goma, République Démocratique du Congo

***Corresponding author**
Jean Jacques Bagalwa
Email: mashibagalwa@yahoo.fr

Abstract: Thermal water springs are considered to be important natural sources. Studies was done in the region concerning the geology, geophysics, hydrochemistry but no was concentrated on the hydro-chemical characteristics of thermal water in Katana region. A large number of chemical analysis of Katana thermal spring waters were evaluated in order to identify the major chemical characteristics and investigate the origin of thermal waters. This could demonstrate the hydrochemical homogeneity or diversity at the scale of the region and the possibilities of deep the same flows waters. Water sample was collected from the different thermal springs of Katana region for 3 years (July 2006, July 2008 and July 2010) and analyzed for temperature and pH *in situ,* Total Suspended Sediment, Alkalinity, Total hardness, Calcium hardness, magnesium hardness, bicarbonate, sulfate, chloride, Total phosphorus, total nitrogen, ammonia and nitrate. Piper Diagram, in which major cations and major anions was plotted on ternary diagrams in order to illustrate which cations and anions dominate. The physic-chemical parameters of the thermal water in Katana region varied from one spring to another. The variation of temperature of the springs was not significant (F= 0.1902; p = 0.833) during the study period. The high values when until to 70 °C in same springs at Kankule. This diagram indicates that Katana thermal spring waters have very similar hydrochemical characteristics and therefore may share a common source area. The springs are originating directly from crystalline rocks and belong to the two types of thermal water (Ca–HCO_3 and Ca–Mg–HCO_3 type waters). The diagnostic chemical character of water solutions in hydrologic systems has been determined with the application of the concept of hydro chemical facies. The Ca-Mg-HCO_3 plot conforms thermal water falls in Ca-Mg domain.
Keywords: water springs, thermal waters¸ hydro chemical, Total Suspended Sediment, Alkalinity, Total hardness, Calcium.

INTRODUCTION

Lake Kivu watershed is characterized by many manifestations of thermals water in the fault create by earthquake frequent in the region. It is among the most active region in this Rift [1, 2]. The tectonic process of Lake Kivu watershed might be in a nascent stage of development [3, 4]. Magmatic and volcanic processes, the high mountain chains and active fault systems favour the rise of deep waters that discharge at the surface as thermal springs [5]. Thermal springs are natural geological phenomena that occur on all continents [6]. Intense volcanic activity in Lake Kivu watershed is known from the presence of volcanic rocks found in the entire region. This volcanic activity is closely related to fault systems that favour the displacement in depth of ground waters and the development of thermal springs [5].

Thermal water springs are considered to be important natural sources [7]. Owing to their therapeutic and health-improving effects, some of them are widely popular for medical therapy, tourism, recreation, rehabilitation, drinking and power generated [7]. Chemical studies of thermal waters provide information regarding the type of geothermal reservoir (liquid or vapor dominated), reservoir base temperature, subsurface flow patterns and chemical quality. Evaluate the hydro-geothermal in the region need a good knowledge of the data of geological and geophysics but also the repartition of chemical characteristics, temperature, hydro-dynamic of the reservoir and the petro-physics characteristics [8, 9]. A large amount of research has been studied the origins of geothermal water and hydro-geochemical processes in many countries in the world and showed that hydro-geochemical indicators, such as major ion ratios, can be used to study recharge origin and mixing behavior of thermal groundwater [10, 11, 12]. Physico-chemical data in geothermal aquifers can also indicate structural elements of geothermal systems [13].

Geological studies in Lake Kivu region revealed the existence of many permeable sub-watersheds which can play the role of potential reservoir of thermals water [14, 15]. Therefore, the thermal springs are listed in different geological structures. They emerge in the sub-watershed with varied lithologic nature and varied ages [16]. In order to determine the origin of thermal water, geo-chemical features and aquifer lithology, it is necessary to characterize the physic-chemical parameters of the spring of thermal water of the region. There are many tools and methods to understand the model of hydrodynamic operating in a aquifer system. Thus, the chemical analyses put in a diagram of Piper can give the type of thermal water and then different source of the thermal water.

A large number of studies were done in the region concerning the geology, geophysics, hydrochemistry [14, 17, 18, 19, 20, 21, 22] but no study was concentrated on the hydro-chemical characteristics of thermal water.

The aim of this paper is to identify the major chemical characteristics in a preliminary study of the Katana thermal waters and investigate the origin of thermal waters. This could demonstrate the hydro-chemical homogeneity or diversity at the scale of the region and the possibilities of deep the same flows waters.

MATERIALS AND METHODS

Study site

Katana geothermal field is located between the western of Lake Kivu and the Mitumba Mountains. It's possesses large exposed units of carbonate rocks covering the region. The carbonate rocks are karstified and feed a large number of springs. They offer a resource which is exploited by springs for water supply. The water temperatures are abnormally high in some places. In Lake Kivu watershed, the oldest carbonate formations (Proterozoic and Cambrian) are represented by marbles. However, the main carbonate rocks in the region, consisting of marble, limestone and dolomite were formed at middle Cambrian and Triassic periods [18]. The Watershed is an area of substantial tectonic movement due to the presence of one of the main active strike –slip faults in South-East Bukavu [4, 14, 17].

Tectonic movements along the major faults and the related fracturing must enhance the deep flow paths of fluids, especially as the region is the site of strong neotectonic activity. As many as 200 earthquakes have been observed annually [23]. The earthquake of February, 3rd 2008 scored 6 on the Richter scale and caused disappearance of some springs in the Katana watershed. The hypocenter of this earthquake was located on the principal fault in Birava in the Lake Kivu watershed which is thus currently active [4]. The intense fracturing resulting from these tectonic movements allows the infiltration of water and has increased temperature of some springs.

Twenty sites of sampling was chose in the watershed subdivided by Kankule (n=11), Maziba (n=2), Ciziri (n=3), Buhandahanda (n=3) and Cimenki (n=3). These 5 sub-watersheds are the principal site in the watershed containing thermal water.

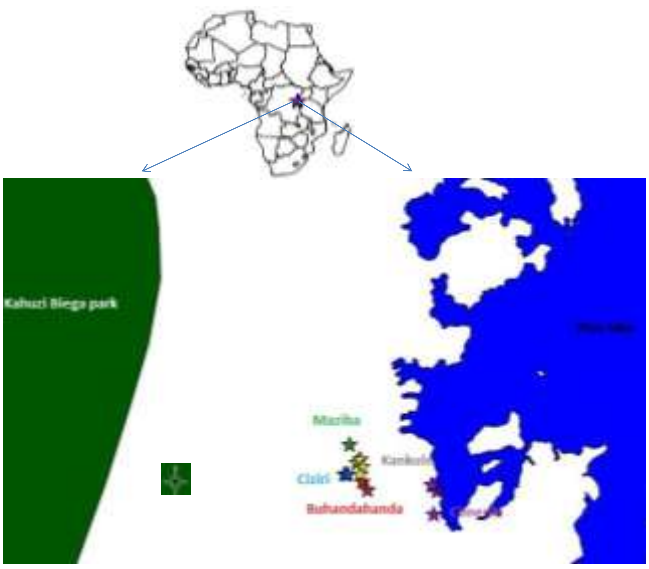

Fig-1:Localization of Katana thermal water sites

Water Sampling and Physico-chemical analysis

Water sample was collected from the different springs of Katana region for 3 years (July 2006, July 2008 and July 2010) in sterile bottles and brought into the laboratory at the Department of Biology, Centre de Recherche en Sciences Naturelles of Lwiro, Democratic Republic of Congo. Temperature was measured by using mercury bulb thermometer and pH was determined using a standard laboratory pH meter both *in situ*. Measurements were done in the morning between 8 h00' and 11 h00'. Total Suspended Sediment (mg/L) was estimated by filtration of 1 L of water through analytical filter paper (Whatman 589, 185 µm pore size) which was dried at 105 ºC and pre- weighed. Alkalinity of water is measured by titration method with 0.1 N hydrochloric acid in the presence of methyl orange (0.5%). Hardness is measured by EDTA complexometric method after addition of a buffer solution (ammonium chloride, ammonium tartrate and potassium and sodium) and a color indicator which is the Erichrome Black T. Calcium hardness was also determined by complexometric EDTA but after adjusting the addition of NaOH and murexide as color indicator; the magnesium hardness in turn, is deduced from the difference between the two previous [24]. Similarly the percentage of bicarbonate is calculated by Bromo-cresol method whereas sulphate is done by gravimetric analysis and chloride by Mohr's method [25, 26]. Total phosphorus was measured using persulphate digestion and molybdate method, total nitrogen, ammonia by colorimetric indophenols bleu method, nitrate and nitrite by colorimetric method after zinc reduction and cadmium reduction respectively. Water for these analyses was filtered through Whatman GF/F filter [27].

The hydro chemical facies analysis (HFA) technique was developed in the 1960s as a tool for categorizing waters based on their major ion composition [28]. One form of HFA is the Piper Diagram, in which major cations and major anions are plotted on ternary diagrams in order to illustrate which cations and anions dominate. When plotted in this fashion, the data can be used to illustrate the evolution of water quality as it migrates through the ground (typically from bicarbonate-rich water to chloride-rich water) or as it mixes with water of a different composition. In this study, the Piper Diagram was used to compare the characteristic of the different springs in order to determine if the springs come from the same bedrock.

RESULTS

Classification and Hydrochemical Characteristics of Thermal Springs

Physico-chemical characteristics of different springs of thermal water in the Katana region during the 3 years (2006, 2008 and 2010) of sampling are present in the table 1.

Table-1: Mean physico-chemical parameters of different springs of thermal water in the Katana region*

	Kankule (n=11)	Buhandahanda (n=3)	Maziba (n=2)	Ciziri (n=3	Cimenki (n=3)
Hardness (mg/L)	166.24	158.93	158.93	154.5	157.46
Ca^{++} hardness (mg/L)	13.69	4.11	4.11	2.24	3.49
Mg^{++} hardness (mg/L)	150.65	154.87	154.87	152.2	153.98
TSS (mg/L)	0.01	0.01	0.01	0.009	0.01
Cl^{-} (mg/L)	6.93	6.03	6.03	5.75	5.94
SO_4^{--} (mg/L)	515.70	522.40	522.40	463.2	502.67
HCO_3^{-} (mg/L)	337.59	294.33	294.33	292.5	293.72
TP (µmole/L)	0.26	0.34	0.34	0.3155	0.33
PO_4^{---} (µmole/L)	0.09	0.12	0.12	0.1085	0.11
TN (µmole/L)	103.74	124.07	124.07	124.975	124.37
NH_4^{+} (µmole/L)	65.22	80.47	80.47	67.15	76.03
NO_3^{-} (µmole/L)	20.55	26.07	26.07	26.6	26.24
Temperature	62.04	60.89	38.67	60.83	46.22
pH	7.28	7.17	6.92	7.18	6.93

*Mean values of 3 years of sampling (2006, 2008 and 2010)

The mean temperature of the thermal springs at Katana region is between 62.04 °C (Kankule) to 38.67 °C (Maziba), while the pH varied from 7.28 to 6.92 revealed a neutral pH. The hardness varied from 166.24 mg/L (Kankule) to 154.5 mg/L (Ciziri), mainly due to magnesium, the concentration of calcium also varied during the studies years (13.69 mg/L to 2.24 mg/L), the magnesium from 154.87 mg/L to 150.65 mg/L, the absence of carbonate and comparatively high concentration of bicarbonates (337.59 mg/L to 292.5 mg/L), the hardness is permanent hardness. The chlorides varied from 6.93 mg/L to 5.75 mg/L) in the different sampling sites whereas sulphates was high from 522.4 mg/L to 463.2 mg/L.

The temperature of the different springs during the sampling period (Figure 2) shows that the difference during the years of sampling is not very high.

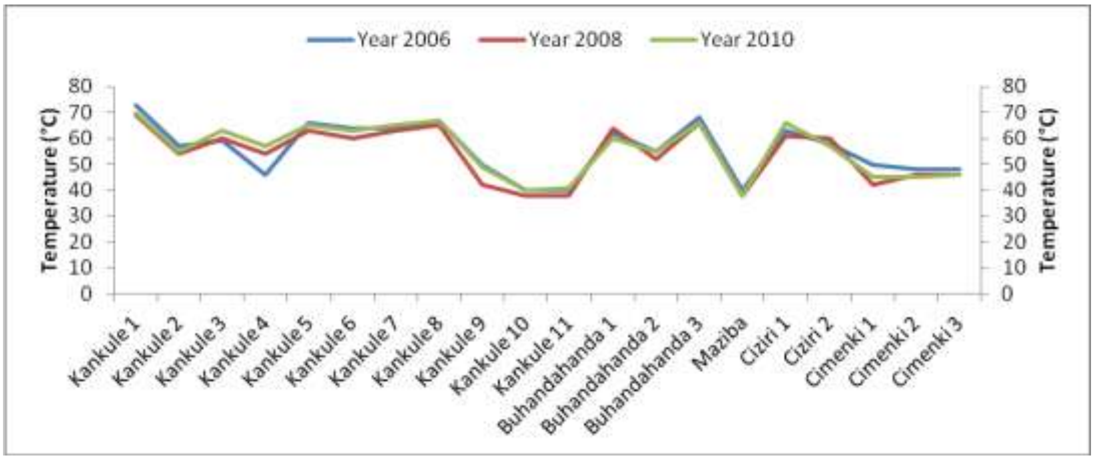

Fig-2: Temperature variation during the sampling period (2006, 2008 and 2010)

During the study area, the variation of temperature of the springs was not significant (F= 0.1902; p = 0.833). The high values when until to 70 °C in same springs at Kankule. The same trend is observed in the three period of sampling.

Classification of Katana region thermal waters

A Piper diagram (Figure 3) is used to illustrate the chemical character of the thermal spring waters and to identify the degree of correspondence between the source areas of the springs. The explanation of the Piper diagram is based on that of Johnston (1975) as given in Lloyd and Heathcote [29].

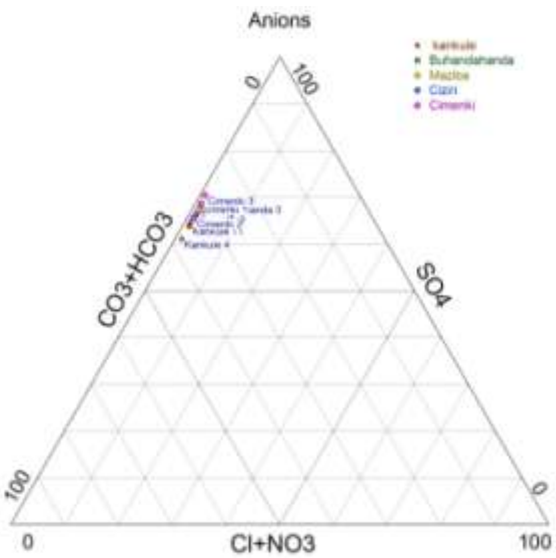

Fig-2: Piper diagram showing the chemical characteristics of Katana thermal spring waters

This diagram indicates that Katana thermal spring waters have very similar hydrochemical characteristics and therefore may share a common source area. Katana thermal spring waters are typical bicarbonates and magnesium and chloride sulfate. Most of the ions in the Katana thermal spring waters could have been acquired from the granite, and, to a lesser degree, diabase and basic rocks such as amphibolites present in the granite. The presence of Chloride is regarded as a conservative element even in geothermal environments. Its behaviour is thus particularly interesting in studies of the origin of salinity. Waters from Katana thermal spring waters have higher concentrations of HCO_3^- and SO_4^{--} ions which are less in Cl^-. In terms of cation concentrations, Katana thermal spring waters differs from the other running waters in the region in that it is richer in Mg ions.

DISCUSSION

Thermal springs are any natural geothermal spring or a natural discharge of groundwater with elevated temperature with respect to the surrounding. Katana thermal water has high temperature ranged between 62 to 39°C. Calcium hardness was less in the thermal water in the region compared to WHO standards [30]. But the concentration of magnesium was high to the standards water for drinking. The high concentration of magnesium is probably due to the high temperature which facilitated the dissolution of the mineral contained magnesium. Higher concentration of Magnesium and low concentration of Calcium was also recorded in some sites around the Coastal Algiers watershed [31]. The concentration of Chloride was less when WHO standards (200 mg/L) but sulfate was high 500 mg/L excepted in the sites of Ciziri. The concentration of TP and PO_4^{--} was the same as then obtained in natural rivers in the region [22].

Kankule and Buhandahanda thermals waters are Hydro-carbonate sulfate type, with total hardness and temperatures higher than the ones of the regional waters. This composition can be derived from the regional water composition assuming the dissolution of evaporite minerals, cation exchange and precipitation of calcite as observed Estorial in Portugal [32].

Owing to the presence of the limestone, Calcium Carbonate saturated water forms Travertine on crystallization. Around the Katana springs, there are a various types of geological components of physical abiotic and biotic matter like micro flora forms distinct stratums around the springs. These abiotic and biotic matters determine the characteristics of any hot springs as well as its suitability for human use. Therefore, in the present study we studied several physical and chemical parameters of water from these hot springs.

The diagram is used for a first classification of Katana thermal spring waters using the selected water quality analysis show that the springs are originating directly from crystalline rocks and belong to the two types of thermal water (Ca–HCO_3 and Ca–Mg–HCO_3 type waters). After Ellis and Machon [33] HCO_3^- waters are considered to occur in volcanic areas where steam containing CO_2 condenses into the liquid phase. Giggenbach [34] indicates that HCO_3^- waters can also reflect interaction of CO_2 charged fluids at lower temperatures as well as mixing with local groundwater. The water falls in Ca- Mg cation rich domain and Cl-SO_4 anion rich domain. In the water strong acid exceeds weak acid.

The depletion of magnesium could be attributed to the ion exchange process at high temperature in several calcium-magnesium silicate minerals [35, 36] or to the following reactions that, according to Schoeller and Schoeller [37], could be taking place in crystalline rocks.

CONCLUSION

The diagnostic chemical character of Katana thermal waters solutions in hydrologic systems has been determined with the application of the concept of hydro chemical facies. The Ca-Mg-HCO_3 plot conforms thermal water falls in Ca-Mg domain. Katana thermal waters are Ca–HCO_3 and Ca–Mg–HCO_3 type waters with high bicarbonate and calcium concentration. The higher temperature of Katana thermal waters dissolved ions during the deep circulation. A major challenge is that of distinguishing volcanic or magmatic from non-magmatic waters in the Katana thermal region. Isotopic technique studies can help to differentiate this ambiguity.

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